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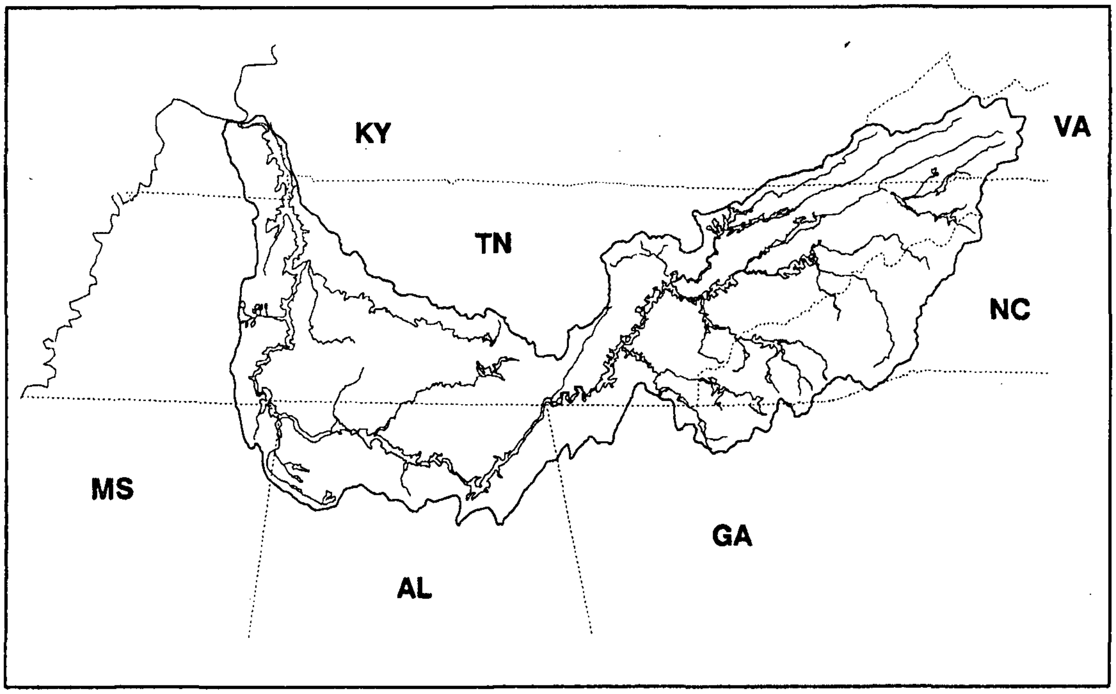
TENNESSEE VALLEY RESERVOIR AND STREAM QUALITY - 1993
SUMMARY OF VITAL SIGNS AND USE SUITABILITY MONITORING

VOLUME I



CLEAN WATER
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TENNESSEE VALLEY AUTHORITY
Resource Group
Water Management

TENNESSEE VALLEY RESERVOIR AND STREAM QUALITY - 1993
SUMMARY OF VITAL SIGNS AND USE SUITABILITY MONITORING

Volume I

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EXECUTIVE SUMMARY

TVA initiated a systematic, Valley-wide water quality and aquatic ecological monitoring program in 1986. The program started with a stream component, and a reservoir monitoring component was added in 1990. The two primary objectives of these monitoring efforts are to evaluate the ecological health (Vital Signs Monitoring) of major streams and reservoirs in the Tennessee Valley and to examine how well these water resources meet the swimmable and fishable goals of the Clean Water Act (Use Suitability Monitoring).

Vital Signs Monitoring

Stream monitoring has been conducted on 12 large tributaries since 1986. Beginning in 1994, six additional tributaries will be monitored; all with watersheds of at least 500 square miles. Reservoir monitoring started with 12 reservoirs (mostly mainstream reservoirs) in 1990 and has expanded progressively to the full complement of 30 reservoirs in 1993. No further expansion of either stream or reservoir monitoring is planned. This report summarizes results of these monitoring efforts in 1993. Volume I is the main body of the report and Volume II is a data summary organized by sample locations within watershed areas.

Until 1991, the ecological health evaluations were based on subjective evaluation of the data. A weight-of-evidence approach was used--a stream or reservoir was deemed healthy if most of the physical, chemical, and biological monitoring components appeared healthy. Beginning with the 1991 results, a more quantitative approach was developed that has been used the last three years. This approach integrates information on important indicators of ecological health. For reservoirs, five indicators are used--dissolved oxygen, chlorophyll, sediment quality, benthic macroinvertebrates, and fishes. Stream evaluations are similar except dissolved oxygen is not rated and nutrient concentrations are substituted for chlorophyll concentrations. For each indicator (or metric), scoring criteria are developed that assign a score ranging from 1 to 5 representing very poor to excellent conditions, respectively. Scores for all indicators at a location are summed. For streams and smaller reservoirs, only one site is monitored. For larger reservoirs, multiple sites are monitored, and the overall reservoir score is achieved by totaling scores for all locations. The resulting total is divided by the maximum possible score. Thus, the possible range of scores is from 20 percent (all metrics very poor) to 100 percent (all metrics excellent). Hence, an overall ecological health rating of good, fair, or poor is obtained for each stream site or reservoir. A health rating border-line between two of these categories is considered poor-fair or fair-good. Each year, the most recent information is evaluated with the same basic approach, modified to incorporate improvements based on comments from reviewers and additional data.

Stream monitoring results for 1993 indicated seven streams rated good (three of these received perfect scores), three streams rated fair to good, and one stream rated poor. Full evaluation was not possible for one stream because only three of the four indicators were monitored in 1993. The only stream to receive a poor rating was the French Broad River. This overall rating was caused by poor scores for nutrients and fishes, a fair score for benthos, and a good score for sediment quality.

Reservoirs are stratified into two groups for evaluation: run-of-river reservoirs and deep storage reservoirs. Separate scoring criteria were used for the two categories. Overall ratings for the 11 run-of-river reservoirs in 1993 ranged from 58 to 88 percent. Four reservoirs rated good (75 to 88 percent), three rated fair to good (71 to 73 percent), three rated fair (63 to 68 percent), and one rated poor to fair (58 percent). Overall ratings for the 19 storage reservoirs ranged from 52 to 72 percent. Two reservoirs rated fair to good (both 72 percent), 14 rated fair (58 to 67 percent), and three rated poor (52 to 56 percent).

Most streams and reservoirs had ratings comparable to those observed in 1991 and 1992. Tributary reservoirs had generally poorer ratings, primarily because of low dissolved oxygen in the hypolimnion. This is an ecologically undesirable condition that is partly due to the strong thermal stratification that occurs in deep reservoirs with relatively long retention times.

Use Suitability Monitoring

Use Suitability Monitoring provides screening level information on the suitability of selected areas within TVA reservoirs for water contact activities (swimmable) as determined by bacteriological studies and suitability of fish from TVA reservoirs for human consumption (fishable) as determined by fish tissue studies.

Bacteriological Studies--Bacteriological samples are collected at over 260 sites in the Tennessee Valley. These include designated swimming areas, canoe access sites, highly used recreational areas, and selected nonrecreation sites that provide information on pollution sources or inflow stream water quality. Recreation sites are sampled at least once every two years.

In 1993, 71 swimming areas and 14 canoe access points were sampled for bacteriological conditions. All but two swimming areas met the regulatory criterion to be considered safe. Even those two sites met the criterion if samples collected after heavy rains were excluded. Four canoe access points on the Duck River exceeded the criterion, both in dry and wet weather.

Bacteriological sampling at nonrecreational areas was conducted at 35 sites in 1993. Only one reservoir site and two stream sites failed to meet recreation criteria.

These results are consistent with previous surveys. Fecal coliform concentrations were generally lower in 1993 due to lower than normal summer rainfall. Bacteriological water quality in most areas of TVA reservoirs is good. In streams it is much poorer, especially after rainfall.

Fish Tissue Studies--Fish tissue studies examine fillets from important fish species for selected metals, pesticides, and polychlorinated biphenyls (PCBs) on the U.S. Environmental Protection Agency's list of priority pollutants. Resulting data are provided to appropriate state agencies to determine whether further study is needed or fish consumption advisories should be issued. Fish tissue data reported here represent autumn 1992 collections. Results for fish collected in autumn 1993 were not available at the time this report was prepared due to the time delay required for laboratory analysis.

Results of fish tissue screening studies in 1992 did not reveal any new areas in need of intensive investigations. Concentrations of at least one contaminant were high enough to warrant sampling again at the screening level in 1993. Results of intensive studies (i.e., in-depth studies on waterbodies where there are known or suspected problems) did not indicate substantial changes from previous years.

1.0 INTRODUCTION

1.1 Background

The Tennessee Valley Authority (TVA) started a Stream Monitoring Program in 1986 to evaluate the major tributaries of the Tennessee Valley at fixed locations. A parallel program, Reservoir Monitoring, was begun in 1990 when funds were appropriated by Congress for TVA to strengthen its stewardship responsibilities. The combined Stream and Reservoir Monitoring efforts consolidated several newly-developed activities along with several existing activities to form an integrated program. These monitoring efforts, in addition to River Action Team watershed examinations and public information/educational activities, are now part of TVA's comprehensive Clean Water Initiative.

1.2 Objectives

Objectives of these monitoring efforts are to provide information on the "health" or integrity of the aquatic ecosystem in major Tennessee River tributaries and reservoirs and to provide screening level information for describing how well these water resources meet the "fishable" and "swimmable" goals of the Clean Water Act.

The ecological integrity of stream and reservoir ecosystems is examined as part of an activity called Vital Signs monitoring. The basis of Vital Signs monitoring is examination of key physical, chemical, and biological indicators to evaluate the health of each stream or reservoir and to target detailed assessment studies if significant problems are found. In addition, this information establishes a baseline for comparing future water quality conditions as watershed improvements are made.

Another activity, Use Suitability monitoring, examines how well streams and reservoirs meet the fishable and swimmable goals of the Clean Water Act. Examination of levels of toxic contaminants in fillets from important fish species is the basis for the fishable use evaluation. Swimmable or water contact uses are examined by conducting bacteriological sampling at designated swimming beaches and other highly used recreation areas.

Using a quantitative approach to evaluate ecological health of water resources is relatively new, especially for reservoirs. This is only the third year TVA has used this approach, and we continue to make improvements based on experience gained each year. Ecological health evaluations drawn from this newly implemented monitoring program are subject to revision in future years as more data and experience are acquired on each reservoir. We welcome comments and suggestions for improvements in these ecological health evaluation methodologies. Please send comments/suggestions to the address above or contact appropriate individuals listed under key contacts on page ii.

1.3 Summary Report Description

Volume I of this report summarizes and integrates results from TVA's stream and reservoir monitoring activities in 1993. Chapter 1 provides background and objectives for the monitoring program. Chapter 2 describes the basis for study design and specific methods for sample collection. Chapter 3 describes the philosophical approach and data evaluation methods used for each indicator to determine stream and reservoir ecological health.

Chapter 4 provides an overview of hydrologic and meteorologic conditions for 1993. Conditions in streams and reservoirs are greatly affected by streamflow, rainfall, and temperature, as well as by physical and geologic characteristics of the watershed. Dams, and resulting reservoirs' dynamics, are important factors in the ecological health of regulated river systems. It is important to consider all these variables and their effects in evaluating ecological conditions of the Tennessee River system in any given year.

Chapter 5 discusses the 1993 monitoring results from a Valley-wide perspective. Discussion topics include an overview of ecological conditions, ecological indicators which "drove" the health ratings, changes from previous years, embayment monitoring (initiated in 1993), and swimmable and fishable conditions.

Chapters 6-17 provide a watershed-by-watershed summary and conclusions for each of the 12 watershed drainage areas in the Tennessee Valley. Each chapter provides a physical description of the watershed followed by a description of the physical characteristics, ecological health, and use suitability of each reservoir and stream monitoring site within the watershed. The ecological health evaluation is based on an integration of physical, chemical, and biological information gathered using the different Vital Signs monitoring tools.

Detailed summaries of 1993 results on each reservoir and stream are provided in Volume II of this report. Volume II is for technical audiences who prefer to form their own evaluation of conditions. It also serves as a detailed technical summary of conditions at TVA monitoring sites in 1993.

In addition to this technical summary report, a nontechnical document, *RiverPulse*,is available. *RiverPulse* (TVA, 1994) is broadly distributed to Tennessee Valley residents and users of TVA reservoirs. Annual issues of the technical report have been prepared since 1990, and annual issues of *Riverpulse* are available for 1991, 1992, and 1993. There also is a series of annual activity reports providing detailed results for each monitoring tool (e.g., water, sediment, benthos, fish, etc.). These detailed reports provide the basis for the summary report. Specific citations for summary and detailed reports are in the list of references. Copies of any of these documents are available from: TVA Water Management Library, 1101 Market Street, HB 2C-C, Chattanooga, TN 37402, Telephone: (615) 751-7338, FAX: (615) 751-7479.

2.0 DATA COLLECTION METHODS

2.1 Vital Signs Monitoring

2.1.1 Introduction

The study design for Vital Signs Monitoring is based on meeting the objectives outlined in Section 1.2. Several assumptions are fundamental to the study design:

1. Ecological health evaluations must be based on information on physical, chemical, and biological components of the ecosystem;

2. Vital Signs monitoring is a long-term effort to document the status of the river/reservoir system and track results of water quality improvement efforts;

3. Monitoring methods must be responsive by providing current information to resource managers;

4. The basic design must be considered dynamic and flexible, rather than rigid and static, and must allow adoption of new environmental monitoring techniques as they develop to meet specific needs; and

5. This is a monitoring program; it does not address specific cause/effect mechanisms. (The step beyond monitoring is assessment in which cause/effect investigations would target specific, identified concerns.)

Three important aspects were considered in establishing the study design: representative sampling locations; important ecological indicators; and frequency of sampling. The program that emerged balances these considerations as follows.

Sampling Locations--For reservoirs, the following three areas were selected for monitoring: the inflow area, generally riverine in nature; the transition zone or mid-reservoir area where water velocity decreases due to increased cross-sectional area, suspended materials begin to settle, and algal productivity increases due to increased water clarity; and the forebay, the lacustrine area near the dam, Figure 2.1. Overbanks, basically the floodplain which was inundated when the dam was built, were included in transition zone and forebay areas. Another important reservoir area, embayments, also was considered. However, monitoring all embayments is beyond the scope of this program. Previous studies have shown that ecosystem interactions within an embayment are mostly controlled by activities and characteristics within the embayment watershed, usually with relatively little influence from the main body of the reservoir. As a result, only four, large embayments, all with drainage areas greater than 500 square miles and surface areas greater than 4500 acres, are included in the Vital Signs Monitoring Program. These were added in 1993 and are reported on here for the first time.

The stream monitoring sampling locations were located to sample the cumulative water quality for as large a percentage of a tributary watershed as possible, with sampling locations located in the free-flowing reaches of the river near the downstream end of the watershed, but upstream of any impounded water.

Ecological Indicators--Selection of appropriate ecological indicators for monitoring was tailored to the specific objective and type of monitoring location. Physical, chemical, and biological indicators were selected to provide information from various habitats or ecological compartments on the health of that particular habitat or compartment. In reservoirs (Figure 2.1) the open water or pelagic area was represented by physical and chemical characteristics of water (including chlorophyll) in midchannel. The shoreline or littoral area was evaluated by sampling the fish community. The bottom or benthic compartment was evaluated using two indicators: quality of surface sediments in midchannel (determined by chemical analysis of sediments and acute toxicity testing of pore water); and examination of benthic macroinvertebrates from a transect across the full width of the sample area (including overbanks if present).

In streams, all available habitats were included to truly characterize the sample site. This is more easily accomplished in streams than in reservoirs because most habitats are visible. The same basic indicators used for reservoirs were also used in streams.

For both reservoirs and streams, information from each indicator was evaluated separately and results were then combined (without weighing) to arrive at an overall evaluation of reservoir ecological health. (See Chapter 3 for more details on the ecological health evaluation and scoring process.)

Sampling Frequency--Sampling frequencies were selected to take into consideration the expected temporal variation for each indicator. Physical and chemical components vary significantly in the short term, whereas biological components are more representative of long-term conditions. As a result, sampling for physical and chemical indicators is needed more frequently than biological indicators. In reservoirs, physical and chemical indicators were examined monthly from spring to fall and in streams every other month throughout the year. Biological indicators were sampled once each year for reservoir and stream sites. In reservoirs, benthic macroinvertebrate sampling was conducted in early spring (February-April), and fish assemblage sampling was conducted in autumn

(September-November). In streams, benthic and fish community sampling is conducted in late spring-early summer (May-June).

2.1.2 Reservoir Vital Signs Monitoring

The Vital Signs component of reservoir monitoring includes four main activities to examine and evaluate reservoir health:

(1) physical/chemical characteristics of water;

(2) acute toxicity and physical/chemical characteristics of sediment;

(3) benthic macroinvertebrate community sampling; and,

(4) fish assemblage sampling.

(In addition, aquatic macrophyte community information is included to provide a more comprehensive evaluation of each reservoir's ecological health.)

Data collection methods for each of these activities are given below. Sampling locations and specific monitoring activities for each reservoir are listed in Table 2.1 and shown in Figure 2.2.

Physical/Chemical Characteristics of Water--In 1993, physical/chemical water quality variables were measured at a total of 57 sampling locations on 30 reservoirs. Three specific QA/QC measures were incorporated in the reservoir physical/chemical water sampling activities. These included: (1) collection and analysis of triplicate sets of water samples once during the year at all forebay sampling locations to assess sample collection, laboratory analysis, and natural sample variability; (2) preparation and analysis of sample container blanks each collection day to assess the degree of contamination associated with the sample bottles and/or the sample handling processes; and, (3) preparation and analysis of sample filtration blanks with each set of filtered samples to assess the degree of contamination associated with the field sample filtration and handling.

The water quality monitoring activities on the Vital Signs reservoirs followed a "basic" (11 run-of-the-river reservoirs) or a "limited" (19 tributary reservoirs) sampling strategy (Table 2.1).

Basic--Monitoring on the run-of-the-river reservoirs included monthly water quality surveys (April through September) at forebays and transition zones. Basic monthly water quality sampling included in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; surface fecal coliform; photic zone (defined as twice the Secchi depth) composite chlorophyll-a samples; and photic zone composite and near-bottom samples for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, total phosphorus, and dissolved orthophosphorus), total organic carbon, color, and suspended solids. Physical/chemical water quality sampling was not conducted at most run-of-the-river reservoir inflows because most of these locations are tailwater areas of upstream dams; water quality characteristics there are more representative of processes in the upstream reservoir.

Limited--Tributary storage reservoirs were sampled monthly (April through October) for a smaller list of parameters. The approach was the same as for the run-of-the-river reservoirs, except that no fecal coliform, color, or suspended solids samples were collected, and only photic zone composites for nutrients and organic carbon samples were collected and only in April and August. The April and August nutrient samplings were designed to provide information on nutrient concentrations available at the beginning of the growing season, then near the end of the growing season. Forebays were sampled on all these reservoirs, and mid-reservoir locations were sampled on all but the smaller reservoirs.

Physical/chemical water quality data were stored on EPA's water quality data storage and retrieval (STORET) system. Reservoir health evaluation methods used to assess physical/chemical quality are described below (Section 3.1.2).

Acute Toxicity and Physical/Chemical Characteristics of Sediment--Annual sediment samples and near-bottom water samples were collected during the summer of 1993 from 59 locations, i.e., the forebays and transition zones (or mid-reservoir) of the 11 mainstream reservoirs and 19 tributary reservoirs as shown in Table 2.1. In addition, ten of the 59 locations were randomly selected for replicate QA/QC sampling. Sampling efforts were repeated at each of the ten sites. Replicate samples were handled and processed independently. Results from these ten sets of replicates were used to assess field methods consistency, variations in laboratory toxicity and physical/chemical analyses, and spatial homogeneity of the sediment. Eckman dredge samplers were used to collect the top three centimeters of sediment and Kemmerer or Isco water samplers were used to collect the near-bottom water. Each sediment sample was a composite of at least three subsamples independently collected at each sampling location from the original stream channel bed. At each sampling site, the subsamples were composited, thoroughly mixed to uniform color and consistency, and split into two fractions: one fraction for acute toxicity testing, and one fraction for physical/chemical analyses. Samples were placed on ice immediately after collection, compositing, and splitting, and were shipped or carried to the appropriate laboratory. One split from each sampling location and the sample of near-bottom water were shipped to the Toxicity Testing Laboratory (TTL) for toxicity testing; the other split at each sampling location was shipped or carried to the Environmental Chemistry Laboratory (ECHE) for chemical and physical analyses.

Acute Toxicity Testing--Within 36 hours of collection, all sediment samples were screened for toxicity using Rotox® (rotifer, Brachionus calyciflorus survival) and daphnid (Ceriodaphnia dubia) acute tests. Organisms were exposed to undiluted interstitial (pore) water from the sediment and near bottom water. Interstitial water was obtained by refrigerated centrifugation of sediment. Control water consisted of Moderately Hard Reconstituted Water, MHRW (TVA, 1992b), (hardness of 80-100 mg/L as $CaCO_3$) enriched with 10 percent Tennessee River water from TTL's experimental channels for the daphnid test and MHRW adjusted to pH=7.5 using HCl for the rotifer test. All samples were aerated to bring dissolved oxygen levels to near saturation (8.4 mg/L at 25°C) before testing. Water chemistry (temperature, DO, pH, conductivity, alkalinity, and hardness) was measured for all samples and controls. After centrifugation of the sediment, pore water samples were collected and preserved and sent to the Environmental Chemistry Laboratory for un-ionized ammonia analysis. Four replicates of five individuals each were used in both tests. Rotifer (24-hr) and daphnid (48-hr) acute toxicity was reported if average survival in the four replicates was significantly reduced (95 percent probability) from the control.

Physical/Chemical Characteristics--Splits of the same sediment samples used in the toxicity testing were analyzed for 13 metals, un-ionized ammonia (in pore water), total and volatile solids, particle size, and 26 selected trace organics (organochlorine pesticides and PCBs, Table 2.3).

Additional details for the collection methods, acute toxicity testing protocols and results, and the physical/chemical analytical results are given in TVA technical report (Moses, Simbeck, and Wade, 1994). How this sediment quality information was used in the reservoir health evaluations is described below in Section 3.1.2, Reservoir Sediment Quality Rating Scheme.

Benthic Macroinvertebrate Community Sampling--Benthic macroinvertebrate community samples were collected in the spring (March and April) of 1993 at 69 locations on the 30 Vital Signs reservoirs, Table 2.1. At each sample location, a line-of-sight transect was established across the width of the reservoir, and Ponar grab samples were collected at ten equally-spaced locations along this transect. When rocky substrates were encountered, a Peterson dredge was used. Only those samples which were collected from the permanently wetted bottom portion of the reservoir (i.e., those Ponar or Peterson samples collected below the elevation of the minimum winter pool level) were used to evaluate the condition of the benthic community. Samples were washed in the field, transferred to a labeled collection jar, and fixed with 10 percent buffered formalin solution. Specimens were sent to the laboratory where they were sorted, counted, and identified to the lowest practical taxon, typically genus or species, and reported as number per square meter. Six metrics (Table 3.1) were chosen to evaluate the benthic macroinvertebrate community as it relates to the overall ecological health of the reservoir. These metrics and the rating scheme are described in Section 3.1.2, Reservoir Benthic Community Rating Scheme.

To assess the reproducibility of benthic macroinvertebrate sampling results, replicate samples were collected at nine of the 69 sampling locations in 1993, with all types of reservoir locations (i.e., forebay, transition zone, and inflow) included. At each of the replicate sampling locations, the sampling protocol involved collection of a first set of ten samples, leaving the sampling location, and then returning as near as possible to the original transect site (on the same day) and repeating the collection of a second (replicate) set of ten samples. The results from the nine sets of replicate samples were then evaluated for reproducibility. Benthic macroinvertebrate data are available in computer-readable form from TVA upon request.

Fish Assemblage Sampling--In the autumn of 1993, electrofishing and/or gill netting data were collected from 69 locations on the 30 Vital Signs reservoirs to evaluate the fish assemblage, Table 2.1. Fifteen electrofishing runs (300 meters in length) were made at each location (forebay, transition or mid-reservoir, and inflow) with all habitats sampled in approximate proportion to their occurrence at the sampling location. Habitat distinctions were based on major changes in substrate (e.g., bluff, rip-rap, mud, etc.) and/or presence of cover such as brush or boat docks. Twelve experimental gill nets were also set overnight at each location covering all habitat types where conditions permitted. At some inflow locations, flow and/or lack of suitable sites limited the number of nets that could be set. All fish collected from either electrofishing or gill netting were enumerated, with length and weight measurements taken on important sport species. Estimated numbers were used when high densities of fish were encountered during electrofishing. Young-of-the-year (YOY) fish were counted separately from adults. All fish measured were inspected for external diseases, parasites, and anomalies. Twelve metrics (Table 3.3) were chosen to evaluate the fish assemblage as it relates to the overall ecological health of the reservoir and are described in Section 3.1.2, Reservoir Fish Assemblage Rating Scheme.

If the fish assemblage at a particular sampling location appeared to have changed substantially (up or down) from the previous year, the site was resampled (within one to two weeks) to assure that sampling conditions were not causing anomalous results. Resample results were used for two sampling locations (Cherokee Reservoir forebay and Guntersville Reservoir transition zone) during 1993 fish assemblage evaluations.

All data were recorded on a portable field data logger and downloaded to a personal computer before being added to the TVA mainframe fisheries data base. Fish assemblage data are available in computer-readable form from TVA upon request.

Aquatic Macrophytes--Coverage of aquatic macrophytes was determined from large-scale (1 inch=600 feet or 1 inch=1000 feet) color aerial photography flown during maximum submerged macrophyte coverage (late summer or early fall of 1993). Boat surveys to determine species composition of the dominant macrophyte communities were conducted at selected sites at the approximate time of the aerial overflight. Aquatic macrophyte colonies were delineated on mylar overlays attached to photographic prints, labeled according to species, and areal coverage determined using an electronic planimeter. Reservoirs flown for aerial photography in 1993 included Kentucky, Wilson, Wheeler, Guntersville, Nickajack, Chickamauga, Tellico, South Holston, and lakes in the Beech River project. For reservoirs where aerial photography was unavailable, standard field surveys and historical information were used to estimate community composition and coverage. Submersed aquatic plant populations generally are rare in tributary reservoirs because of the wide fluctuations of water surface elevations associated with their operation for floodwater storage. Known populations have been extremely small, short-lived, and of little significance.

A detailed summary of TVA's Aquatic Plant Management Program for 1993 and planned work for 1994 is available in a technical report (Burns, Bates, and Webb, 1994) that is updated and published annually.

2.1.3 Stream Vital Signs Monitoring

In 1993, Vital Signs stream sampling locations were located on 12 major tributaries to the Tennessee River (Figure 2.3 and Table 2.2). At each stream sampling location, four types of information were collected and examined to assess the ecological health of the stream and to provide information for evaluating the conditions found in the downstream receiving reservoir. These four components of stream monitoring (which complement the same four components for reservoir monitoring) were:

(1) physical/chemical characteristics of water;

(2) acute toxicity and physical/chemical characteristics of sediment;

(3) benthic macroinvertebrate community sampling; and

(4) fish community sampling.

Physical/Chemical Characteristics of Water--In 1993, physical/chemical water quality characteristics were measured bimonthly (odd numbered months) at 12 stream locations (Table 2.2). QA/QC methods for the stream water quality sampling activities included: (1) collection and analysis of duplicate sets of water samples at five stream locations to assess sample collection, laboratory analysis, and natural sample variability; (2) preparation and analysis of sample container blanks (for metals and nutrient analyses) each collection day to assess the degree of contamination associated with the sample bottles and/or the sample handling processes; and, (3) preparation and analysis of sample filtration blanks (dissolved nutrients and dissolved metals) with each set of filtered samples to assess the degree of contamination associated with the field sample filtration and handling. Physical/chemical water quality characteristics measured in 1993 included:

On-Site Measurements--flow, temperature, dissolved oxygen, pH, conductivity, alkalinity, and fecal coliform bacteria; and

Laboratory Measurements--physical analyses (hardness, color, turbidity, total suspended solids, total dissolved solids, and chemical oxygen demand), nutrient analyses (organic nitrogen, ammonia nitrogen, nitrite+nitrate nitrogen, total phosphorus, dissolved orthophosphorus, and total organic carbon), major cations/anions analyses (calcium, magnesium, sodium, potassium, chloride, and sulfate), and metal analyses (total and dissolved aluminum, dissolved cadmium, total and dissolved copper, total and dissolved iron, dissolved lead, total and dissolved manganese, dissolved nickel, dissolved silver, and total and dissolved zinc).

The physical/chemical water quality data are stored on EPA's water quality data storage and retrieval (STORET) system. Methods used to assess physical/chemical quality of each stream sampling location in regard to the ecological health evaluations are described in Section 3.1.3.

Acute Toxicity and Physical/Chemical Characteristics of Sediment--During the summer of 1993, an annual sediment and bottom water sample was collected at each of the 12 Vital Signs stream sampling locations, Table 2.2. Each sediment sample was a composite of at least five surficial sediment subsamples. At stream sampling locations with shallow and wadable water, subsamples were collected using clean stainless steel spoons. At sampling locations with deeper water, divers collected subsamples using one-liter glass jars. The subsamples were composited and thoroughly mixed to ensure uniform color and texture. At each sampling location the composited sample was then split for acute toxicity and for physical/chemical analyses. The split samples were placed on ice immediately and shipped to the Toxicity Testing Laboratory (TTL) at Browns Ferry Nuclear Plant for toxicity testing and to the Environmental Chemistry Laboratory (ECHE) for chemical and physical analyses.

Acute toxicity testing and physical/chemical analyses of the split samples were performed in exactly the same manner as described in Section 2.1.2, Reservoir Acute Toxicity and Physical/Chemical Characteristics of Sediment. Additional details for the collection methods, acute toxicity testing protocols and results, and the physical/chemical analytical results are given in a TVA technical report (Moses, Simbeck, and Wade, 1994b). How this sediment quality information was used in the stream health evaluations is described in Section 3.1.3, Stream Sediment Quality Rating Scheme.

Benthic Macroinvertebrate Community Sampling--Benthic macroinvertebrates were sampled at the 12 stream sites between mid-May and early July (streamflow conditions permitting) in order to maximize collection before hatching of winged adults. The benthic sampling sites were located as close as possible to the corresponding water quality sampling location (Table 2.2), with exact site selection depending upon the presence of suitable habitat types. Stream habitat in Tennessee Valley rivers and streams can generally be classified as riffle, run, or pool.

Both quantitative (Hess and Surber) and qualitative (D-net and handpicking) samples were collected to define relative abundance and species occurrence at each site. Quantitative sampling was completed in substrate types ranging from rubble to gravel in both riffle and pool habitats. Qualitative sampling was limited to a maximum of two man-hours per site, or was discontinued when redundancy in organisms being collected was observed. In total, seven samples were collected per station. These include: (a) three Hess samples in pools at the head of a riffle in substrate that contained a light covering of silt; (b) three Surber samples collected in shallow riffle habitat and along the borders of emergent vegetation (limited to areas where the water did not exceed the depth of the sampling frame); and (c) a single qualitative sample of bottom fauna organisms using D-nets and handpicking from all habitats present. Habitats targeted for qualitative sampling were leaf packs, woody debris, emergent aquatic vegetation, and boulders.

All specimens were preserved in 10 percent formalin solution and returned to the laboratory for sorting, enumeration, and identification. Specimens were identified to the lowest practical taxon, typically genus or species. Twelve metrics, based on a classification system developed by Kerans et.al (1992), were used to evaluate the stream benthic ecological health (Table 3.4). Methods used to assess the ecological health of the benthic community at each stream sampling location are described below (Section 3.1.3, Stream Benthic Community Rating Scheme). Benthic macroinvertebrate data are available in computer-compatible form from TVA, upon request.

Fish Community Sampling--Fish community sampling was conducted in summer (May-July) at 11 of the 12 stream sampling locations in 1993, Table 2.2. (The Elk River site was not sampled.) A boat-mounted electrofishing unit was used for deep pool habitats, and a backpack electrofishing unit, dip nets, and seine were used for wadable habitats. At each stream site, at least four general habitats (run, riffle, shallow pool, and deep pool) were sampled until three consecutive units of sampling effort (seine haul or timed shocking run) produced no additional species per habitat. Additional habitats were sampled as determined by the field crew leader. Fish specimens that were difficult to identify were preserved and their identity later confirmed. All fish collected were enumerated. Numbers were estimated if high densities were encountered during electrofishing. Young-of-the-year (YOY) fish were counted separately from adults. All fish measured were inspected for external diseases, parasites, and anomalies.

A modified version of Karr's (1981) index of biotic integrity (IBI) was used to assess the condition of the resident fish community, Table 3.5. This evaluation scheme is described in Section 3.1.3, Stream Fish Community Rating Scheme. Fish community data are available in computer-readable form from TVA upon request.

2.2 Use Suitability Monitoring

Use Suitability monitoring provides screening level information on the suitability of selected reservoir areas and stream reaches in the Tennessee Valley for water contact recreation (swimmable) and suitability of fish for human consumption (fishable). The use suitability evaluation is based on results of: (1) bacteriological sampling at recreation areas, and (2) collection and analysis of fish tissue.

2.2.1 Bacteriological Sampling

In 1989, TVA began periodically sampling recreation sites in the Tennessee Valley for fecal coliform bacteria to determine each site's suitability for water contact recreation. In addition to swimming beaches, many other recreation sites were also included in the program, such as canoe launch areas, picnic areas, boat ramps, and marinas. This bacteriological sampling program now includes approximately 260 sites and is designed to sample all locations on a frequency of about once every other year. Prior to 1993, the sampling frequency was approximately once every five years.

Samples are collected in a manner to conform with state criteria and federal guidelines; at each site at least ten fecal coliform samples are collected within a 30-day sampling period during the summer recreation season. QA/QC procedures include running at least one duplicate sample at each site and preparation and analyses of sample container blanks each collection day to assess degree of contamination associated with sample containers, handling process, and analytical equipment. The suitability of a recreation site for water contact recreation is based on EPA guidelines for fecal coliform bacteria (EPA, 1991).

In 1993, fecal coliform samples were collected in spring and summer at 59 designated swimming beaches and 14 canoe access sites to evaluate use suitability for whole body water contact recreation. In addition, 53 informal recreation sites where incidental water contact may occur (e.g., boat launch ramps, picnic areas, parks, marinas, etc.), were sampled.

Monthly (April through September) bacteriological samples were collected at 20 forebay and transition zone locations and four major tributary embayments on the run-of-the-river reservoirs as part of the basic Vital Signs Reservoir Monitoring (Table 2.1).

All TVA bacteriological sampling data are stored on EPA's water quality data storage and retrieval (STORET) system. A technical report (Fehring, 1994) provides specific details and evaluations of TVA's 1993 bacteriological monitoring results, and is available upon request.

2.2.2 Fish Tissue Sampling

In cooperation with Valley states, since 1987 TVA has collected and analyzed fish from over 80 Tennessee Valley reservoir and stream locations as part of both "screening" and "intensive" evaluations. In screening studies, composited fillets of indicator fish species (primarily channel catfish) are analyzed for a wide range of potential contaminants to identify possible problem areas where intensive investigation may be needed. Intensive studies are conducted on reservoirs or streams where contamination problems are known or suspected, based on the screening study information. For intensive studies, individual fillets from several important fish species are analyzed for specific contaminants to better document the number of species contaminated and level of contamination in each species. Intensive studies also include a higher density of sampling locations in the reservoir or stream of interest to better define the spatial extent of the contamination. The intent is to provide information that state public health officials can use to determine whether fish consumption advisories should be issued to protect human health.

> *Screening Studies*--Channel catfish were collected from 16 reservoirs in autumn of 1992. Fillets were removed, composited by location, and analyzed for metals, PCBs, and pesticides on EPA's Priority Pollutant List (Table 2.3). During the preparation process, observations of external and internal conditions of each fish were recorded along with length, weight, sex, fillet weight, and liver weight.
>
> *Intensive Studies*--The following six TVA reservoirs were examined intensively in 1992: Wheeler, Nickajack, Watts Bar, Fort Loudoun, Melton Hill, and Ocoee No. 1 (Parksville Reservoir). In each case, the contaminant of concern was PCBs, except for Wheeler, where DDT is the problem. Chlordane was also of concern in some reservoirs. Fish consumption advisories that recommend either limiting the quantity of fish eaten or avoiding any consumption are in effect for all these reservoirs except Ocoee No. 1.

All fish tissue data are stored on EPA's water quality data storage and retrieval (STORET) system. A technical report (Williams and Dycus, 1993) provides specific details and evaluations of TVA's 1991 and 1992 fish tissue studies and is available on request.

Figure 2.1

Schematic of Key Reservoir Sampling Areas

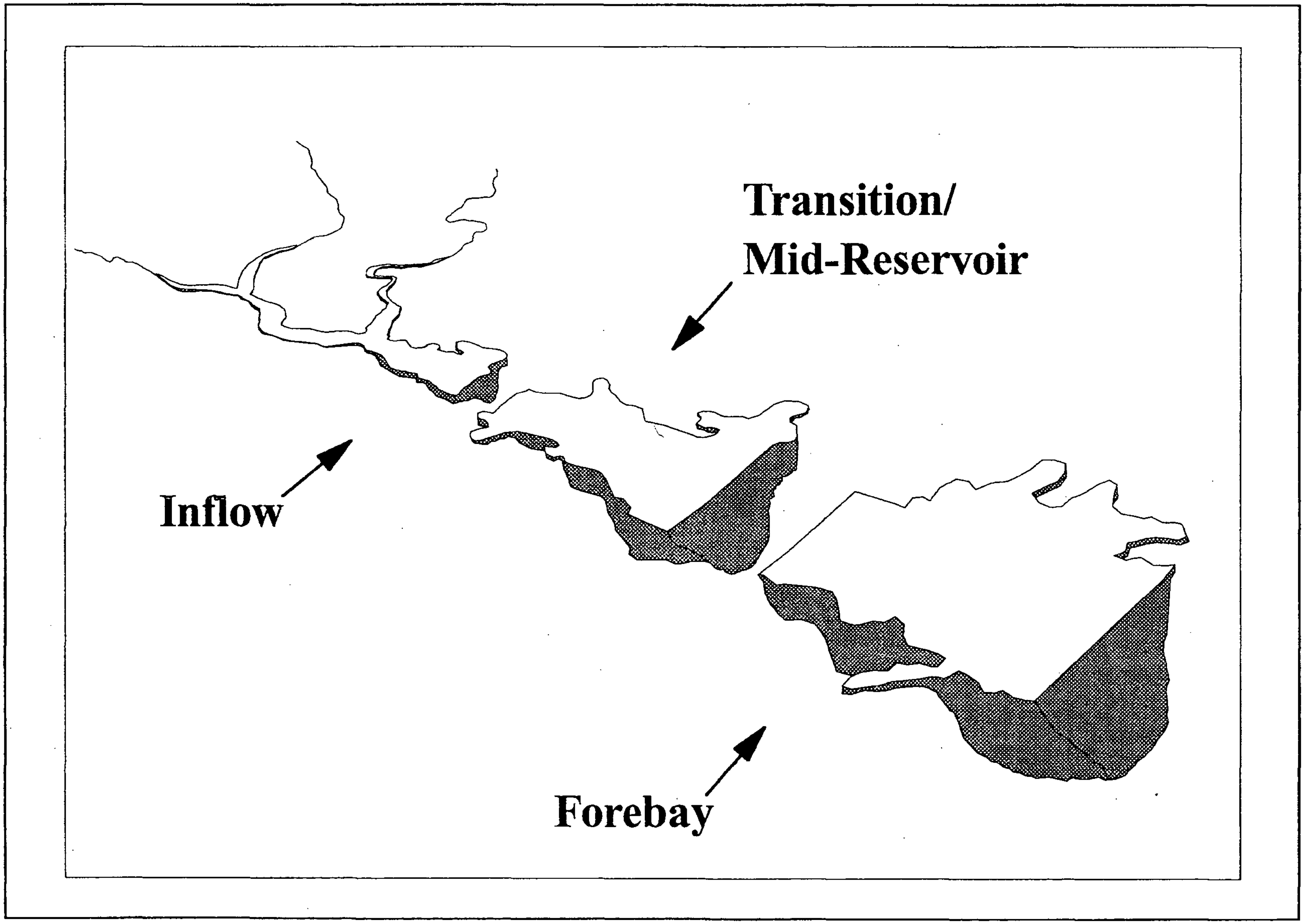

FIGURE 2.2

RESERVOIR VITAL SIGNS MONITORING LOCATIONS - 1993

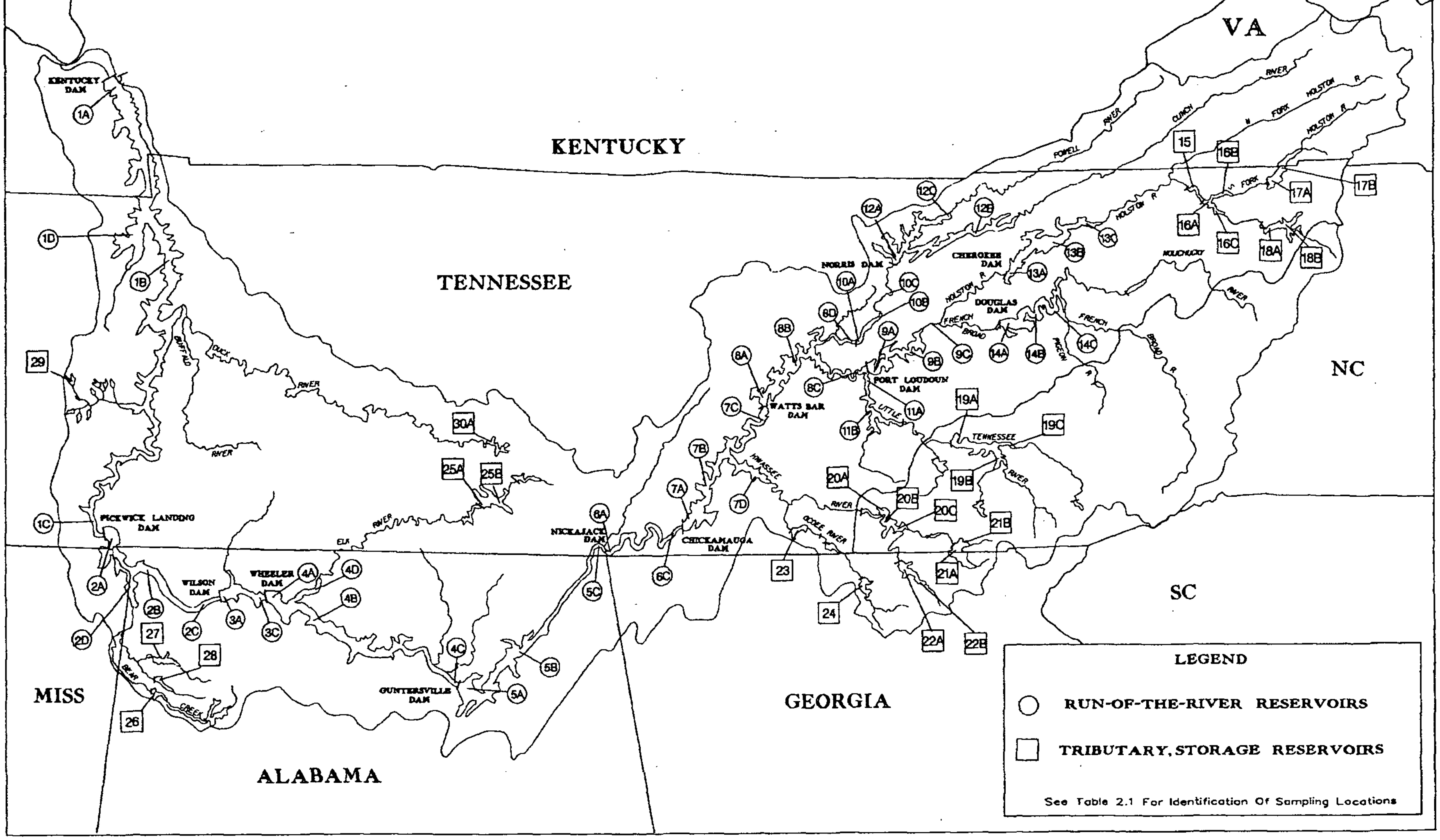

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FIGURE 2.3

STREAM VITAL SIGNS MONITORING LOCATIONS - 1993

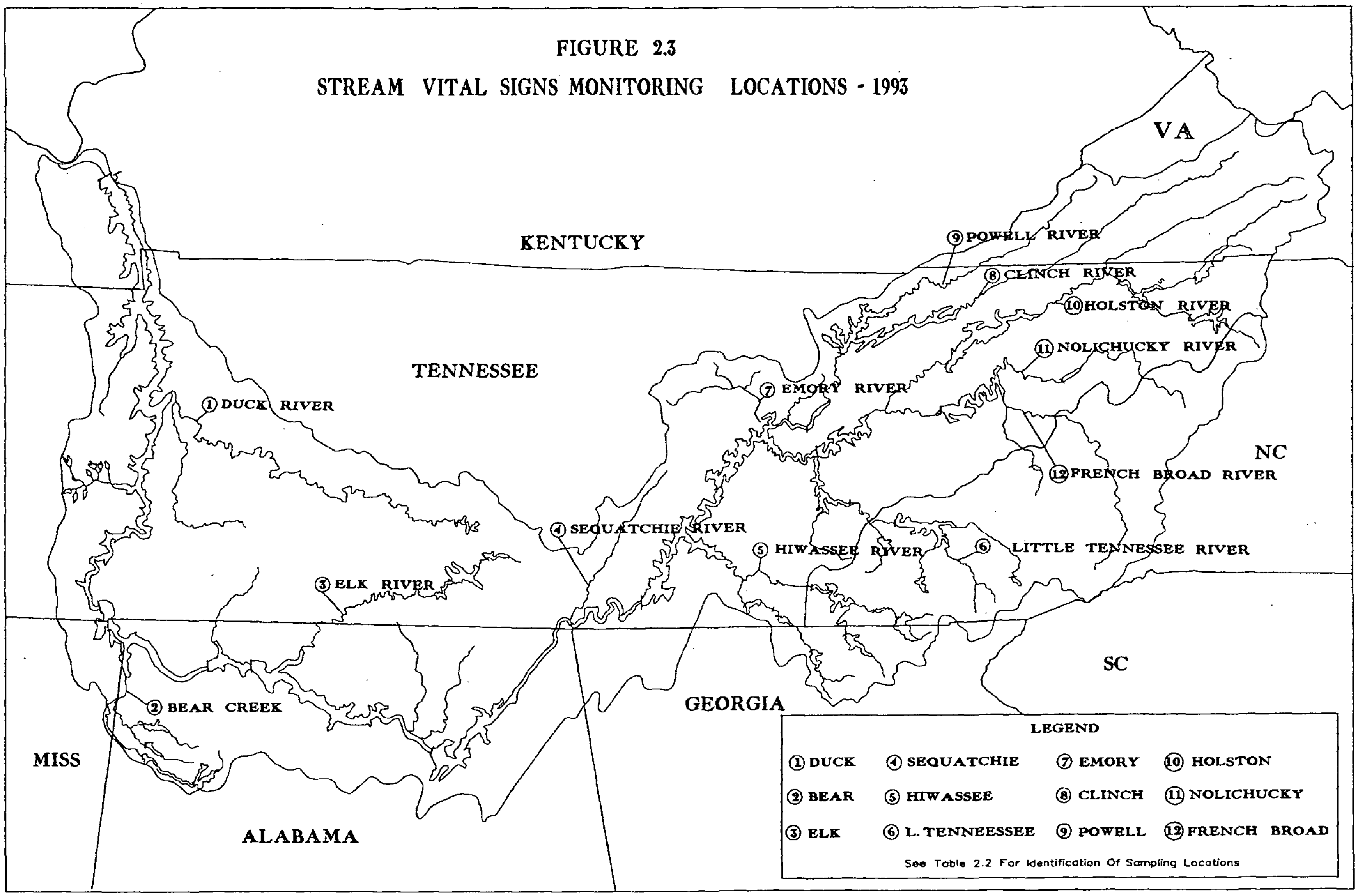

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Table 2.1
1993 Vital Signs Monitoring

Run-of-the-River Reservoirs
--Basic Monitoring Strategy--

				Reservoir Vital Signs Monitoring Tools				
					Sediment Quality[d]			Fish Community[f]
Reservoir	Sampling Locations[a]	STORET ID #	Description[b]	Water Quality[c]	Toxicity	Phy/Chem	Benthic Invertebrates[e]	Diversity/RFAI
Kentucky	TRM 23.0	202832	1A-FB	M	A	A	A	A
	TRM 85.0	477403	1B-TZ	M	A	A	A	A
	TRM 200-206	--	1C-I	-	-	-	A	A
	Big Sandy 7.4	477210	1D-E	M	A	A	A	A
Pickwick	TRM 207.3	476799	2A-FB	M	A	A	A	A
	TRM 230.0	016923	2B-TZ	M	A	A	A	A
	TRM 253-259	--	2C-I	-	-	-	A	A
	Bear Cr 8.4	017849	2D-E	M	A	A	A	A
Wilson	TRM 260.8	016912	3A-FB	M	A	A	A	A
	TRM 273-274	--	3C-I	-	-	-	A	A
Wheeler	TRM 277.0	016900	4A-FB	M	A	A	A	A
	TRM 295.9	017009	4B-TZ	M	A	A	A	A
	TRM 347-348	--	4C-I	-	-	-	A	A
	Elk River 6.0	017850	4D-E	M	A	A	A	A
Guntersville	TRM 350.0	017261	5A-FB	M	A	A	A	A
	TRM 375.2	017522	5B-TZ	M	A	A	A	A
	TRM 420-424	--	5C-I	-	-	-	A	A
Nickajack	TRM 425.5	476344	6A-FB	M	A	A	A	A
	TRM 469-470	--	6C-I	-	-	-	A	A
Chickamuaga	TRM 472.3	475358	7A-FB	M	A	A	A	A
	TRM 490.5	475265	7B-TZ	M	A	A	A	A
	TRM 518-529	--	7C-I	-	-	-	A	A
	Hiwassee 8.5	477512	7D-E	M	A	A	A	A

Table 2.1 (continued)
1993 Vital Signs Monitoring

Run-of-the-River Reservoirs
--Basic Monitoring Strategy (continued)--

				Reservoir Vital Signs Monitoring Tools				
					Sediment Quality[d]			
Reservoir	Sampling Locations[a]	STORET ID #	Description[b]	Water Quality[c]	Toxicity	Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Watts Bar	TRM 531.0	475317	8A-FB	M	A	A	A	A
	TRM 560.8	476041	8B-TZ	M	A	A	A	A
	TRM 600-601	--	8C-I	-	-	-	A	A
	CRM 19-22	--	8D-I	-	-	-	A	A
Fort Loudoun	TRM 605.5	477404	9A-FB	M	A	A	A	A
	TRM 624.6	475603	9B-TZ	M	A	A	A	A
	TRM 652	--	9C-I	-	-	-	A	A
Melton Hill	CRM 24.0	477064	10A-FB	M	A	A	A	A
	CRM 45.0	476194	10B-TZ	M	A	A	A	A
	CRM 59-66	--	10C-I	-	-	-	A	A
Tellico	LTRM 1.0	476260	11A-FB	M	A	A	A	A
	LTRM 15.0	476456	11B-TZ	M	A	A	A	A
	LTRM 21.0	476295	-	-	A	A	-	-
			Totals	24	25	25	35	35

Table 2.1 (continued)
1993 Vital Signs Monitoring

Tributary Storage Reservoirs
--Limited Monitoring Strategy--

				Reservoir Vital Signs Monitoring Tools				
					Sediment Quality[d]			Fish Community[f]
Reservoir	Sampling Locations[a]	STORET ID #	Description[b]	Water Quality[c]	Toxicity	Phy/Chem	Benthic Invertebrates[e]	Diversity/RFAI
Norris	CRM 80.0	476009	12A-FB	M	A	A	A	A
	CRM 125.0	477186	12B-MR	M	A	A	A	A
	PRM 30.0	477187	12C-MR	M	A	A	A	A
Cherokee	HRM 53.0	475025	13A-FB	M	A	A	A	A
	HRM 76.0	475028	13B-MR	M	A	A	-	A
	HRM 91	--	13C-I	-	-	-	A	A
Douglas	FBRM 33.0	475081	14A-FB	M	A	A	A	A
	FBRM 51.0	477510	14B-MR	M	A	A	-	A
	FBRM 61	--	14C-I	-	-	-	A	-
Ft.Pat Henry	SFHR 8.7	477509	15-FB	M	A	A	A	A
Boone	SFHR 19.0	475858	16A-FB	M	A	A	A	A
	SFHR 27.0	476221	16B-MR	M	A	A	A	A
	WRM 6.5	477511	16C-MR	M	A	A	A	A
South Holston	SFHR 51.0	475859	17A-FB	M	A	A	A	A
	SFHR 62.5	475573	17B-MR/I	M	A	A	A	A
Watauga	WRM 37.4	475576	18A-FB	M	A	A	A	A
	WRM 45.5	477513	18B-MR	M	A	A	A	A
Fontana	LTRM 62.0	370004	19A-FB	M	A	A	A	A
	LTRM 81.5	370177	19B-MR	M	A	A	A	A
	TkRM 3.0	370162	19C-MR	M	A	A	A	A

Table 2.1 (continued)
1993 Vital Signs Monitoring

Tributary Storage Reservoirs
--Limited Monitoring Strategy (continued)--

Reservoir	Sampling Locations[a]	STORET ID #	Description[b]	Reservoir Vital Signs Monitoring Tools: Water Quality[c]	Sediment Quality[d] Toxicity	Sediment Quality[d] Phy/Chem	Benthic Invertebrates[e]	Fish Community[f] Diversity/RFAI
Hiwassee	HiRM 77.0	370001	20A-FB	M	A	A	A	A
	HiRM 85.0	370154	20B-MR	M	A	A	A	A
	HiRM 90	--	20C-I	-	-	-	A	A
Chatuge	HiRM 122.0	370003	21A-FB	M	A	A	A	A
	Shooting Cr 1.5	370178	21B-FB	M	A	A	A	A
Nottely	NRM 23.5	120883	22A-FB	M	A	A	A	A
	NRM 31.0	120806	22B-MR	M	A	A	A	A
Ocoee No.1	ORM 12.5	475684	23-FB	M	A	A	A	A
	ORM 16.5	--	-	-	A	-	-	-
Blue Ridge	ToRM 54.1	130032	24-FB	M	A	A	A	A
Tims Ford	ERM 135.0	477072	25A-FB	M	A	A	A	A
	ERM 150.0	475768	25B-MR	M	A	A	A	A
Bear Creek	BCM 75.0	017041	26-FB	M	A	A	A	A
Cedar Creek	CCM 25.2	017233	27-FB	M	A	A	A	A
L.Bear Creek	LBCM 12.5	017474	28-FB	M	A	A	A	A
Beech	BRM 36.0	475876	29-FB	M	A	A	A	-
Normandy	DRM 249.5	477453	30-FB	M	A	A	A	A
			Totals	33	34	33	34	34

Footnotes

a. BCM - Bear Creek Mile
CRM - Clinch River Mile
FBRM - French Broad River
LBCM - Little Bear Creek Mile
ORM - Ocoee River Mile
TRM - Tennessee River Mile
WRM - Watauga River Mile
BRM - Beech River Mile
DRM - Duck River Mile
HiRM - Hiwassee River Mile
LTRM - Little Tennessee River Mile
PRM - Powell River Mile
ToRM - Toccoa River Mile
PRM - Powell River Mile
CCM Cedar Creek Mile
ERM - Elk River Mile
HRM - Holston River Mile
NRM - Nottely River Mile
SFHR - So Fork Holston River Mile
TkRM - Tuckaseegee River Mile

b. Numbers are keyed to Figure 2.2. FB - forebay; TZ - transition zone; MR - mid-reservoir; I - Inflow; and E - embayment. MR/I - Sampling location was referred to as an inflow location in the fish community evaluation (sampling done in autumn at lower reservoir water level elevations); and, as a mid-reservoir location in the evaluation of the water quality data (sampling done in summer at higher water level elevations).

c. --Basic Monitoring Strategy--
M - monthly water quality surveys (April through September). The surveys include: in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; surface fecal coliform and photic zone chlorophyll-a samples; and surface and near-bottom water samples for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, phosphorus, and dissolved ortho phosphorus), total organic carbon, color, and suspended solids.
--Limited Monitoring Strategy--
M - monthly water quality surveys (April through October). The surveys include: in situ water column measurements of temperature, dissolved oxygen, pH, and conductivity; Secchi depth measurements; and, photic zone chlorophyll-a samples. Twice a year (April and August) surface water samples are collected for nutrients (organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, phosphorus, and dissolved ortho phosphorus), and total organic carbon. Once a year (August) bottom water samples are collected for ammonia nitrogen. No samples are collected for fecal coliform, color, and suspended solids.

d. A - annual summer samples of sediment pore water and bottom water are examined for acute toxicity (rotifers and Ceriodaphnia). At the same time, the sediment is collected and analyzed for metals, total and volatile solids, particle size, and twenty-six trace organics (organochlorine pesticides and PCBs).

e. A - annual benthic invertebrate samples are collected, enumerated and identified to lowest practical taxon (genus or species) in the spring of year.

f. A - annual electroshocking and gill-netting techniques are used to evaluate the near-shore fish community, during autumn.

Table 2.2
1993 Vital Signs Monitoring

STREAM VITAL SIGNS MONITORING LOCATIONS, 1993

Tributary Stream	River Mile	STORET ID #	Description
Duck River	26.0	475793	USGS stream gage above Hurricane Mills, TN
Bear Creek	27.3	017019	TVA stream gage near Bishop, AL
Elk River	36.5	477330	USGS stream gage at Veto Road bridge near Prospect, TN
Sequatchie River	6.3	477177	Valley Road bridge near Jasper, TN
Hiwassee River	36.9	477369	East Patty Road bridge near Benton, TN
Little Tennessee River	94.7	370158	USGS stream gage near Needmore, NC
Emory River	18.3	475838	USGS stream gage at Oakdale, TN
Clinch River	159.8	475846	USGS stream gage near Tazewell, TN
Powell River	65.4	475098	TVA stream gage near Arthur, TN
Holston River	118.7	475945	TVA stream gage near Surgoinsville, TN
Nolichucky River	10.3	477150	TVA stream gage at David Thomas bridge near Lowland, TN
French Broad River	77.5	475086	US Hwy 411 bridge at Oldtown, TN

Table 2.3
1993 Vital Signs Monitoring

PHYSICAL/CHEMICAL MEASUREMENTS - SEDIMENT		
Description, units	**Detection Limits (dry weight)**	**Sediment Quality Guidelines[a]**
Metals and Ammonia		
Aluminum, mg/g	1 mg/g	--
Arsenic, mg/kg	1 mg/kg	8 mg/kg[b]
Cadmium, mg/kg	0.5 mg/kg	6 mg/kg[b]
Calcium, mg/g	0.5 mg/g	--
Chromium, mg/kg	10 mg/kg	75 mg/kg[b]
Copper, mg/kg	2 mg/kg	50 mg/kg[b]
Iron, mg/g	1 mg/g	--
Lead, mg/kg	5 mg/kg	60 mg/kg[b]
Magnesium, mg/g	0.5 mg/g	--
Manganese, mg/g	0.1 mg/g	--
Mercury, mg/kg	0.1 mg/kg	1 mg/kg[b]
Nickel, mg/kg	5 mg/kg	50 mg/kg[b]
Zinc, mg/kg	10 mg/kg	300 mg/kg
Un-ionized Ammonia (in pore water), μg NH_3/l	10 μg/l	200 μg/l
Solids		
Total solids, %	0.1%	--
Total volatile solids, %	0.1%	--
Particle size, <0.062 mm diameter, %	0.1%	--
Particle size, <0.125 mm diameter, %	0.1%	--
Particle size, <0.50 mm diameter, %	0.1%	--
Particle size, <2.0 mm diameter, %	0.1%	--
Organochlorine Pesticides and PCB's		
Aldrin, μg/kg	10 μg/kg	10 μg/kg
α-Benzene Hexachloride (BHC), μg/kg	10 μg/kg	10 μg/kg
β-Benzene Hexachloride (BHC), μg/kg	10 μg/kg	10 μg/kg
γ-Benzene Hexachloride (Lindane), μg/kg	10 μg/kg	10 μg/kg
δ-Benzene Hexachloride (BHC), μg/kg	10 μg/kg	10 μg/kg
Chlordane, μg/kg	10 μg/kg	10 μg/kg
Dieldrin, μg/kg	10 μg/kg	10 μg/kg
ρ,ρ DDT, μg/kg	10 μg/kg	10 μg/kg
ρ,ρ DDD, μg/kg	10 μg/kg	10 μg/kg
ρ,ρ DDE, μg/kg	10 μg/kg	10 μg/kg

Table 2.3 (continued)
1993 Vital Signs Monitoring

PHYSICAL/CHEMICAL MEASUREMENTS - SEDIMENT		
Description, units	**Detection Limits (dry weight)**	**Sediment Quality Guidelines[a]**
Organochlorine Pesticides and PCB's (continued)		
α-Endosulfan, μg/kg	10 μg/kg	10 μg/kg
ß-Endosulfan, μg/kg	10 μg/kg	10 μg/kg
Endosulfan Sulfate, μg/kg	10 μg/kg	10 μg/kg
Endrin, μg/kg	10 μg/kg	10 μg/kg
Endrin Aldehyde, μg/kg	10 μg/kg	10 μg/kg
Heptachlor, μg/kg	10 μg/kg	10 μg/kg
Heptachlor Epoxide, μg/kg	10 μg/kg	10 μg/kg
Methoxychlor, μg/kg	10 μg/kg	10 μg/kg
PCB-1221, μg/kg	100 μg/kg	100 μg/kg
PCB-1232, μg/kg	100 μg/kg	100 μg/kg
PCB-1242, μg/kg	100 μg/kg	100 μg/kg
PCB-1248, μg/kg	100 μg/kg	100 μg/kg
PCB-1254, μg/kg	100 μg/kg	100 μg/kg
PCB-1260, μg/kg	100 μg/kg	100 μg/kg
PCB-1016, μg/kg	100 μg/kg	100 μg/kg
PCBs, Total, μg/kg	100 μg/kg	100 μg/kg
Toxaphene, μg/kg	500 μg/kg	500 μg/kg

[a] Unless otherwise noted, guidelines are suggested TVA Sediment Quality Guidelines.
[b] EPA Region V Guidelines for polluted freshwater sediment (EPA, 1977).

3.0 ECOLOGICAL HEALTH AND USE SUITABILITY DETERMINATION METHODS

3.1 Vital Signs Monitoring

3.1.1 Introduction

The objective of Vital Signs monitoring is to determine the health or integrity of the aquatic ecosystem within each reservoir or at each stream sampling location. There are no official or universally accepted guidelines or criteria upon which to base such an evaluation. Consequently, an evaluation methodology was developed to assess the overall ecological health or condition of each of the 30 TVA Vital Signs reservoirs and 12 Vital Signs stream monitoring locations. The ecological health evaluation system combines both biological and physical/chemical information to examine reservoir and stream health. Five aquatic ecosystem indicators are used for reservoirs: dissolved oxygen, chlorophyll-a, sediment quality, benthic macroinvertebrates, and fish community; and four aquatic ecosystem indicators are used for streams: nutrient concentration, sediment quality, benthic macroinvertebrates, and fish community.

A critical step in developing an ecological health evaluation is deciding for each indicator what represents good conditions and what indicates poor conditions. This is more easily done for evaluation of streams because there usually are essentially unaltered reference sites that can be examined to define "good" conditions for each indicator, for example the various indices of biotic integrity for fish and benthic stream communities. Because reservoirs are man-made alterations of natural streams, there are no "reference reservoirs." An alternative approach to "reference conditions" is required.

3.1.2 Reservoir Ecological Health

Scoring criteria for the reservoir dissolved oxygen and chlorophyll-a indicators were based on what could be considered a conceptual model. This simply means that the criteria were developed subjectively, based on several years experience in evaluating biological systems in reservoirs. This experience has shown that below a threshold level of chlorophyll, primary production is not sufficient to support an active, biologically healthy food chain. In addition, chlorophyll concentrations above a higher threshold levels result in undesirable eutrophic conditions. Minimum and maximum chlorophyll concentrations were selected based on this experience and professional judgment. The conceptual model for dissolved oxygen criteria for a reservoir is quite complicated due to the combined effects of flow regulation and the potential for oxygen depletion in the hypolimnion. The scoring criteria described below attempt a multidimensional approach that includes considering dissolved oxygen levels both in the water column and near the bottom of the reservoir.

For the benthic macroinvertebrate and fish community indicators, scoring criteria are developed based on statistical examination of two or more years of data from TVA reservoirs. For these indicators, all previously collected TVA reservoir data for a selected community characteristic (e.g., number of taxa, total abundance, etc.) were ranked and divided into good, fair, and poor groupings. (Specific procedures used to determine scoring criteria for each grouping are given in Section 3.1.2, Benthic Community Rating Scheme and Fish Assemblage Rating Scheme.) Data for the current year of monitoring (e.g., 1993) are then compared to these criteria and scored accordingly. This approach is valid if the data base is sufficiently large and if it can be safely assumed that the data base covers the full spectrum of good to poor conditions.

The sediment quality indicator scoring criteria uses a combination of two characteristics: sediment toxicity to test organisms; and sediment chemical analyses for ammonia, heavy metals, pesticides, and PCBs (using published guidelines for many of these analytes).

Dissolved Oxygen (DO) Rating Scheme--Oxygen is vital for life. In situations where funding is limited and only one indicator of reservoir health could be measured, DO would likely be the indicator of choice. Hutchinson (1975) states that probably more can be learned about the nature of a lake from a series of oxygen measurements than from any other kind of chemical data. The presence, absence, and levels of DO in a lake or reservoir both control and are controlled by many physical, chemical, and biological processes (e.g., photosynthesis, respiration, oxidation-reduction reactions, bacterial decomposition, temperature). DO measurements coupled with observations of water clarity (Secchi depth), temperature, nutrients, and some basic hydrologic and morphometric information provide meaningful insight into the ecological health of a reservoir.

Ideally, a reservoir has near-saturation concentrations of DO throughout the water column available to fish, insects, and zooplankton for respiration. This is usually the case during winter and spring, when most reservoirs are well mixed. However, in summer (characterized by more available sunlight, warmer water temperatures, and lower flows) both thermal stratification and increased biological activity may combine to produce a greater biochemical demand for oxygen than is available, particularly in the deeper portions of the reservoir. As a result, summer levels of DO often are low in the metalimnion and hypolimnion. Hypolimnetic and metalimnetic oxygen depletion are common, but undesirable, occurrences in many reservoirs, especially storage impoundments. Not only do lower concentrations of DO in the water column affect the assimilative capacity of a reservoir, but if they are low enough and/or sustained long enough, they adversely affect the health and diversity of the fish and benthic communities. Sustained near-bottom anoxia also promotes the biochemical release of ammonia, sulfide, and dissolved metals into the interstitial pore and near-bottom waters. If this phenomenon persists long enough, these chemicals can cause chronic or acute toxicity to bottom-dwelling animals.

A dissolved oxygen concentration of 2 mg/L was selected as a level below which undesirable ecological conditions exist. Values below this level primarily cause adverse impacts on benthic macroinvertebrate organisms and loss of quality habitat for fish. Historic information for reservoirs in the Tennessee Valley has shown that the burrowing mayfly (Hexagenia sp.) disappears from the benthic community at DO concentrations of 2 mg/L and below (Masters and McDonough, 1993). Most fish species avoid areas with DO concentrations below 2.0 mg/L (loss of habitat); fish growth and reproduction is reduced at these levels, and many highly desirable species such as sauger and walleye simply cannot survive at such low levels of DO.

The ecological health evaluation considers oxygen concentrations in both the water column (WC_{DO}) and near the bottom of the reservoir (B_{DO}). The DO rating at each sampling location (ranging from 1 "poor" to 5 "good") is based on monthly summer water column and bottom water DO concentrations. (Summer is defined as a six-month period when maximum thermal stratification and maximum hypolimnetic anoxia is expected to occur: April through September for the run-of-the-river reservoirs and May through October for the tributary reservoirs.) The final DO rating is the average of the water column DO rating and the bottom DO rating:

$$\text{DO Rating} = 0.5\ (WC_{DO}\ \text{rating} + B_{DO}\ \text{rating}),\ \text{where:}$$

WC_{DO} (Water Column DO) Rating--a six-month average of the percent of the reservoir cross-sectional area (at the location where the sampling was conducted--see Figure 3.1) that has a dissolved oxygen (DO) concentration less than 2.0 mg/L.

Average Cross-Sectional Area (DO less than 2 mg/L)	WC_{DO} Rating for Sampling Location
$<5\%$	5 (good);
$\geq 5\%$ but $\leq 10\%$	3 (fair);
$>10\%$	1 (poor).

Because most state DO water quality criteria for fish and aquatic life specify a minimum of 5.0 mg/L DO at the 1.5 meter (5 foot) depth, the WC_{DO} rating was lowered if the measured DO at the 1.5 meter depth at a sampling location was below 5.0 mg/L at any time. These adjustments were as follows:

Minimum DO at 1.5 meter depth	Sampling Location WC_{DO} Rating Change
<5.0 mg/L	Decreased one unit (e.g., 5 to 4);
<4.0 mg/L	Decreased two units (e.g., 5 to 3);
<3.0 mg/L	Decreased three units (e.g., 5 to 2);
etc.	etc.

B_{DO} (Bottom DO) Rating--a six month average of the percent of the reservoir cross-sectional bottom length (at the location where sampling was conducted, Figure 3.1) that has a DO concentration less than 2.0 mg/L, as follows:

Average Cross-Sectional Length (DO less than 2 mg/L)	B_{DO} Rating for Sampling Location
0%	5 (good);
0 to 10%	4
10 to 20%	3 (fair);
20 to 30%	2
>30%	1 (poor).

The average percent cross-sectional bottom length was computed based on the total cross-sectional bottom length at average minimum winter pool elevation. In addition, if anoxic bottom conditions (i.e., 0 mg/L) were observed at a location, the B_{DO} rating was lowered one unit, with a minimum rating of 1.

Chlorophyll Rating Scheme--Algae are the base of the aquatic food chain. Consequently, measuring algal biomass or primary productivity is important in evaluating ecological health. Without algae converting sunlight energy, carbon dioxide, and nutrients into oxygen and new plant material, a lake or reservoir could not support other aquatic life. Chlorophyll-a is a simple, long-standing, and well-accepted measurement for estimating algal biomass, algal productivity, and trophic condition of a lake or reservoir (Carlson, 1977). Too little primary productivity in reservoirs (mean summer chlorophyll-a concentrations less than 3 μg/L) indicates an inability to sustain a well-fed, growing, balanced, and healthy aquatic community. This eventually results in low standing stocks of fish. Too much primary productivity (mean summer concentrations greater than 15 μg/L) often is evidenced by occasional dense algal blooms, poor water clarity, and the predominance of noxious blue-green algae, and indicates poor ecological health. The large amounts of algal plant material produced under these conditions also deplete oxygen concentrations as the algae die and decompose. This can cause or aggravate problems of low DO in bottom waters.

Chlorophyll ratings at each sampling location are based on the average summer concentration of monthly, photic zone chlorophyll-a samples (corrected) collected from April through September (or October), as shown below. If triplicate samples are collected at a sampling location, the median value of the triplicate is used in calculating the summer average and the maximum.

Average Chlorophyll-a Concentration*	Sampling Location Chlorophyll Rating
Less than 3 μg/L	3 (fair);**
3 to 10 μg/L	5 (good);
10.1 to 15 μg/L	3 (fair);
Greater than 15 μg/L	1 (poor).

* If any single chlorophyll-a sample exceeds 30 μg/L, the value is not included in calculating the average, but the rating is decreased one unit, (i.e., 5 to 4, or 4 to 3, etc.) for each sample that exceeded 30 μg/L.

** If nutrients are present (e.g., nitrate+nitrite greater than 0.05 mg/L and total phosphorus greater than 0.01 mg/L) but chlorophyll-a concentrations are generally low (e.g., $\leq$ 2 μg/L), another/other limiting or inhibiting factors such as toxicity is likely. When these conditions exist, chlorophyll is rated 2 (poor).

Sediment Quality Rating Scheme--Contaminated bottom sediments can have direct adverse impacts on bottom fauna and can often be long-term sources of toxic substances to the aquatic environment. They may impact wildlife and humans through the consumption of contaminated food or water or through direct contact. These impacts may occur even though the water above the sediments meets water quality criteria. There are many sediment assessment methods, but there is no single method that measures all contaminated sediment impacts at all times and to all biological organisms (EPA, 1992). TVA's approach combines two sediment assessment methods--one biological, the other chemical--to evaluate sediment quality. TVA's scoring criterion is based on ratings for the toxicity of sediment pore water (S_{TOX}) to test organisms, and the chemical analysis of sediment (S_{CHM}) for heavy metals, PCBs, organochlorine pesticides, and un-ionized ammonia (Table 2.3). The final sediment quality score or rating is the average of these two ratings:

Sediment Quality Rating = 0.5 (S_{TOX} rating + S_{CHM} rating), where:

***S_{TOX}* (Sediment Toxicity) Rating**--Sediment toxicity is evaluated using both Rotox® (rotifer Brachionus calyciflorus survival) and daphnid (Ceriodaphnia dubia) acute tests. The acute toxicity evaluations entail the exposure of these organisms (zooplankton) to interstitial pore water from sediment. The survival rates of the organisms are based on the average survival in four replicates of five individuals each, compared to a control. If average survival is significantly reduced (95 percent probability) from the control, the sample is considered to be toxic. Sampling locations are rated as follows:

Sampling Location S_{TOX} Rating	Percent Survival of Ceriodaphnia and/or Branchionus
5 (good)	Survival not significantly different than control and greater than or equal to 80 percent for both species, (i.e., no significant toxicity);
3 (fair)	Survival not significantly different from control, but less than 80 percent survival for either species; or
1 (poor)	Survival of either organism significantly less than control, (i.e., significant toxicity).

S_{CHM} (Sediment Chemistry) Rating--Splits of the same sediment used in the sediment toxicity testing are analyzed for heavy metals, organochlorine pesticides and PCBs, and un-ionized ammonia. Sediment chemistry ratings are based on: (a) concentrations of heavy metals (Cd, Cr, Cu, Pb, Hg, Ni, and Zn) that exceed freshwater sediment guidelines (EPA, 1977); (b) detectable amounts of PCBs or pesticides; and (c) concentrations of un-ionized ammonia in pore water above 200 μg NH_3/L. Each sampling location is rated as follows:

Sampling Location S_{CHM} Rating	Sediment Chemistry*
5 (good)	No analytes exceed guidelines;
3 (fair)	One or two analytes exceed guidelines;
1 (poor)	Three or more exceed guidelines.

* Analytes (i.e., heavy metals, pesticides, PCBs and ammonia) and guidelines are listed in Table 2.3.

Benthic Community Rating Scheme--Six community characteristics (or metrics), with scoring criteria specific to either run-of-the-river or storage reservoirs, are used to evaluate the ecological health of the benthic macroinvertebrate community (Table 3.1). These characteristics are:

1. **Taxa Richness**--The number of different taxa present. An increase in total taxa or taxa richness is used to indicate better conditions than low taxa richness.

2. **Longed-Lived species**--The number of taxa (Corbicula, Hexagenia, mussels, and snails) present. These organisms are long-lived and their presence indicate conditions which allow long-term survival.

3. **EPT**--The number of different taxa within these orders (Ephemeroptera-mayflies, Plecoptera-stoneflies, and Tricoptera-caddisflies). Higher numbers of this metric indicate good water quality conditions in streams. A similar use is incorporated here despite expected lower numbers in reservoirs than in streams.

4. **Proportion as Chironomidae**--The percent of the total organisms in the sample that are chironomids. A higher proportion indicates poor conditions.

5. **Proportion as Tubificidae**--The percent of the total organisms present that are tubificids. A higher proportion indicates poor quality.

6. **Proportion as Dominant Taxa**--The percent of total organisms present that are members of the dominant taxon. This metric is used as an evenness indicator. A large proportion comprised by one or two taxa indicates poor conditions.

Specific scoring criteria were developed for each of the six metrics for both run-of-the-river reservoirs and tributary reservoirs. And given the substantial habitat differences among forebays, transition zones/mid-reservoirs, and inflows, specific scoring criteria were also developed for each of these areas (Table 3.1). Data handling also differed among the metrics. Metric 1, taxa richness, is the average total number of taxa per sample at each site. Metrics 2 and 3 are handled similarly. For Metric 4 the proportion of chironomids in each sample is calculated, then these proportions are averaged for a location. An alternative that was considered was to sum the number of chironomids in all samples and divide by the sum of the total individuals for all samples. The approach selected gives equal weight to all samples regardless of sample size or sampling gear (Ponar or Peterson dredge). This eliminates the bias introduced in the alternate approach when one sample at a site has an exceptionally large or small density. Metric 5 is calculated in the same way. Metric 6, proportion as dominant taxa, is calculated as proportion for each sample, similar to computations for Metrics 4 and 5. The proportion is calculated for the dominant taxon in each sample even if the dominant taxon differed among the samples at a site. This allows more discretion to identify imbalances at a site than developing an average for a single dominant taxon for all samples at the site.

A quantitative approach is used to evaluate the benthic macroinvertebrate community information. The range of values for each of the six metrics found in the available data base (in this case, all the 1991, 1992, and 1993 Vital Signs benthic monitoring data) serves as the basis for evaluation criteria. For each metric at each of the three reservoir sampling zones (forebay, transition zone/mid-reservoir, and inflow) and two reservoir types (run-of-the-river and tributary) the data base values are divided into three groups using Ward's minimum variance analysis (SAS, 1989). This procedure places observations into three homogenous groups of approximate equal size. The groups are sorted and categorized as poor, fair, or good. Scoring criteria represent values between the highest and the lowest value in each group (Table 3.1). Results for each metric for the current year are then compared with these criteria and assigned quantitative values of 1 (poor), 3 (fair), or 5 (good) if they fall within the bottom-, middle-, or top-group, respectively. This results in a minimum score of 6 if all metrics at a site are poor, and a maximum score of 30 if all metrics are good. Detailed scoring criteria for each metric are provided in Table 3.1.

Metrics are summed for each reservoir sampling site to yield a final benthic score and are evaluated as follows:

Sum of Benthic Community Metric Scores	Sampling Location Benthic Rating
6-10	1 (poor)
11-15	2
16-20	3 (fair)
21-25	4
26-30	5 (good)

Fish Assemblage Rating Scheme--In 1993, a Reservoir Fish Assemblage Index (RFAI) (Hickman et.al, 1994) was used to rate fish assemblages as they relate to the overall ecological health of the reservoir. The RFAI is based on 12 metrics with scoring criteria specific to either run-of-the-river or storage reservoirs. Scoring criteria also are specific for the type of sample location within reservoirs--forebay, transition zone/mid-reservoir, or inflow; and for the type of sampling gear used (i.e., electrofishing for littoral fish communities and gill netting for pelagic fish communities). The metrics address the following 12 reservoir fish assemblage characteristics. Table 3.2 lists the trophic, reproductive, and tolerance designations of fish species collected as part of Vital Signs Reservoir Monitoring activities.

Species Richness and Composition

1. **Total number of species**--Greater numbers of species are considered representative of healthier aquatic ecosystems. As conditions degrade, numbers of species at a site decline.

2. **Number of piscivore species**--Higher diversity of piscivores is indicative of better quality environment.

3. **Number of sunfish species**--Lepomid sunfish (excludes black basses, crappies, and rock bass) are basically insectivores, and high diversity of this group is indicative of reduced siltation and high sediment quality in littoral areas.

4. **Number of sucker species**--Suckers are also insectivores but inhabit the pelagic and more riverine sections of reservoirs. This metric closely parallels the lithophilic spawning species metric (Metric 10) and may be deleted from future RFAI calculations.

5. **Number of intolerant species**--This group is made up of species that are particularly intolerant of habitat degradation. Higher densities of intolerant individuals represent better environmental quality.

6. **Percentage of tolerant individuals** (excluding Young-of-Year)--This metric signifies poorer quality with increasing proportions of individuals tolerant of degraded conditions.

7. **Percent dominance by one species**--Ecological quality is considered reduced if one species dominates the resident fish community.

Trophic Composition

8. **Percentage of individuals as omnivores**--Omnivores are less sensitive to environmental stresses due to their ability to vary their diets. As trophic links are disrupted due to degraded conditions, specialist species such as insectivores decline while opportunistic omnivorous species increase in relative abundance.

9. **Percentage of individuals as insectivores**--Due to the special dietary requirements of this group of species and the limitations of their food source in degraded environments, proportion of insectivores increases with environmental quality.

Reproductive Composition

10. **Number of lithophilic spawning species**--Lithophilic broadcast spawners are selected due to their sensitivity to siltation. Numbers of lithophilic spawning species increase in reservoirs providing suitable conditions reflective of good environmental quality.

Abundance and Fish Health

11. **Total catch per unit effort** (number of individuals)--This metric is based upon the assumption that high quality fish assemblages support large numbers of individuals.

12. **Percent individuals with anomalies**--Incidence of diseases, lesions, tumors, external parasites, deformities, blindness, and natural hybridization are noted for all fish measured, with higher incidence indicating poor environmental conditions.

Each metric is assigned a score of 5, 3, or 1 -- representing "good," "fair," or "poor," conditions, respectively. Due to the distinct habitat differences among reservoirs and sampling locations--and the differences in fish assemblages they support--different scoring criteria are used for each of the 12 metrics for: (a) each reservoir type (i.e., run-of-the-river and tributary storage reservoirs); (b) each sampling location (forebay, transition/mid-reservoir, and inflow); and (c) each type of sampling gear used to collect the fish data (electrofishing and gill netting). Scoring criteria by reservoir type, by sampling location, and by sampling gear type are listed for each of the 12 fish community metrics in Table 3.3. There is not yet enough information for inflow sampling locations on tributary reservoirs to establish criteria for the fish community metrics at these particular sites.

The average of the sum of the electrofishing scores and the sum of the gill netting scores results in the Reservoir Fish Assemblage Index (RFAI) for each sampling location. The range of "attainable" RFAI values could be from 12 (if all metrics scored 1) to 60 (if all metrics scored 5). This range of RFAI values, from 12 to 60, is divided into five equal groupings to evaluate the overall health of the fish assemblage at each sampling location, as follows:

RFAI Score	Sampling Location Rating
12-21	1 (poor)
21-31	2
32-41	3 (fair)
42-51	4
52-60	5 (good)

A discussion of the development of the RFAI and results of the fish evaluations for the 1991-1993 Vital Signs Monitoring data are available in TVA technical reports (Scott, et. al, 1992; Brown, et. al, 1993; and Hickman et. al, 1994).

Overall Reservoir Health Determination--The overall ecological evaluation methodology combines the five previously discussed aquatic ecosystem indicators (DO, chlorophyll, sediment quality, benthic macroinvertebrates, and fish assemblage) into a single numeric value. This facilitates spatial comparisons among reservoirs and temporal comparisons for a reservoir through time.

The first step in determining an overall reservoir health score is to sum the ratings for all indicators (ranging from 1-poor to 5-excellent) at a sample site. The number of indicators monitored at each site varies. Generally, all five indicators are included; however, this is not always the case. For example, chlorophyll and sediment quality are not monitored at the inflows on run-of-the-river reservoirs because in situ plankton production of chlorophyll does not occur significantly in that part of a reservoir and because sediments do not accumulate there. The number of sites per reservoir also varies from one (the forebay) in small tributary reservoirs to four (forebay, transition zone, inflow, and embayment) in selected run-of-the-river reservoirs. As a result, the number of ratings vary from five to 18 for the 30 reservoirs monitored in 1993. Specific information on what indicators were sampled in each reservoir is in Table 2.1.

To arrive at an overall health evaluation for a reservoir, the sum of the ratings from all sites are totaled, divided by the maximum potential ratings for that reservoir, and expressed as a percentage. For example, a small reservoir with only one sample site, the minimum health evaluation would be 20 percent (all five indicators rated poor-1 for a total score of 5 divided by the maximum possible total of 25) and the maximum would be 100 percent (all five indicators rated good-5). This same range of 20 to 100 percent applies to all reservoirs regardless of the number of sample sites, and the same calculation process is used.

The next step is to divide the 20-100 percent scoring range into categories representing good, fair, and poor ecological health conditions. This has been achieved as follows:

1. Results are plotted and examined for apparent groupings.

2. Groupings are compared to known, a priori conditions (focusing on reservoirs with known poor conditions), and good-fair and fair-poor boundaries were established subjectively.

3. The groupings are compared to a trisection of the overall scoring range. A scoring range is adjusted up or down a few percentage points to ensure a reservoir with known conditions falls within the appropriate category. This is done only in circumstances where a nominal adjustment is necessary.

Based on these considerations, during the first two years of development (1991-1992), scoring ranges were as follows:

	Poor	Fair	Good
Run-of-the-river reservoirs	≤52%	>52-72%	>72%
Tributary, storage reservoirs	≤56%	>56-72%	>72%

The difference in the poor scoring range between the two types of reservoirs is due to the fact that two storage reservoirs with known poor conditions rated slightly higher than the boundary for the lower (poor) grouping on the run-of-the-river reservoirs. Hence, the high end of the lower scoring range for storage reservoirs was shifted upward from 52 to 56 percent to accommodate these reservoirs with known poor conditions.

Based on the experience gained in developing this evaluation process, review of the evaluation scheme by other state and federal professionals, and results of another year of monitoring, slight modifications were made in the original evaluation process and the numerical scoring criteria for each of the five ecological health indicators. In 1993, run-of-the-river reservoirs with overall scores greater than 72 percent were evaluated as "good"; those between 52 percent and 72 percent were rated "fair"; and those whose overall scores were less than 52 percent were rated "poor." Similarly, in 1993, tributary storage reservoirs were evaluated as "good" if their overall reservoir percentage was greater than or equal to 72 percent; "fair" if its overall reservoir percentage was between 57 percent and 72 percent; and "poor" if its overall reservoir percentage was less than 57 percent. The 1993 scoring ranges were:

	Poor	Fair	Good
Run-of-the-river reservoirs	<52%	52-72%	>72%
Tributary, storage reservoirs	<57%	57-72%	≥72%

Two examples that illustrate the overall reservoir health evaluation methodology are presented in Tables 3.6 and 3.7. Wilson Reservoir (Table 3.6) has five aquatic health indicators at one location and three indicators at another location. Cherokee Reservoir (Table 3.7) has five aquatic health indicators at one location and four indicators at another location.

3.1.3 Stream Ecological Health

An evaluation methodology similar to the Reservoir Ecological Health Evaluation (Section 3.1.2) is used to assess the overall ecological health at each of the 12 stream monitoring locations. Particular emphasis is given to the relationship between the conditions found at the stream sampling site and the potential for impacts on conditions in the downstream reservoir. The following overview summarizes TVA's stream ecological health evaluation methodology. The evaluations are based on four aquatic health indicators: (1) total phosphorus (as a measure of nutrient enrichment and potential for excessive algal productivity); (2) sediment quality; (3) benthic community; and (4) fish community.

At each stream sampling location the four aquatic health indicators are rated as "good," "fair," or "poor." Equal weights are given to each indicator, and each rating is assigned a numeric value of 1, 3, or 5 corresponding to "poor," "fair," or "good." The four scores are summed to produce an overall stream health evaluation at the sampling location ranging from 4 to 20. A stream sampling location with an overall rating of 9 or less ($\leq$45 percent) was rated "poor"; 10 to 15 (50 percent to 75 percent) "fair"; and 16 to 20 (80 percent to 100 percent) "good."

Nutrient Concentration Rating Scheme--Phosphorus is an essential nutrient required by aquatic plants for photosynthesis and growth. In freshwater ecosystems phosphorus is most often the nutrient least available to plants relative to their needs, and thus can limit algal productivity. When present in excess of critical concentrations, in combination with sufficient nitrogen phosphates, it can stimulate algae and other aquatic plant growth, sometimes to an undesirable level that interferes with water uses. To prevent the development of biological nuisances and to control accelerated phosphorus loading for the protection of downstream receiving waterways, EPA recommends a guideline for maximum total phosphorus concentration of 0.10 mg/L for streams or flowing waters and 0.05 mg/L at the point where any stream enters a lake or reservoir (EPA, 1986). These guidelines are used as the basis to evaluate total phosphorus concentrations in Tennessee Valley streams (average of 6 samples per year):

Average Total Phosphorus Concentration*	Sampling Location Nutrient Enrichment Rating
Less than 0.05 mg/L	5 (good);
0.05 to 0.10 mg/L	3 (fair);
Greater than 0.10 mg/L	1 (poor).

* In addition, waters that receive high nitrogen concentrations in the presence of sufficient phosphorus often stimulate the growth of algae and other aquatic plants to an undesirable extent. High average (relative to the majority of Valley streams) nitrate+nitrite nitrogen concentrations greater than 0.65 mg/L resulted in lowering a rating from "good" to "fair" or from "fair" to "poor," as appropriate.

Sediment Quality Rating Scheme--The stream sediment quality evaluation methodology is the same as for reservoir sediment quality. The scoring criterion is based on ratings for the acute toxicity of sediment pore water (S_{TOX}) to both Rotox® (rotifer, Brachionus calyciflorus survival) and daphnid (Ceriodaphnia dubia), and the chemical analysis of sediment (S_{CHM}) for heavy metals, PCBs, organochlorine pesticides, and un-ionized ammonia. The final sediment quality score or rating is the average of these two ratings. (Details are given in Section 2.1.2, Reservoir Sediment Quality Rating Scheme.)

Sediment Quality Rating = 0.5 (S_{TOX} rating + S_{CHM} rating).

Benthic Community Rating Scheme--A modified version of the benthic index of biotic integrity (BIBI) (Kerans et. al, 1992) is used to rate the condition of the benthic community. Twelve benthic community attributes such as total taxa richness and richness of specific taxa, relative abundance of functional and trophic groups and certain tolerant organisms, and total abundance are used. Each of the 12 metrics is scored based on best expected conditions at reference sites supporting healthy benthic communities and good water quality. At each site three Surber (riffle), three Hess (pool), and one qualitative sample were taken. EPT, intolerant snail and mussel species metrics were computed pooling all qualitative and quantitative samples. Total abundance was computed pooling all quantitative samples. The remaining metrics were computed separately for each quantitative sample at a site.

Taxa Richness and Community Composition

1. Taxa richness
2. Occurrence of intolerant snail and mussel species*
3. Number of mayfly (Ephemeroptera) taxa
4. Number of stonefly (Plecoptera) taxa
5. Number of caddisfly (Trichoptera) taxa
6. Total number of EPT taxa*
7. Percentage as oligochaetes
8. Percentage in the two most dominant taxa

Trophic and Functional-Feeding Group

9. Percent as omnivores and scavengers
10. Percent as collector-filterers
11. Percent as predators

Abundance

12. Total abundance of individuals (combined quantitative samples, lower score given for extremely low values or extremely high values)

* Metric applied to qualitative and quantitative samples combined. All other metrics applied to individual quantitative samples and resultant scores averaged.

Values obtained for each of these metrics are scored (1-poor, 3-fair, or 5-good) against best expected value based on data from reference sites supporting healthy fish communities and having good water quality (Table 3.4). Metric scores are then summed to produce an index ranging from 12 to 60. The resultant benthic community index for each stream location is classified as "poor" (<30), "fair" (34-44), or "good" (>45). If the index score falls between 30-33, professional judgment is used to categorize the benthic community as either poor or fair.

Fish Community–A modified version of Karr's (1981) index of biotic integrity (IBI) is used to assess the condition of the resident fish community at 11 of the 12 stream monitoring locations. (Fish community sampling was not conducted on the Elk River in 1993.) An index and rating are produced for each site by applying the following 12 metrics.

Species richness and composition

1. Number of native species
2. Number of darter species
3. Number of native sunfish species (excluding Micropterus sp.)
4. Number of sucker species
5. Number of intolerant species
6. Percentage of individuals as tolerant species

Trophic structure

7. Percentage of individuals as omnivores
8. Percentage of individuals as specialized insectivorous minnows and darters
9. Percentage of individuals as piscivores

Fish abundance and condition

10. Catch rate (average number per unit of sampling effort, seine hauls and shocking runs)
11. Percentage of individuals as hybrids
12. Percentage of individuals with poor condition, injury, deformity, disease, or other anomaly

Actual values obtained for each of these metrics are scored (1-poor, 3-fair, or 5-good) against values expected under pristine conditions (i.e., best expected value, Table 3.5). The 12 metric scores are then summed to produce an index ranging from 12 to 60, and the fish community at the stream sampling location is rated as "poor" (index <36), "fair" (index 40-44), or "good" (index >46). Professional judgment is involved when a fish community index falls between ratings. For example, an index of 38 falls between "poor" and "fair" and would be either "poor" or "fair" depending on the judgment of the biologist taking the sample. Judgment usually is influenced by which of the 12 metrics rates poorest, condition of the coexisting macroinvertebrate community, or previous IBI ratings obtained for the site.

3.2 Use Suitability

3.2.1 Bacteriological Quality Evaluation

Each of the seven Valley states follows the EPA guideline of using a geometric mean fecal coliform concentration of 200 colonies per 100 milliliters (200/100 mL) of water to determine use suitability for whole body water contact recreation (EPA, 1991). Six of the states use an additional fecal coliform criterion to determine if a site is unsuitable for water contact recreation; either a percentage of samples exceeds 400/100 mL, or a maximum concentration of 1000/100 mL for any one sample.

TVA reports on the bacteriological condition of stream and reservoirs throughout the Valley in its publication *RiverPulse* using the following three categories:

Posted by the State:

+ The state has issued a public advisory against water contact and has posted signs near the body of water with the advisory.

+ Each area presently posted exceeds the geometric mean criterion due to a known human source of contamination.

Exceeds Criterion:

+ The geometric mean of a minimum of ten fecal coliform bacteria samples collected by TVA over a period of not more than 30 days from May through September exceeds 200/100 mL.

+ Each site identified is believed to exceed criterion due to animal waste.

Meets Criterion:

+ The geometric mean of a minimum of ten fecal coliform bacteria samples collected by TVA over a period of not more than 30 days from May through September is less than 200/100 mL.

TVA recommends no water contact recreation for at least two days following rain events at locations which only partially support water contact because of the bacteria which are washed into the water. In addition, TVA recommends no water contact recreation in the immediate vicinity of wastewater discharges regardless of what fecal bacteria data show, because of the possibility of mechanical breakdowns and sewage bypasses or overflows.

3.2.2 Fish Tissue Consumption Advisories

TVA and state agencies coordinate with one another in conducting fish tissue studies in the Tennessee Valley. There is a shared interest in the status of TVA reservoirs as important and valuable resources. As the government organizations responsible for regulatory and public health decisions related to lakes and streams, state agencies are interested in knowing both the ecological health of Valley reservoirs and whether the fish are safe to eat.

Prior to initiating sample collections each autumn, TVA and involved Valley state agencies meet to discuss the previous year's results and decide appropriate direction for further study. The group reaches agreement on species to collect, locations to sample, and the agencies responsible for conducting each part of the work. TVA provides its results to the appropriate states, then the states take action to protect public health. This usually involves deciding whether to issue an advisory against consuming selected species or age classes of fish. TVA's role in this process is to provide accurate results, to provide consultation to the state(s) as appropriate, and support the state's decisions.

Figure 3.1

Cross-section of Tellico Reservoir Forebay Showing Areas where Summer DO Concentrations averaged less than or equal to 2 mg/l.

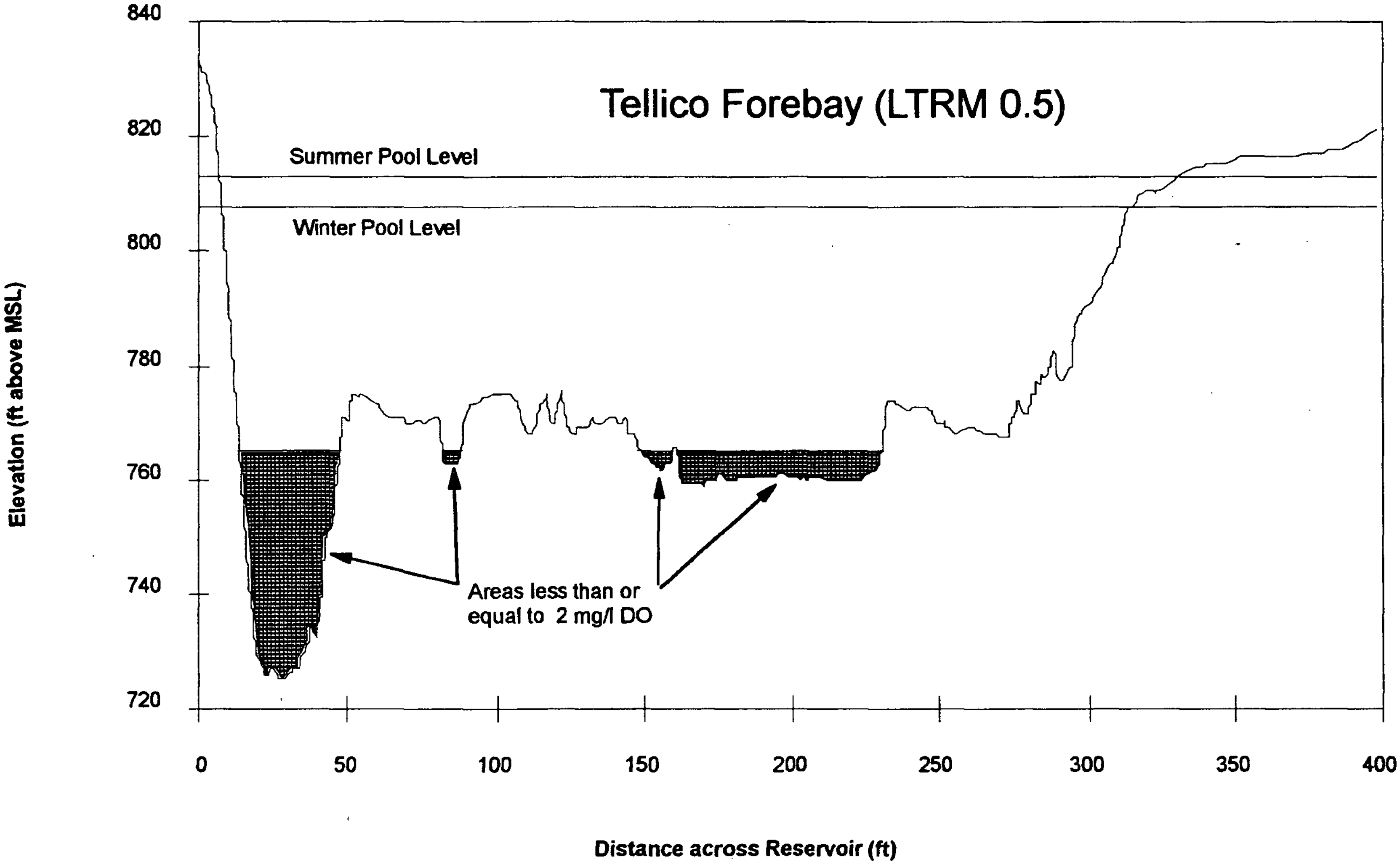


Table 3.1
1993 Vital Signs Monitoring

Reservoir Benthic Macroinvertebrate Community metrics and scoring criteria developed for Tennessee Valley Reservoirs, with a score of 5 representing highest quality, and a score of 1 the poorest.

Run-of-the-River Reservoirs

Benthic Community Metrics	Forebay			Transition			Inflow		
	5	3	1	5	3	1	5	3	1
Taxa Richness	>6.1	4.6-6.1	<4.6	>7.6	6.5-7.6	<6.5	>8.0	5.2-8.0	<5.2
Long Lived Species	>1.2	0.35-1.2	<0.35	>2.4	1.3-2.4	<1.3	>1.9	1.3-1.9	<1.3
EPT (mayfly, stonefly, caddisfly)	>0.95	0.5-0.95	<0.5	>0.95	0.6-0.95	<0.6	>1.4	0.6-1.4	<0.6
% Chironomidae	<30	30-45	>45	<25	25-40	>40	<10	10-30	>30
% Tubificidae	<25	25-50	>50	<20	20-40	>40	<11	11-25	>25
% Dominant Taxa	<75	75-90	>90	<65	65-70	>70	<70	70-80	>80

Tributary Reservoirs

Benthic Community Metrics	Forebay						Mid-Res/Inflow		
	5	3	1				5	3	1
Taxa Richness	>4.3	2.3-4.3	<2.3	--	--	--	>6.2	3.4-6.2	<3.4
Long Lived Species	>1.0	0.15-1.0	<0.15	--	--	--	>0.45	0.15-0.45	<0.15
EPT (mayfly, stonefly, caddisfly)	>0.35	0.15-0.35	<0.15	--	--	--	>0.3	0.09-0.3	<0.09
% Chironomidae	<30	30-50	>50	--	--	--	<25	25-70	>70
% Tubificidae	<30	30-60	>60	--	--	--	<45	45-75	>75
% Dominant Taxa	<78	78-91	>91	--	--	--	<70	70-80	>80

Table 3.2
1993 Vital Signs Monitoring

Core fish species list with trophic tolerance, and reproductive designations (*) for use in Reservoir Fish Assemblage Index (RFAI) for TVA reservoirs, 1993.

Species	Trophic Guild	Tolerance	Lithophilic Spawner
Chestnut lamprey	PS		L
Spotted gar	PI		
Longnose gar	PI	TOL	
Shortnose gar	PI	TOL	
Bowfin	PI		
American eel	PI		
Skipjack herring	PI	INT	
Gizzard shad	OM	TOL	
Threadfin shad	PL		
Mooneye	IN		L
Chain pickerel	PI		
Central stoneroller	HB		
Common carp	OM	TOL	
Goldfish	OM	TOL	
Silver chub	IN	INT	
Golden shiner	OM	TOL	
Emerald shiner	IN		
Ghost shiner	IN		
Spotfin shiner	IN		
Mimic shiner	IN	INT	
Steelcolor shiner	IN		
Pugnose minnow	IN		
Bluntnose minnow	OM		
Fathead minnow	OM		
Bullhead minnow	IN		
River carpsucker	OM		
Quillback	OM		
Northern hog sucker	IN	INT	L
Smallmouth buffalo	OM		
Bigmouth buffalo	PL		
Black buffalo	OM		
Spotted sucker	IN	INT	L
Silver redhorse	IN		L
Shorthead redhorse	IN		L
River redhorse	IN	INT	L
Black redhorse	IN	INT	L
Golden redhorse	IN		L

Table 3.2 (continued)
1993 Vital Signs Monitoring

Core fish species list with trophic tolerance, and reproductive designations (*) for use in Reservoir Fish Assemblage Index (RFAI) for TVA reservoirs, 1993.

Species	Trophic Guild	Tolerance	Lithophilic Spawner
Blue catfish	OM		
Black bullhead	OM	TOL	
Yellow bullhead	OM	TOL	
Brown bullhead	OM	TOL	
Channel catfish	OM		
Flathead catfish	PI		
Blackstripe topminnow	IN		
Blackspotted topminnow	IN		
Mosquitofish	IN	TOL	
Brook Silverside	IN		
White bass	PI		L
Yellow bass	PI		L
Rock bass	PI	INT	
Redbreast sunfish	IN	TOL	
Green sunfish	IN	TOL	
Warmouth	IN		
Orangespotted sunfish	IN		
Bluegill	IN		
Longear sunfish	IN	INT	
Redear sunfish	IN		
Spotted sunfish	IN		
Smallmouth bass	PI		
Spotted bass	PI		
Largemouth bass	PI		
White crappie	PI		
Black crappie	PI		
Yellow perch	IN		
Logperch	IN		L
Sauger	PI		L
Walleye	PI		L
Freshwater drum	IN		

*Designations:
Trophic: herbivore (HB), parasitic (PS), planktivore (PL), omnivore (OM), insectivore (IN), piscivore (PI)
Tolerance: tolerant (TOL), intolerant (INT)
Lithophilic spawning species (L)

Table 3.3
1993 Vital Signs Monitoring

Reservoir Fish Assemblage Index metrics and scoring criteria developed for TVA ***Run-of-the-River*** reservoirs. Scoring reflects fish community quality, with a score of 5 representing highest quality, and a score of 1 the poorest.

Metric	Gear*	Inflow			Transition			Forebay		
		5	3	1	5	3	1	5	3	1
Species Richness										
1. Total species	E	>27	21-27	<21	>25	19-25	<19	>25	21-25	<21
	G	--	--	--	>21	18-21	<18	>19	17-19	<17
2. Piscivore species	E	>9	5-9	<5	>8	6-8	<6	>8	7-8	<7
	G	--	--	--	>9	7-9	<7	>9	8-9	<8
3. Sunfish species	E	>4	3-4	<3	>5	4-5	<4	>5	4-5	<4
	G	--	--	--	>2	2	<2	>2	2	<2
4. Sucker species	E	>5	4-5	<4	>3	2-3	<2	>2	2	<2
	G	--	--	--	>3	2-3	<2	>3	2-3	<2
5. Intolerant species	E	>4	3-4	<3	>2	2	<2	>2	2	<2
	G	--	--	--	>2	2	<2	>2	2	<2
6. Percent tolerant individuals	E	<40	40-60	>60	<30	30-60	>60	<30	30-60	>60
	G	--	--	--	<20	20-35	>35	<25	25-40	>40
7. Percent dominance by one species	E	<30	30-50	>50	<40	40-60	>60	<40	40-60	>60
	G	--	--	--	<30	30-40	>40	<30	30-40	>40
Trophic Composition										
8. Percent individuals as omnivores	E	<30	30-60	>60	<30	30-60	>60	<30	30-60	>60
	G	--	--	--	<35	35-55	>55	<35	35-50	>50
9. Percent individuals as insectivores	E	>50	30-50	<30	>70	40-70	<40	>60	30-60	<30
	G	--	--	--	>15	5-15	<5	>10	5-10	<5
Reproductive Composition										
10. Lithophilic spawning species	E	>7	5-7	<5	>4	3-4	<3	>5	4-5	<4
	G	--	--	--	>5	5	<5	>5	5	<5
Abundance and Health										
11. Total catch per unit effort	E	>120	70-120	<70	>130	70-130	<70	>130	80-130	<80
	G	--	--	--	>30	15-30	<15	>40	20-40	<20
12. Percent individuals with anomalies	E	<1	1-3	>3	<1	1-3	>3	<1	1-3	>3
	G	--	--	--	<1	1-3	>3	<1	1-3	>3

* E=electrofishing; G=gill netting

Table 3.3 (continued)
1993 Vital Signs Monitoring

Reservoir Fish Assemblage Index metrics and scoring criteria developed for TVA ***Tributary*** reservoirs. Scoring reflects fish community quality, with a score of 5 representing highest quality, and a score of 1 the poorest.

Metric	Gear*	Inflow			Mid-Reservoir			Forebay		
		5	3	1	5	3	1	5	3	1
Species Richness										
1. Total species	E	--	--	--	>17	15-17	<15	>25	21-25	<21
	G	--	--	--	>16	13-16	<13	>14	11-14	<11
2. Piscivore species	E	--	--	--	>6	5-6	<5	>5	4-5	<4
	G	--	--	--	>7	7	<7	>6	5-6	<5
3. Sunfish species	E	--	--	--	>3	3	<3	>4	3-4	<3
	G	--	--	--	>1	1	<1	>1	1	<1
4. Sucker species	E	--	--	--	>3	2-3	<2	>2	2	<2
	G	--	--	--	>3	2-3	<2	>3	2-3	<2
5. Intolerant species	E	--	--	--	>2	2	<2	>3	2-3	<3
	G	--	--	--	>1	1	<1	>1	1	<1
6. Percent tolerant individuals	E	--	--	--	<20	20-40	>40	<20	20-40	>40
	G	--	--	--	<20	20-40	>40	<20	20-40	>40
7. Percent dominance by one species	E	--	--	--	<40	40-60	>60	<40	40-60	>60
	G	--	--	--	<30	30-50	>50	<30	30-50	>50
Trophic Composition										
8. Percent individuals as omnivores	E	--	--	--	<15	15-30	>30	<20	20-40	>40
	G	--	--	--	<30	30-50	>50	<30	30-50	>50
9. Percent individuals as insectivores	E	--	--	--	>70	50-70	<50	>70	40-70	<40
	G	--	--	--	>10	5-10	<5	>15	5-15	<5
Reproductive Composition										
10. Lithophilic spawning species	E	--	--	--	>5	4-5	<4	>4	3-4	<3
	G	--	--	--	>4	3-4	<3	>3	2-3	<2
Abundance and Health										
11. Total catch per unit effort	E	--	--	--	>100	60-100	<60	>120	60-120	<60
	G	--	--	--	>25	15-25	<15	>20	10-20	<10
12. Percent individuals with anomalies	E	--	--	--	<1	1-3	>3	<1	1-3	>3
	G	--	--	--	<1	1-3	>3	<1	1-3	>3

* E=electrofishing; G=gill netting

Table 3.4
1993 Vital Signs Monitoring

Benthic Macroinvertebrate Community Index of Biotic Integrity (IBI) metrics and scoring criteria developed for Tennessee Valley Streams, with a score of 5 representing highest quality, and a score of 1 the poorest.

Stream Benthic Index of Biotic Integrity Metrics				
Metric	**Sampling Gear**	**Score**		
		1	**3**	**5**
Taxa Richness and Community Composition				
1. Taxa Richness	Surber or Hess	<9	9-17	≥18
2. Occurrence of mollusk species*	Combined	0	--	≥1
3. Number of mayfly (Ephemeroptera) taxa	Surber or Hess	<3	3-5	≥6
4. Number of stonefly (Plecoptera) taxa	Surber or Hess	<2	--	≥2
5. Number of caddisfly (Trichoptera) taxa	Surber or Hess	<2	2-3	≥4
6. Number of EPT taxa*	Combined	<14	14-24	≥25
7. Proportion of oligochaetes	Surber or Hess	≥0.05	0.01-0.049	<0.01
8. Proportion of the two most abundant taxa	Surber or Hess	≥0.75	0.5-0.749	<0.5
Trophic and Functional-Feeding Group				
9. Proportion as omnivores and scavangers	Surber or Hess	≥0.9	0.6-0.89	<0.6
10. Proportion as collectors/filterers	Hess	≥0.5	0.2-0.49	<0.2
	Surber	≥0.6	0.3-0.59	<0.3
11. Proportion as predators	Surber or Hess	≤0.04	--	>0.04
Abundance				
12. Total abundance in quantitative samples (Lower scores given for extremely low and high values)	Combined	≤400 >5000	401-500 4001-5000	501-4000
* Metric applied to qualitative and quantitative samples combined. All other metrics applied to individual quantitative samples and resultant scores averaged.				

Table 3.5
1993 Vital Signs Monitoring

Fish Community Index of Biotic Integrity (IBI) metrics and scoring criteria developed for Tennessee Valley Streams, with a score of 5 representing highest quality, and a score of 1 the poorest.

Stream Fish Community Index of Biotic Integrity Metrics

Metric	Duck River 22.5			Bear Creek 25.2			Sequatchie River 7.1			Hiwassee River 37.0		
	1	3	5	1	3	5	1	3	5	1	3	5
Species Richness and Composition												
1. Number of native species	<27	27-53	>53	<23	23-44	>44	<23	23-45	>45	<21	21-41	>41
2. Number of darter species	<5	5-9	>9	<4	4-7	>7	<5	5-8	>8	<5	5-8	>8
3. Sunfish species, less Micropterus	<3	3-5	>5	<3	3-5	>5	<3	3-5	>5	<2	2-3	>3
4. Number of sucker species	<4	4-7	>7	<4	4-7	>7	<4	4-7	>7	<4	4-7	>7
5. Number of intolerant species	<4	4-6	>6	<2	2-3	>3	<3	3-4	>4	<2	2	>2
6. Percent tolerant individuals	>20	10-20	<10	>20	10-20	<10	>20	10-20	<10	>20	10-20	<10
Trophic Composition												
7. Percent omnivores	>30	15-30	<15	>30	15-30	<15	>30	15-30	<15	>30	15-30	<15
8. Percent specialized insectivores	<25	25-50	>50	<25	25-50	>50	<25	25-50	>50	<25	25-50	>50
9. Percent piscivores	<2	2-5	>5	<2	2-5	>5	<2	2-5	>5	<2	2-5	>5
Abundance and Health												
10. Catch rate*	<8	8-16	>16	<8	8-16	>16	<8	8-16	>16	<8	8-16	>16
11. Percentage hybrids	>1	0-1	0	>1	0-1	0	>1	0-1	0	>1	0-1	0
12. Percent individuals with anomalies	>5	2-5	>2	>5	2-5	>2	>5	2-5	>2	>5	2-5	>2

* Average number per seine haul or five minutes of boat electroshocking

Table 3.5 (continued)
1993 Vital Signs Monitoring

Fish Community Index of Biotic Integrity (IBI) metrics and scoring criteria developed for Tennessee Valley Streams, with a score of 5 representing highest quality, and a score of 1 the poorest.

Stream Fish Community Index of Biotic Integrity Metrics

Metric	Little Tenn River 94.3			Emory River 21.7			Powell River 65.4			Clinch River 172.3		
	1	3	5	1	3	5	1	3	5	1	3	5
Species Richness and Composition												
1. Number of native species	<11	11-20	>20	<15	15-29	>29	<21	21-39	>39	<22	22-42	>42
2. Number of darter species	<3	3-4	>4	<5	5-8	>8	<5	5-8	>8	<5	5-8	>8
3. Sunfish species, less Micropterus	0	1	>1	<2	2	>2	<2	2-3	>3	<2	2-3	>3
4. Number of sucker species	<2	2-3	>3	<2	2	>2	<3	3-4	>4	<3	3-5	>5
5. Number of intolerant species	<2	2	>2	<2	2	>2	<3	3-4	>4	<3	3-5	>5
6. Percent tolerant individuals	>20	10-20	<10	>20	10-20	<10	>20	10-20	<10	>20	10-20	<10
Trophic Composition												
7. Percent omnivores	>30	15-30	<15	>30	15-30	<15	>30	15-30	<15	>30	15-30	<15
8. Percent specialized insectivores	<25	25-50	>50	<25	25-50	>50	<25	25-50	>50	<25	25-50	>50
9. Percent piscivores	<2	2-5	>5	<2	2-5	>5	<2	2-5	>5	<2	2-5	>5
Abundance and Health												
10. Catch rate*	<7	7-13	>13	<7	7-13	>13	<8	8-16	>16	<8	8-16	>16
11. Percentage hybrids	>1	0-1	0	>1	0-1	0	>1	0-1	0	>1	0-1	0
12. Percent individuals with anomalies	>5	2-5	>2	>5	2-5	>2	>5	2-5	>2	>5	2-5	>2

* Average number per seine haul or five minutes of boat electroshocking

Table 3.5 (continued)
1993 Vital Signs Monitoring

Fish Community Index of Biotic Integrity (IBI) metrics and scoring criteria developed for Tennessee Valley Streams, with a score of 5 representing highest quality, and a score of 1 the poorest.

Stream Fish Community Index of Biotic Integrity Metrics

Metric	Holston River 118.0			Nolichucky River 8.5			French Broad R 78.0		
	1	3	5	1	3	5	1	3	5
Species Richness and Composition									
1. Number of native species	<20	20-38	>38	<19	19-36	>36	<21	21-40	>40
2. Number of darter species	<4	4-7	>7	<5	5-8	>8	<4	4-7	>7
3. Sunfish species, less Micropterus	<2	2-3	>3	<2	2-3	>3	<2	2-3	>3
4. Number of sucker species	<3	3-5	>5	<4	4-6	>6	<4	4-6	>6
5. Number of intolerant species	<3	3-4	>4	<2	2-3	>3	<2	2-3	>3
6. Percent tolerant individuals	>20	10-20	<10	>20	10-20	<10	>20	10-20	<10
Trophic Composition									
7. Percent omnivores	>30	15-30	<15	>30	15-30	<15	>30	15-30	<15
8. Percent specialized insectivores	<25	25-50	>50	<25	25-50	>50	<25	25-50	>50
9. Percent piscivores	<2	2-5	>5	<2	2-5	>5	<2	2-5	>5
Abundance and Health									
10. Catch rate*	<8	8-16	>16	<8	8-16	>16	<7	7-13	>13
11. Percentage hybrids	>1	0-1	0	>1	0-1	0	>1	0-1	0
12. Percent individuals with anomalies	>5	2-5	>2	>5	2-5	>2	>5	2-5	>2

* Average number per seine haul or five minutes of boat electroshocking

Table 3.6
1993 Vital Signs Monitoring

Computational Method For Evaluation of Reservoir Health

Wilson Reservoir - 1993 (Run-of-the-river reservoir)

Aquatic Health Indicators	Observations			Ratings		
	Forebay	Transition Zone	Inflow	Forebay	Transition Zone	Inflow
Dissolved Oxygen:		No Samples	Tailrace DOs	1	No Rating	4
Less Than 2 mg/L (Summer Avg.)				(poor)		(fair)
% of X-Sectional Area	11.0 (1)	-	-			
% of X-Sectional Bottom Length	44.2 (1)*	-	-	*DO was 0 mg/L on the bottom		
Less Than 5 mg/l at 1.5m						
Yes/No	No	-	Yes*	*Minimum DO was 4.3 mg/L		
Chlorophyll-a, µg/L:		No Samples	No Samples	3	No Rating	No Rating
Summertime Average	10.2	-	-	(fair)		
Maximum Concentration	25.0	-	-			
Sediment Quality:		No Samples	No Samples	4.5	No Rating	No Rating
Toxicity	T1 T2			(good)		
Ceriodaphnia Survival	100% 95%	-	-			
Rotifer Survival	65% 85%	-	-			
Chemistry						
Metals/NH3/pesticides	None (5)	-	-			
Benthic Community:		No Samples		3	No Rating	5
Dominance	5		5	(fair)		(good)
Tubificidae	5		5			
Chironomidae	1		5			
EPT	1		5			
Long-lived	3		5			
Taxa richness	5		5			
Total	20	-	30			
Fish Community:		No Samples		4	No Rating	4
Electrofishing Score	46		-	(fair)		(fair)
Gill Netting Score	38		42			
Overall	42	-	42			
		Sampling Location Sum		15.5 of 25	--	13 of 15
		Reservoir Sum		28.5 of 40 [71%]		
		OVERALL RESERVOIR EVALUATION		"fair" (yellow)		

Overall Reservoir Evaluation Key:
- Less than 52% - poor (red)
- 52% to 72% - fair (yellow)
- Greater than 72% - good (green)

Table 3.7
1993 Vital Signs Monitoring

Computational Method For Evaluation of Reservoir Health

Cherokee Reservoir - 1993 (Tributary storage reservoir)

Aquatic Health Indicators	Observations			Ratings		
	Forebay	Transition Zone	Inflow	Forebay	Transition Zone	Inflow
Dissolved Oxygen:			No Samples	1 (poor)	1 (poor)	No Rating
Less Than 2 mg/L (Summer Avg.)						
% of X-Sectional Area	21.5 (1)	26.0 (1)	-			
% of X-Sectional Bottom Length	43.0 (1)*	52.0 (1)*	-	*DO was 0 mg/L on the bottom		
Less Than 5 mg/L at 1.5m						
Yes/No	No	No				
Chlorophyll-a, µg/L:			No Samples	5 (good)	5 (good)	No Rating
Summertime Average	7.6	9.4	-			
Maximum Concentration	17.0	14.0	-			
Sediment Quality:			No Samples	4 (fair)	2 (poor)	No Rating
Toxicity						
Ceriodaphnia Survival	100% (5)	95% (1)	-			
Rotifer Survival	90%	75%	-			
Chemistry						
Metals/NH3/pesticides	NH3 (3)	Cu, NH3 (3)	-			
Benthic Community:		No Samples		3 (fair)	No Rating	5 (good)
Dominance	3		5			
Tubificidae	3		5			
Chironomidae	1		3			
EPT	3		5			
Long-lived	1		5			
Taxa richness	5		5			
Total	16	-	28			
Fish Community:				3 (fair)	3 (fair)	3 (fair)
Electrofishing Score	32	30	34			
Gill Netting Score	40	38	36			
Overall	36	34	35			
		Sampling Location Sum		16 of 25	11 of 20	8 of 10
		Reservoir Sum		35 of 55 [64%]		
		OVERALL RESERVOIR EVALUATION		"fair" (yellow)		

Overall Reservoir Evaluation Key:
- Less than 57% - poor (red)
- >57% and <72% - fair (yellow)
- Greater than 72% - good (green)

4.0 HYDROLOGIC OVERVIEW OF 1993

Many water quality characteristics (e.g., temperature, dissolved oxygen, conductivity, water clarity, suspended solids, etc.) exhibit changes due to seasonal variations in atmospheric temperature and rainfall. During those times of the year when runoff is minimal (normally August-October), streamflow is largely derived from the base flow of groundwater. Because of greater contact between the water and the soil/rock and the longer groundwater residence times, groundwater contains more dissolved minerals (i.e., higher concentrations of hardness and alkalinity, higher pHs and conductivities, etc.) than does surface water. During those times of the year when runoff is higher (normally January-March), streamflow is principally derived from rapid overland runoff that allows little time for mineral dissolution.

Consequently, during those times of the year with higher rainfall and subsequent higher flows, base flow accounts for a smaller proportion of the total streamflow, resulting in lower concentrations of most dissolved constituents. In addition, periods of intense rainfall and high overland flows wash off or "flush" a watershed and transport soil particles to streams, often carrying large loads of nonpoint source pollutants (nutrients, suspended solids, fecal bacteria, etc.) to streams and rivers.

In addition to flood control, electric power generation, and navigation, an important benefit of the TVA's system of dams and reservoirs is its ability to maintain adequate streamflow during extended periods of low rainfall and low runoff by the controlled release of water from tributary storage impoundments. However, this alteration of natural streamflow (diminishing high flows during floods and augmenting low flows during droughts) by storing and then slowly releasing water from tributary storage impoundments creates conditions of strong thermal stratification and low dissolved oxygen in the bottom waters of these tributary storage impoundments. (Additional details about reservoir stratification and water quality impacts are discussed in Chapter 5.)

From a water quality perspective, the lower streamflows occurring during the warmer summer months, combined with naturally occurring higher water temperatures and lower dissolved oxygen concentrations, result not only in lakes becoming thermally stratified but also having less water and less oxygen available to dilute and assimilate the wastes discharged to them. In addition, the warmer water temperatures increase aquatic biological processes (respiration, bacteriological decomposition, etc.). This results in oxygen being used at a faster rate, which can further lower oxygen concentrations. In combination, these factors (low streamflows and diminished assimilative capacity, warmer temperatures and higher biological oxygen consumption rates, and the inhibition of mixing and reaeration caused by thermal stratification) result in low dissolved oxygen concentrations and adversely impact the health of aquatic life. The summer of 1993 was a case in point. July 1993 was the hottest month on record (since 1890s) in the Tennessee Valley. Valley-wide temperatures averaged almost 83°F (28.3°C), about 5°F (2.8°C) above normal for July. For example, in Chattanooga, all 31 days in July had temperatures above 90°F (32.2°C), with temperatures up to 104°F (40.0°C) and 15 days with temperatures 98°F (36.7°C) or higher. This record-breaking heat (and low streamflows) resulted in high water temperatures in the Tennessee River. In fact, all nine mainstem Tennessee River reservoirs had surface water temperatures that exceeded 86°F (30.0°C), some with highs up to 90°F (32.2°C).

In addition, Tennessee Valley rainfall and runoff were well below normal in the summer of 1993. In July, Valley-wide rainfall averaged only 1.76 inches (45 mm), a deficit of 3 inches (76 mm) below the long-term July mean of 4.77 inches (121 mm) as a result rainfall runoff was only 0.66 inches (17 mm), compared to the long-term July mean of 1.03 inches (26 mm). Further, runoff was significantly lower in the western half of the Tennessee Valley than in the eastern half. In July, runoff above Chattanooga was 90 percent of the long-term mean, while runoff was only 64 percent of the long-term mean above Kentucky Dam. For the period of January through July, runoff above Chattanooga was 80 percent of the long-term mean, while runoff was 72 percent of the long-term mean above Kentucky Dam. Consequently, flows in the Tennessee River in 1993 increasingly fell below the long-term average as the river flowed downstream from Fort Loudoun Dam to Kentucky Dam.

The high temperatures and low flows of July 1993 adversely impacted dissolved oxygen concentrations in the Tennessee River, particularly in the downstream reservoirs. In mid-July, hypolimnetic anoxia (DOs equal to 0 mg/L) was found in the forebays of Kentucky, Pickwick, Wilson, Wheeler, and Chickamauga Reservoirs. All time low concentrations of DO were recorded in the releases from Chickamauga Dam on July 16 (2.2 mg/L) and Nickajack Dam on July 19 (1.8 mg/L) when flows from both dams were only 9000 cfs. During the first two weeks of July (July 1 to 15), daily flows averaged only about 17,250-17,500 cfs at Chickamauga and Nickajack Dams, or about 55 percent of the normal flow for this period of time. Once the effects of the high temperatures and low flows on DOs in the Tennessee River were recognized, flows were immediately increased (by drawing water from tributary storage reservoirs) and DO concentrations improved. For example, at Chickamauga Dam, from July 16-31, average daily flows were increased to an average of about

24,500 cfs (about 80 percent of the normal flow for July) and DOs in the releases increased to an average of about 4.3 mg/L, ranging from 3.2 to 6.3 mg/L. Compounding this whole situation were the record-setting rains and flooding occurring in the mid-West along the Mississippi and Missouri Rivers during the "flood of the century." During this period, TVA minimized discharge from the Tennessee River through Kentucky Dam so as to not increase flood crests on the lower Ohio and Mississippi Rivers and worsen the already catastrophic flooding in those areas.

Obviously, examining atmospheric temperature, rainfall, and runoff patterns during 1993 aids in interpretation of the Vital Signs monitoring data and the ecological health assessments of the streams and reservoirs. Interestingly, interpretation of the biological components of stream monitoring results for 1993 is not influenced by these extreme hydrologic conditions. The low rainfall and low streamflows during the spring and early summer allowed benthic sample collection before the more stressed conditions developed in mid-to-late summer.

4.1 Atmospheric Temperature

Average annual temperature in the TVA region is approximately 60 degrees Fahrenheit, °F (15.6 degrees Celsius, °C), with January usually being the coldest month and July the hottest. According to U.S. Department of Commerce (USDOC) climatic data, atmospheric temperatures in the TVA region averaged only about 0.3°F (0.2°C) warmer than normal in 1993; however, 1993 was a year of extremes (USDOC, 1993). January and July were unusually warm with 5.0°F (2.8°C) and 4.7°F (2.6°C) above normal, respectively; while, March and April were below normal with departures greater than -2.0°F (-1.1°C) (Figure 4.1a).

In review, 1993 began with an unusually warm January but cooled to below normal in February. As has often occurred in the last 15 years, another cold spring with late freezes was experienced. A record-breaking late season blizzard struck the Valley in mid-March and hit hardest in the eastern half. Summer was hotter than normal, with Tennessee, Alabama, Georgia, North Carolina, and Virginia all having the hottest July on record since the 1890s. The persistent heat and high humidity created great stress on livestock and people. The daily records for Chattanooga Airport provide an indication of the unusual conditions. All 31 days had maximums above 90°F (32.2°C), with the observed maximums ranging from 92°F (33.3°C) to 104°F (40°C) and 15 days of 98°F (36.7°C) or higher. The last four months had near or below normal temperatures, and the annual average temperature was only slightly above normal.

4.2 Rainfall

The Tennessee River basin averages about 51-52 inches (1295-1320 millimeters [mm]) of precipitation annually. However, there are large variations in the spatial distribution of precipitation. The range is from a high of about 93 inches (2360 mm) in the mountains of southwestern North Carolina near Highlands, North Carolina, to a low of about 37 inches (940 mm) in the shielded valleys of these same mountains near Asheville, North Carolina. Elsewhere in the Valley, precipitation usually ranges within five to ten inches (127 mm to 254 mm) of the basin average. March is usually the wettest month and October the driest.

Rainfall across the Tennessee Valley in 1993 averaged only 39.8 inches (1011 mm), almost 12 inches (about 300 mm) or 23 percent less than the long-term 100-year average. The diminished rainfall in 1993 followed another dry year, 1992, when annual rainfall was about 8 inches (204 mm) or about 15 percent below the long-term average. The period January-May 1992 ranked as one of the ten driest on record in the Tennessee Valley. During 1993, only the month of December had rainfall greater than normal (6.1 inches [155 mm] compared to normal December rainfall of 4.8 inches [122 mm]); the greatest rainfall deficit occurred in July (1.8 inches [45 mm] compared to the normal July rainfall of 4.8 inches [122mm]). In addition to the extremes of December and July, March and September precipitation was close to average while February, April, June and October were more than an inch (254 mm) below average (Figure 4.1b). During March 1993, the Tennessee Valley received the equivalent of 5.4 inches (137 mm) of rain, much of this during the "Winter Snow Storm of the Century" when many areas received record amounts (greater than 20 inches [about 500 mm]) of snowfall.

The unusually persistent hot weather and below average rainfall in the summer was related to an unusual upper air pattern, which kept the storm track well west and north of the region and allowed very few cold fronts to reach the Tennessee Valley. This nearly stationary position of a strong upper air trough over the Rocky Mountains was associated with the record flooding in the middle of the country and kept the Southeast hot and dry. This general pattern was most persistent in the summer, but frequently alternated with a pattern having an upper trough over or to the east of the Valley in the other seasons. This latter trough kept most storms associated with it to the south of the TVA region. These two upper air patterns dominated the weather during 1993, so significant rainfall events tended to occur only when there was a transition period between one and the other.

4.3 Streamflow

Streamflow varies seasonally with rainfall, although during the spring and summer evaporation and transpiration also significantly reduce the amount of runoff. Watersheds that receive 50 to 60 inches (1270 to 1524 mm) of precipitation annually average about 20 to 30 inches (508 to 762 mm) of runoff. In a normal year, the discharge of the Tennessee River (approximately 66,000 cfs [1868 meters^3/second]) corresponds to about 22 inches (about 560 mm) of runoff distributed over the 40,900 square mile (105,930 square kilometer) drainage basin. A larger amount of runoff occurs during the wet winter and spring months (January-April) when precipitation events are frequent, temperatures are low, and there are no leaves on deciduous vegetation. Consequently, soil absorption, evaporation, and plant transpiration losses are low at that time of year, and both runoff and streamflow are higher than during the summer and autumn months. Average rainfall in the eastern and western portions of the Tennessee Valley (above and below Chattanooga) is about equal. However, topographic differences (viz. the largely steep and mountainous terrain in the eastern portion of the Valley, compared with the mostly flat and rolling terrain in the western portion of the Valley) and generally shallower soils result in higher amounts of runoff above Chattanooga.

In 1993, runoff for the Tennessee River basin was well below normal, particularly from February through July and particularly in the western half of the Valley. Runoff above Chattanooga was only slightly below normal in 1993, 21.4 inches, or 92 percent of the long-term mean of 23.4 inches. However, runoff above Kentucky Dam was only 17.6 inches, a deficit of almost 5 inches and only 78 percent of the long-term mean of 22.5 inches (Figure 4.1c.). Table 4.1 shows that the 1993 releases from tributary reservoirs in the western part of the Valley (e.g., Normandy, Tims Ford, etc.) were below their long-term means, while the releases from tributary reservoirs in the eastern part of the Valley (e.g., South Holston, Watauga, etc.) were close to normal. Consequently, flows in the Tennessee River in 1993 increasingly fell below the long-term average as the river flowed downstream from Fort Loudoun Dam to Kentucky Dam.

Figure 4.2 presents the relative contributions of streamflow based on long term averages from major tributaries and local inflows to each of the mainstem Tennessee River reservoirs. The flow through each mainstem reservoir is dominated by the inflow from the immediately adjacent upstream reservoir. However, several large tributaries (e.g., Hiwassee River, Elk River, Duck River) do provide substantial inputs to a few mainstem reservoirs, and consequently can have a significant impact on water quality, depending on the volume and chemical quality of the inflows.

FIGURE 4.1 Temperature, Precipitation, and Runoff – Tennessee River Basin, 1993

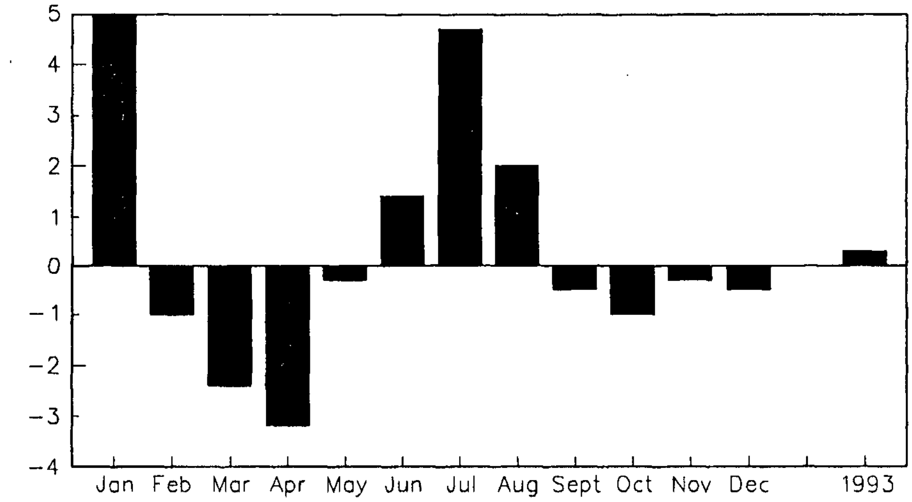


FIGURE 4.1a. Temperature Departures From Long-Term Mean (deg F) in the TVA Region

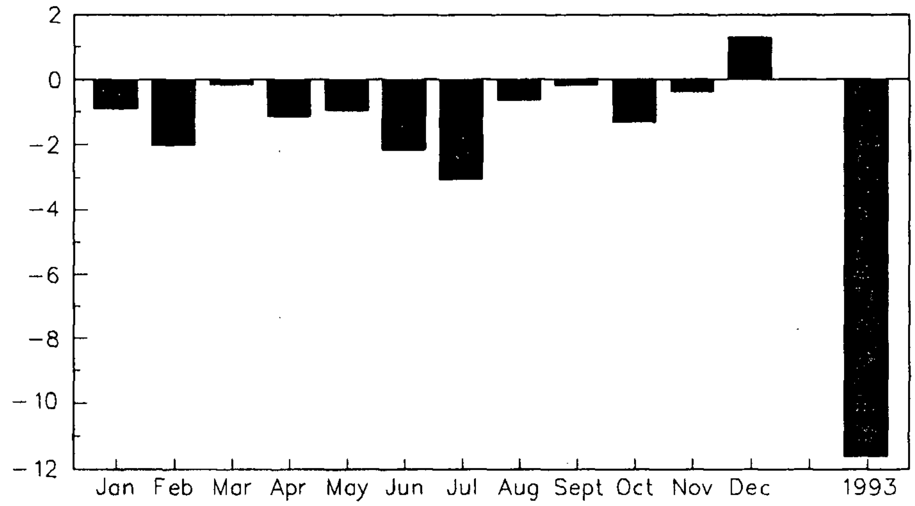


FIGURE 4.1b. Precipitation Departures From Long-Term Mean (Inches)
For The Tennessee River Basin

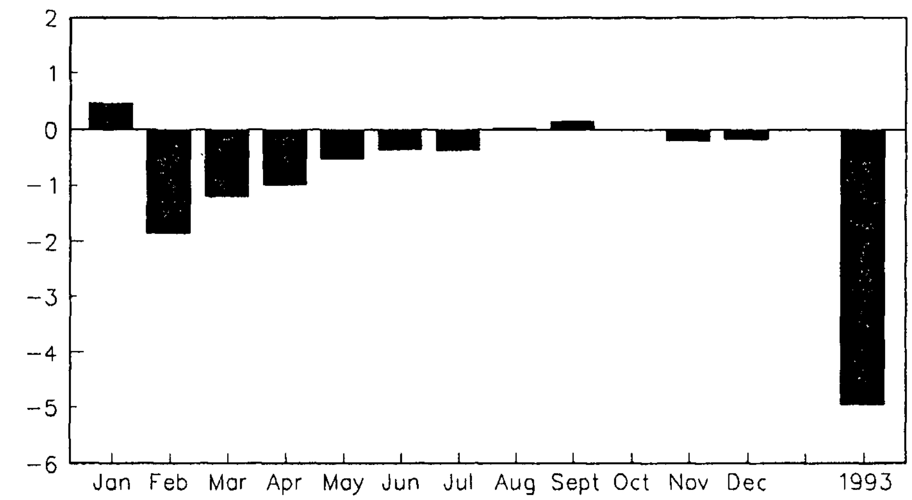


FIGURE 4.1c. Runoff Departures From Long-Term Mean (Inches)
For Tennessee River Basin, Above Kentucky Dam

Figure 4.2 Average Annual Tennessee River Flows Showing Contributions of Major Tributaries and Local Inflows.

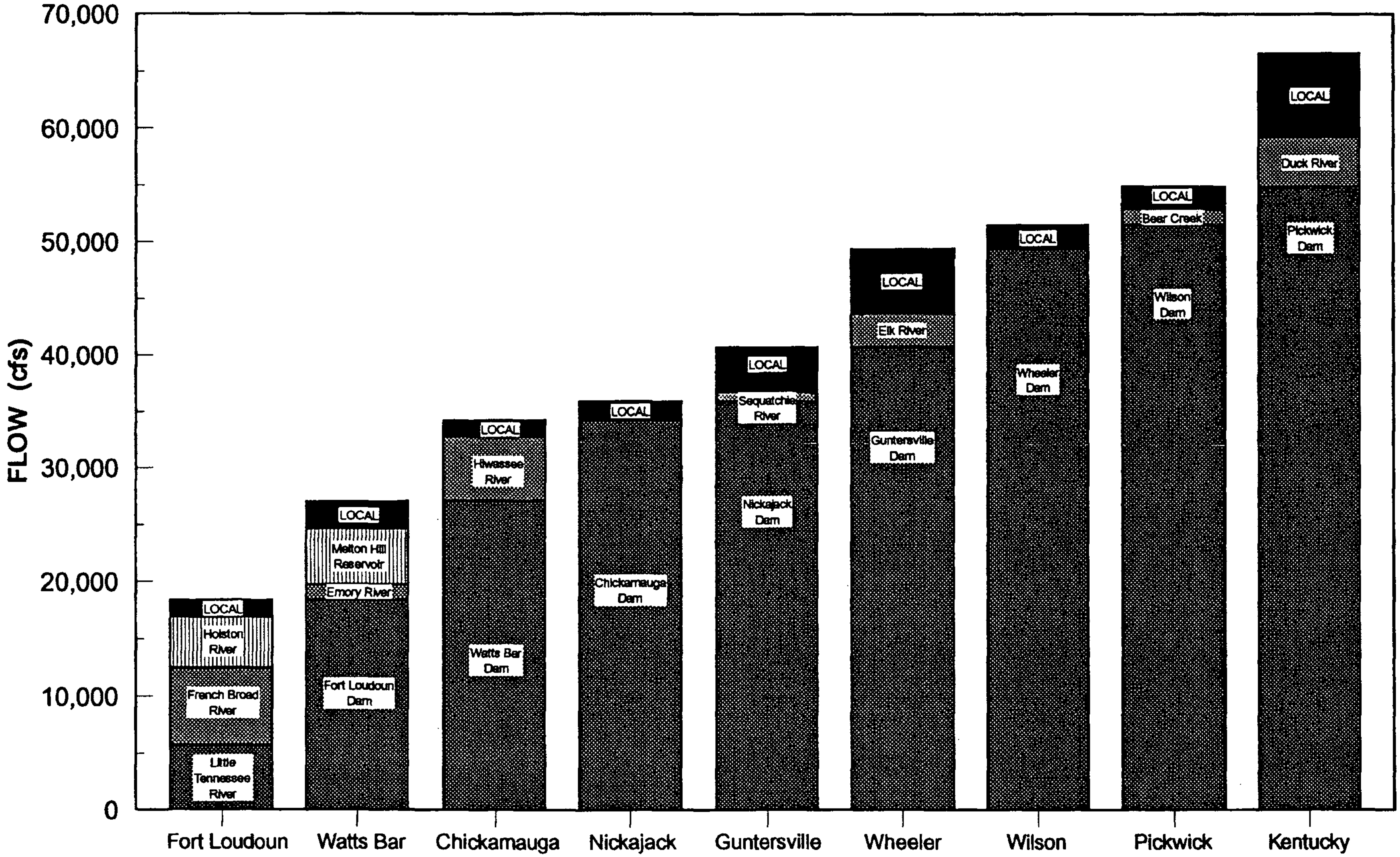


Table 4.1

CHARACTERISTICS OF VITAL SIGNS RESERVOIRS

Reservoir Name	Drainage Area (sq. miles)	Reservoir Length[a] (miles)	Surface Area[a] (acres) 1000's	Depth at Dam[a] (ft)	Volume[a] (ac-ft) 1000's	Average Annual Drawdown[b] (ft)	Average Reservoir Flow-POR (cfs)	Average Hydraulic Residence Time-1993[a] (days)	CY 1993 Reservoir Flow (cfs)
Run-of-the-River Reservoirs									
Kentucky	40,200	184.3	160.3	88	2,839	5	66,600	27.5	52,097
Pickwick	32,820	52.7	43.1	84	924	6	54,900	9.6	48,566
Wilson	30,750	15.5	15.5	108	634	3	51,500	6.8	47,236
Wheeler	29,590	74.1	67.1	66	1,050	6	49,400	11.4	46,264
Guntersville	24,450	75.7	67.9	65	1,018	2	40,700	12.9	39,691
Nickajack	21,870	46.3	10.4	60	241	0	35,900	3.6	34,092
Chickamauga	20,790	58.9	35.4	83	628	7	34,200	9.6	32,887
Watts Bar	17,300	72.0/24.0[c]	39.0	105	1,010	6	27,100	19.5	26,145
Fort Loudoun	9,550	50.0	14.6	94	363	6	18,400	9.7	18,897
Melton Hill	3,343	44.0	5.7	69	120	0	4,920	12.7	4,764
Tellico	2,627	33.2	16.5	80	415	6	6,300[d]	34.0	6,159[d]
Tributary, Storage Reservoirs									
Norris	2,912	73.0/53.0[c]	34.2	202	2,040	32	4,190	249.4	4,124
Cherokee	3,428	54.0	30.3	163	1,481	28	4,460	162.2	4,604
Douglas	4,541	43.1	30.4	127	1,408	48	6,780	109.4	6,490
Ft Patrick Henry	1,903	10.4	0.9	81	27	0	2,650	5.6	2,423
Boone	1,840	17.4/15.3[c]	4.3	129	189	25	2,550	38.5	2,477
South Holston	703	23.7	7.6	239	658	33	976	341.3	972
Watauga	468	16.3	6.4	274	569	26	714	403.5	711
Fontana	1,571	29.0	10.6	460	1,420	64	3,840	173.5	4,126
Hiwassee	968	22.2	6.1	255	422	45	2,020	98.8	2,154
Chatuge	189	13.0	7.0	124	234	10	459	291.3	405
Nottely	214	20.2	4.2	167	170	24	416	228.0	376
Ocoee #1 (Parksville)	595	7.5	1.9	115	85	7	1,420	33.1	1,296
Blue Ridge	232	11.0	3.3	156	193	36	614	156.2	623
Tims Ford	529	34.2	10.6	143	530	12	940	328.7	813
Bear Creek	232	16.0	0.7	74	10	11[e]	380	14.4	337
Cedar Creek	179	9.0	4.2	79	94	14[e]	282	185.7	255
Little Bear Creek	61	7.1	1.6	82	45	12[c]	101	253.9	90
Beech	16	5.3	0.9	32	11	1[e]	14	616.2	9
Normandy	195	17.0	3.2	83	110	11	320	201.7	275

[a] Measurements based on normal maximum pool.
[b] Tennessee River and Reservoir System Operation and Planning Review, Final EIS, TVA/RDG/EQS-91/1, 1990.
[c] Major/minor arms of reservoir.
[d] Estimated flow based on releases from Chilhowee Dam (POR avg. = 4770cfs), and adjusted based on the additional drainage area between Chilhowee Dam (1977 sq miles) and Tellico Dam (2627 sq miles).
[e] Estimated based on difference between normal maximum summer pool and average minimum winter pool elevations.

5.0 DISCUSSION

The quality of water in a river system is a result of the quality of water flowing into it from many sources (e.g., tributary streams, discharges from metropolitan areas, overland runoff) and the internal physical, chemical, and biological processes which occur within the river. The water quality of major tributaries to a river is governed by geologic characteristics, rainfall, and human activities within the watershed.

The Tennessee River originates with the confluence of the French Broad and Holston Rivers at Knoxville, Tennessee. It receives water from a variety of tributaries reflecting the geochemical characteristics of the watersheds they drain. For example, the French Broad and Holston Rivers are nutrient-rich and moderately hard, with greater hardness in the Holston; the Little Tennessee and Hiwassee Rivers are soft and nutrient-poor; the Clinch River is hard with moderate nutrients; while the other two large tributaries, the Elk and Duck Rivers, are relatively hard and nutrient-rich.

Each tributary exerts its influence based on a wide variety of factors, but primarily the volume of inflow and concentrations of various chemical constituents. Nutrient levels are particularly important because of their direct influences on algal primary production and indirect influences on dissolved oxygen.

Just as the characteristics of the Tennessee River are a composite of its major tributaries, each major tributary has characteristics of its tributaries. Given the widely varying geochemical attributes and many different types of land use within a watershed, characteristics of streams and reservoirs vary greatly among major tributary watersheds. These characteristics are further influenced by the location, design, and operation of dams on streams in the watershed.

This report summarizes results and conclusions from 1993 monitoring activities in the Tennessee Valley. This chapter (Chapter 5) examines these results from a Valley-wide perspective. Chapters 6-17 present a watershed-by-watershed perspective for each of 12 delineated drainages that together comprise the Tennessee Valley. Volume II of this report is a detailed summary of the 1993 monitoring results in each of these 12 watershed areas.

5.1 Vital Signs Monitoring

5.1.1 Reservoirs

Reservoirs were divided into two categories for comparative purposes: run-of-the-river reservoirs (the nine mainstream reservoirs plus the two navigable tributary reservoirs) and the 19 tributary storage reservoirs. The primary differences between these two categories are retention time and changes in pool level due to winter drawdown; both have a great effect on the aquatic ecosystem. For comparative purposes, all reservoirs were categorized as good, fair, or poor based on their respective ecological health evaluations.

Run-Of-The-River Reservoirs--The ecological health of all 11 run-of-the-river reservoirs rated fair or better in 1993. The score for Fort Loudoun Reservoir (58 percent) was the lowest of the run-of-the-river reservoirs. This score fell just within the fair range; but low enough to be considered poor-fair. Three reservoirs rated fair - Tellico (63 percent), Watts Bar (68 percent) and Melton Hill (68 percent); four rated good - Nickajack (88 percent), Chickamauga (83 percent), Guntersville (78 percent), and Kentucky (75 percent); and the remaining three reservoirs fell close to the break point used to separate good and fair reservoirs ($\geq$72 percent) - Pickwick (73 percent), Wheeler (72 percent), and Wilson (71 percent).

Figure 5.1 shows an interesting geographical trend to these results. Reservoirs with the lowest scores were at the upstream end of the Tennessee River, followed by reservoirs with the highest scores, and then reservoirs with intermediate scores in the downstream portion of the Tennessee River. There are many factors which in combination result in the observed ecological conditions, and care must be taken not to oversimplify complex ecosystem dynamics. However, one obvious consideration would be the nutrient rich waters from the French Broad and Holston Rivers, coupled with high human population densities in east Tennessee. Together, these create a high potential for undesirable ecological conditions to exist in the upper Tennessee River. Inputs of fairly pristine waters from the Little Tennessee River, further supplemented by inflows from Hiwassee River with low nutrients further downstream, act to dilute the water in the Tennessee River and help diminish the potential for eutrophic conditions in Chickamauga, Nickajack, and Guntersville Reservoirs. In the lower half of the Tennessee River, water naturally rich in nutrients flows from the Elk River to Wheeler Reservoir and from the Duck River to Kentucky Reservoir, stimulating algal growth and potentially shifting ecological conditions toward a more productive state.

The four reservoirs with the lowest ecological health scores (Fort Loudoun, Tellico, Melton Hill, and Watts Bar) had multiple indicators that rated poor or very poor. These were generally dissolved oxygen, sediment, benthos, and/or fish assemblage. For the three reservoirs which scored good (Chickamauga, Nickajack, and Guntersville), all ecological health indicators rated fair or better, except for dissolved oxygen at the inflows to Nickajack and Guntersville Reservoirs. Scores for the next four reservoirs which scored fair to good (Wheeler, Wilson, Pickwick, and Kentucky) varied greatly depending upon the number and location of sample sites within the reservoir. Indicator ratings at sample sites on the Tennessee River portion of each reservoir (i.e., the main body of the reservoir) were fair or better, except for dissolved oxygen at the Wheeler and Wilson forebays. Sample sites in major embayments generally had several indicators with poor or very poor ratings.

Embayments were not monitored prior to 1993. Four of the largest embayments in the Tennessee Valley were included in 1993 monitoring activities--Big Sandy River embayment on Kentucky Reservoir, Bear Creek embayment on Pickwick Reservoir, Elk River embayment on Wheeler Reservoir, and Hiwassee River embayment on Chickamauga Reservoir. All four embayments have surface areas of about 5000 acres (about 2000 hectares) or greater and local drainage areas greater than 500 square miles (1295 km^2). Water quality characteristics within an embayment and the resulting ecological health conditions are largely controlled by factors within the embayment's immediate watershed and the rate of water exchange between the embayment and the main body of the reservoir. The Hiwassee and Elk River embayments have substantial flow through them. The Big Sandy and Bear Creek embayments have much smaller inflows and less water exchange with the main body of the reservoir.

Results from the Hiwassee River and Elk River embayment sites substantiate the above discussion of the potential for inflows from these rivers to affect conditions in the Tennessee River. All five ecological indicators rated good or excellent in the Hiwassee embayment. Three ecological health indicators were poor or very poor, one fair and one good in the Elk River embayment.

Inclusion of monitoring results from embayments had a substantial effect on reservoir health ratings for three of the reservoirs compared to previous years. For example, Kentucky Reservoir rated good (75 percent) in 1993, lower than the 1992 rating, when Kentucky had the best rating (88 percent) of all reservoirs examined. The primary factor responsible for this decrease was addition of the sample site in Big Sandy River embayment. If results from the Big Sandy River embayment were excluded from the overall reservoir score, the revised rating (83 percent) would be similar to that observed for 1992. Pickwick Reservoir had an ecological health rating of 73 percent for 1993. However, if the Bear Creek embayment information were deleted, the reservoir score would be 80 percent. A similar situation is true for Wheeler. The overall health rating for Wheeler would change from 72 percent to 82 percent if results from the Elk River embayment were excluded. Interestingly, the overall ecological health score for Chickamauga Reservoir would change little if results from the site in Hiwassee River embayment were excluded (i.e., 83 percent with and 81 percent without).

Another factor which lowered ecological health scores in the run-of-the-river reservoirs in 1993 was relatively low dissolved oxygen during summer 1993. Extreme summer weather in 1993 caused record high water temperatures and low DO in much of the Tennessee River. Special dam operations and water releases to reduce impacts from these conditions were started as soon as the low DO conditions were detected. Special monitoring showed these releases improved DO concentrations. However, DO concentrations were lower than in previous years causing lower scores for the overall health rating. (See Chapter 4, Hydrologic Overview of 1993, for additional detail.)

The ecological health score for one other reservoir (Tellico) changed substantially from previous years. The rating was 63 percent (fair) for 1993 compared to 48 percent in 1992 and 44 percent in 1991 (both poor). The primary causes of the higher score were better ratings for DO at the forebay (mostly the result of an improved, more accurate method of calculating the score for this indicator) and addition of information from the transition zone collection site which was relocated in 1993. The change in DO scoring resulted in forebay DO being rated fair in 1993; it had previously been rated poor. Two indicators, chlorophyll and DO, received excellent ratings at the new transition zone site; and the other three indicators rated poor. The higher ecological health score for 1993 is considered to be more representative of the true environmental conditions in Tellico Reservoir than scores in previous years.

Tributary Reservoirs--Monitoring on tributary reservoirs was not fully implemented until 1993. The number of tributary reservoirs included in Vital Signs monitoring expanded from three in 1990 to 19 in 1993. Also, the number of ecological health indicators expanded in 1993 when sediment quality and benthic macroinvertebrates were sampled for the first time on tributary reservoirs. Sample design for tributary reservoirs specifies less intensive monitoring for water chemistry constituents (most notably nutrients) than on the run-of-the-river reservoirs because of the more static nature of water within tributary reservoirs. Monitoring efforts for other ecological indicators (chlorophyll, sediment, benthos, and fish) were the same on both run-of-the-river and tributary reservoirs for the first time in 1993.

The ecological health evaluations for the tributary reservoirs are more tentative than for the run-of-the-river reservoirs. The data base generally is quite small, and our understanding of how to weigh and integrate results from various ecological health indicators is still in development.

A problem associated with evaluating the ecological health of tributary reservoirs is the individuality of each reservoir. There is substantial variation in physical characteristics (depth, shoreline development, area, length), reservoir operations (retention time, drawdown, depth of outflow, etc.), watershed geochemistry, and land use. This individuality makes it difficult to establish reference or expected conditions, against which to rate the observed ecological characteristics as good, fair, or poor ecological health. (See Section 3.1 for additional discussion.)

Two attributes, long retention times and deep drawdowns, of tributary reservoirs particularly are significant. Long retention times create high potential for thermal and chemical stratification. As solar warming occurs in upper strata during spring and summer, bottom strata remain cold, and thermal stratification develops. If oxygen demand is sufficient, which is the typically the case, anoxia occurs in the bottom waters. Under these conditions, iron and manganese become more soluble, and their concentrations increase. If anoxia continues long enough, high levels of ammonia and sulfide also can develop. These conditions cause stresses to aquatic life and result in low ecological health ratings.

Deep drawdowns of the pool during winter, sometimes below the elevation of the summer thermocline, also have a pronounced effect on aquatic systems of tributary reservoirs. For example: (1) stable shoreline habitats cannot develop or persist; (2) benthic substrates in upper riverine reaches of the reservoir can be covered with sand and silt when the reservoir is full but be washed to gravel or bedrock when the area returns to a riverine environment at winter, low pool elevations; and (3) spring spawning sites can be left dry or covered with many feet of water depending upon dam operations during spring filling. Again, these have undesirable ecological effects.

Considering these factors, the ecological health of tributary reservoirs is not expected to be as good as run-of-the-river reservoirs. Results for 1993 support this expectation. No tributary reservoir rated good for ecological health, and only two rated fair-to-good. Both Fort Patrick Henry Reservoir and Blue Ridge Reservoir scored 72 percent, just at the break point used to indicate good or fair ecological health conditions. Interestingly, Fort Patrick Henry, even though a tributary reservoir, has retention time and drawdown characteristics like a run-of-the-river reservoir. Blue

Ridge Reservoir has quite low primary productivity, which, coupled with essentially a full depth withdrawal from the dam, helps prevent dissolved oxygen problems.

Only one tributary reservoir rated poor. Parksville (Ocoee No. 1) Reservoir scored 52 percent with poor scores for four of the five indicators. Dissolved oxygen had an excellent rating. This is contrary to expectations for a tributary reservoir, but this reservoir represents an unusual case. A very low oxygen demand exists in the hypolimnion due to very low primary productivity rates. The reservoir is recovering from years of pollution problems related to copper mining and industrial activities at Copperhill. A more thorough discussion of Parksville Reservoir is provided in Section 12.5. Two reservoirs (Normandy and Cedar) scored 56 percent, right at the break point between poor and fair. Dissolved oxygen was the primary problem in both cases. Of the remaining 14 reservoirs, eight rated near the middle of the fair range and six rated in the fair range just above poor (Figure 5.2).

Figure 5.2 indicates there were no geographical patterns associated with overall reservoir scores. No particular watershed had mostly high scoring or low scoring reservoirs. Also, physical characteristics such as size or depth seemed to have little influence on reservoir score.

The ecological health indicator which was most often associated with low ecological health scores was DO. As discussed above, this was expected. Poor or very poor DO scores occurred at one or more sample sites in 13 of the 19 tributary reservoirs sampled. All six tributary reservoirs in the middle and western part of the Tennessee Valley were in this group, along with seven of the 13 tributary reservoirs in the eastern, mountainous area of the Valley. The six reservoirs in the middle and western end of the Valley (Tims Ford, Normandy, Bear Creek, Little Bear Creek, Cedar Creek, and Beech Creek) exhibit strong thermal stratification, generally have high chlorophyll concentrations, and have substantial agriculture activities in their watersheds. The seven in the eastern end of the Valley vary greatly in a number of characteristics. Of these, four (Norris, Douglas, Cherokee, and Nottely Reservoirs) had all or mostly very poor DO ratings, followed by South Holston with one very poor rating and Boone and Fontana with only one poor rating and no very poor ratings.

Of the six reservoirs with fair, good, or excellent DO scores, two were in the Holston watershed (Fort Patrick Henry and Watauga), and four were in the Hiwassee watershed (Hiwassee, Chatuge, Blue Ridge, and Parksville). All except Fort Patrick Henry had relatively low nutrient and chlorophyll concentrations (most with seasonal chlorophyll averages below 3.0 μg/L). Although Fort Patrick Henry had high chlorophyll values, lack of stratification and short retention time helped maintain good DO concentrations.

In most cases, reservoirs with poor DO concentrations would be expected to have poor benthic macroinvertebrate communities. This was true for seven of the 13 reservoirs with DO problems. Interestingly, the remaining six reservoirs with poor DO had fair, good, or even excellent benthos scores. Norris and Cherokee Reservoirs in east Tennessee and Little Bear Creek, Cedar Creek, and Beech Creek Reservoirs in the western end of the Valley had very poor DO scores, yet fair benthic macroinvertebrate communities. Bear Creek, also in the western end of the Valley, had a very poor DO score yet an excellent benthos score. These results and their potential implications are difficult to interpret with only one year of benthic macroinvertebrate data available. Additional monitoring results should help clarify these results. An initial interpretation is that the benthic community is able to recover quickly between autumn reoxygenation of bottom sediments and sample collection the following spring. Another possibility is that some of the samples collected along the transect were above the oxygen-stressed stratum. Results from individual samples suggest both factors may have contributed to the observed ratings.

Just as reservoirs with poor DO ratings typically would be expected to have poor benthos, reservoirs with good DO levels would be expected to have a good benthos community, unless some other factor was negatively influencing the benthos. This was the case on Watauga, Hiwassee, and Parksville Reservoirs. All had fair to excellent DO scores yet all had poor or very poor benthic macroinvertebrate communities. Poor scores for Parksville Reservoir were not surprising, given the problems that reservoir has experienced over the years from upstream mining activities. Results for the other two reservoirs were unexpected. Acute toxicity to at least one test animal was observed in all three reservoirs. More detailed assessment efforts would be required to determine whether there is a real relationship between the apparent toxicity and poor benthic communities. Results from additional monitoring in 1994 will be examined closely to determine whether more detailed assessments should be planned.

5.1.2 Streams

Twelve of the major Tennessee River tributaries were included in Vital Signs Stream Monitoring in 1993 (Table 2.2). Six additional streams will be monitored beginning in 1994.

Results for 1993 showed a wide range of ecological conditions among the 12 streams. Three, Clinch, Powell, and Little Tennessee Rivers, had the highest possible scores for all four ecological health indicators (nutrients, sediment, benthic macroinvertebrates, and fish community).

The lowest score (50 percent) was for the French Broad River where nutrients and fish rated poor, benthos rated fair, and sediments rated good.

Scores for the remaining eight streams were evenly distributed within this range. The Emory and Hiwassee Rivers had good overall scores (90 and 88 percent, respectively) with fair ratings for benthos, the only indicator rating less than the maximum score at each stream. The Nolichucky and Sequatchie Rivers also rated good with scores of 80 percent each. At both streams, two indicators rated good and two fair. Three streams rated fair (Duck River-70 percent, Bear Creek-70 percent, and Holston River-68 percent). High nutrient concentrations on the Duck and Holston Rivers caused a poor rating for nutrients; the other three indicators rated fair or good. The lower score for Bear Creek was due to most indicators rating fair, rather than due to any indicator rating poor. Ratings for the remaining stream, Elk River, must be used conservatively because only three indicators were monitored in 1993. The fish community was not sampled in 1993. The overall score for the other indicators was 60 percent; nutrients rated poor, benthos fair, and sediment good. The fish community will be sampled in 1994.

The ecological health indicator that rated poor most often was nutrients. Four streams (Duck, Elk, Holston, and French Broad Rivers) received poor ratings for nutrients. Bear Creek and the Nolichucky River received a fair rating for nutrients and the remaining six streams rated good. All of these results were expected based on individual watershed characteristics.

5.2 Use Suitability Monitoring

5.2.1 Bacteriological Studies

Fifty-nine designated swimming beaches, 12 informal swimming areas, and 14 canoe launching or landing sites were sampled in 1993. All of the designated swimming beaches and informal swimming areas and eight of the canoe access sites met the regulatory criterion of having geometric mean concentrations of fecal coliform bacteria less than 200/100 mL if rainfall samples were excluded. Two swimming beaches, one each on Tims Ford and Watts Bar Reservoirs, and the canoe site sampled on the Elk River, slightly exceeded the criterion when rainfall samples were included. The four access sites on the Duck River exceeded the geometric mean criterion for both rainfall and nonrainfall samples.

Thirty-five nonrecreation sites were also sampled to provide generic bacteriological water quality data on Wilson, Guntersville, Nickajack, Fort Loudoun, Norris, Douglas, Cherokee, Fort Patrick Henry, Boone, South Holston, and Watauga Reservoirs; four sites were sampled on the

Duck, Clinch, and South Holston Rivers; and three sites on Spring, Beidleman, and Thomas Creeks. All but one reservoir site (Nickajack) and two stream sites (Beidleman and Thomas Creeks) met recreation criteria.

A comparison of the results of this survey with surveys in 1974, 1986, and 1989 through 1992 shows bacteria concentrations in 1974 and 1993 were similar, and lower than during the other years. The differences are probably caused by different weather conditions and sampling methods rather than reflecting long-term changes in bacteriological water quality.

Fecal coliform samples were taken in conjunction with Vital Signs monitoring activities on the 11 run-of-the-river reservoirs from April through September 1993. Fifteen of the 155 samples analyzed had concentrations greater than the normal detection limit of 10/100 mL, seven exceeded 100/100 mL. No location had more than one sample exceed 100/100 mL.

The results of studies summarized above are consistent with previous surveys. Fecal coliform concentrations were generally lower in 1993 due to lower than normal summer rainfall. Bacteriological water quality in most areas of TVA reservoirs is good. In streams it is much poorer, especially after rainfall.

5.2.2 Fish Tissue Studies

Availability of results for fish tissue studies is usually delayed because of the intricate laboratory procedures required to analyze fish tissue samples. This process usually takes several months; so results for samples collected in autumn usually are not available until the next spring. Results in this report are for fish collected during summer and autumn 1992. Additional fish were collected in summer and autumn 1993 but results were not available in time to be included in this report.

Screening Studies--Results of screening studies in 1992 did not indicate any new reservoirs or streams in need of intensive investigations. Two streams and six reservoirs had at least one analyte slightly elevated indicating a need to resample in autumn 1993 at the screening level. Streams included the Emory River (PCB concentration in channel catfish 1.1 $\mu g/g$) and the Holston River (mercury concentration in largemouth bass 0.57 $\mu g/g$). Reservoirs included Pickwick (DDTr 2.5 $\mu g/g$), Bear Creek (mercury 0.45 $\mu g/g$), Little Bear Creek (mercury 0.56 $\mu g/g$), Norris (PCBs 0.9 $\mu g/g$), Fontana (PCBs 1.1 $\mu g/g$ and mercury 0.53 $\mu g/g$), and Cherokee (PCBs 0.8 $\mu g/g$). Although most reservoirs had multiple sites sampled, an elevated concentration of an analyte at any site would cause that reservoir to be included in this list.

All sites listed above were resampled in autumn 1993 for the same fish species. In addition, because several tributary reservoirs had somewhat elevated mercury concentrations, efforts in autumn 1993 were directed at better evaluating this condition by analyzing both channel catfish, the species typically used as the indicator, and largemouth bass, a top predator which would be expected to have higher mercury concentrations than catfish.

Intensive Studies--Six TVA reservoirs (Wheeler, Nickajack, Watts Bar, Fort Loudoun, Melton Hill, and Parksville) were examined intensively in 1992. Intensive studies are conducted on reservoirs where a contaminant problem is known or suspected. PCBs was the contaminant of interest on all these reservoirs, except Wheeler, where DDTr (total DDT) is the problem. Chlordane was also of interest in some of these reservoirs. Fish consumption advisories which recommend either limiting the quantity of fish eaten or avoiding any consumption are in effect for all six reservoirs except Parksville. These advisories issued by the Tennessee Department of Environment and Conservation and by the Alabama Department of Public Health are based in part on the results of these studies.

Results from autumn 1992 collections indicated somewhat lower concentrations of DDTr in fish from Wheeler Reservoir and PCBs in fish from Nickajack Reservoir. Lower concentrations in one year should not be interpreted as a significant decrease in contaminant concentration. Previous results have shown substantial year-to-year variability. The long-term study on Watts Bar Reservoir identified substantially lower PCB concentrations in 1989 and 1990 than in previous years. Subsequent results for 1991 and 1992 returned to the higher concentrations of previous years. For this reason, comparable studies were repeated on these reservoirs in autumn 1993.

Results of 1992 fish tissue samples from Watts Bar, Fort Loudoun, and Melton Hill Reservoirs generally fell within the range observed in previous years. Likewise, limited results for Tellico Reservoir fell within historical ranges.

Screening studies on Parksville (Ocoee No. 1) Reservoir over the past several years have found PCB concentrations near the level used by the state of Tennessee to issue a "Limit Consumption" advisory. As a result, TVA and the state designed and conducted a more detailed sampling of fish from there in autumn 1992. Results of the 1992 effort confirmed previous results of relatively high PCB concentrations in channel catfish - the average of ten fish was 1.5 $\mu g/g$ at the forebay and 1.0 $\mu g/g$ at an upper reservoir location. Largemouth bass were also examined and found to have lower concentrations than catfish--averages at the two sites were 0.6 and 0.7 $\mu g/g$, respectively. Bluegill sunfish and rainbow trout composites from these areas had low concentrations. There had been no action taken on these results at the time this report was prepared.

Figure 5.1 Overall Ecological Health of Run-of-the-River Reservoirs in the Tennessee Valley in 1993. (Ecological Health Indicators are shown as a proportion of their contribution to the overall score for each reservoir.)

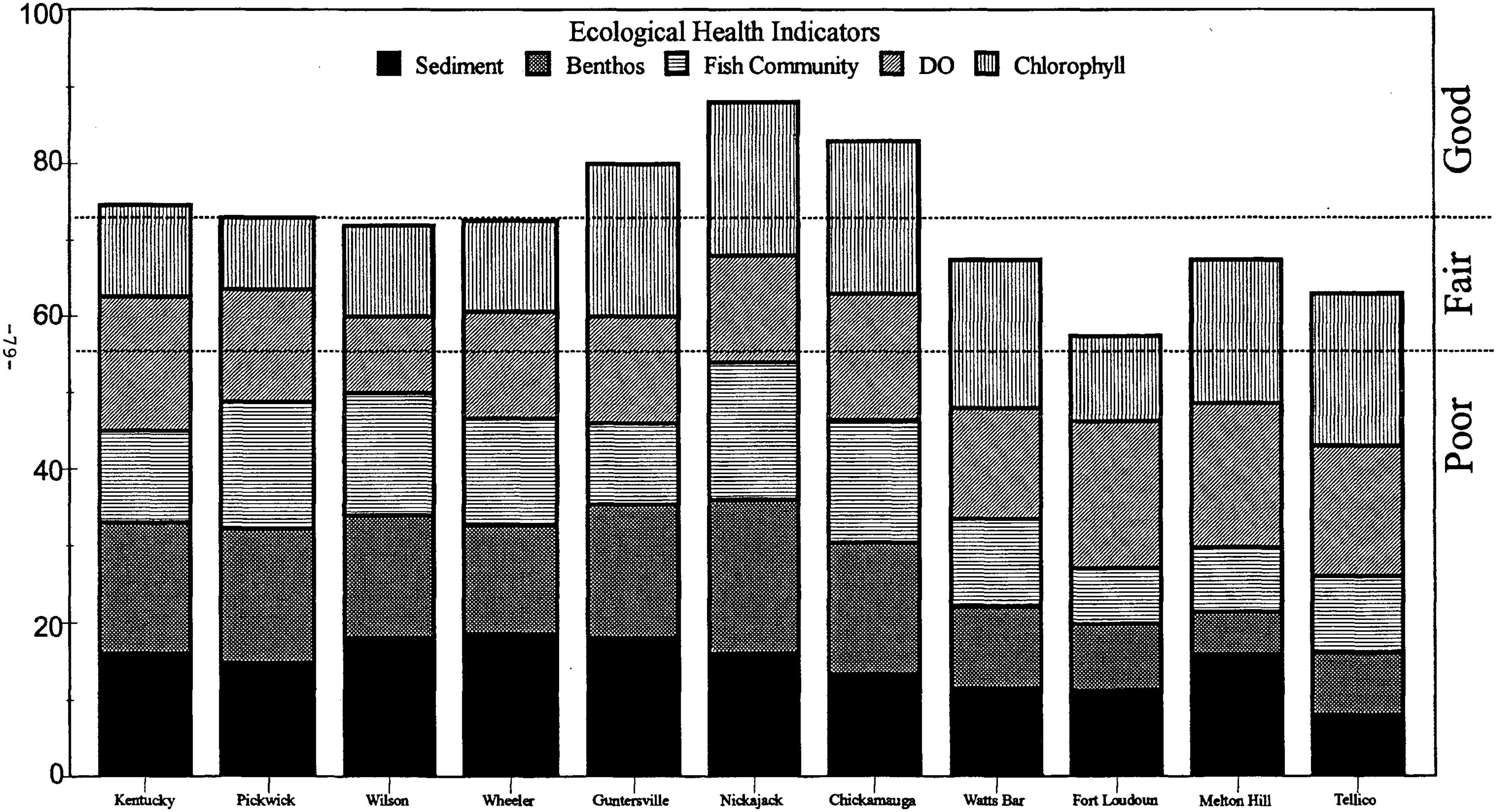
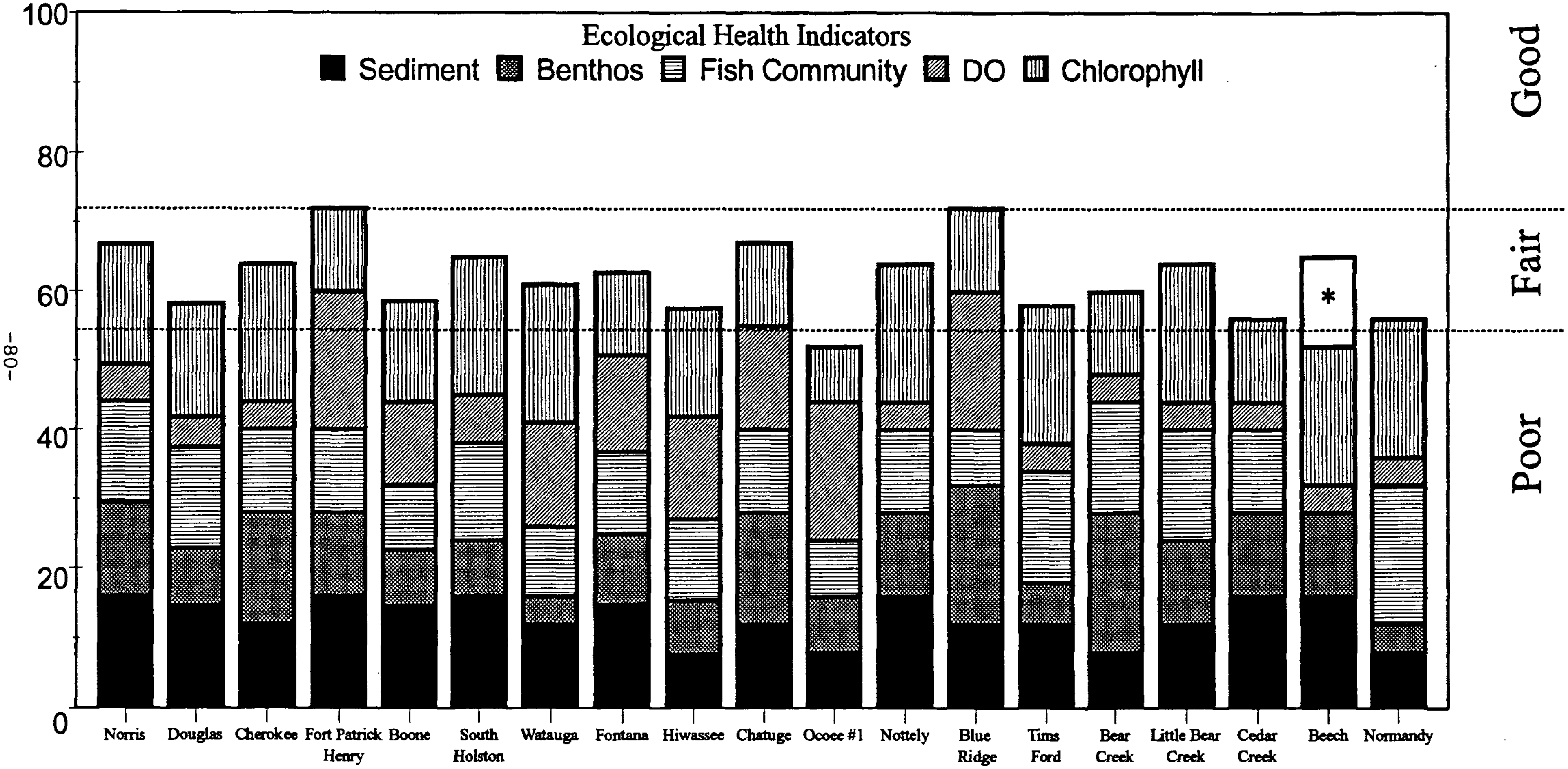


Figure 5.2 Overall Ecological Health of Tributary Reservoirs in the Tennessee Valley in 1993.

(Ecological Health Indicators are shown as a proportion of their contribution to the overall score for each reservoir.)



* Beech Reservoir score is based on four rather than five indicators; indicator and overall scores are shown on the same scale as other reservoirs to facilitate comparisons.

6.0 KENTUCKY RESERVOIR WATERSHED

The Kentucky Reservoir watershed area includes all streams flowing into the Tennessee River downstream of Pickwick Landing Dam at Tennessee River mile (TRM) 206.7 to the confluence of the Tennessee River with the Ohio River. The one exception is the Duck River which is considered a separate watershed. The Kentucky Reservoir watershed area is relatively large (4590 square miles) and has an average annual discharge of about 66,600 cfs. Of that, about 82 percent (54,000 cfs) comes into Kentucky Reservoir from Pickwick Landing Dam. The Duck River supplies about 6 percent (4075 cfs), with the remaining 11 percent coming from local inflows.

Kentucky Reservoir is the dominant feature of this watershed. There are four monitoring sites on Kentucky Reservoir--forebay, transition zone, inflow, and Big Sandy River embayment (Figure 6.1 and Table 2.1). Information from 1993 monitoring activities on Kentucky Reservoir is provided in Section 6.1.

The watershed also includes the seven small reservoirs on the Beech River. The largest, Beech Reservoir, is the only one included in Vital Signs monitoring. Given its small size, the forebay is the only site monitored (Figure 6.1). Monitoring information for Beech Reservoir for 1993 is in Section 6.2.

There were no stream monitoring sites in this watershed in 1993. Beginning in 1994, a site will be established on the Clarks River for monitoring biological conditions.

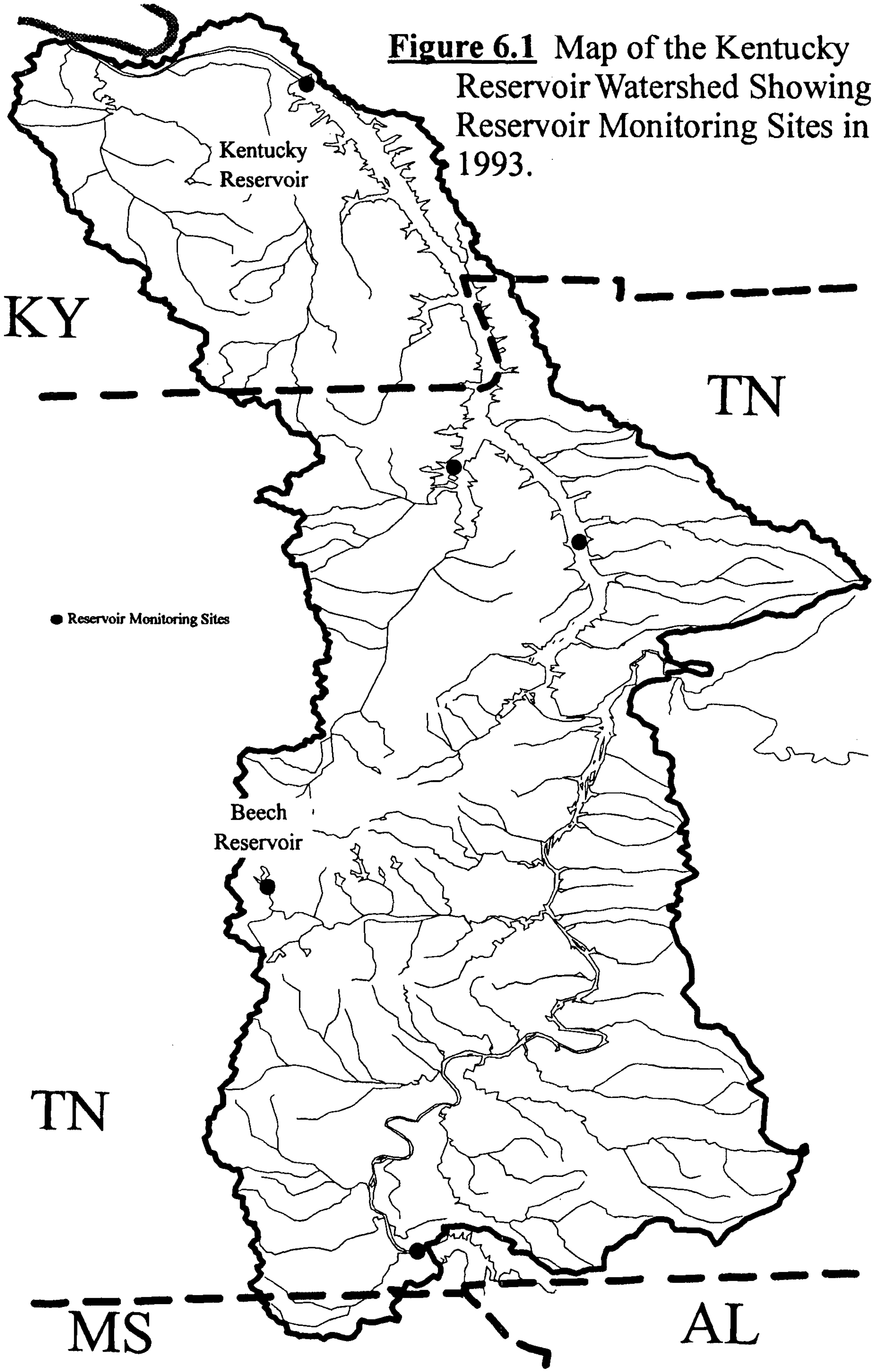


Figure 6.1 Map of the Kentucky Reservoir Watershed Showing Reservoir Monitoring Sites in 1993.

6.1 Kentucky Reservoir

Physical Description

Kentucky Reservoir is the largest reservoir on the Tennessee River. The dam is located at Tennessee River Mile (TRM) 22.4, and the reservoir extends 184 miles upstream to Pickwick Dam at TRM 206.7. At full pool the surface area is 160,300 acres, and the shoreline is 2280 miles. Average annual discharge is about 66,600 cfs, which provides an average hydraulic retention time of about 22 days. Additional information about Kentucky Reservoir is provided in Table 4.1.

The Duck River, a major tributary to the Tennessee River (and Kentucky Reservoir), provides about 6 percent of the total flow through Kentucky Reservoir. The confluence of the Duck River with the Tennessee River is at TRM 110.7.

The transition zone sample location was moved prior to the 1992 sample season from TRM 112.0 to TRM 85.0. Results for 1990 and 1991 at TRM 112.0 indicated that location was more representative of a riverine environment than a transition environment. The 1992 and 1993 results indicate the new transition zone site is correctly located.

Vital Signs monitoring was expanded in 1993 to include a sample site in four of the largest embayments in the Tennessee Valley. One, the Big Sandy River embayment on Kentucky Reservoir, is the largest embayment in the Tennessee Valley. It covers 15,238 surface acres and has over 93 miles of shoreline. Because its watershed is only 629 square miles, there is very little water exchange.

Ecological Health

The ecological health of Kentucky Reservoir rated good (75 percent) in 1993. This is lower than the ecological health index for 1992, when Kentucky had the best rating (88 percent) of all reservoirs examined. It is also lower than the overall rating in 1991. Primary factors responsible for this decrease were lower dissolved oxygen (DO) concentrations due to the hot, dry summer of 1993, and the addition of a sample site in Big Sandy River embayment. If results for the sample site in Big Sandy embayment were excluded from calculating the overall reservoir score, the revised rating (83 percent) would be similar to that observed for 1992.

The transition zone was the best of the four sites examined in 1993. All ecological health indicators (DO, chlorophyll-a, sediment quality, benthos, and fish) rated good or excellent at that site. The site in the Big Sandy embayment approached the other extreme. Three indicators rated poor or very poor: chlorophyll because of high concentrations, sediment quality because of high ammonia and toxicity to test organisms, and fish assemblage because of low fish abundance and species richness. No indicators at the other two sites (forebay and inflow) rated poor or very poor.

Aquatic plants covered about 3465 acres in 1993 compared to about 2600 acres in 1992 and 2800 in 1991. Most plants were found around islands and shallow embayments downstream of the Duck River.

Reservoir Use Suitability

Use Suitability monitoring activities did not identify any impairments on Kentucky Reservoir in 1993. Twenty-four recreation sites have been sampled for fecal coliform bacteria one or more times on Kentucky Reservoir since 1989. None has exceeded the geometric mean criteria for recreation. In 1992 three sites exceeded one of EPA's recommended guidelines--more than 10 percent of the samples had fecal coliform concentrations greater than 400/100 mL. In 1993 these three sites were resampled, and all met the EPA guideline. Fecal coliform bacteria concentrations have been very low at the Vital Signs locations sampled since 1990.

Examination of channel catfish fillets in autumn 1992 from six locations between Kentucky and Pickwick Dams found only low levels of heavy metals and pesticides at all locations. The only analyte high enough to be of interest was lead at 0.6 $\mu g/g$ at one location in 1992. Similar concentrations have been found sporadically in previous years, but there has been no pattern in space or time.

6.2 Beech Reservoir

Physical Description

Beech Reservoir, the largest of seven small flood control projects on the Beech River system in western Tennessee, is formed by Beech Dam at Beech River mile 35.0. Beech Reservoir is only 5.3 miles long and averages only about 12 feet deep. It has no hydropower generating facilities, but is the primary source of water for the city of Lexington. The reservoir is an urban lake with considerable residential lakefront development. Consequently, it receives a large amount of recreational use relative to its small size (about 900 acres). Discharge from Beech Dam averages only about 14 cfs per day, resulting in a long hydraulic residence times of 300 to 400 days.

Reservoir Health

During 1991 and 1992 only water quality monitoring was conducted in Beech Reservoir. The 1991 and 1992 data indicated poor ecological health in Beech Reservoir, as evidenced by very low concentrations of dissolved oxygen and high chlorophyll-a concentrations.

In 1993 four of the five ecological health indicators (algae, dissolved oxygen, sediment quality, and benthos) were sampled on Beech Reservoir. Overall, the ecological health rated fair (65 percent). Chlorophyll rated excellent (at the upper end of the mesotrophic range), below observed concentrations during 1991 and 1992. As expected, DO rated very poor. Sediment quality rated good and benthic macroinvertebrates rated fair. The fish assemblage will be added to the sampling regime in 1994.

Reservoir Use Suitability

No bacteriological studies were conducted in 1993. Fecal coliform concentrations were low at the swimming beach in 1990. There are no fish consumption advisories on Beech Reservoir. Fish tissue samples have not been collected by TVA from this reservoir.

7.0 DUCK RIVER WATERSHED

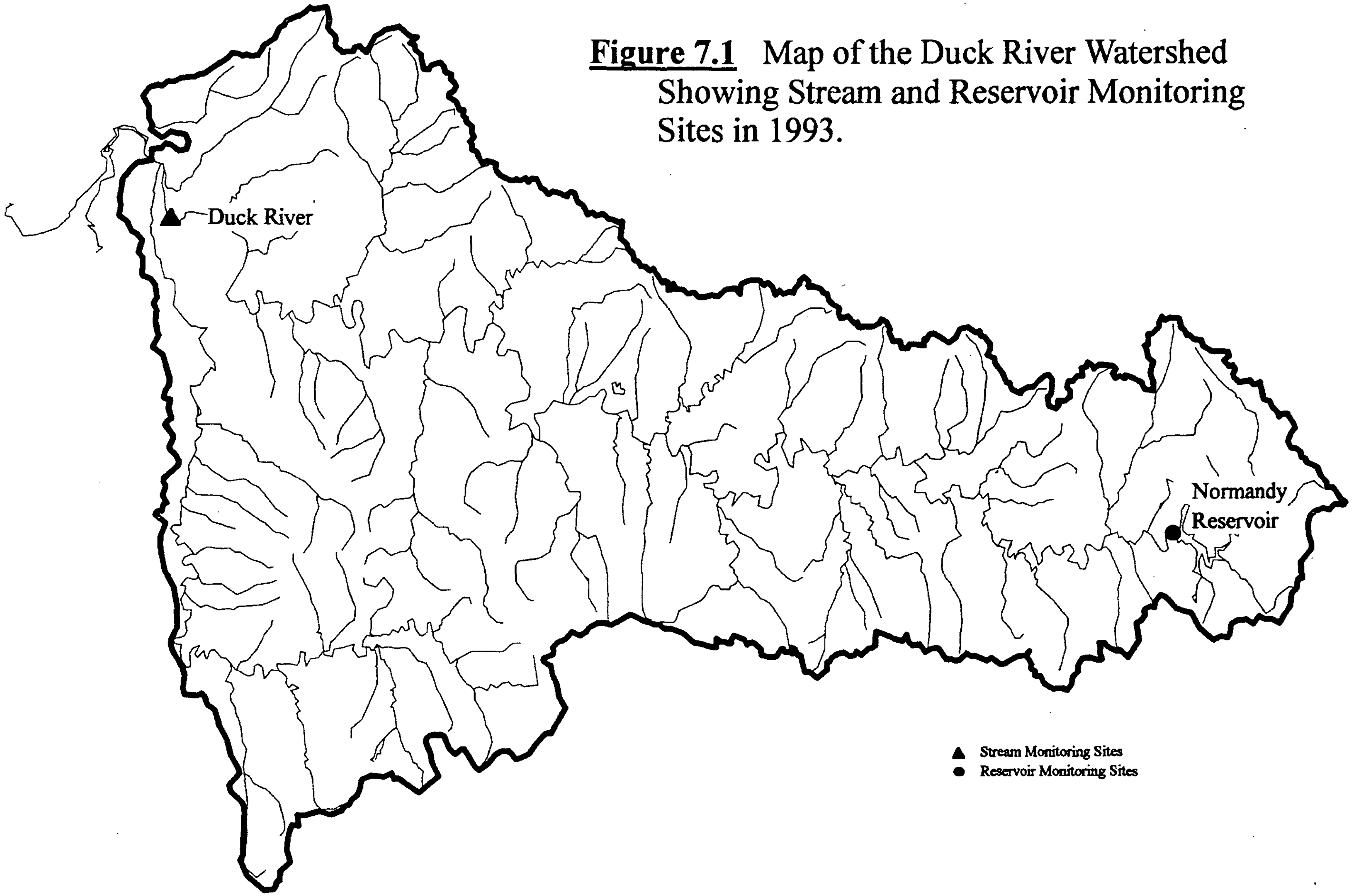
The Duck River Watershed includes all streams flowing into the Duck River. It has an area of 3500 square miles and an average annual discharge of 4075 cfs to Kentucky Reservoir on the Tennessee River. The Duck River basin is underlain almost entirely by limestone, or phosphatic limestone; consequently, waters in the streams draining this basin are fairly hard and contain large concentrations of minerals. Large deposits of phosphate ores permit phosphate mining and refining operations in the basin. Phosphate concentrations in surface and groundwater are significantly higher than in most of the Tennessee Valley. The soils are thin with limestone outcrops at the surface in many places, and sinkholes are common throughout the watershed.

Normandy Reservoir is the only reservoir in this watershed. This is a relatively small reservoir and only the forebay is included in the Vital Signs monitoring program (Figure 7.1).

There is one stream monitoring site on the Duck River at mile 26.0 (Figure 7.1).

Information from monitoring activities on Normandy Reservoir and the Duck River are in Sections 7.1 and 7.2, respectively.

Figure 7.1 Map of the Duck River Watershed Showing Stream and Reservoir Monitoring Sites in 1993.



7.1 Normandy Reservoir

Physical Description

Normandy Reservoir is formed by Normandy Dam at Duck River mile (DRM) 248.6. Normandy Reservoir, constructed primarily for flood control and water supply, has a drainage area of 195 square miles and no electric power generation capacity. One of TVA's smaller reservoirs, Normandy at full pool elevation has about 3200 surface acres, 73 miles of shoreline, and about 17 miles of impounded backwater. The reservoir has an average depth of about 35 feet and an average annual drawdown of about 11 feet. The average annual discharge from Normandy Dam is about 320 cfs, providing an average annual retention time of about 175 days.

Ecological Health

The ecological health of Normandy Reservoir rated poor-fair (56 percent) in 1993. Vital Signs monitoring previously had not been conducted on this reservoir, although several special studies had been completed. As expected, DO conditions were among the poorest observed on any Vital Signs reservoir in 1993. DO rated very poor because anoxia existed, 77 percent of the cross-sectional bottom length had DO concentrations <2.0 mg/L, and 48 percent of the cross-sectional area had DO levels <2.0 mg/L. Sediment quality rated poor due to high levels of ammonia and toxicity to test animals. Benthic macroinvertebrates also rated very poor, likely due to such poor bottom conditions.

Based on past studies, there was concern about very high levels of primary productivity in Normandy Reservoir. Sampling in 1993 did not find this to be the case. Chlorophyll rated good at the forebay sample location because the annual average chlorophyll concentration was within the mesotrophic range, and no single sample had a very high chlorophyll concentration.

The other indicator, fish assemblage, rated excellent. Normandy Reservoir had one of the best fish assemblages examined on tributary reservoirs in 1993. Most of the 12 metrics received the highest possible score.

Reservoir Use Suitability

Fecal coliform samples were collected at two swimming beaches and three boat ramps in 1992. While concentrations were low at the boat ramps, several samples were high at each of the beaches, although the geometric means were well within recreation criteria. The two beaches were sampled again in 1993. Fecal coliform concentrations were much higher, but the geometric means were still within criteria. Local geese populations are the probable source of the high bacteria concentrations.

There are no fish consumption advisories on Normandy Reservoir. A composite sample of channel catfish collected from the forebay in autumn 1992 was screened for pesticides, PCBs, and selected metals. All analytes were either not detected or found in only low concentrations.

7.2 Duck River Stream Monitoring Site

Physical Description

The Duck River flows westward from its headwaters in northwestern Coffee County, Tennessee, for more than 280 miles through the Nashville basin and Highland Rim physiographic provinces in middle Tennessee to meet the Tennessee River. The basin is approximately 125 miles long and 30 miles wide and drains 3500 square miles.

The stream monitoring location is at the USGS stream gage above Hurricane Mills, Tennessee. The Duck River basin above Hurricane Mills is 2557 square miles or 73 percent of the entire Duck River basin. Principal tributaries in the monitored area include the Piney River (223 square miles), Big Swan Creek (155 square miles), Lick Creek (101 square miles), and Big Bigby Creek (129 square miles) which drain the Highland Rim province; and Rutherford Creek (116 square miles), Fountain Creek (103 square miles), Big Rock Creek (121 square miles), and Garrison Fork (130 square miles) which drain the Nashville Basin. Normandy Dam forms the only major impoundment located on the upstream reach of the Duck River stream monitoring site.

A principal tributary that flows into the Duck River below the stream monitoring location is the Buffalo River that drains 764 square miles (22 percent of the Duck River basin). The Buffalo River basin lies entirely within the Highland Rim province and the streams generally contain low concentrations of dissolved minerals.

Ecological Health

The stream monitoring site on the Duck River showed generally fair ecological health in 1993, similar to 1992. This was driven by high phosphorus concentrations and fair conditions for the fish community. Sediment quality and the benthic macroinvertebrate community both rated good, an improvement over 1992 observations. Undesirable conditions at this site included extensive bank erosion and unstable bottom substrate conditions. Although the Duck contributes only about 6.5 percent of the total flow of Kentucky Reservoir under average flow conditions, it can contribute significant amounts of nutrients and sediment to the reservoir.

Use Suitability

A reach of the Duck River from 3.5 to 7.1 miles downstream of Normandy Dam was found to greatly exceed bacteriological criteria for water contact recreation in 1993, probably due to dairies.

All metal and organic analytes in fish tissue samples were not detected or found in low concentration.

8.0 PICKWICK RESERVOIR - WILSON RESERVOIR WATERSHED

Pickwick Reservoir and Wilson Reservoir on the Tennessee River are the most notable features of this drainage area. Only a small part of the flow leaving this watershed actually originates within the watershed itself. The average annual discharge from Pickwick Dam is 54,900 cfs. Of that, 49,500 cfs (90 percent) is the discharge from Wheeler Dam into Wilson Reservoir. About 2100 cfs enters Wilson Reservoir through local tributaries and about 3400 cfs originates in tributaries to Pickwick Reservoir. The streams within this watershed drain an area of about 3230 square miles. The largest tributaries are Bear Creek, a tributary to Pickwick Reservoir with a drainage area of about 945 square miles, and Shoal Creek, a tributary to Wilson Reservoir, with a drainage area of about 445 square miles.

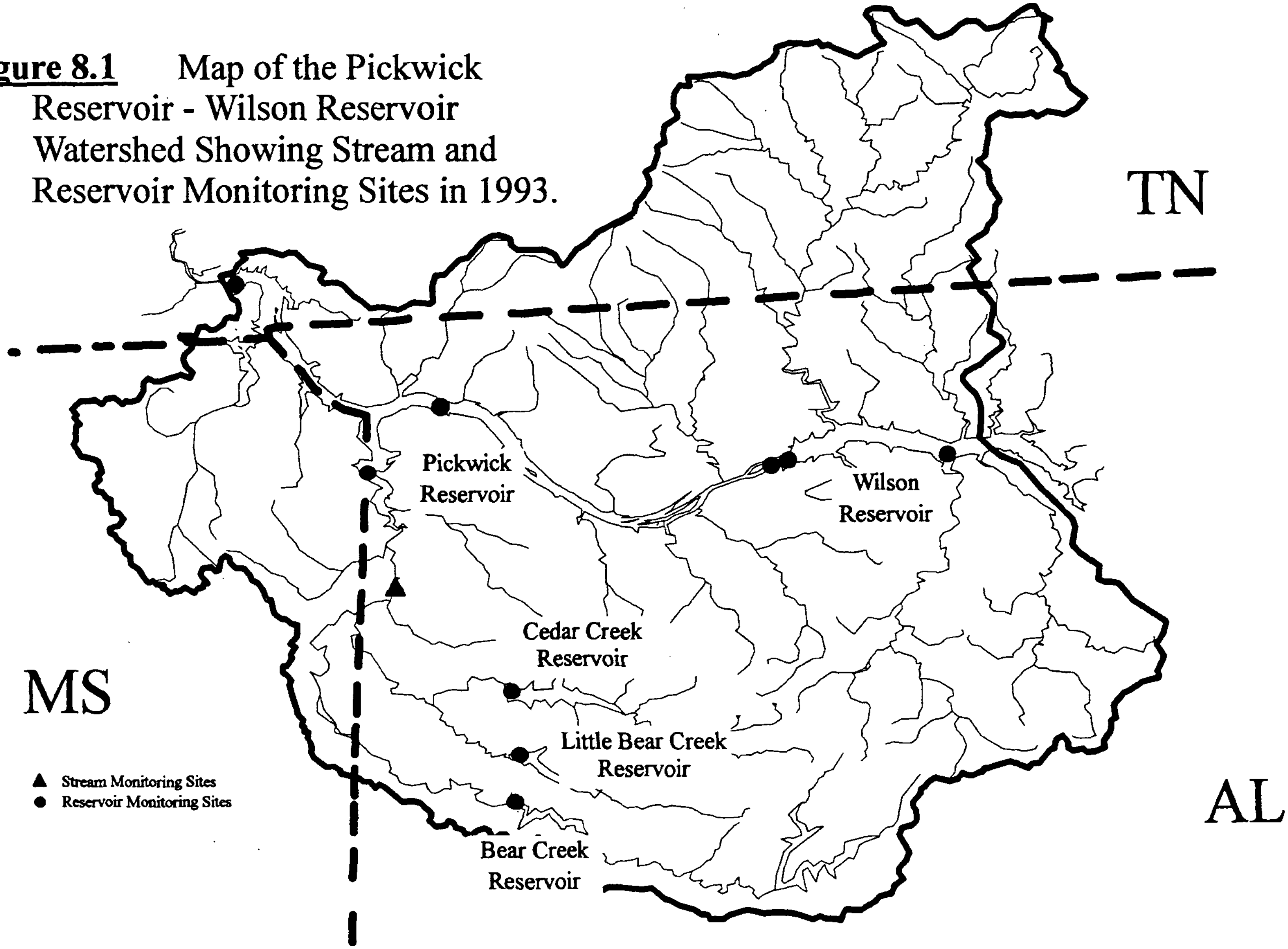
Four small reservoirs were built on Bear Creek in the late 1970s and early 1980s for flood control and recreation. These are Bear Creek, Little Bear Creek, Cedar Creek, and Upper Bear Creek Reservoirs.

Reservoir monitoring activities occur at the forebay, transition zone, and inflow on Pickwick Reservoir and at the forebay and inflow on Wilson Reservoir (Figure 8.1). Wilson is relatively short and has no definable transition zone. Because of their smaller size, only the forebays of Bear Creek, Little Bear Creek, and Cedar Creek Reservoirs are monitored. No monitoring activities are conducted on Upper Bear Creek because of TVA's program to destratify and oxygenate water in the forebay.

The only stream monitoring site is on Bear Creek at Bear Creek mile 27.3. Results for 1993 reservoir and stream monitoring activities within this watershed are provided in the following sections:

8.1 Pickwick Reservoir
8.2 Wilson Reservoir
8.3 Bear Creek Reservoir
8.4 Little Bear Creek Reservoir
8.5 Cedar Creek Reservoir
8.6 Bear Creek Stream Monitoring Site

Figure 8.1 Map of the Pickwick Reservoir - Wilson Reservoir Watershed Showing Stream and Reservoir Monitoring Sites in 1993.



8.1 Pickwick Reservoir

Physical Description

Pickwick Reservoir is immediately upstream of Kentucky Reservoir on the Tennessee River. Pickwick Dam is located at TRM 206.7. Like the rest of the mainstream, run-of-the-river reservoirs, Pickwick is much shorter (53 miles long) and smaller (43,100 acres and shoreline of 496 miles) than Kentucky Reservoir. Average annual discharge is about 55,000 cfs, which provides an average hydraulic retention time of about eight days. Additional information about reservoir characteristics is in Table 4.1.

A major tributary, Bear Creek, joins the Tennessee River in Pickwick Reservoir at about mile 225. Bear Creek provides, on the average, about 2.5 percent of the flow through Pickwick Reservoir.

Reservoir Monitoring activities were expanded on Pickwick Reservoir in 1993 to include a Vital Signs monitoring site in Bear Creek embayment. This rather large embayment (7200 acres) extends from the mouth of Bear Creek upstream about 17 miles to the point where flow is not affected by backwater from Pickwick Dam.

Ecological Health

The ecological health of Pickwick Reservoir was fair to good in 1993 (73 percent), similar to 1992 and 1991. All ecological health indicators rated between fair and excellent at all locations, except chlorophyll, which rated very poor (indicating high algal productivity) at the new sample site in Bear Creek embayment. There was a general decline in DO conditions throughout the reservoir in 1993 with DO rated fair to good at all locations. In 1992 DO was good to excellent at all locations. Summer 1993 was characterized by low rainfall, low flows, and high temperatures, hence lower DO concentrations were expected.

Conditions at the transition zone improved in 1993 for chlorophyll and sediment quality. Sediments contained lower mercury concentrations than in previous years; however, concentrations were still slightly above background. Although chlorophyll concentrations were in the fair range in 1993 (because of relatively high average concentrations), this was an improvement over 1992 when concentrations were even higher.

Benthic macroinvertebrates at the inflow location, downstream of Wilson Dam, were improved in 1993, rating excellent as compared to fair in 1992 and poor in 1991. The improvement between 1991 and 1992 was partly due to an improved evaluation system and partly due to actual improvements in the health of the community of bottom animals. The 1993 results indicate continued improvements in the benthos.

At the forebay, the fish assemblage evaluation has shown substantial variation from year to year. The rating was good in 1991, poor in 1992 (very few fish collected), and good in 1993. Interestingly, a low number of fish were collected from this location by electrofishing in 1993, yet an abundance of fish were collected by gill netting. The 1992 rating was based only on electrofishing results, whereas the 1993 rating was based on results from both techniques. Overall, there appeared to be little change in the fish assemblage among years.

The new sample site in Bear Creek embayment had one very poor indicator (chlorophyll--too high), three fair indicators (DO--zero on bottom; sediment--toxicity to test organisms; benthos--mostly tolerant organisms present), and one good indicator (fish). Of the four sites sampled on Pickwick Reservoir in 1993, the Bear Creek embayment site had the poorest ecological health. If results for this site were deleted from calculating the overall reservoir score, the reservoir score would be 80 percent.

There were only about 105 acres of aquatic plants on Pickwick Reservoir in 1993, similar to the 100 acres in 1992.

Reservoir Use Suitability

Use Suitability monitoring did not identify bacteriological nor fish tissue contamination problems. There are no fish consumption advisories on Pickwick Reservoir based on fish collected from 1988 through 1992. Concentrations of metals, PCBs, and pesticides in composited catfish fillets were relatively low except for total DDT concentrations in the fall 1992 inflow sample. Given the rare occurrence of elevated total DDT concentrations in fish from Pickwick, it is likely that one of the catfish in the composite came from Wheeler Reservoir, which has a significant, localized DDT contamination problem. Fecal coliform bacteria concentrations were low at ten swimming areas sampled in 1993. Bacteria concentrations at the Vital Signs locations sampled since 1990 have been low.

8.2 Wilson Reservoir

Physical Description

Wilson Reservoir is quite different from other mainstream Tennessee River reservoirs in both length and depth. Wilson Dam is located at TRM 259.4 and Wheeler Dam is at TRM 274.9, providing a length of only 15.5 miles, a shoreline of 154 miles, and surface area of 15,500 acres. Water depth in the forebay is slightly over 100 feet. This short, deep pool, coupled with the largest hydroelectric generating plant in the TVA system, provides for short hydraulic retention times (six days). Average annual discharge from Wilson is 51,500 cfs. Because of the physical characteristics, design, and operation of Wilson Dam (primarily upper strata withdrawal for hydropower generation), low DO conditions develop in deeper strata of the forebay during summer months.

Ecological Health

Ecological health of Wilson Reservoir improved somewhat in 1993 compared to 1992 and 1991. Overall, Wilson Reservoir rated fair to good (71 percent) in 1993 compared to 60-70 percent in previous years. One of the persistent problems in Wilson Reservoir is low concentrations of dissolved oxygen (< 1 mg/L) in the forebay during summer months. The problem was more severe in summer 1993 due to the drought conditions (high temperatures, low rainfall, and low flows). Anoxia developed near the bottom, and a large proportion of the bottom and water column had DO concentrations <2.0 mg/L, leading to a very poor rating.

A massive algal bloom caused extremely high chlorophyll concentrations at the forebay in 1992 resulting in a poor rating that year. Chlorophyll concentrations were lower in 1993, but still relatively high and, therefore, rated fair in 1993. The benthic macroinvertebrate community at the forebay rated better in 1993 (fair) compared to previous years (consistently poor). Poor ratings had been attributed to the low concentrations of DO near bottom during summer. Given that benthos collections were made in March 1993, prior to the severe DO problems later that summer, these samples would have been more representative of 1992 conditions. Even though DO concentrations in summer 1992 were not good, they were the best documented on Wilson since the Vital Signs monitoring program began in 1990. The duration of low DO concentrations was relatively short in 1992 and the proportion of bottom with low DO concentrations was small. These conditions may have provided sufficient opportunity for recolonization of several benthic species resulting in the improved community rating for 1993. Samples to be collected in March 1994 will help determine whether this hypothesis is correct. If correct, the benthos rating for 1994 should be poor because of the severe DO conditions in summer 1993.

Sediment quality at the forebay was good in 1992 and 1993, indicating no impairment due to bottom substrates. This was an improvement over 1991 when fair sediment quality conditions were found due to lower survival rates for test organisms. All ecological health indicators measured at the inflow location (DO, fish, and benthos) were good or excellent in 1993.

There were only 54 acres of aquatic plants on Wilson Reservoir in 1993.

Reservoir Use Suitability

There are no fish consumption advisories on Wilson Reservoir based on fish tissue studies conducted over the past several years.

Fecal coliform bacteria concentrations were very low at the two boat ramps tested in 1993 and at the Vital Signs location in the forebay. The low rainfall in 1993 may have contributed to low concentrations at the boat ramps. All fecal coliform samples collected in the forebay since 1990 have been low.

8.3 Bear Creek Reservoir

Physical Description

With a surface of only 700 acres, Bear Creek is one of the smallest reservoirs in the TVA system. It is relatively long (16 miles), narrow, and deep (74 feet at the dam). The average annual discharge is 380 cfs providing an average hydraulic retention time of about 13 days. Average annual drawdown is about 11 feet. Bear Creek Reservoir stratifies in the summer and develops hypolimnetic anoxia. Another water quality concern is abandoned strip mines in the watershed.

Ecological Health

The ecological health of Bear Creek Reservoir rated fair (60 percent) in 1993. Vital Signs monitoring previously had not been conducted on this reservoir. This reservoir appears to have a high rate of primary productivity and significant hypolimnetic DO depletion. Summer chlorophyll concentrations were higher on Bear Creek Reservoir than on any of the other tributary reservoirs monitored in 1993. Only one of the five indicators (benthic macroinvertebrates) rated excellent and one rated good (fish). Such high ratings would not be expected given the very poor rating for DO (anoxia and large proportion of the water column with low DO concentrations) and poor rating for sediment quality (high ammonia and toxicity to test animals). Continued monitoring in future years will help to better define the ecological health of Bear Creek Reservoir.

Use Suitability

Fecal coliform bacteria concentrations were low at both of the swimming areas surveyed in 1993. The low rainfall in 1993 may have contributed to low concentrations. During a wetter period in 1991, fecal coliform concentrations were higher, but still well within water quality criteria for recreation. A single composite of channel catfish was collected from the forebay in autumn 1992. All metal and organic analytes were low or not detected, except for mercury which was high enough to warrant reexamination in autumn 1993 but not high enough to indicate a need for an in-depth, intensive study.

8.4 Little Bear Creek Reservoir

Physical Description

Little Bear Creek Reservoir is relatively short (7.1 miles long) and deep (84 feet at the dam). It has a surface area of 1600 acres. With an average annual discharge of 101 cfs, the hydraulic retention time is 225 days. Compared to Bear Creek Reservoir, the lower flow into the reservoir and larger reservoir volume make the retention time much longer in Little Bear Creek Reservoir. Average annual drawdown is about 12 feet.

Ecological Health

Little Bear Creek Reservoir had a fair (64 percent) ecological health rating in 1993. This was the first year for Vital Signs monitoring on Little Bear Creek Reservoir. Similar to the other reservoirs in the Bear Creek watershed, the most obvious problem was very poor DO conditions at the forebay. Other indicators rated good (chlorophyll and fish assemblage) or fair (sediment quality and benthos). Given the hot, dry summer of 1993, additional information in future years will help to better evaluate and define the ecological health of Little Bear Creek Reservoir.

Reservoir Use Suitability

Fecal coliform bacteria concentrations were very low at both swimming areas tested in 1993. The low rainfall in 1993 may have contributed to low concentrations. During a wetter period in 1991, fecal coliform concentrations were much higher at both beaches. During the 1991 survey period, bacteriological water quality at both sites was within state water quality criteria for recreation; however, both exceeded one of EPA's recommended guidelines--more than 10 percent of the samples had fecal coliform concentrations greater than 400/100 mL.

A composite of channel catfish was collected from the forebay of Little Bear Creek Reservoir in autumn 1992. Only one metal analyte (mercury) was detected, and no PCB or pesticide analytes were detected. The mercury concentration (0.56 μg/g) was relatively high. As a result, channel catfish from this site were reexamined in autumn 1993. Results were not available at the time this report was prepared.

8.5 Cedar Creek Reservoir

Physical Description

Like the other reservoirs in the Bear Creek watershed, Cedar Creek Reservoir is small (only nine miles long and 4200 acres surface area) and deep (79 feet at the dam). The low average annual discharge from the dam (282 cfs) creates a relatively long average retention time (168 days). This combination of physical features lead to thermal stratification and hypolimnetic anoxia in the summer. Average annual drawdown is about 14 feet.

Ecological Health

The ecological health of Cedar Creek Reservoir rated poor-fair (56 percent) in 1993, the first year of Vital Signs monitoring. As expected based on the other reservoirs in the Bear Creek watershed, DO rated very poor because of anoxic conditions and a very large proportion of both the bottom and the water column with DO concentrations <2.0 mg/L. Chlorophyll, benthos, and fish assemblage all rated fair. The only fair to good rating was for sediment quality. There were no excellent ratings.

Reservoir Use Suitability

Fecal coliform bacteria concentrations were low at the Slickrock Ford swimming area in 1993. The low rainfall in 1993 may have contributed to low concentrations. During a previous survey period in 1991 with more normal rainfall, higher fecal coliform concentrations were found. Despite being higher, they were within state water quality criteria for recreation.

A single composite of channel catfish fillets collected from the forebay of Cedar Creek Reservoir in autumn 1992 did not have detectable concentrations of any pesticide or PCB analyte. Mercury, found at a low concentration, was the only metal analyte detected.

8.6 Bear Creek Stream Monitoring Site

Physical Description

Bear Creek flows through the southwest boundary of the Highland Rim physiographic province in northwestern Alabama (85 percent) and northeastern Mississippi to join the Tennessee River as an embayment of Pickwick Reservoir. The Bear Creek watershed is approximately 65 miles long and 15 miles wide and drains 946 square miles.

The watershed area above the Bishop, Alabama, monitoring location is 667 square miles or 70 percent of the entire Bear Creek basin. Within the monitored area, Cedar Creek, with a drainage area of 329 square miles, is the principal tributary. There are four reservoirs (Cedar Creek, Little Bear Creek, Bear Creek, and Upper Bear Creek) that control the runoff from about half of the watershed.

The Bear Creek basin is underlain by sandstone or has limestone outcroppings. Approximately 70 percent of the watershed is forested, the remainder agricultural. Some iron ore has been mined in the basin and bacterial pollution from agricultural operations has been recognized as a water quality concern. Several active and abandoned coal mines are located on the uppermost portions of the watershed above the upper Bear Creek Reservoir. Russellville and Haleyville, Alabama, are the primary urban areas.

Ecological Health

The monitoring location on Bear Creek, far upstream of any influence of impoundment from Pickwick Reservoir, showed fair ecological health in 1993. The fish community was fair in 1993; but not as good as in 1992, which was much improved over past years. Benthic macroinvertebrates also rated fair in 1993, similar to 1992.

Use Suitability

The only bacteriological samples collected from the Bear Creek watershed in 1993 were those collected for reservoir Vital Signs monitoring and are reported with those sections.

Fish for tissue analysis are not collected from the Bear Creek stream monitoring site.

9.0 WHEELER RESERVOIR - ELK RIVER WATERSHED

The Wheeler Reservoir - Elk River watershed drains about 5140 square miles in north central Alabama and south central Tennessee. Wheeler Reservoir is the fourth of nine reservoirs on the Tennessee River. About 24,500 square miles of the Tennessee Valley are upstream of this watershed. Wheeler Reservoir receives an average annual inflow of 40,700 cfs from Guntersville Dam. Discharges from Wheeler Dam average 49,400 cfs on an annual basis leaving 8700 cfs which originate within the watershed.

The largest tributary to Wheeler Reservoir is the Elk River, which has a drainage area of about 2250 square miles and contributes about 3000 cfs. The remaining flow enters from tributaries directly to Wheeler Reservoir.

Wheeler Reservoir is the largest reservoir within this watershed followed by Tims Ford Reservoir on the Elk River. There are four Vital Signs monitoring sites on Wheeler Reservoir--forebay, transition zone, inflow, and the Elk River embayment (Figure 9.1 and Table 2.1). Two sites are monitored for Vital Signs on Tims Ford Reservoir--forebay and mid-reservoir. Woods Reservoir on the Elk River is not included in this monitoring program because it is property of the Arnold Engineering Development Center, Arnold Air Force Base.

The only stream monitoring site within this watershed is on the Elk River at mile 36.5.

Results from 1993 monitoring activities are provided in Section 9.1 for Wheeler Reservoir, Section 9.2 for Tims Ford Reservoir, and Section 9.3 for the stream site on the Elk River.

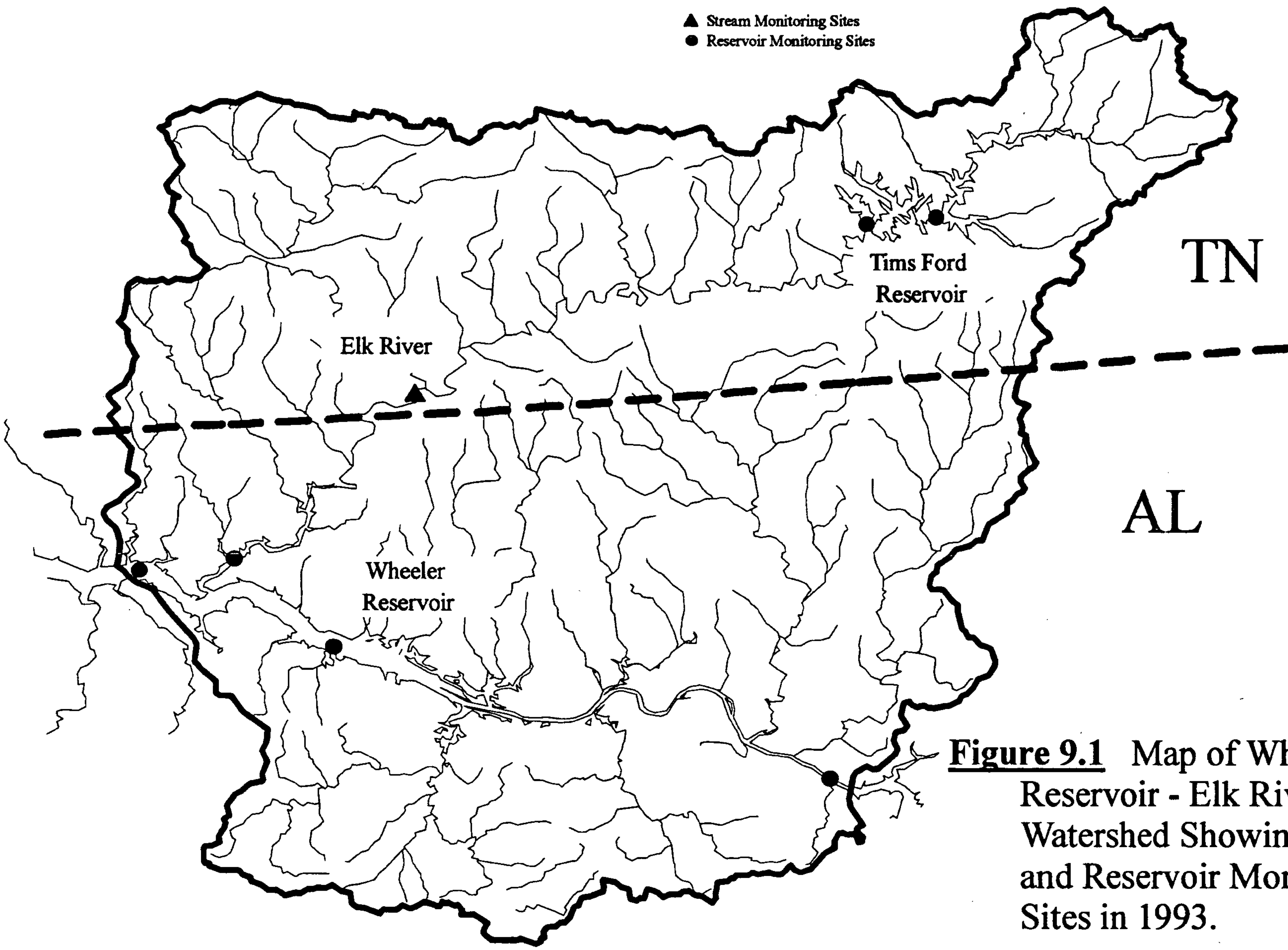


Figure 9.1 Map of Wheeler Reservoir - Elk River Watershed Showing Stream and Reservoir Monitoring Sites in 1993.

9.1 Wheeler Reservoir

Physical Description

Wheeler Reservoir has the third-largest surface area (67,100 acres) of all reservoirs in the TVA system. It is 74 miles long (dam at TRM 274.9) and has 1063 miles of shoreline. Average annual discharge is about 49,400 cfs which provides an average hydraulic retention time of about 11 days. Information collected in 1990 and 1991 indicated a more riverine than transition environment at TRM 307.5; consequently, in 1992 the transition zone sampling location was relocated further downstream to TRM 295.9. Results for 1992 and 1993 are being evaluated to determine if this new site is suitably located or if it needs to be moved further downstream.

The Elk River joins the Tennessee River in the downstream portion of Wheeler Reservoir at about mile 284 and provides, on the average, about 6 percent of the flow through Wheeler Reservoir.

Vital Signs monitoring activities were expanded in 1993 to include a site in the Elk River embayment. This was one of four embayments added to the Vital Signs program in 1993. The Elk River embayment covers about 4900 acres. Given the relatively high flows in the Elk River (about 3000 cfs annual average), there is substantial water exchange in this embayment.

Reservoir Health

Like several other Tennessee River reservoirs, the overall ecological health index of Wheeler Reservoir was lower in 1993 compared to 1992 and 1991. Overall, Wheeler Reservoir rated fair to good (72 percent) in 1993 compared to good in 1992 (80 percent) and in 1991 (87 percent). The primary contributor to this lower reservoir rating was addition of information from the Elk River embayment, which had three poor ratings (chlorophyll--very poor; DO and benthos--poor). Of the four sites monitored on Wheeler Reservoir in 1993, the Elk River embayment site had the poorest ecological health. If data from the Elk River site were deleted from the overall score, Wheeler would rate good (82 percent), consistent with findings in 1991 and 1992.

DOs less than 2 mg/L were measured at lower depths in the forebay during summer with an anoxic area near bottom. As a result, DO rated poor at the forebay. (Ratings for DO at the forebay had been good in 1991 and fair in 1992.) This stressed condition was likely related to the low flows during the 1993 summer. Interestingly, DO rated excellent at the inflow and transition zone, indicating the problem developed within the downstream, forebay region of the reservoir. When low reservoir flows and high water temperatures occur, respiration and oxygen demand (both sediment and biological) increase and can exceed the DO made available by reaeration and photosynthesis. This downstream portion of Wheeler Reservoir usually has relatively high algal productivity due to input of high levels of phosphorus from Elk River. The combination of stagnant water and a high oxygen demand required to decompose dead algae settling to the bottom contributes to low DOs in lower depths at the forebay. All other ecological health indicators rated fair, good, or excellent, similar to previous years. The transition zone and inflow had mostly good or excellent rating for all indicators. The fish assemblage and sediment quality were fair, good, or excellent at all sample sites.

Aquatic macrophytes colonized about 6600 acres on Wheeler Reservoir in 1993, compared to about 4400 acres in 1992 and 3500 acres in 1991.

Reservoir Use Suitability

No bacteriological studies were conducted at recreation sites in Wheeler Reservoir in 1993. In 1990, bacteriological water quality met the Alabama criterion for recreation at the four swimming beaches and four boat ramps tested. Fecal coliform bacteria concentrations have generally been low at the Vital Signs locations in the forebay and transition zones. Since 1990, only two samples have been high, one in 1990 and one in 1993, both in the transition zone.

The Alabama Department of Public Health advises that most fish species from within the Indian Creek embayment on Wheeler Reservoir should not be eaten due to DDT contamination. An intensive study was conducted in autumn 1991 to determine if high concentrations existed in fish from the Tennessee River in an area 15 miles downstream to five miles upstream of the Indian Creek embayment. Based on the 1991 results the public was further advised not to eat largemouth bass, channel catfish, and smallmouth buffalo from within one mile either side of the area where Indian Creek and the Tennessee River join. Other bottom feeding fish species (such as carp and suckers) from the area should also be avoided. Furthermore, channel catfish caught from the Tennessee River between Indian Creek and the Interstate 65 bridge should not be eaten. Fish were again collected from these areas in the Tennessee River in 1992 to continue examining DDT concentrations. The 1992 fish had much lower concentrations than those in 1991. The study was reported in autumn 1993, but results were not available at the time this report was prepared.

9.2 Tims Ford Reservoir

Physical Description

Tims Ford Reservoir in middle Tennessee is formed by Tims Ford Dam at Elk River mile (ERM) 133.3. The reservoir is 34 miles long at full pool and has a surface area of 10,600 acres. The depth at the dam is 143 feet and the average depth is about 50 feet. Average annual discharges from Tims Ford Dam are about 940 cfs, resulting in a hydraulic residence time of about 280 days. Tims Ford Reservoir is designed for a useful controlled drawdown of 30 feet (895-865 feet MSL) for flood protection; however, annual drawdowns average about 18 feet.

Ecological Health

The ecological health of Tims Ford Reservoir rated poor-fair (58 percent) in 1993 with very little change from previous years of Vital Signs monitoring. The most obvious ecological health problem was the low concentrations of DO near bottom (rated very poor at both the forebay and mid-reservoir sites in 1993). Although undesirable, low DO concentrations often exist in deep, tributary storage reservoirs like Tims Ford with long detention times and strong summer stratification. In spite of these low dissolved oxygen conditions, the fish assemblage rated good at both monitoring sites in 1993. However, the benthos, sampled for the first time in 1993, rated very poor at the forebay and poor at the mid-reservoir site. Sediment quality, also sampled for the first time in 1993, had high levels of ammonia at both locations and toxicity to test animals at the mid-reservoir site which rated poor. Chlorophyll ratings at both locations on Tims Ford Reservoir were good in 1993, indicating adequate primary productivity to support the food web, but not overly productive, potentially leading to eutrophic conditions.

Reservoir Use Suitability

Four sites were tested for fecal coliform bacteria in 1992; two sites were retested in 1993 because of high concentrations. The 1993 concentrations were low at the Estill Springs Park, but at the Dry Fork swimming area, bacteria concentrations were within state criteria only if samples collected within 24-hours of rainfall are excluded.

There are no fish consumption advisories for Tims Ford Reservoir. All analytes were either not detected or found in only low concentrations in channel catfish composites collected from the forebay and transition zone in autumn 1992.

9.3 Elk River Stream Monitoring Site

Physical Description

The Elk River flows for more than 200 miles from its headwaters near Monteagle, Tennessee, on the edge of the Cumberland plateau, southwest through south-central Tennessee into northern Alabama where it meets the Tennessee River about nine miles above Wheeler Dam. The basin, which lies principally in the Highland Rim province, is approximately 100 miles long and 50 miles wide at its greatest width, but it averages only 25 miles wide. Approximately one-third of the north central basin above the Elk River lies in the Nashville basin. The Elk River drainage basin area is 2249 square miles.

The TVA monitoring station is located at the USGS stream gage near Prospect, Tennessee. At this location, 1784 square miles or 79 percent of the entire Elk River basin is monitored. Major tributaries of the Elk River basin include Sugar Creek (177 square miles), Richland Creek (488 square miles), Cane Creek (106 square miles), Mulberry Creek (99 square miles), and Beans Creek (92 square miles). Tims Ford Dam and Elk River Dam control most of the runoff from the upper quarter of the watershed.

The Elk River drains an area underlain for the most part by limestone. Consequently, the water is high in dissolved minerals and fairly hard. About 60 percent of the Elk River basin is farmland. Urban areas include Pulaski, Fayetteville, Tullahoma, and Winchester, Tennessee.

Ecological Health

The monitoring site on the Elk River, far upstream of any influence of backwater from Wheeler Reservoir, was rated poor to fair in 1993, a slight improvement over 1992. Improvements were noted in sediment quality and benthic macroinvertebrates. (Fish were not sampled in 1993.) Nutrient concentrations were quite high, resulting from phosphorus-rich soils in the watershed. These high nutrient inflows from the Elk River can stimulate algal blooms in Wheeler Reservoir.

Use Suitability

Bacteriological water quality at an access location about one and one-half miles downstream of Tims Ford Dam was poor immediately after rainfall, but met recreation criterion if samples collected within 24-hours of rainstorms were excluded.

PMs with the technical staff, region, residents and licensee. This should include spending time (~ 1 week) with the resident staff to promote understanding of the capabilities, limitations and responsibilities of the inspection program and the resident staff.

4. Given the lack of regulatory licensing expertise with some of the BCs, targeted questions should be provided along with the responses. Also it may be worthwhile that credit for performance objectives be signed off by a qualified PM

5. Add a requirement to have another BC have a discussion on the application of knowledge. These questions would be situation based examples.

All analytes in fish tissue samples collected in summer 1992 were either not detected or found in low concentrations.

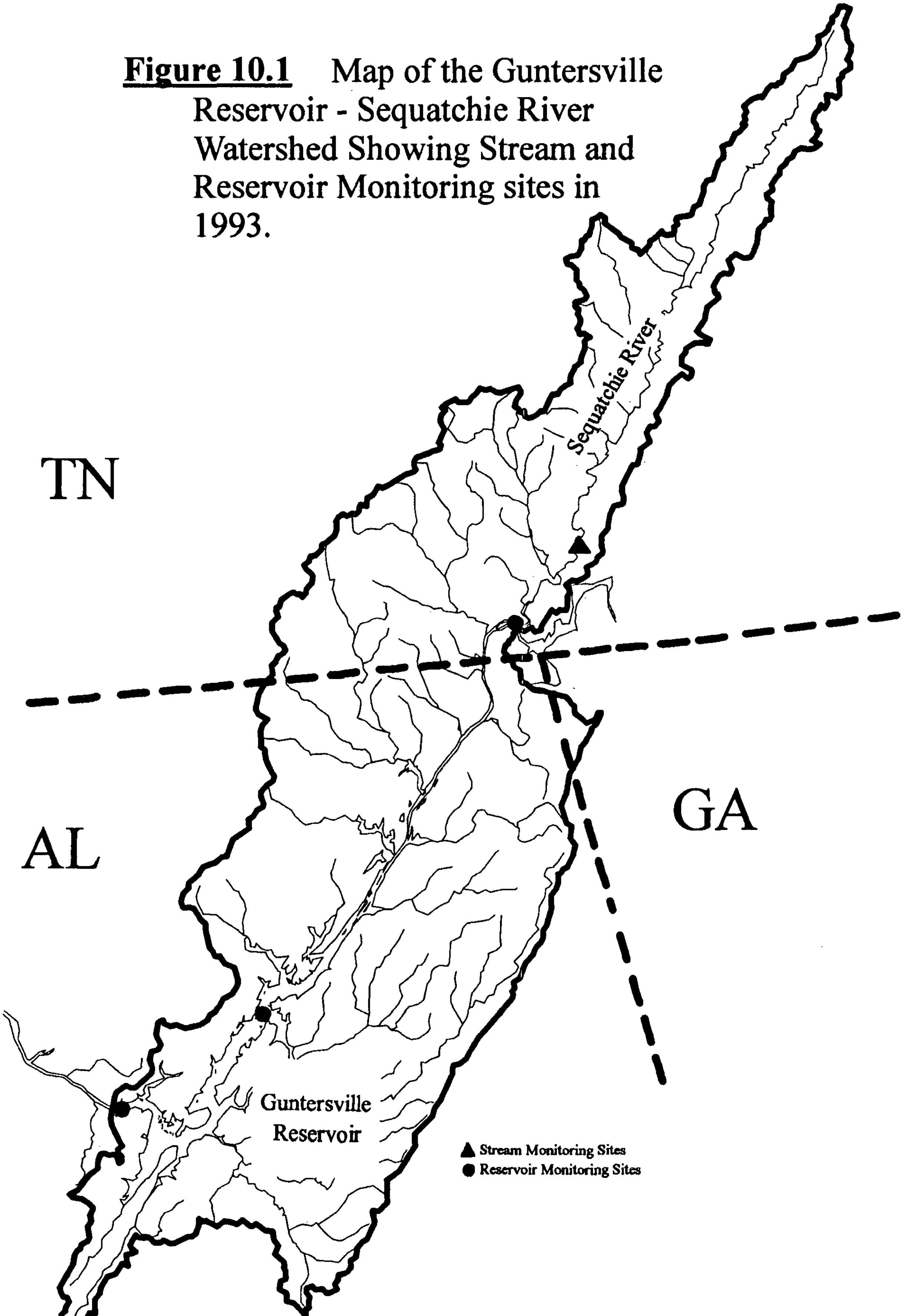
10.0 GUNTERSVILLE RESERVOIR - SEQUATCHIE RIVER WATERSHED

This watershed includes Guntersville Reservoir and all tributaries draining directly to Guntersville Reservoir. As with the other watershed areas on the mainstem of the Tennessee River, most of the water leaving the watershed through Guntersville Dam enters the watershed area through discharges from the upstream dam (Nickajack). About 35,900 cfs enter from Nickajack Dam and about 40,700 cfs is discharged from Guntersville Dam on an annual average basis. The remaining 4800 cfs originates with the Guntersville Reservoir-Sequatchie River watershed area. The largest contributor of this flow is the Sequatchie River (about 800 cfs). The total watershed area is 2669 square miles. The area drained by the Sequatchie River is about 600 square miles.

Guntersville Reservoir is the dominant characteristic of this watershed. There are three Vital Signs monitoring site on Guntersville Reservoir: forebay, transition zone, and inflow (Figure 10.1 and Table 2.1). Information from 1993 monitoring activities is provided in Section 10.1.

There is a stream monitoring site on the Sequatchie River at mile 6.3. Monitoring information for this site for 1993 is provided in Section 10.2.

Figure 10.1 Map of the Guntersville Reservoir - Sequatchie River Watershed Showing Stream and Reservoir Monitoring sites in 1993.



10.1 Guntersville Reservoir

Guntersville Dam, located at TRM 349.0, creates a 76 mile long reservoir with a surface area of 67,900 acres and a shoreline of 949 miles at full pool. Average annual discharge is about 40,700 cfs, corresponding to an average hydraulic retention time of about 13 days.

Guntersville Reservoir is similar to Wheeler Reservoir in several size characteristics, but it differs in one important feature. The average controlled storage volume of Guntersville is about half that of Wheeler. This is due to the shallow nature of Guntersville Reservoir at the inflow area and extensive shallow overbank areas. As a result, winter drawdown on Guntersville Reservoir is nominal to maintain navigation. The shallow drawdown allows the large overbank areas to be permanently wetted creating good habitat for aquatic macrophytes. Guntersville has the greatest area coverage of aquatic plants of any TVA reservoir.

The Sequatchie River joins the Tennessee River at about TRM 423, in the upstream portion of Guntersville Reservoir, just downstream from Nickajack Dam. On the average the Sequatchie River contributes less than 2 percent to the total flow of the Tennessee River through Guntersville Reservoir.

Data collected in 1990 and 1991, indicated a more riverine than transition environment at TRM 396.8. Consequently, in 1992 the transition zone sampling location was relocated further downstream to TRM 375.2. Results from the new site are being reviewed to determine if it is suitably located.

Ecological Health

Ecological health conditions were good (78 percent) in Guntersville Reservoir in 1993, similar to those observed in 1992 (83 percent). All ecological health indicators rated fair, good, or excellent at all reservoir sites, except for DO at the inflow, which rated very poor (compared to fair in previous years). A very low DO concentration (1.8 mg/L, the lowest ever recorded in the discharge from Nickajack Dam) was measured in July and was related to the usual flow patterns associated with the summer drought and special hydroelectric operations.

As in 1992, 1993 results indicated the transition zone had the best ecological health of the three sample sites on Guntersville Reservoir. Four of the five aquatic health indicators from this site had excellent ratings both years; only the fish assemblage rated less than excellent (fair).

Aquatic macrophytes covered about 7600 acres in 1993 compared to 5993 acres in 1992 and 5165 acres in 1991. Guntersville Reservoir contains more acres of aquatic plants than any other reservoir in the TVA system.

Reservoir Use Suitability

All sites tested for fecal coliform bacteria in 1992 and 1993 in Guntersville Reservoir met the Alabama water quality criterion for recreation. At most sites, bacteria concentrations were quite low. High fecal coliform concentrations were found in the Vital Signs sampling at the forebay in 1990 and 1991, but bacteria concentrations at both the forebay and transition zone were very low in 1992 and 1993.

There are no fish consumption advisories on Guntersville Reservoir. Channel catfish composites collected from Guntersville Reservoir in autumn 1990 had sufficiently high PCB concentrations to warrant further examination but were not high enough for the state to issue an advisory. Catfish collected from the same locations in 1991 and 1992 had progressively lower concentrations than those from 1990 with the 1992 concentrations generally indicative of "background" levels found in channel catfish throughout the Tennessee River. Other analytes were low or nondetectable in the 1992 samples.

10.2 Sequatchie River Stream Monitoring Site

Physical Description

The Sequatchie River basin is a narrow limestone valley of the Valley and Ridge physiographic province, surrounded by the Cumberland Plateau to the west and Walden Ridge to the east. The Sequatchie flows from its headwaters south of the Emory-Obed River basin for more than 110 miles to form an embayment at the upstream end of Guntersville Reservoir, just downstream from Nickajack Dam. The Sequatchie River drainage basin is 605 square miles.

The TVA monitoring station is located at the Valley Road bridge near Jasper, Tennessee. The upstream drainage basin is 575 square miles or 95 percent of the entire Sequatchie River basin. Principal tributaries in the monitored area include the Little Sequatchie River (132 square miles) and Big Brush Creek (69 square miles).

Dolomite and limestone underlie the floor of the Sequatchie River valley, which is predominantly farmland. Sandstones underlie the surrounding steep escarpments and plateaus, which are predominantly forested. Coal mines operate in some areas of the Cumberland Plateau. Whitwell, Dunlap, and Pikeville, Tennessee, are the primary urban area in the basin.

Ecological Health

The ecological health of the Sequatchie River monitoring site was good in 1993. All ecological health indicators were either good or fair. Coal mining activities may be hindering the fish community and bottom-dwelling animals as indicated by deposits of coal fines and other sediments.

Use Suitability

Four canoe sites were sampled in 1992 and 1993 for fecal coliform bacteria. Although some samples collected after rainfall had high concentrations, all sites met Tennessee water quality criterion for recreation both years.

Fish tissue samples from the Sequatchie River collected during summer 1992 had nondetectable or only low concentrations of all analytes.

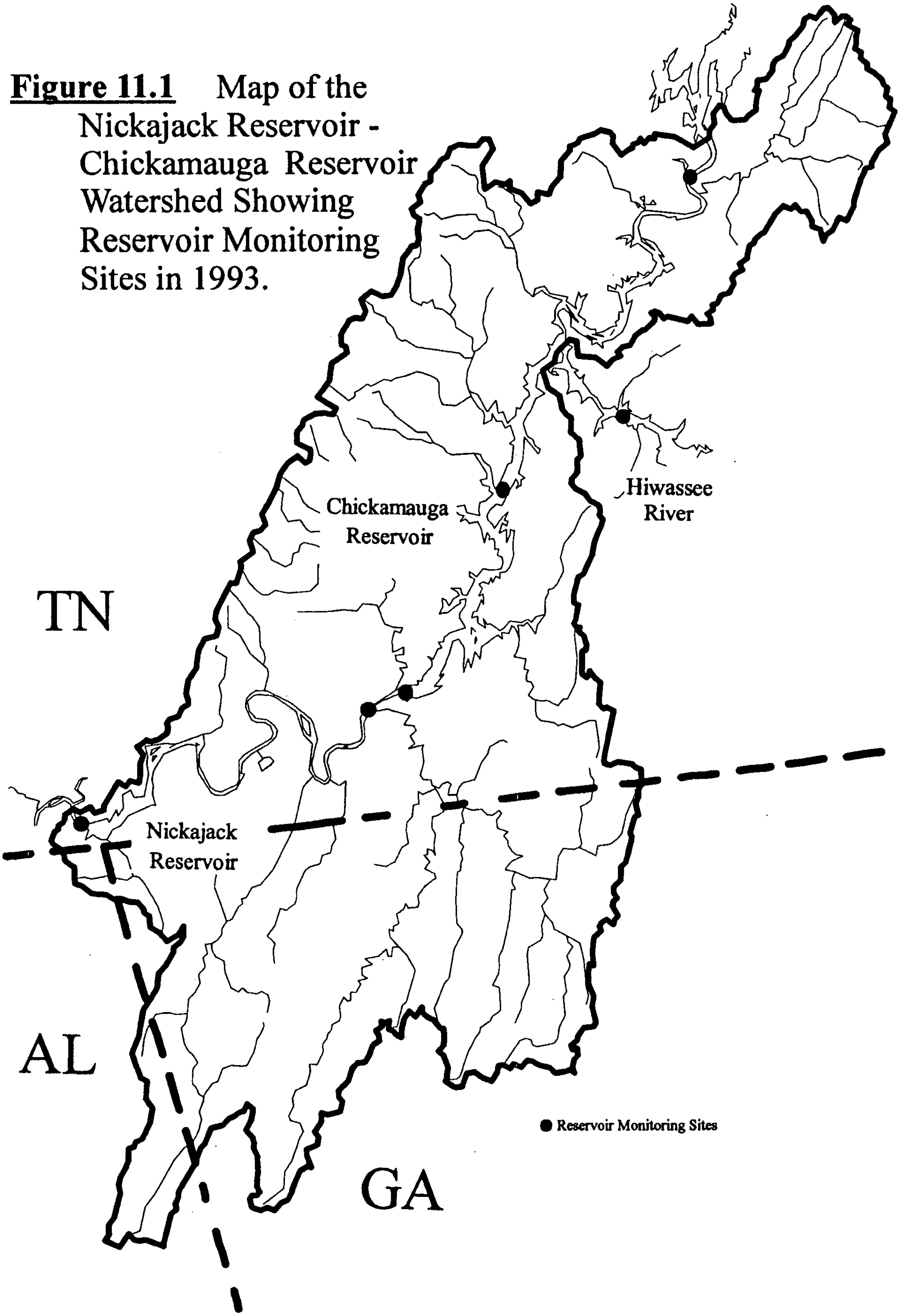
11.0 NICKAJACK RESERVOIR - CHICKAMAUGA RESERVOIR WATERSHED

Nickajack and Chickamauga Reservoirs are primary features of this watershed. The Hiwassee River is the only sizeable tributary which merges with the Tennessee River within the watershed area. The drainage basin of the Hiwassee River is large enough to be designated a separate watershed (see Section 12). The remaining area drained by tributaries to these two reservoirs is 1780 square miles. On an annual average basis, about 3200 cfs is contributed to the Tennessee River from streams within this watershed. This compares to 27,100 cfs entering the upper end of Chickamauga Reservoir from Watts Bar Dam and 5600 cfs from the Hiwassee River, for a total average annual discharge from Nickajack Dam of 35,900 cfs.

There are two Vital Signs monitoring sites on Nickajack Reservoir, one at the forebay and one at the inflow. There is no transition zone site on Nickajack because the reservoir is short and water exchange is quite rapid. This causes conditions at the location that might be considered the transition zone to be similar to those at the forebay. Chickamauga Reservoir has four Vital Signs monitoring sites--the forebay, the transition zone, the inflow, and a new site established in 1993 in the Hiwassee River embayment (Figure 11.1).

Results from 1993 monitoring activities are in Section 11.1 for Nickajack Reservoir and 11.2 for Chickamauga Reservoir.

Figure 11.1 Map of the Nickajack Reservoir - Chickamauga Reservoir Watershed Showing Reservoir Monitoring Sites in 1993.



11.1 Nickajack Reservoir

Physical Description

Nickajack Reservoir is one of the smallest reservoirs on the mainstem of the Tennessee River. With the dam at TRM 424.7, Nickajack has a length of 46 miles, surface area of 10,370 acres, and a shoreline of 192 miles at full pool. Average annual discharge from Nickajack is approximately 35,900 cfs which provides an average hydraulic retention time of only about three or four days, the shortest retention time among the reservoirs monitored in this program.

Results from the 1990 and 1991 monitoring indicated that both the forebay and transition zone sampling sites had quite similar water quality. This was expected since the two sites are relatively close together (separated by only 7.5 river miles), and Nickajack is a well-mixed, run-of-the-river reservoir. Therefore, sampling at the transition zone in Nickajack Reservoir was discontinued in 1992.

Ecological Health

Nickajack Reservoir had a good ecological health rating (88 percent) in 1993, the same as in 1992 and 1991 (83 percent both years). Nickajack had the highest overall ecological health rating of all Vital Signs reservoirs in 1993. The only poor rating was for DO at the upper end of Nickajack Reservoir. This was due to low DOs (minimum 2.2 mg/L) in the releases from Chickamauga Dam in July 1993. Low DO concentrations had been observed there in previous years, but concentrations measured in 1993 were the lowest ever recorded from Chickamauga Dam. These concentrations were not low enough to cause mortality for common species present, but were low enough to affect organism health and growth. Although the DO rating at the Nickajack forebay was excellent (no DO concentrations less than 2.0 mg/L were measured), it cannot be concluded that no DO problems existed. Because low DO concentrations were found in water entering Nickajack Reservoir from Chickamauga Dam and low DO concentrations were found in water leaving Nickajack Dam, it is clear that low DOs existed in the Nickajack forebay at some time. The lack of low measurements at the forebay likely is due to the timing of monthly measurements; sampling dates in July and August bracketed the period with most severe DO problems.

Other than the poor DO rating for the inflow, all other ecological health indicators at the forebay and inflow sample sites scored good or excellent. Even if low DO concentrations had been measured at the forebay, the high scores for the other indicators would have kept the overall rating for Nickajack Reservoir in the good range.

Aquatic macrophytes on Nickajack Reservoir covered about 1000 acres in 1993 compared to 830 acres in 1991 to 580 acres in 1992.

Reservoir Use Suitability

The Tennessee Department of Environment and Conservation has issued an advisory that catfish should not be eaten by children, pregnant women, and nursing mothers because of PCB levels (about 1.0 $\mu g/g$); other individuals should limit consumption to no more than 1.2 pounds per month. Fillets from catfish collected autumn 1992 had PCB concentrations about half those previously found in the five years of fish tissue studies on Nickajack Reservoir. The study was repeated in autumn 1993 to determine if lower PCB concentrations are found again. Results were not available at the time this report was prepared.

Fecal coliform bacteria concentrations in areas of Nickajack Reservoir tested during the recreation site sampling in 1992 and 1993 and Vital Signs sampling since 1990 were generally low. Exceptions include the boat ramp at Smith's Camp-On-The-Lake, where large populations of geese probably account for the high concentrations, and North Chickamauga Creek after rainfall.

11.2 Chickamauga Reservoir

Physical Description

Chickamauga Dam is located at TRM 471.0. The reservoir is 59 miles long, has 810 miles of shoreline, and has a surface area of 35,400 acres at full pool. The average annual discharge is approximately 34,200 cfs which provides an average hydraulic retention of nine to ten days (Table 4.1).

The Hiwassee River, a major tributary to the Tennessee River, flows into the middle portion of Chickamauga Reservoir at about TRM 499. The flow from the entire Hiwassee River watershed contributes approximately 16.5 percent of the flow through Chickamauga Reservoir. About 10 percent of the 16.5 percent is from the Ocoee River and tributaries in the lower end of the Hiwassee watershed (i.e., downstream of Apalachia Dam).

Vital Signs monitoring activities were expanded in 1993 to include a site in the Hiwassee River embayment, which covers about 6500 acres. Given the relatively high flows in the Hiwassee River (about 5600 cfs annual average), there is substantial water exchange in this embayment, much greater than in any of the other three embayments monitored.

Ecological Health

The overall ecological health rating for Chickamauga Reservoir was good in 1993 (83 percent), the second-highest rating of all reservoirs. This is an improvement over the fair to good rating in 1992 (73 percent) and is more like the good rating in 1991 (90 percent). Unlike the other three reservoirs which had a major embayment monitored for the first time in 1993 (Kentucky, Pickwick, and Wheeler), results from the Hiwassee River embayment did not lower the overall rating of Chickamauga Reservoir. Of the five ecological health indicators, two were excellent (chlorophyll and DO) and three were good (sediment quality, benthos, and fish assemblage) at the Hiwassee embayment site. If results from the Hiwassee River embayment site were excluded from determining the overall score for Chickamauga Reservoir, the score would be changed slightly to 81 percent.

Several health indicators had higher ratings in 1993 than in 1992. In particular, the sediment quality rating improved from poor in 1992 to fair in 1993 at both the forebay and transition zone. The poor ratings at these two sites in 1992 resulted from elevated concentrations of copper and zinc and toxicity to test organisms. In 1993 copper and zinc (in addition to trace levels of chlordane) were again found at the forebay, but no toxicity was found, resulting in a fair rating. The fair rating at the transition zone in 1993 was caused by an indication of toxicity (some mortality of rotifers, although not significantly different from controls) and presence of chlordane in the sediment; copper and zinc were not elevated. Chlordane in sediments was detected for the first time in 1993. This is related to improved laboratory methods rather than a true environmental change. New equipment which allowed better extraction of organic contaminants from sediments was used on 1993 samples.

DO levels on Chickamauga Reservoir were not impacted as much by the hot, dry summer as on several other Tennessee River reservoirs in 1993. The DO ratings at the forebay and transition zone were good, but there were small areas during June and July with very low DO concentrations. These areas are thought to have been too short in duration and too small in area to have had a significant impact. DO at the inflow rated fair due to a relatively low concentration (3.7 mg/L) in one sample from the releases of Watts Bar Dam.

Improvements in ratings for both the benthos (poor in 1992 and fair in 1993) and fish assemblage (fair in 1992 and excellent in 1993) were noted at the inflow. About twice as many benthic macroinvertebrate taxa were found in 1993 as in 1992, indicating improved conditions. Most fish assemblage metrics were excellent; this was a distinct improvement over 1992 results. Aquatic macrophytes on Chickamauga Reservoir covered 1185 acres in 1993 compared to 387 acres in 1992 and 680 acres in 1991. Aquatic macrophytes peaked at about 7500 acres in 1988 and continuously declined until summer 1993.

Reservoir Use Suitability

There are no fish consumption advisories for Chickamauga Reservoir. Fillets from Chickamauga Reservoir catfish have been examined for several years as part of a variety of studies. Study results have indicated no consistent or reservoir-wide problems. Results from most of these studies have usually found higher concentrations of PCBs in catfish from the inflow area than from other sites in the reservoir. Channel catfish were collected for screening purposes in autumn 1992 from the inflow, transition zone, and forebay. Concentrations of all analytes from all locations were low, including PCBs.

No bacteriological studies were conducted at recreation sites on Chickamauga Reservoir in 1993. Bacteriological water quality met the Tennessee criterion for recreation at the ten sites tested in 1989 and 1990. Fecal coliform bacteria concentrations have generally been low at the Vital Signs locations during all years monitoring activities have occurred.

12.0 HIWASSEE RIVER WATERSHED

The headwaters of the Hiwassee River extend into the Blue Ridge Mountains in Tennessee, North Carolina, and Georgia. Streams in this watershed have naturally low concentrations of nutrients and dissolved minerals. These streams change from steep gradient, cold water trout streams in the mountains to lower gradient warm water streams in the valley.

The Hiwassee River Watershed has an area of 2700 square miles and an average annual discharge to the Tennessee River of 5640 cfs. The confluence of the Hiwassee River with the Tennessee River is in Chickamauga Reservoir at Tennessee River Mile 499.4. The lower portion of the Hiwassee River is impounded by backwater from Chickamauga Dam. The impounded portion of the Hiwassee River forms a large embayment (about 6500 surface acres) which extends over 20 miles up the Hiwassee River.

The largest tributary to the Hiwassee River is the Ocoee River, with a drainage area of about 640 square miles. Due to past copper mining and industrial activities in the Copperhill area, several streams and reservoirs in the Ocoee River basin have degraded water quality.

There are eight TVA reservoirs in the Hiwassee River watershed (Figure 12.1 and Table 2.1). Vital Signs monitoring activities are conducted on the five largest reservoirs: Hiwassee Reservoir (forebay, mid-reservoir, and inflow); Chatuge Reservoir (forebay sites on the Hiwassee River and Shooting Creek arms); Nottely Reservoir (forebay and mid-reservoir); Ocoee Reservoir No. 1 (forebay only); and Blue Ridge Reservoir (forebay only). Apalachia, Ocoee No. 2, and Ocoee No. 3 Reservoirs are not included in this monitoring because of their small size.

There is a stream monitoring site on the Hiwassee River at HiRM 36.9, about 2.5 miles upstream of the confluence of the Ocoee River. A new site will be added in 1994 on the Ocoee River at mile 2.5. Vital Signs monitoring also includes a site on the Hiwassee River embayment (at HiRM 10) of Chickamauga Reservoir. Results from that monitoring site are provided in Chapter 11.

Results from 1993 reservoir and stream Vital Signs and Use Suitability monitoring activities are provided in the following sections:

12.1 Hiwassee Reservoir

12.2 Chatuge Reservoir

12.3 Nottely Reservoir

12.4 Blue Ridge Reservoir

12.5 Ocoee Reservoir No. 1 (Parksville Reservoir)

12.6 Hiwassee River Stream Monitoring Site

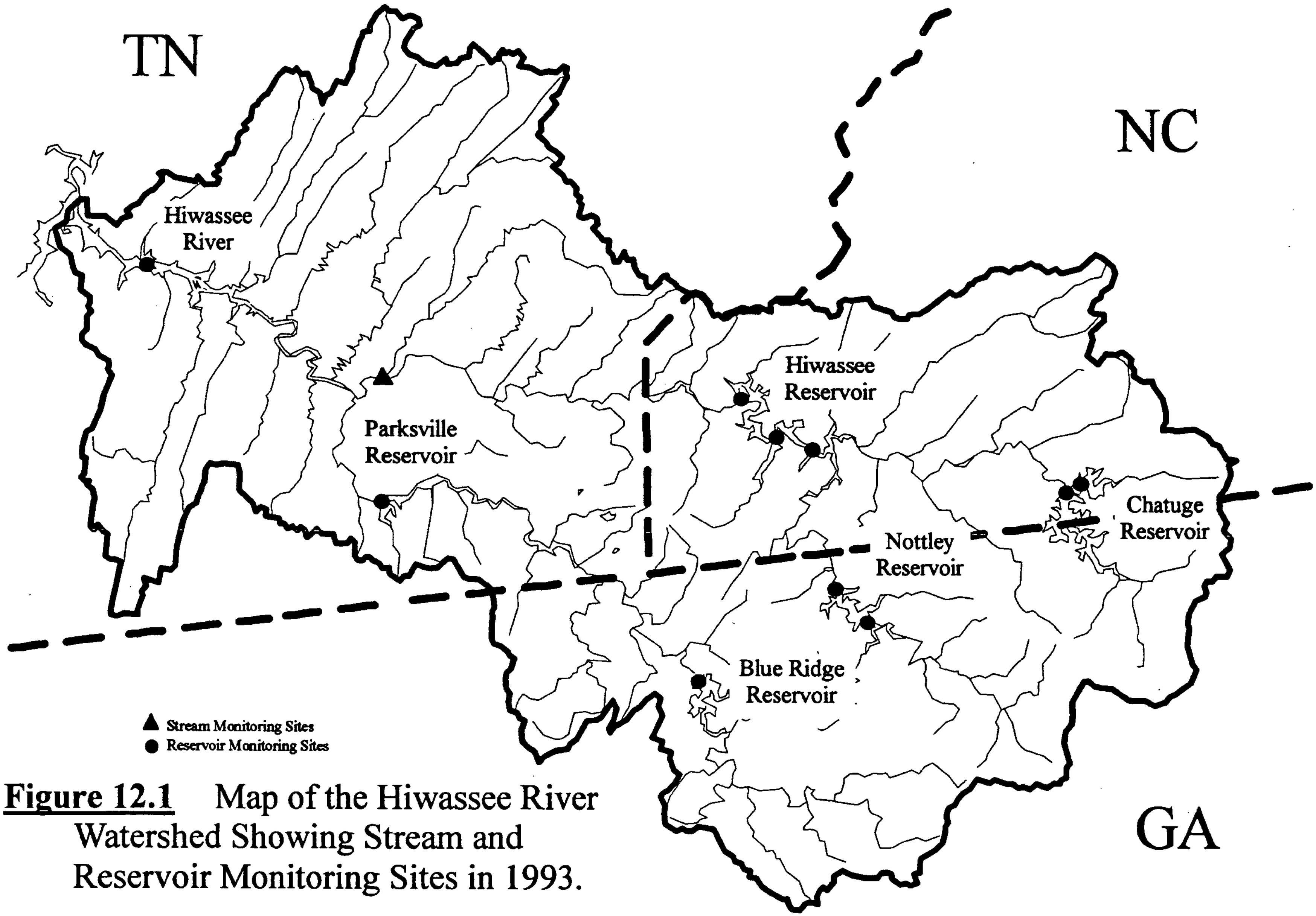


Figure 12.1 Map of the Hiwassee River Watershed Showing Stream and Reservoir Monitoring Sites in 1993.

12.1 Hiwassee Reservoir

Physical Description

Hiwassee Reservoir, in the southwestern corner of North Carolina, is the second-largest of the five reservoirs in the Hiwassee River watershed included in the Vital Signs monitoring program. Hiwassee Reservoir is impounded by Hiwassee Dam at river mile 75.8. At full pool level, its backwater storage pool is about 22 miles long, 6100 acres in surface area, and has a mean depth of about 69 feet (with a maximum depth of about 255 feet at the dam). It has an average annual discharge of about 2020 cfs and average residence time of about 105 days. Hiwassee Reservoir has an average annual drawdown of 45 feet.

Ecological Health

Ecological health of Hiwassee Reservoir rated poor-fair (58 percent) in 1993; lower than in 1992 and 1991. The primary factor contributing to reduced ecological health rating was addition of sediment quality and benthic macroinvertebrates sampling in 1993. Both these indicators rated poor or very poor at both the forebay and mid-reservoir sites. There were no other poor ratings for any indicator, not even for DO, which was poor at the forebay in 1992. If scores for these two new indicators (sediment quality and benthos) were deleted from calculating the overall ecological health rating for Hiwassee Reservoir, the rating would change substantially to fair-good (72 percent), consistent with rating for previous years. Poor ratings for sediment quality were due to toxicity to test organisms and detectable concentrations of chlordane. Most benthos metrics were very poor and received the lowest score possible.

Like most deep, tributary storage reservoirs with long retention times, thermal stratification occurs during the summer in Hiwassee Reservoir. During periods of extended thermal stratification, low concentrations of dissolved oxygen develop near the bottom of the reservoir when oxygen is consumed by respiration and biochemical processes in the reservoir and in the sediment at a faster rate than it is replenished by photosynthesis and reaeration from the atmosphere. Although this low DO area develops in Hiwassee Reservoir, especially in the forebay, it is relatively small. Hence, DO rated fair at the forebay and good at the mid-reservoir site in 1993.

The upper Hiwassee River watershed is largely forested with few sources of waste to the river. Consequently, concentrations of nutrients are generally low and primary productivity in the Hiwassee watershed reservoirs is also generally low. This can be seen in the fair chlorophyll rating at the Hiwassee Reservoir forebay in 1993 caused by low chlorophyll concentrations. Chlorophyll concentrations were just high enough at the mid-reservoir site to rate in the good range. As is frequently the case in oligotrophic reservoirs, lower standing stocks of fish reflect the small food base. The fish assemblage rated fair at all locations.

Reservoir Use Suitability

No bacteriological studies were conducted in 1993. In 1990, bacteriological water quality at four boat ramps was sampled. Fecal coliform bacteria concentrations were very low at all four sites.

There are no fish consumption advisories on Hiwassee Reservoir. The most recent fish tissue information is for a channel catfish composite from the forebay collected in autumn 1991. No pesticide or PCB analytes were detected. With the exception of mercury, metal concentrations in fish tissue were low or at expected concentrations. The mercury concentration, however, was relatively high (0.69 $\mu g/g$) and so was further investigated in autumn 1993. Both channel catfish and largemouth bass composites were collected from the forebay and transition zone during autumn 1993. Results were not available at the time this report was prepared.

12.2 Chatuge Reservoir

Physical Description

Chatuge Reservoir is located on the Georgia-North Carolina state line in northeastern Georgia and is formed by Chatuge Dam at Hiwassee River mile (HiRM) 121.0. At full pool elevation, the reservoir is 13 miles long and has a surface area of about 7000 acres. Its maximum depth at the dam is 124 feet, and it has a mean depth of 33 feet. An average annual discharge of 459 cfs results in an average hydraulic residence time of about 260 days. Chatuge Reservoir has a potential useful controlled storage of 23 feet (1928-1905 feet MSL), however, the annual drawdown averages only ten feet.

Only the forebay of Chatuge Reservoir was monitored prior to 1993. A new monitoring site was added in 1993 in the Shooting Creek arm to further evaluate this rather large part of the lake. Because of its physical features, the Shooting Creek site would be expected to be representative of forebay conditions.

Ecological Health

The ecological health of Chatuge Reservoir rated better in 1993 than in previous years of Vital Signs monitoring. Chatuge rated fair (67 percent) in 1993 compared to poor-fair in 1992 (56 percent) and 1991 (60 percent). One of the reasons for the higher rating in 1993 was improved scores for DO, which rated good at the forebay site on the Hiwassee River and fair at the forebay site on Shooting Creek. In 1992 DO rated poor at the forebay and a mid-reservoir site. Besides an actual slight improvement in DO conditions, the higher DO rating in 1993 was due to an improvement in the method for scoring for DO. Also, inclusion of scores for benthic macroinvertebrates, sampled for the first time in 1993 and rated good at both sample sites, helped to elevate the overall ecological health rating for Chatuge.

All other indicators (chlorophyll, sediment quality, and fish assemblage) rated fair at both sample sites. The fair ratings for chlorophyll were due to naturally low concentrations, indicative of the low availability of nutrients characteristic of the Hiwassee watershed. The fair ratings for sediment quality were due to toxicity to test organisms at the forebay site on the Hiwassee River and elevated concentrations of chromium, copper, and nickel at the Shooting Creek site.

Reservoir Use Suitability

There are no fish consumption advisories on Chatuge Reservoir. The most recent information available is from a channel catfish composite collected from the forebay in autumn 1991. None of the pesticide or PCB analytes were detected. Although several metals were detected, they occurred at low or expected concentrations.

No bacteriological studies were conducted in 1993. In 1990, bacteriological water quality at three swimming beaches, three boat ramps, and five locations in the middle of the channel were sampled. Fecal coliform bacteria concentrations were very low at all sites.

12.3 Nottely Reservoir

Physical Description

Nottely Reservoir is formed by Nottely Dam at Nottely River mile 21.0 in northern Georgia. At full pool elevation, the reservoir is 20 miles long, covers 4200 acres, and has a mean depth of 40 feet, with a maximum depth of about 165 feet at the dam. Long-term flows from Nottely Dam average about 415 cfs which result in an average hydraulic retention time of about 206 days. The annual drawdown averages about 24 feet on Nottely Reservoir.

Ecological Health

The ecological health of Nottely Reservoir rated fair again in 1993 (64 percent), slightly higher than the fair rating in 1992 and 1991 (60 percent). The primary concern in Nottely Reservoir is low DO conditions near bottom as evidenced by very poor DO ratings at both the forebay and mid-reservoir locations in 1993. The only other poor rating for an indicator in 1993 was benthos at the forebay. Interestingly, the benthos rated good at the mid-reservoir despite the very poor DO conditions. Chlorophyll rated good at both sample sites in 1993 and sediment quality rated excellent at the mid-reservoir site. The fish assemblage rated fair at both sample sites in 1993.

Nottely Reservoir's ecological health may not be as good as these monitoring results suggest, however. For example, there was a fish kill near the dam in the fall of 1992 which was probably related to low dissolved oxygen. Also, the water in Nottely Reservoir is frequently turbid due to excessive erosion on the lands surrounding the reservoir. Of the five reservoirs in the Hiwassee watershed (Hiwassee, Chatuge, Nottely, Blue Ridge, and Ocoee No. 1), Nottely has had the lowest water clarity, highest chlorophyll concentrations, and highest phosphorus concentrations over the last three years.

Reservoir Use Suitability

No fish consumption advisories have been issued for Nottely Reservoir. The most recent fish tissue results are for a channel catfish composite collected from the forebay in autumn 1991. The only organic analyte detected was PCBs (at a concentration of 0.2 μg/g) just above the detection limit. A few metals were detected but only mercury (0.47 μg/g) was sufficiently high to be of interest. Similar concentrations have been found, although not consistently, in previous screening studies on reservoirs in the Hiwassee basin. Both channel catfish and largemouth bass composites were collected from the forebay in autumn 1993 and analyzed for mercury to further examine this situation. Results were not available at the time this report was prepared.

No information was collected for bacteriological contamination at recreation areas on Nottely Reservoir in 1993. However, the recreation area at Poteet Creek was sampled in 1990 for fecal coliform bacteria and found to fully support water contact recreation.

12.4 Blue Ridge Reservoir

Physical Description

Blue Ridge Dam impounds the Toccoa River at mile 53.0 in rural northwest Georgia. The watershed is mountainous and forested, with a significant portion of the basin lying within the Chattahoochee National Forest. At full pool, Blue Ridge Reservoir is about 11 miles long, 3300 acres in surface area, and 155 feet deep at the dam, with a average depth of 59 feet. The rate of discharge of water from Blue Ridge Reservoir averages about 610 cfs, which results in an average theoretical residence time of about 159 days. The annual drawdown of Blue Ridge Reservoir averages 36 feet.

Ecological Health

The ecological health of Blue Ridge Reservoir was good in 1993 (72 percent), similar to that found in 1992 and 1991. Blue Ridge is an oligotrophic reservoir as evidenced by very low summer chlorophyll concentrations at the forebay, rated fair in 1993. The excellent rating for DO was in part related to the low primary productivity because a low oxygen demand would be required to decompose relatively few dead algal cells. The benthic macroinvertebrate community, sampled for the first time in 1993, rated excellent at the forebay. The fish assemblage rated poor due to low abundance and diversity, as might be expected in an oligotrophic reservoir. Compared to the other reservoirs in the Hiwassee watershed, Blue Ridge has had the highest water clarity and lowest nitrogen concentrations over the three years of Vital Signs monitoring.

Reservoir Use Suitability

There are no fish consumption advisories on Blue Ridge Reservoir. The most recent fish tissue information from Blue Ridge Reservoir is from a channel catfish composite from the forebay collected in autumn 1991. Most pesticide and PCB analytes were not detected; those that were, occurred in low concentrations. Likewise, all metal analytes were either not detected or were found in low or expected concentrations.

No bacteriological studies were conducted in 1993. In 1990, bacteriological water quality at one swimming beach was sampled. Fecal coliform bacteria concentrations were very low.

12.5 Ocoee Reservoir No. 1 (Parksville Reservoir)

Physical Description

Ocoee No. 1 Reservoir, also known as Parksville Reservoir, is formed by Ocoee No. 1 Dam at Ocoee River mile 11.9. At full pool elevation, the reservoir has a surface area of about 1900 acres and length of 7.5 miles. Ocoee No. 1 Reservoir is located downstream from the Copper Basin, and decades of erosion have caused significant filling of the reservoir. Ocoee No. 1 Reservoir has lost about 25 percent of its original volume, has an average depth of 45 feet and is about 115 feet deep at the dam. An average annual discharge of about 1400 cfs from Ocoee No. 1 Dam results in a reservoir retention time of approximately 30 days. Although Ocoee No. 1 Reservoir is not operated for flood control (only for peaking power generation), its annual drawdown averages about seven feet.

Ecological Health

The ecological health of Ocoee No. 1 Reservoir rated poor in 1993 (52 percent), with little change from the previous years of Vital Signs monitoring activities. Four indicators rated poor--chlorophyll, sediment quality, benthic macroinvertebrates, and the fish assemblage. The reservoir is recovering from years of pollution problems related to copper mining and industrial activities at Copperhill. Sediment quality, sampled for the first time in 1993, reflected these historic problems with very high concentrations of copper, lead, and zinc. Also, PCBs were detected in forebay sediments in 1993.

In spite of the apparent availability of nutrients, algal productivity was low. High DO concentrations (rated excellent in 1993) existed in Parksville Reservoir throughout the year. High DO concentrations were present even in the hypolimnion at the forebay. As expected under such conditions, the fish assemblage rated poor in 1993, comparable to previous years.

Reservoir Use Suitability

There are no fish consumption advisories in effect for Parksville Reservoir. However, screening studies over the past several years have found PCB concentrations near the level used by the state of Tennessee to issue a "Limit Consumption" advisory. As a result, TVA and the state designed and conducted a more detailed sampling of fish in autumn 1992. Results of the 1992 effort confirmed previous results of relatively high PCB concentrations in channel catfish; the average of ten fish was 1.5 μg/g at the forebay and 1.0 μg/g at an upper reservoir location. Largemouth bass were also examined and found to have lower concentrations than catfish; averages at the two sites were 0.6 and 0.7 μg/g, respectively. Bluegill sunfish and rainbow trout composites from these areas had low PCB concentrations ($\leq$0.3 μg/g). The state of Tennessee had taken no action on these results at the time this report was prepared.

No bacteriological studies were conducted in 1993. In 1991, the swimming area at Mac Point was surveyed. Fecal coliform bacteria concentrations were low.

12.6 Hiwassee River Stream Monitoring Site

Physical Description

The headwaters of the Hiwassee River are in the Chattahoochee, Nantahala, and Cherokee Forests of the Blue Ridge physiographic province. It emerges from the mountains to flow through the Valley and Ridge province to join the Tennessee River as an embayment of Chickamauga Reservoir.

The TVA monitoring station is located at the Patty Bridge near Benton, Tennessee. The watershed area above the sampling site is 1300 square miles or 48 percent of the Hiwassee River basin. Principal tributaries in the Hiwassee watershed include the Valley River (117 square miles), Nottely River (287 square miles), Conasauga Creek (103 square miles), Toccoa-Ocoee River (639 square miles), Chestuee Creek (132 square miles), and Oostanaula Creek (69 square miles). Oostanaula Creek, Chestuee Creek, and the Ocoee River are located below this station.

Igneous and metamorphic rocks underlie much of the basin yielding water that is very soft and low in dissolved minerals. The major urban areas of the Hiwassee River basin include Athens, Etowah, and Cleveland, Tennessee, in the lower basin. The smaller urban communities of the mountains include Andrews and Murphy in North Carolina, Blue Ridge and McCaysville in Georgia, and Copperhill in Tennessee. Runoff from land denuded by historical mining and ore processing near Copperhill affects water quality in the Ocoee River and its three reservoirs downstream to the confluence with the Hiwassee River.

Ecological Health

The ecological health of the stream monitoring site on the Hiwassee River was good in 1993, as in 1992. All ecological health indicators (nutrients, sediment quality, benthos, and fish community) rated either good or fair.

Use Suitability

No fecal coliform samples were collected in 1993. In 1989, the canoe sites, Shallow Ford Bridge on Toccoa River upstream of Blue Ridge Reservoir, and at Mission Dam on the Hiwassee River between Chatuge and Hiwassee Reservoirs were sampled. In 1991, the two access locations on the Ocoee River upstream of Parksville Reservoir, and the three access sites on Hiwassee River upstream of Chickamauga Reservoir were sampled. Bacteriological water quality at each of the sites met the appropriate state's criterion for recreation.

All metal and organic analytes in fish tissue samples were either not detected or found in low concentrations.

13.0 WATTS BAR RESERVOIR, FORT LOUDOUN RESERVOIR, AND MELTON HILL RESERVOIR WATERSHED

This watershed area is relatively small (1370 square miles) and includes three reservoirs: Fort Loudoun and Watts Bar Reservoirs on the Tennessee River and Melton Hill Reservoir on the Clinch River. All three are run-of-the-river reservoirs with relatively short retention times and annual pool drawdowns of only a few feet. The inflow of Fort Loudoun Reservoir is actually the origin of the Tennessee River. The Holston and French Broad Rivers merge at that point to form the Tennessee River. The Little Tennessee River, another major tributary to the Tennessee River, enters Fort Loudoun Reservoir near the forebay. Watts Bar Reservoir is immediately downstream of Fort Loudoun. The Clinch River, another major tributary, merges with the Tennessee River upstream of the transition zone on Watts Bar Reservoir. Melton Hill Dam bounds the upper end of Watts Bar Reservoir on the Clinch River and Fort Loudoun Reservoir bounds it on the Tennessee River.

Like the other watershed areas formed around one or more of the reservoirs on the mainstream of the Tennessee River, very little of the water leaving this watershed area originates from within. The average annual discharge through Watts Bar Reservoir is about 27,000 cfs. Of this, about 25 percent (6800 cfs) enters from the French Broad River, 16 percent (4500 cfs) from the Holston River, 21 percent (5700 cfs) from the Little Tennessee River, and 15 percent (4200 cfs) from the Melton Hill Dam on the Clinch River. Another five percent (1400 cfs) is contributed by the Emory River, a tributary to the Clinch River near the confluence with the Tennessee River. The remaining 18 percent (4800 cfs) originates from streams which drain directly to one of these reservoirs.

Vital Signs monitoring activities are conducted at the forebays, transition zones, and inflows of all three of these reservoirs. Watt Bar Reservoir has two inflow sites, one near Fort Loudoun Dam and one near Melton Hill Dam. There is one stream monitoring site on the Emory River at Emory River Mile 18.3 (Figure 13.1).

Results for 1993 monitoring activities are provided in the following sections:

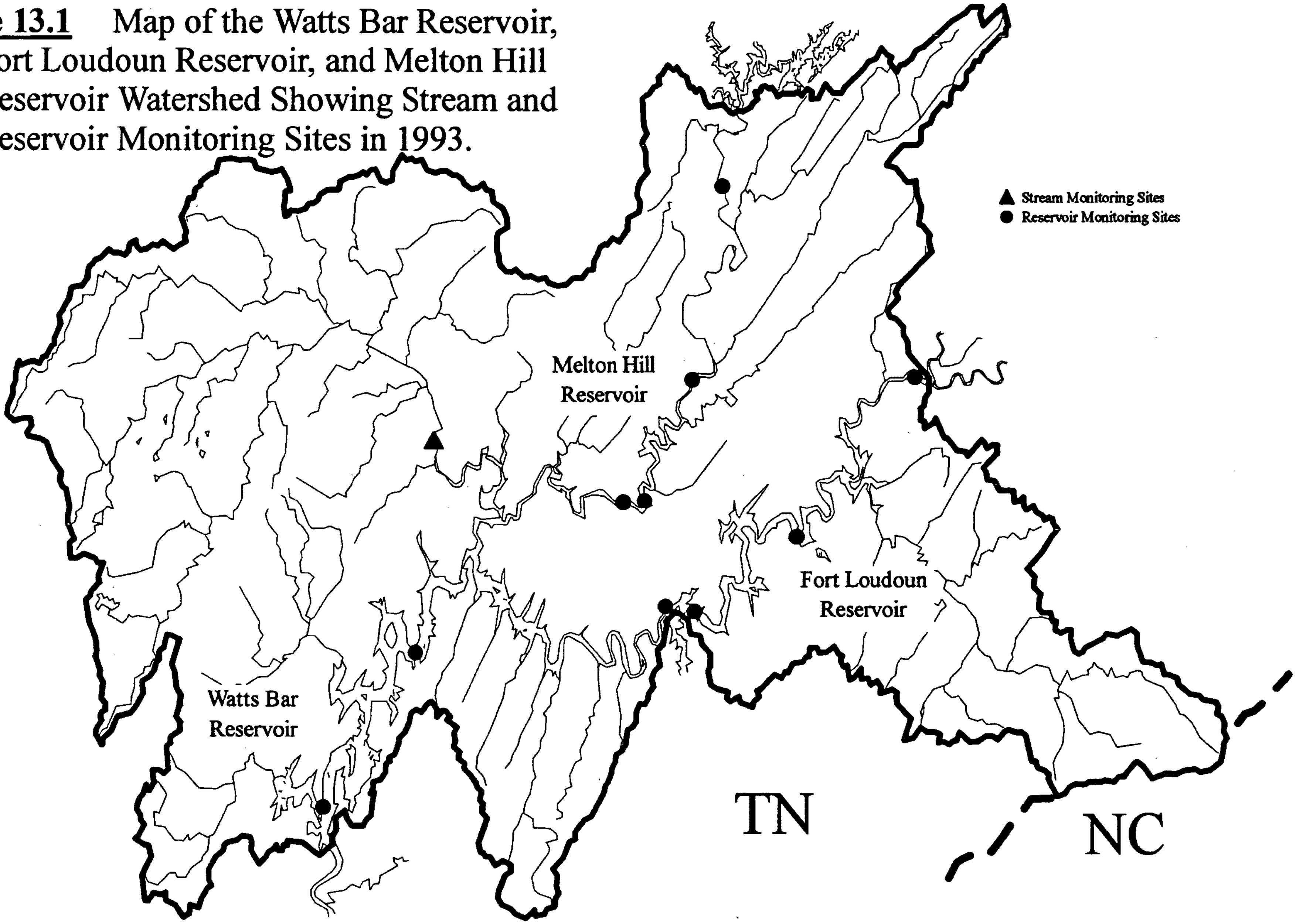
13.1 Watts Bar Reservoir

13.2 Fort Loudoun Reservoir

13.3 Melton Hill Reservoir

13.4 Emory River Stream Monitoring Site

Figure 13.1 Map of the Watts Bar Reservoir, Fort Loudoun Reservoir, and Melton Hill Reservoir Watershed Showing Stream and Reservoir Monitoring Sites in 1993.



13.1 Watts Bar Reservoir

Physical Description

Watts Bar Reservoir impounds water from both the Tennessee River and one of the major tributaries to the Tennessee River, the Clinch River. The three dams which bound Watts Bar Reservoir are: Watts Bar Dam located at Tennessee River Mile (TRM) 529.9, Fort Loudoun Dam located at TRM 602.3, and Melton Hill Dam located at Clinch River mile (CRM) 23.1. The total length of Watts Bar Reservoir, including the Clinch River arm is 96 miles, the shoreline length is 783 miles, and the surface area is 39,000 acres. The average annual discharge from Watts Bar is approximately 27,000 cfs, providing an average hydraulic retention time of about 19 days.

The confluence of the Clinch and Tennessee Rivers is upstream of the transition zone sampling location in Watts Bar, so biological sampling was conducted at the forebay, transition zone, and both the Tennessee River and Clinch River inflows. Water entering Watts Bar from Melton Hill Reservoir is quite cool due to the hypolimnetic withdrawal from Norris Reservoir (a deep storage impoundment) upstream from Melton Hill. Water entering Watts Bar Reservoir from Fort Loudoun Dam is usually warmer and lower in DO during summer months than water entering from Melton Hill Dam.

The Emory River is a major tributary to the Clinch River arm of Watts Bar Reservoir and supplies about 5 percent of the average annual flow through Watts Bar Reservoir. The Tennessee and Little Tennessee Rivers (i.e., discharge from Fort Loudoun Dam) account for about 75 percent of the flow, and the Clinch River (i.e., discharge from Melton Hill Dam) accounts for about 15 percent through Watts Bar Reservoir.

Ecological Health

The ecological health of Watts Bar Reservoir was fair in 1993 (68 percent), similar to 1992 (71 percent) and 1991 (69 percent). Chlorophyll rated good at both the forebay and transition zone locations. Sediment quality testing at the forebay found low survival of test organisms and high concentrations of ammonia, leading to a poor rating. A fair to good rating for sediments at the transition zone was due to traces of chlordane; no other chemical analyte was problematic and no toxicity was found. Because of the release of water with low DOs from Fort Loudoun Dam, DO concentrations were less than 5 mg/L (minimum 3.9 mg/L) in the Tennessee River inflow to Watts Bar Reservoir. Benthic macroinvertebrates rated poor in 1993 at this site (as in both 1992 and 1991), possibly related to the low DO concentrations. The fish assemblage was also poor at this inflow site in 1993. The inflow site on the Clinch River, downstream of Melton Hill Dam, had good DOs, but the benthos were poor and fish assemblage fair. Compared to 1992, this was a slight decrease for the benthos, but was similar to the previous results. All aquatic health indicators were good or excellent at the transition zone, generally similar to 1992 observations.

Aquatic plants have declined from about 700 acres in the late 1980s to about ten acres in 1993.

<u>Reservoir Use Suitability</u>

Fourteen swimming areas were tested for fecal coliform concentrations in 1993. Two other swimming sites were tested in 1990. Bacteriological water quality was within criteria at 14 sites. The other two sites met criteria if rainfall samples are excluded. Fecal coliform concentrations at Watts Bar swimming beaches are generally higher than at other Tennessee River Reservoirs. Monthly fecal coliform bacteria samples have been collected at the Vital Signs locations since 1990. All samples collected from April through September have been very low.

As a result of PCB contamination, the Tennessee Department of Environment and Conservation (TDEC) has issued advisories on consumption of several fish species from Watts Bar Reservoir. In the Tennessee River portion a "do not consume" advisory exists for catfish, striped bass, and striped bass/white bass hybrids. A precautionary advisory (children and pregnant or lactating women do not eat fish; all others limit fish consumption to 1.2 pounds per month) is in effect for largemouth bass, white bass, sauger, carp and smallmouth buffalo. In the Clinch River arm striped bass should not be eaten, and a precautionary advisory is in effect for catfish and sauger.

Also, TDEC has issued a "do not consume" advisory for fish taken from the east fork of Poplar Creek due to mercury, metals, and organic chemical contamination.

13.2 Fort Loudoun Reservoir

Physical Description

Fort Loudoun Reservoir is the ninth and uppermost reservoir on the Tennessee River with the dam located at TRM 602.3. The surface area and shoreline are relatively small (14,600 acres and 360 miles, respectively) considering the length (61 miles), indicating it is mostly a run-of-the-river reservoir. The average annual discharge from Fort Loudoun Dam is 18,400 cfs which provides an average hydraulic retention time of about ten days.

Fort Loudoun Reservoir (and the Tennessee River) is formed by the confluence of the French Broad and Holston Rivers, with both of these rivers having a major reservoir upstream. Douglas Dam, 32.3 miles up the French Broad River, and Cherokee Dam, 52.3 miles up the Holston River, form deep storage impoundments, each having long retention times. Both of these deep storage impoundments become strongly stratified during summer months resulting in the release of cool, low DO, hypolimnetic water during operation of the hydroelectric units. Some warming and reaeration of the water occurs downstream from Cherokee and Douglas Dams, but both temperature and DO levels are sometimes low when the water reaches Fort Loudoun Reservoir.

Fort Loudoun Reservoir also receives surface waters from the Little Tennessee River, via the Tellico Reservoir canal, which connects the forebays of the two reservoirs. (Since Tellico Dam has no outlet, under most normal conditions, water flows into Fort Loudoun Reservoir from Tellico Reservoir.) Water from Tellico Reservoir (Little Tennessee River) is often cooler and higher in DO, and has a much lower conductivity than water in Fort Loudoun Reservoir (Tennessee River). In 1992, the forebay sampling location on Fort Loudoun Reservoir (originally located at TRM 603.2) was moved upstream to TRM 605.5. This resulted in a better assessment of the water quality conditions of the Tennessee River in the forebay portion of Fort Loudoun Reservoir by minimizing the effects of the Little Tennessee River and Tellico Reservoir on the data gathered in the forebay of Fort Loudoun Reservoir.

Although Fort Loudoun Reservoir is a mainstream reservoir, its complex set of hydrologic conditions (cool water inflows from the Holston, French Broad, and Little Tennessee Rivers) often causes it to exhibit several characteristics that are more typical of a storage impoundment. In fact, analysis of historical fisheries data for the Tennessee Valley indicates the fish community of Fort Loudoun Reservoir is more similar to that in Valley storage impoundments than in other mainstream reservoirs.

Ecological Health

Vital Signs monitoring information showed the ecological health of Fort Loudoun Reservoir was between fair and poor in 1993 (58 percent), basically similar to 1992 (53 percent) and 1991 (60 percent). The only ecological health indicator which rated good or excellent on Fort Loudoun was DO at the forebay and transitions zone (no data were available from the inflow). Such good ratings for DO were surprising based on observations of lower DOs in 1993 in other mainstream reservoirs and historical concerns about DO in Fort Loudoun Reservoir.

Several indicators rated poor or very poor. Sediment quality at the forebay rated poor due to high zinc concentrations, presence of chlordane, and toxicity to Ceriodaphnia. Transition zone sediments rated fair with similar conditions as the forebay, but no toxicity to test organisms was found. These findings are consistent with results found in previous years. The fish assemblage rated poor at all three sample sites (forebay, transition zone, and inflow) mostly due to low species richness and low capture rate of individuals (similar to previous years). Benthic macroinvertebrates rated very poor at the inflow site due to low species richness and abundance (comparable to previous years). Benthos rated fair at the forebay and transition zone. Similar results had been found at the transition zone in previous years, but benthic invertebrates at the forebay improved in several metrics, especially species richness and reduced dominance by tolerant organisms.

Aquatic macrophytes only covered 25 acres on Fort Loudoun Reservoir in 1993. Coverage over the past decade has ranged 25 to 140 acres.

Reservoir Use Suitability

TDEC has issued advisories on consumption of two fish species from Fort Loudoun Reservoir. Tennessee advises people not to eat catfish taken from Fort Loudoun Reservoir because of high levels of PCBs. Also, largemouth bass should not be eaten if they weigh over two pounds or are caught in the Little River embayment due to PCB contamination.

Fort Loudoun Reservoir has had a PCB problem for more than 20 years. Initially, TVA and state agencies examined a variety of species from throughout the reservoir to document the geographical and species variation. The study now continues as a trend study in which there is an annual collection of catfish from one location. PCB concentrations in catfish have varied over the years with no distinct trend.

Fecal coliform concentrations at one boat ramp tested in 1993 were within criteria for recreation. In 1989, 1990, and 1992, fecal coliform samples were collected at a total of three swimming beaches and 16 other sites. Bacteria concentrations were low at the swimming beaches and other sites in the downstream portion of the reservoir. Concentrations in the upstream portion of the reservoir, especially near downtown Knoxville, were much higher, with four sites exceeding Tennessee criteria. Fecal coliform concentrations at the monthly Vital Signs locations sampled since 1990 have been very low except for the April 1993 samples.

13.3 Melton Hill Reservoir

Physical Description

Melton Hill Dam is located at mile 23.1 on the Clinch River and is 56.7 miles downstream of Norris Dam. Impounded water extends upstream from Melton Hill Dam about 44 miles. Melton Hill Reservoir has about 170 miles of shoreline and 5690 surface acres at full pool. Average flow through Melton Hill is about 4900 cfs resulting in an average retention time of approximately 12 days. Melton Hill is TVA's only tributary dam with a navigation lock.

The predominant factor influencing the aquatic resources of Melton Hill Reservoir, especially the inflow and mid-reservoir areas, is the cold water entering from Norris Dam discharges. During summer, water discharged from Norris is cold and low in oxygen content. Oxygen concentrations are improved by a re-regulation weir downstream of Norris Dam and by atmospheric reaeration in the river reach between Norris Dam and upper Melton Hill Reservoir. However, water is warmed little and is still quite cool when it enters upper Melton Hill Reservoir. Bull Run Steam Plant, located at about CRM 47, warms the water some, but water temperatures are still too cool to support warm water biota and too warm to support cold water biota.

Ecological Health

The ecological health of Melton Hill Reservoir was in the upper end of the fair range in 1993 (68 percent, similar to 1992 and 1991). Chlorophyll and DO were excellent at both the forebay and the transition zone. However, a poor fish assemblage was found at forebay and inflow, generally similar to previous years. Primary problems in the fish assemblage were low species richness and abundance in electrofishing samples. Cool water flowing in from the bottom layer of Norris Lake causes problems for fish in Melton Hill, especially in the middle and upper sections. The water is too cold to support fish that like warm water, but too warm to support fish that thrive in cold water. The benthic macroinvertebrate community rated poor at the forebay and very poor at the transition zone and inflow, generally similar to previous years. Components of the benthos resulting in poor metrics were absence of long-lived and intolerant species and dominance by tolerant species.

Aquatic macrophyte coverage on Melton Hill Lake in 1993 was about 240 acres. During the past decade, coverage has ranged from about 100 to 250 acres.

Reservoir Use Suitability

No bacteriological studies were conducted at recreation areas in 1993. In 1989, samples were collected at four boat ramps during a period of high rainfall, and fecal coliform concentrations were high. In 1990, two swimming beaches and six other sites were tested during a more normal rainfall period. Concentrations were lower and within recreation criteria. Fecal coliform concentrations at the monthly Vital Signs locations sampled since 1991 have generally been low.

TDEC has advised the public to avoid consumption of catfish from Melton Hill Reservoir because of PCB contamination. Samples are collected annually from the transition zone and near the inflow by TVA and from the forebay by the Oak Ridge National Laboratory as part of ongoing, cooperative studies. PCB concentrations in catfish collected in autumn 1992 generally fell within the range found in previous years.

13.4 Emory River Stream Monitoring Site

Physical Description

The majority of the Emory River drainage area lies in the Cumberland Plateau and flows through the Tennessee counties of Cumberland, Morgan, and Roane. The Emory River leaves the plateau and cuts more than 600 feet down the eastern escarpment to join the Clinch River in the Valley and Ridge physiographic province as a major embayment to Watts Bar Reservoir.

The TVA monitoring station is located at the USGS stream gage at Oakdale. The Emory River drainage above Oakdale is 764 square miles or 88 percent of the entire Emory River basin. The principal tributary to the Emory is the Obed River (520 square miles). The principal tributaries to the Obed are Clear Creek (173 square miles) and Daddy's Creek (175 square miles).

Sandstone, shale, and conglomerates underlie most of the Emory River basin. Most of the basin is forested. About one-fourth of the basin lies within the Catoosa Wildlife Management Area, while about 5 percent is used for agriculture and 1 percent is used for surface coal mining. The only urban area above Oakdale is Crossville, Tennessee, near the headwaters of the Obed River.

Ecological Health

The overall ecological health of the Emory River at the stream monitoring site was good in 1993. This is an improvement over 1992 when fair conditions were found. The primary problem found in 1992 was poor sediment quality, evidenced by poor survival of test organisms. This was not the case for 1993 as no sediment toxicity was found.

Use Suitability

There were no bacteriological studies conducted on the Emory River in 1993.

A five fish composite each of carp, channel catfish, and largemouth were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. Only PCBs in channel catfish were high enough to be of interest. The concentration was near that used to indicate need of more intensive investigation. Samples collected in summer 1993 should help evaluation of this situation.

14.0 CLINCH RIVER AND POWELL RIVER WATERSHED

This long, narrow watershed lies in southwest Virginia and northeast Tennessee. Streams in the watershed have high concentrations of dissolved minerals and generally low concentrations of nutrients.

For management purposes, an artificial ending point of the watershed has been established at Norris Dam, which is near Clinch River mile 80. The remainder of the Clinch River is associated with the Watts Bar, Fort Loudoun, and Melton Hill Reservoir Watershed area. As defined, this watershed drains an area of 2912 square miles and has an average annual discharge of about 4200 cfs. The Clinch and Powell Rivers contribute about 80 percent of this flow.

Norris Reservoir is the only major reservoir in the watershed; essentially all streams upstream from Norris are free flowing. There are three Vital Signs monitoring sites in Norris Reservoir (forebay and mid-reservoir sites on the Clinch and Powell arms) and two stream sites, one each on the Clinch and Powell Rivers (Figure 14.1). Results from 1993 monitoring activities are in Section 14.1 for Norris Reservoir, Section 14.2 for the Clinch River stream monitoring site, and Section 14.3 for the Powell River stream monitoring site.

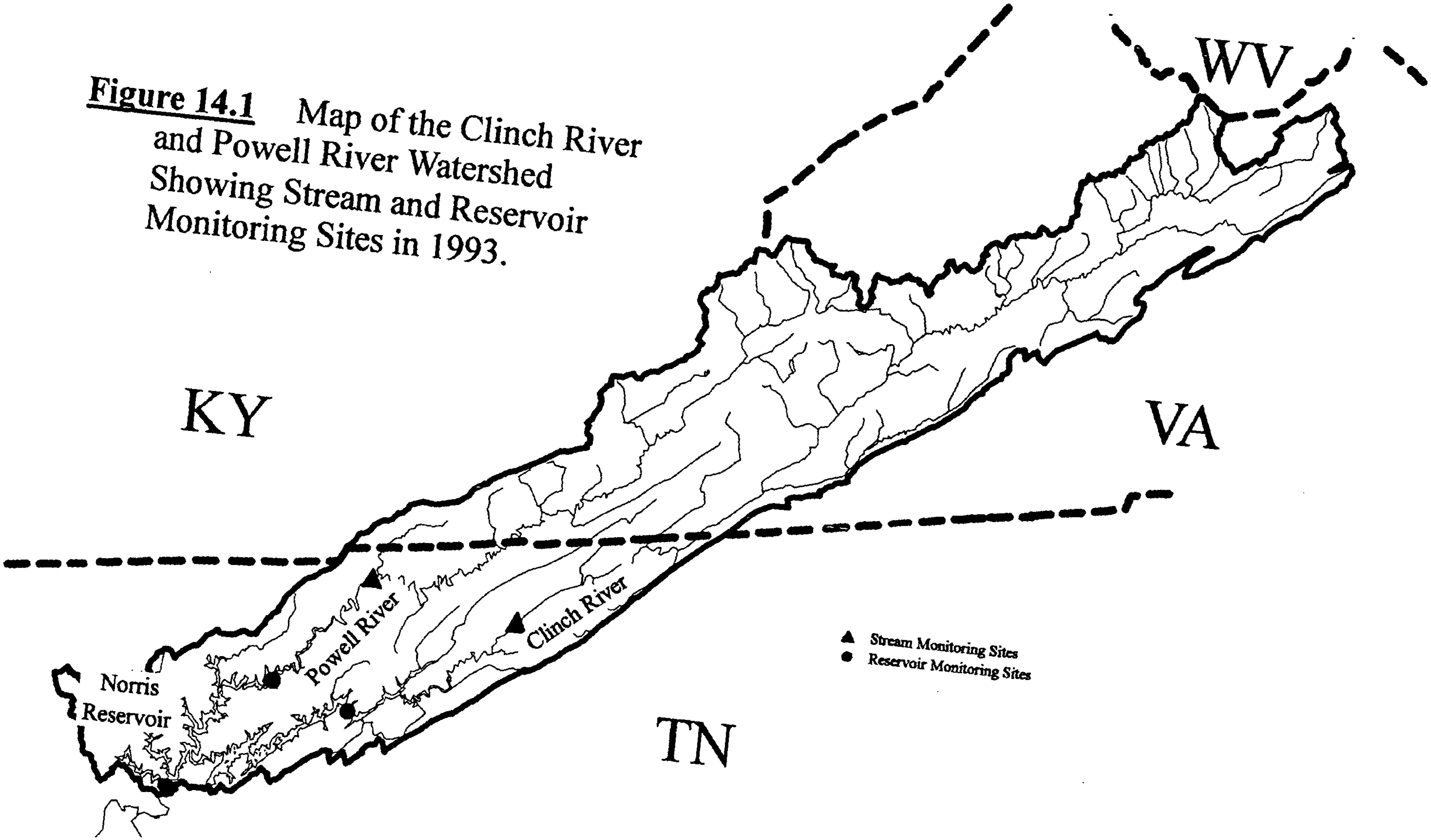


Figure 14.1 Map of the Clinch River and Powell River Watershed Showing Stream and Reservoir Monitoring Sites in 1993.

14.1 Norris Reservoir

Physical Description

Norris Reservoir is formed by Norris Dam at Clinch River mile (CRM) 79.8. It is a large, dendritic, tributary storage impoundment of the Clinch and Powell Rivers which flow together about nine miles upstream of the dam. Norris is one of the deeper TVA tributary reservoirs, with depths over 200 feet. Annual drawdown averages about 32 feet. At full pool, the surface area of the reservoir is 34,200 acres, the shoreline is about 800 miles in length, and water is impounded 73 miles upstream on the Clinch River and 53 miles upstream on the Powell River. Norris Reservoir has a long average retention time (about 245 days) and an average annual discharge of approximately 4200 cfs. Due to the great depth and long retention time of Norris Reservoir, significant vertical stratification is expected. Additional information about the physical and hydrologic characteristics of Norris Reservoir are given in Table 4.1.

Because of the confluence of the Clinch and Powell Rivers relatively close to the dam, three reservoir sampling locations were established: one forebay site; and two mid-reservoir sites--one on the Clinch River and one on the Powell River.

Ecological Health

Norris is an oligotrophic reservoir with very clear water. There is little algal primary production because of phosphorus limitations. The ecological health of Norris Reservoir in 1993 was fair (67 percent), with conditions about the same as in 1992 and 1991 (60-67 percent). Dissolved oxygen concentrations in the deeper portions of Norris Reservoir, particularly at the mid-reservoir locations on the Clinch and Powell Rivers, have historically been low. This condition, although undesirable, is often observed in deep, thermally stratified tributary reservoirs with long retention times.

As expected, 1993 DO concentrations rated very poor at both mid-reservoir sites. The rating for DO at the forebay was poor in 1993 compared to fair in 1992. The 1992 results had indicated a slight improvement over 1991 conditions.

As in the past, low nutrient concentrations in the forebay resulted in low algal levels and a fair rating for chlorophyll in 1993. The effects of low primary productivity usually manifests itself throughout the food chain and results in a low overall abundance of fish. The fish assemblage rated fair at the forebay in 1993, primarily due to low abundance and low species richness. At both mid-reservoir sites, both chlorophyll and fish assemblages rated good. The benthic macroinvertebrate community rated fair at the forebay and mid-reservoir site on the Clinch arm of Norris Reservoir and good at the mid-reservoir site on the Powell arm. Given the low DO concentrations near the bottom, fair to good ratings for benthic macroinvertebrates are better than would be expected. This suggests that the benthic community is able to recover quickly between autumn reoxygenation of bottom sediments and sample collection the following spring. Another possible explanation is that some of the samples collected along the transect were above the oxygen-stressed stratum. Results from individual samples suggest both factors contributed to the observed ratings.

Reservoir Use Suitability

There are no fish consumption advisories on Norris Reservoir. Channel catfish were collected for screening purposes in autumn 1992. All analytes were low or not detected except PCBs. The highest PCB concentration was 0.9 $\mu g/g$. Concentrations this high had not been found before. Areas were resampled in autumn 1993 to further examine PCB concentrations, but results were not available at the time this report was prepared.

Fecal coliform bacteria samples were collected at five sites in 1993. Concentrations were very low at all five sites. In 1991, ten sites were sampled. Fecal coliform concentrations were generally higher in 1991 than in 1993, possibly due to higher rainfall in 1991. However, in 1991 all sites met the geometric mean bacteriological water quality criterion for recreation. In 1991 three sites exceeded one of EPA's recommended guidelines; more than 10 percent of the samples had fecal coliform concentrations greater than 400/100 mL. Fecal coliform sampling at the Vital Signs locations was discontinued in 1993. Fecal coliform concentrations at the three Vital Signs stations sampled from 1990 to 1991 were very low.

14.2 Clinch River Stream Monitoring Site

Physical Description

The TVA stream monitoring station is located at the USGS stream gage near Tazewell, Tennessee, just upstream of the impounded water of Norris Reservoir, at CRM 159.8. The Clinch River basin above the monitoring site is 1474 square miles or 33 percent of the total Clinch River basin. Three-quarters of the monitored area lies within Virginia. Principal tributaries in the monitored area are the North Fork Clinch River (87 square miles), Guest River (102 square miles), Little River (126 square miles), Copper Creek (133 square miles), and Big Cedar Creek (86 square miles).

The headwaters of the upper Clinch River drain the eastern escarpment of the Cumberland Plateau (including portions of the Jefferson National Forest), then flow southwest through the Valley and Ridge physiographic province in a valley parallel to and southeast of the Powell River. Land use in the basin is 70 percent forestry and 30 percent agriculture. Coal mining occurs in some areas.

Ecological Health

The overall ecological health of the Clinch River at this site was good as in 1992. Conditions for fish and bottom-dwelling animals remained good in 1993. Sediment quality showed an improvement over 1992, with the rating changing from fair to good.

Use Suitability

Concentrations of fecal coliform bacteria were very low in 1993 at the weir and canoe launch site in the Clinch River downstream of Norris Dam. Concentrations were higher in 1991 when the canoe launch site had been tested.

All analytes in fish tissue samples collected during summer 1992 were either not detected or found in low concentrations.

14.3 Powell River Stream Monitoring Site

Physical Description

The Powell River joins the Clinch River 10 miles upstream from Norris Dam and forms a major embayment to Norris Reservoir. Most of the Powell River headwaters and tributary streams drain portions of the eastern border of the Cumberland Plateau, but the main river is predominantly in the Valley and Ridge physiographic province. The river flows for more than 195 miles through southwestern Virginia and northeastern Tennessee. The total drainage of the Powell River basin is 938 square miles.

The TVA monitoring station is located near Arthur, Tennessee. Above this location the area of the basin is 685 square miles or 73 percent of the entire Powell River watershed. Principal tributaries above Arthur include Indian Creek (66 square miles) and the North Fork Powell River (90 square miles).

Land use in the basin is 75 percent forest, 20 percent agriculture, and almost 5 percent surface mining, primarily in the upper reaches in southwestern Virginia. Only small urban areas are located in the Powell River watershed.

Ecological Health

Conditions for fish and bottom-dwelling animals improved to good in 1993. The change from a fair to a good classification was a result of greater numbers and higher quality bottom-dwelling organisms present. The Powell River watershed is heavily mined for coal and has a history of illegal discharges of blackwater into the river from coal washing facilities.

Use Suitability

There were no bacteriological studies conducted on the Powell River in 1993.

All analytes in fish tissue samples collected in summer 1993 wre either nondetectable or found low concentrations.

15.0 LITTLE TENNESSEE RIVER WATERSHED

The Little Tennessee River Watershed encompasses 2672 square miles, mostly in Tennessee and North Carolina with a small area in Georgia. Much of the watershed is forested, with the headwaters in the Blue Ridge Mountains. The basin is underlain mostly by crystalline and metasedimentary rocks of the Blue Ridge province. This watershed is home to a large variety of federally listed threatened and endangered species.

Most of the streams in the watershed are steep gradient and generally have low concentrations of both dissolved minerals and nutrients. The two largest tributaries to the Little Tennessee River are the Tuckasegee River which merges with the Little Tennessee in Fontana Reservoir and the Tellico River which merges with the Little Tennessee in Tellico Reservoir.

There are several reservoirs in the watershed but only Fontana Reservoir in the mountainous area and Tellico Reservoir at the lower end of the watershed are monitored (Figure 15.1). TVA does not monitor the other reservoirs either because of their small size or because they are owned by the Aluminum Company of America (ALCOA).

Two sites are monitored on Tellico Reservoir (the forebay and transition zone) and three sites on Fontana Reservoir (the forebay and mid-reservoir sites on the Little Tennessee River and Tuckasegee River). There is one stream monitoring site in the watershed, on the Little Tennessee River upstream of Fontana Reservoir. Another stream monitoring site (on the Tuckasegee River) is being added in 1994. Results of 1993 monitoring activities are provided in the following sections:

15.1 Tellico Reservoir

15.2 Fontana Reservoir

15.3 Little Tennessee River Stream Monitoring Site

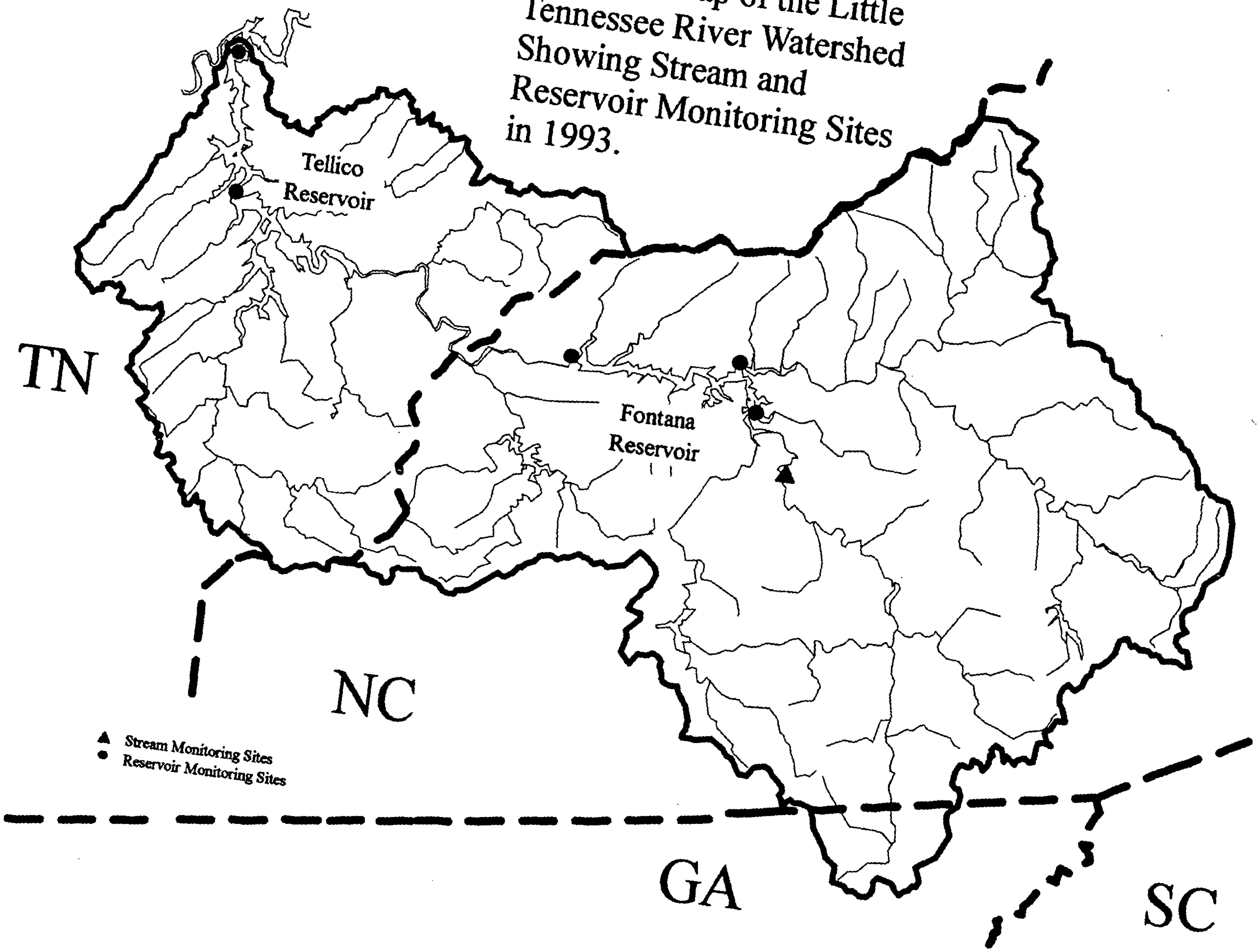


Figure 15.1 Map of the Little Tennessee River Watershed Showing Stream and Reservoir Monitoring Sites in 1993.

15.1 Tellico Reservoir

Physical Description

Tellico Dam is located on the Little Tennessee River just upstream of the confluence of the Little Tennessee and Tennessee Rivers. It is the last dam completed in the TVA system with dam closure in 1979. Tellico Reservoir is 33 miles long, has a shoreline of 373 miles, and has a surface area of about 16,000 acres at full pool. The average estimated flow through Tellico Reservoir is approximately 5700 cfs which provides an average retention time of about 37 days. Very little of this water is discharged through Tellico Dam. Rather, it is diverted through a navigation canal to Fort Loudoun Reservoir near the dam for hydroelectric power production. Water characteristics in these two reservoirs differ considerably as discussed in Section 13.2, Fort Loudoun Reservoir. The hydrodynamics and exchange of water via the inter-connecting canal significantly affect water quality within Tellico Reservoir (and Fort Loudoun Reservoir). The canal is only 20-25 feet deep, but the depth of Tellico Reservoir at the forebay is about 80 feet. Thus, water at strata below about 25 feet is essentially trapped and becomes anoxic during much of the summer in the forebay of Tellico Reservoir.

The impounded water of Tellico Reservoir extends upstream of the confluence of the Little Tennessee and Tellico Rivers. The transition zone site selected for sample collection in 1990, 1991, and 1992 was in the Little Tennessee River, just upstream of the confluence with the Tellico River at Little Tennessee River Mile (LTRM) 21.0. Water conditions at that site are largely controlled by discharges from Chilhowee Dam at LTRM 33.6. This water is cold, nutrient poor, and has a low mineral content, conditions that are not conducive to establishing a diverse, abundant aquatic community. In 1993, the transition zone sampling location in Tellico Reservoir was moved six miles downstream to LTRM 15.0, just below the confluence of the Tellico River--a site more characteristic of lacustrine rather than riverine conditions.

Ecological Health

Tellico Reservoir received a better ecological health rating in 1993 than in previous years. The rating was 63 percent (fair) for 1993 compared to 48 percent in 1992 and 44 percent in 1991 (both poor). The primary causes of the higher score were better ratings for DO at the forebay (mostly the result of an improved, more accurate method of calculating the score for this indicator) and addition of information from the transition zone collection site which was relocated in 1993. The change in DO scoring resulted in forebay DO being rated fair in 1993, whereas it had preciously been rated poor every year. Other than that change, all indicators at the forebay rated the same in 1993 as in previous years--poor sediment quality and benthic macroinvertebrate community, good chlorophyll, and fair fish assemblage.

Two indicators, chlorophyll and DO, received excellent ratings at the new transition zone site. The other three rated poor--sediment quality (presence of chlordane and significant toxicity), benthos (mostly due to absence of long-lived and sensitive organisms), and fish assemblage (few fish collected in gill netting efforts, which affected several metrics).

The higher ecological health score for 1993 is considered to be more representative of the true environmental conditions in Tellico Reservoir than previous scores.

Most of the 246 acres of aquatic macrophytes on Tellico Lake in 1993 were in the Tellico River arm of the reservoir.

Reservoir Use Suitability

No bacteriological studies were conducted at recreation areas in 1993. In 1992, fecal coliform samples were collected at four swimming beaches and five other sites on the reservoir. Bacteria concentrations were low. Fecal coliform concentrations at the monthly Vital Signs locations sampled since 1991 have been very low.

The state has advised that catfish from Tellico Reservoir should not be eaten because of PCB contamination. Fish were collected in autumn 1992 for tissue analysis. Channel catfish were collected as part of a continuing effort to examine the trend in PCB concentrations. Results indicate the PCB problem continued to exist with no downward trend.

15.2 Fontana Reservoir

Physical Description

Fontana Reservoir is located in the Blue Ridge Mountains of western North Carolina. Fontana is the deepest reservoir in the TVA system. At full pool it has a maximum depth of 460 feet, a length of 29 miles, a shoreline of 248 miles, and a surface area of 10,640 acres. Fontana Reservoir has a relatively large drawdown, which averages about 64 feet annually. Every fifth year Fontana is drawn even deeper to allow sluice gate access for maintenance.

Fontana Dam is located at Little Tennessee River Mile 61.0. Average annual discharge is 3840 cfs which provides an average hydraulic retention time in the reservoir of 186 days.

Water in Fontana Reservoir is quite clear due to limited photosynthetic activity and a mostly forested watershed. Water entering the reservoir is low in nutrients and dissolved minerals.

Ecological Health

Fontana Reservoir rated fair in 1993 (64 percent), the first year of Vital Signs monitoring. Fontana is an oligotrophic reservoir with very low chlorophyll concentrations resulting in fair ratings at all three sites. Further evidence of the low primary productivity is the clear, blue water (indicating low abundance of algae and lack of green phytoplankton pigments). Secchi depths averaged almost 6 meters in the forebay of Fontana in 1993. The fish assemblage also rated fair at all locations, probably related to the low primary productivity. Ratings for DO varied from excellent at the mid-reservoir site on the Little Tennessee River to poor at the mid-reservoir site on the Tuckasegee River, with a fair rating at the forebay. Sediment quality also varied greatly among the three locations--poor at the forebay, good at the mid-reservoir site on the Tuckasegee arm, and excellent on the Little Tennessee arm. Rating for the benthic macroinvertebrate community also varied greatly from very poor at the forebay to fair at the Little Tennessee River mid-reservoir site. The benthos rating at the forebay was not included in determining the overall ecological health score because part of the transect sampled was in the drawdown zone.

Reservoir Use Suitability

Channel catfish were collected in autumn 1992 from the forebay and mid-reservoir site on the Little Tennessee River. Analysis of composited fillets from each area found most analytes were not detected or had low concentrations. The exceptions to this were mercury at both locations (maximum of 0.53 $\mu g/g$) and PCBs at the forebay (1.1 $\mu g/g$). Channel catfish were collected again in 1993 from both locations and analyzed for the same analytes with close attention for PCBs at the forebay. Largemouth bass were also collected in autumn 1993 from both locations to further examine mercury concentrations. Results were not available at the time this report was prepared.

There were no bacteriological studies conducted on Fontana Reservoir in 1993.

15.3 Little Tennessee River Stream Monitoring Site

Physical Description

The Little Tennessee River drains 2727 square miles and flows more than 140 miles through the Blue Ridge physiographic province of western North Carolina and the Valley and Ridge province of East Tennessee. It joins the Tennessee River near Lenoir City, Tennessee.

The TVA monitoring station is located near Needmore, North Carolina. The drainage area upstream from the monitoring site is 440 square miles or 16 percent of the entire Little Tennessee River basin. Principal tributaries to the Little Tennessee River include Abrams Creek (88 square miles), Cheoah River (215 square miles), Nantahala River (175 square miles), Cullasaja River (93 square miles), and the Tuckasegee-Oconaluftee River (734 square miles). The Cullasaja River is the only major tributary within the monitored area. The basin has been extensively developed with TVA reservoirs (Tellico and Fontana) and private power dams (Chilhowee, Calderwood, Cheoah, Santeetlah, Nantahala, Franklin, and Thorpe).

Igneous and metamorphic rock underlies all of the basin. Much of the basin is located within the federally managed lands of the Great Smoky Mountains National Park and Cherokee and Nantahala National Forests. Franklin, Sylva, Bryson City, and Robbinsville, North Carolina, are the primary urban areas in the basin.

Ecological Health

The stream monitoring site on the Little Tennessee River (at LTRM 94.5) had a very good ecological health rating in 1993 (as in 1992). All indicators (nutrients, sediment quality, benthos, and fish) were rated good.

Use Suitability

No bacteriological studies have been conducted in the streams of this watershed under this monitoring program.

All analytes in fish tissue samples collected during summer 1993 were either below detection limits or found in low concentrations.

16.0 FRENCH BROAD RIVER WATERSHED

The French Broad River watershed is one of the largest (5124 square miles) watersheds in the Tennessee Valley. About half the watershed is in Tennessee and half is in North Carolina. The French Broad River and its two large tributaries (Nolichucky and Pigeon Rivers) originate in the Blue Ridge Mountains. All three of these rivers merge at the upper end of Douglas Reservoir, the only sizable reservoir in the watershed. The water in the French Broad River is moderately hard and relatively high in nutrients.

There are three reservoir Vital Signs monitoring sites on Douglas Reservoir and one stream monitoring site each on the French Broad and Nolichucky Rivers (Figure 16.1). A stream monitoring site on the Pigeon River is being added in 1994. All stream monitoring sites are upstream of Douglas Reservoir.

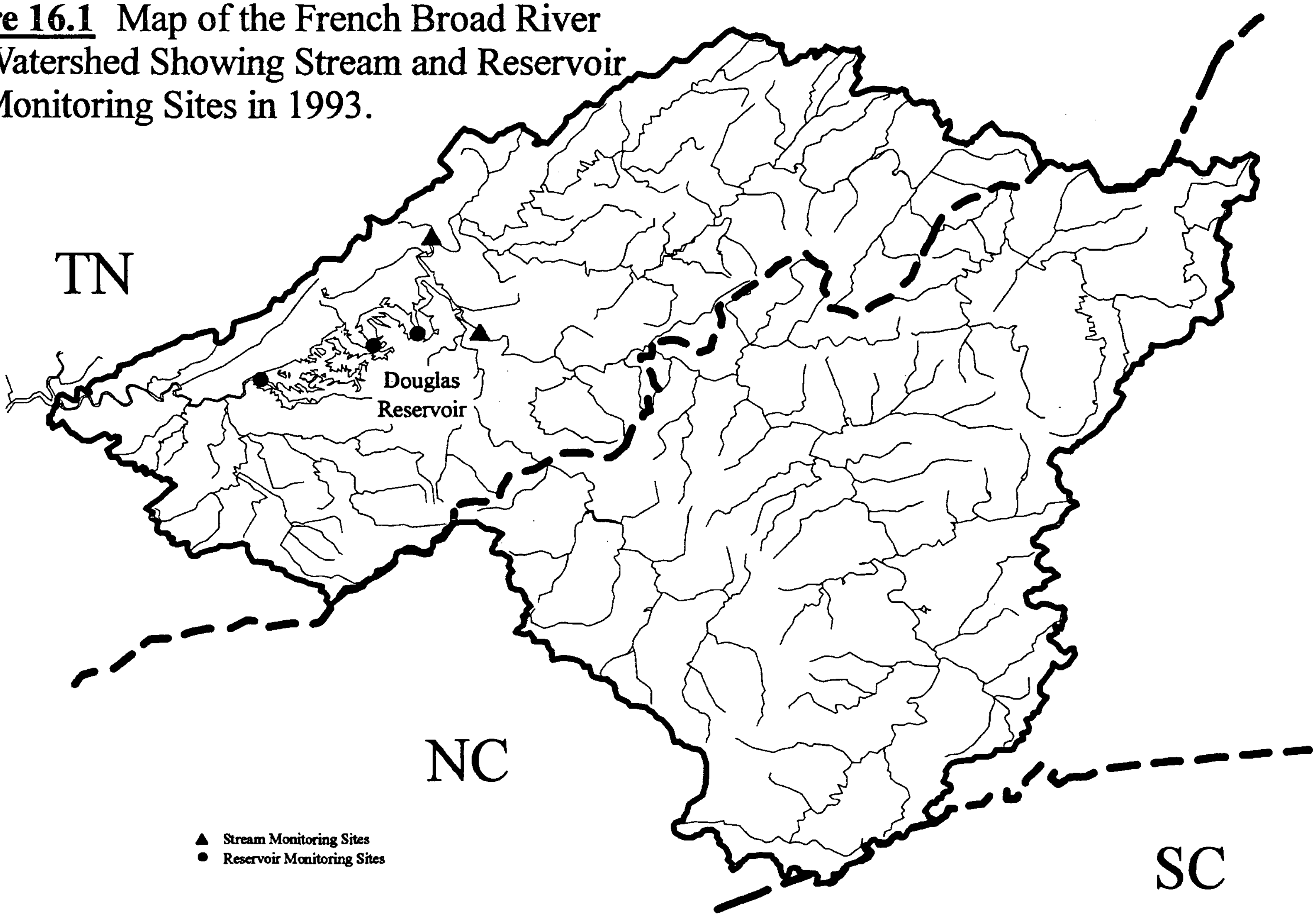
Results from 1993 Vital Signs monitoring activities are provided in the following sections:

16.1 Douglas Reservoir

16.2 French Broad River Stream Monitoring Site

16.3 Nolichucky River Stream Monitoring Site

Figure 16.1 Map of the French Broad River Watershed Showing Stream and Reservoir Monitoring Sites in 1993.



16.1 Douglas Reservoir

Physical Description

Douglas Reservoir is a deep storage impoundment (tributary reservoir) on the French Broad River. Douglas Dam is located 32.3 miles upstream of the confluence of the French Broad and Holston Rivers which form the Tennessee River. Reservoir drawdown during late summer and autumn is rather large, with an annual average of about 48 feet. The large annual fluctuation in surface water elevation causes other physical characteristics such as surface area, reservoir length, and retention time to vary greatly during the year. At full pool, maximum depth at the dam is 127 feet, surface area is 30,400 acres, the shoreline is 555 miles, and the length is 43 miles. Average annual discharge is approximately 6780 cfs, which provides an average hydraulic retention time of about 105 days.

Lengthy retention times and lack of mixing due to their deep nature tend to cause storage impoundments to have strong thermal stratification during summer months. Undesirable conditions often develop in the hypolimnion due to anoxia, which in most cases extends from the forebay to the mid-reservoir sampling location.

Ecological Health

The ecological health of Douglas Reservoir was fair to poor (58 percent) in 1993, with little change compared to 1991 and 1992. Factors adversely affecting the ecological health of Douglas Reservoir were strong thermal stratification and high nutrient loadings. This combination results in hypolimnetic anoxia and release of iron and manganese, phosphorus, and ammonia from the sediment and excessive eutrophication of the reservoir. Ratings for DO were very poor at both the forebay and mid-reservoir sites in 1993 due to very low hypolimnetic DO at both locations and low surface DO at the forebay. This hypolimnetic anoxia promoted the release of ammonia (and sulfide) from the sediment and negatively impacted the benthic community. The benthic macroinvertebrates rated poor at the forebay (samples were not collected from the mid-reservoir site). Sediment quality rated good at the forebay but poor at the mid-reservoir site. The fish assemblage was fair at the forebay and good at the mid-reservoir site. Chlorophyll rated good at the forebay, but only fair at the mid-reservoir site because concentrations were relatively high, indicative of high nutrients and high primary productivity.

Reservoir Use Suitability

There are no fish consumption advisories on Douglas Reservoir. However, fish from the Pigeon River upstream of Douglas Reservoir should not be eaten because of dioxin contamination. The most recent collection of fish from Douglas Reservoir was in autumn 1992. TVA collected fish samples and provided fillets to the Tennessee Department of Environment and Conservation for analysis. Results were not available at the time this report was prepared.

Fecal coliform concentrations were very low at the swimming beach and two boat ramps tested in 1993. Fecal coliform bacteria sampling at the two Vital Signs stations was dropped in 1993. From 1990 to 1992, concentrations were very low.

16.2 French Broad River Stream Monitoring Site

Physical Description

The French Broad River is a major tributary to the Tennessee River system, flowing westward out of the Appalachian Mountains for more than 220 miles to meet the Holston River and form the Tennessee River.

The drainage basin above the stream monitoring site at the USGS stream gage at near Newport, Tennessee, is 1858 square miles or 36 percent of the watershed. Principal tributaries in the monitored area include Big Laurel Creek (132 square miles), Ivy Creek (161 square miles), the Swannanoa River (133 square miles), Hominy Creek (104 square miles), and Mud Creek (113 square miles). Two major tributaries enter the French Broad River below the monitoring site. They include the Nolichucky River (1756 square miles) and the Pigeon River (689 square miles).

Ecological Health

The ecological health of the stream monitoring site at the French Broad River site rated poor in both 1993 and 1992. Nutrients rated poor because of high concentrations of phosphorus. Inflows of nutrients promote the excessive algal productivity in Douglas Reservoir. The fish community on the French Broad River was poor in 1993, same as in 1992. Given the poor water quality of the Nolichucky and French Broad Rivers flowing into Douglas Reservoir, the poor-fair ecological health of the reservoir is not unexpected. Together the Nolichucky and French Broad Rivers provide about 75 percent of the total inflow to Douglas Reservoir.

Use Suitability

No bacteriological studies were conducted as part of the monitoring program in 1993. All analytes in fish tissue samples collected during summer 1993 were either not detected or found in low concentrations.

16.3 Nolichucky River Stream Monitoring Site

Physical Description

The Nolichucky River is a major tributary to the French Broad River basin and joins the French Broad River at the upstream end of Douglas Reservoir. The Nolichucky River Basin is 1756 square miles. The upper portion of the basin (approximately 60 percent) lies in the Blue Ridge physiographic province while the remainder lies in the Valley and Ridge province.

The stream monitoring location is at the TVA stream gage at the David Thomas bridge near Lowlands, Tennessee. The Nolichucky River basin above the monitoring site is 1686 square miles or 96 percent of the entire Nolichucky River basin. Principal tributaries in the monitored area include North Toe River (442 square miles) and Cane River (158 square miles) in the Blue Ridge physiographic province and Lick Creek (266 square miles) in the lower Valley and Ridge province.

The upper portion of the Nolichucky River basin is primarily forested, while the lower portion is agricultural. High concentrations of solids from mica and feldspar mining and processing near Spruce Pine on the North Toe River have severely impacted the streambed downstream. In addition to Spruce Pine, other urbanized areas include Greeneville and Erwin, Tennessee.

Ecological Health

The overall ecological health of the Nolichucky River at this site was good in 1993, as opposed to fair in 1992. The change was driven by improvements in the fish community, the absence of acute sediment toxicity, and improvements in nutrient concentrations. The conditions for bottom-dwelling animals remained unchanged.

Use Suitability

Bacteriological studies were not conducted as part of this monitoring program in this watershed in 1993.

All analytes in fish tissue samples collected during summer 1993 were either not detected or found in low concentrations.

17.0 HOLSTON RIVER WATERSHED

The Holston River Watershed encompasses 3776 square miles, mostly in upper east Tennessee and southwest Virginia and a small area in North Carolina. The area is relatively highly populated with substantial industrial development.

Much of the area is underlain with limestone and dolomite which results in high concentrations of dissolved minerals in the streams. There is also substantial zinc mining in the watershed.

There are several reservoirs in the watershed with varying size, depth, flow, and water quality characteristics. The largest is Cherokee Reservoir on the Holston River near the lower end of the watershed. The uppermost reservoirs are Watauga Reservoir on the Watauga River and South Holston Reservoir on the South Fork Holston River. Downstream from these reservoirs, the Watauga and South Holston Rivers merge in Boone Reservoir. Immediately downstream from Boone Dam is Fort Patrick Henry Reservoir, the smallest of the five reservoirs in this watershed included in the Vital Signs Monitoring Program. A few miles downstream from Fort Patrick Henry Dam the South Fork and North Fork Holston Rivers merge to form the Holston River.

Vital Signs monitoring activities are conducted at one, two, or three locations depending on reservoir size and characteristics (Figure 17.1). There is also a stream monitoring site on the Holston River upstream of Cherokee Reservoir.

The average annual discharge from Cherokee Dam is 4460 cfs. The Holston River merges with the French Broad River at Knoxville to form the Tennessee River.

Results from Vital Signs monitoring activities in 1993 are in the following sections:

17.1 Cherokee Reservoir

17.2 Fort Patrick Henry Reservoir

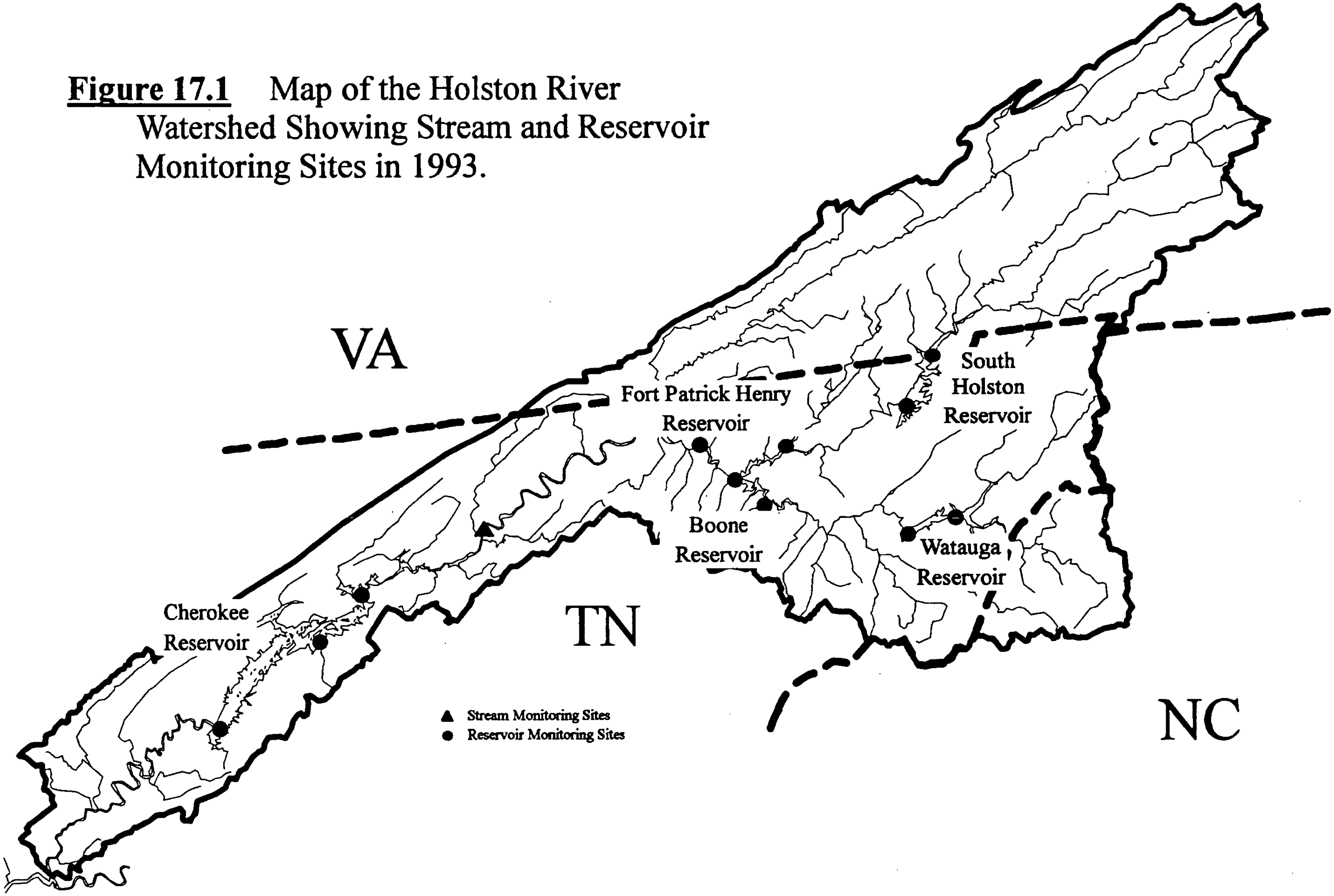
17.3 Boone Reservoir

17.4 South Holston Reservoir

17.5 Watauga Reservoir

17.6 Holston River Stream Monitoring Site

Figure 17.1 Map of the Holston River Watershed Showing Stream and Reservoir Monitoring Sites in 1993.



17.1 Cherokee Reservoir

Physical Description

Cherokee Reservoir is formed by Cherokee Dam at Holston River mile (HRM) 52.3. Like Norris and Douglas Reservoirs, it is a large, relatively deep, tributary storage impoundment with a substantial drawdown which begins in late summer. When the water surface is at full pool, maximum depth at the dam is 163 feet and winter drawdown is 53 feet. However, full pool is not reached most years, and the long-term average drawdown is about 28 feet. At full pool, Cherokee Reservoir is 54 miles long, has a surface area of 30,300 acres, and a shoreline of 393 miles. Average annual discharge is about 4500 cfs which provides an average hydraulic retention time (at full pool) of approximately 165 days.

Like other deep storage impoundments with long retention times, Cherokee Reservoir exhibits strong vertical stratification during summer months. The hypolimnetic oxygen deficit on Cherokee is one of the worst of all Vital Signs monitoring reservoirs and has been well documented in numerous past studies (Iwanski, 1978; Iwanski et al., 1980; Hauser et al., 1987).

Ecological Health

The ecological health of Cherokee Reservoir rated fair (64 percent) in 1993, which was higher than poor ratings in 1992 (55 percent) and poor to fair ratings in 1991 (60 percent). The improved ecological health rating compared to 1992 resulted mostly from addition of benthic macroinvertebrate information from the upper reservoir sample site, and from slight improvements (decreases) in chlorophyll concentrations at the mid-reservoir site. Although benthos data were collected from Cherokee Reservoir in 1992, ratings were not available for 1992 results because of an insufficient data base to establish expected (reference) conditions for the benthic macroinvertebrate community in tributary storage reservoirs. Additional benthos sampling in 1993 on Cherokee plus several other similar reservoirs provided sufficient data to establish at least preliminary expectations for reservoirs of this type. The benthic community rated fair at the forebay and excellent at the upper monitoring site indicating very good conditions there. Improvements noted for chlorophyll at the mid-reservoir site in 1993, rated good compared to fair in 1992 (due to high averages during summer), also helped elevate the overall ecological rating in 1993 compared to 1992.

A problem consistently found in Cherokee Reservoir is very low DO concentrations at the forebay and mid-reservoir sites. Both rated very poor in 1993. This near-bottom low dissolved oxygen condition, often observed in deep tributary reservoirs with long retention times, is especially severe in Cherokee Reservoir, resulting in high concentrations of un-ionized ammonia in sediment. The fair fish community observed at all monitoring sites in 1993 was probably also influenced to some extent by the low oxygen concentrations in Cherokee Reservoir. Sediment quality rated poor at the mid-reservoir site due to high ammonia and copper concentrations coupled with significant toxicity to rotifers.

Reservoir Use Suitability

There are no fish consumption advisories on Cherokee Reservoir. Channel catfish for screening tissue analysis were collected in autumn 1992. All analytes were not detected or found in low concentrations except PCBs. Maximum PCB concentrations were 0.8 $\mu g/g$ at the forebay in 1992. Screening samples were collected again in 1993 to further examine PCB concentrations, but results were not available at the time this report was prepared.

Fecal coliform concentrations were low at all test sites in 1993--a swimming beach, seven boat ramps, and one other site tested. Fecal coliform bacteria sampling at the two Vital Signs stations was discontinued in 1993. From 1990 to 1992, concentrations were very low.

17.2 Fort Patrick Henry Reservoir

Physical Description

Fort Patrick Henry Reservoir is one of the smaller reservoirs included in the Vital Signs Monitoring Program. It is only ten miles long, has a surface area of about 870 acres, and has a shoreline of 37 miles. Although it is a tributary reservoir, it has characteristics of a run-of-river reservoir, rather than a storage reservoir. Annual fluctuation in elevation is only five feet. Also, retention time is short; with an average discharge of 2650 cfs, the hydraulic retention time is only about five days. Maximum depth is about 80 feet. Fort Patrick Henry Dam is located at South Fork Holston River mile 8.2.

This reservoir had not been sampled as part of this monitoring effort prior to 1993. Because of its small size, only the forebay is monitored for Vital Signs.

Ecological Health

The ecological health of Fort Patrick Henry Reservoir was fair to good (72 percent) in 1993. DO was the only indicator which rated excellent and sediment quality was the only indicator which rated good. Chlorophyll rated fair, with the average annual concentration only slightly above the level considered good. The benthos and fish assemblage also rated fair.

Reservoir Use Suitability

Fecal coliform concentrations at Warriors Path State Park were within Tennessee's criteria for recreation during 1993 studies. TVA's first fish tissue studies on this reservoir were conducted in autumn 1993; results were not available at the time this report was prepared.

17.3 Boone Reservoir

Physical Description

Boone Dam is located at South Fork Holston River mile (SFHRM) 18.6, approximately 1.4 miles downstream of the confluence of the South Fork Holston and the Watauga Rivers. At normal maximum pool (1384 feet MSL), Boone Reservoir extends upstream approximately 17.4 miles on the South Fork Holston River and 15.3 miles on the Watauga River for a total reservoir length of approximately 32.7 miles. Boone Reservoir has a surface area of 4300 acres, a shoreline length of approximately 122 miles, an average depth of 44 feet, and a maximum depth of 129 feet near the dam. Annual average discharge from Boone Dam is about 2500 cfs, which results in an average hydraulic residence time of about 38 days. Annual drawdowns of Boone Reservoir usually average about 25 feet.

Three locations were selected for ecological health monitoring in Boone Reservoir, one at the forebay and two mid-reservoir sampling locations, one on the Watauga River arm and one on the South Fork Holston River arm. Sediment and benthic macroinvertebrate sampling were added for the first time in 1993.

Ecological Health

The ecological health evaluation of Boone Reservoir was lower in 1993 compared to 1992. The rating for 1993 was toward the low end of the fair range (59 percent) whereas it was in the middle of the range in 1992 (64 percent). Ecological health ratings in both 1992 and 1993 were higher than in 1991 when poor conditions were found (51 percent). Primary contributors to lower scores in 1993 compared to 1992 were lower ratings for DO (fair at two locations and poor at one); lower ratings for the fish assemblage (poor at two locations and fair at one); and addition of ratings for the benthic macroinvertebrates (fair at two locations and poor at one). The ecological health indicator with the best rating in 1993 was chlorophyll, which rated good at the forebay.

The DO problem at the forebay and mid-reservoir site on the South Fork Holston River arm is different than other tributary, storage reservoirs. The typical problem is hypolimnetic anoxia, which is the case at the Watagua River mid-reservoir site. At the other two Boone Reservoir sites, the DO problem occurs in the middle stratum of the water column (metalimnion) due to oxygen demand of local sewage treatment plant discharges.

Reservoir Use Suitability

Studies conducted by the state of Tennessee found PCBs and chlordane in fish tissue, resulting in a state-issued advisory that catfish and carp should not be eaten by children, pregnant women, and nursing mothers. Further, all other people should limit their consumption of these particular fish. Additional fish samples were collected by TVA in autumn 1993, but results were not available at the time this report was prepared.

Bacteriological sampling was conducted at two swimming areas and four boat ramps in 1993. The geometric mean concentrations of fecal coliform bacteria were well within Tennessee's criteria for recreation, although one sample at the Boone Dam swimming area was high.

17.4 South Holston Reservoir

Physical Description

South Holston Reservoir in northeastern Tennessee and southwestern Virginia is created by South Holston Dam, located on the South Fork of the Holston River at mile 49.8. The dam creates a storage pool approximately 24 miles long, over 230 feet deep near the dam, with an average depth of 86.5 feet and approximately 7600 acres in surface area. With an average annual discharge of about 980 cfs from the dam, the average hydraulic residence time is almost one year (340 days)--one of the longest residence times of any TVA reservoir. Average annual drawdown of South Holston Reservoir is about 33 feet.

Two locations are monitored for Vital Signs--the forebay and mid-reservoir. Sediment and benthic macroinvertebrate sampling were added for the first time in 1993.

Ecological Health

The ecological health evaluation of South Holston Reservoir was fair (65 percent) in 1993, slightly better than in 1992 (57 percent) and 1991 (60 percent). A consistent problem has been with DO concentrations (as is the case with most deep storage impoundments), which rated poor at the forebay and very poor at the mid-reservoir site in 1993. Despite the poor ratings for DO, conditions were slightly improved at the forebay in 1993, compared to 1992. The ecological health indicator primarily responsible for the higher overall reservoir rating in 1993 was sediment quality (rated good at both sample sites). Sediments had not been sampled in previous years. Another indicator added in 1993, the benthic macroinvertebrate community, received a very poor rating at the forebay (with most metrics receiving the lowest score possible) and a fair rating at the mid-reservoir sample site. Interestingly, scores for the benthos do not parallel those for DO at the two sample sites, indicating other factor(s) may be affecting benthic macroinvertebrates at the forebay. The fish assemblage rated good at the forebay and fair at the mid-reservoir site.

Reservoir Use Suitability

There are no fish consumption advisories on South Holston Reservoir. The most recent TVA data for fish tissue samples for fish collected in autumn 1991 found low or nondetectable concentrations of all pesticides, PCBs, and metals (except mercury which was slightly elevated).

17.5 Watauga Reservoir

Physical Description

Watauga Dam in the northeastern corner of Tennessee impounds the Watauga River at mile 36.7. It forms a pool 16 miles in length, approximately 6400 acres in surface area, about 274 feet deep at the dam, and an average depth of about 89 feet, making it the second-deepest reservoir sampled as part of TVA's Vital Signs Monitoring Program. With an annual average discharge of about 700 cfs, Watauga Reservoir also has the longest hydraulic residence time of any of the Vital Signs reservoirs (about 400 days). Average annual drawdown of Watauga Reservoir is about 26 feet.

Two locations are monitored on Watauga Reservoir, the forebay and mid-reservoir. Sediment quality and benthic macroinvertebrates were examined for the first time in 1993.

Ecological Health

The overall ecological health for Watauga Reservoir was fair in 1993 (61 percent), about the same as in 1992 (57 percent). The ecological health in both 1992 and 1993 rated lower than in 1991, although all three years fell within the fair range. Similar to previous years, chlorophyll rated good at both sample sites in 1993. DO rated excellent at the forebay and fair at the mid-reservoir sites in 1993, a slight improvement compared to 1992. The fish assemblage was poor at the forebay in 1993 due to low abundance and diversity and rated fair at the mid-reservoir site, mostly due to low abundance. The benthic macroinvertebrate community, not sampled in Watauga Reservoir prior to 1993, was very poor at both locations. The benthos community was among the poorest in all Vital Signs reservoirs examined in 1993. This would not appear to be related to low DO concentrations; instead, the poor sediment quality at the forebay (due to toxicity to test animals and high ammonia) may have contributed to the poor benthos.

Reservoir Use Suitability

There are no fish consumption advisories on Watauga Reservoir. The most recent fish tissue collections by TVA were made in autumn 1991. All pesticides, PCBs, and metals (except mercury which was sightly elevated) were low or not detected.

Fecal coliform bacteria concentrations were very low at all five sites tested in 1993, which included one designated and an informal swimming area.

17.6 Holston River Stream Monitoring Site

Physical Description

The TVA stream monitoring station on the Holston River is located near Church Hill, Tennessee. The Holston River basin above this location is 2819 square miles or 74 percent of the entire Holston River basin. Two major tributaries, the North Fork Holston River (729 square miles) and the South Fork Holston River (2048 square miles), meet above Church Hill to form the Holston River. Principal tributaries to the South Fork Holston River include the Watauga River (869 square miles) and the Middle Fork Holston River (244 square miles). Two notable tributaries to the Watauga River include the Doe River (137 square miles) and Roan Creek (167 square miles).

There are five reservoirs in the basin. Fort Patrick Henry Dam and Boone Dam impound the lower South Fork Holston River. The South Fork Holston Dam impounds the upper South Fork Holston River and the Middle Fork Holston River. Wilbur Dam and Watauga Dam impound the Watauga River.

Although most of the basin land use is agricultural or forestry, several urban areas (Kingsport, Johnson City, and Elizabethton, Tennessee, and Marion and Abingdon, Virginia) are within the basin.

Ecological Health

The overall ecological health of the Holston River at this site was fair for 1993 as in 1992. Sediment quality improved from fair to good, and the fish community showed a slight improvement over 1992. Bottom-dwelling animals and nutrient ratings remain unchanged.

Use Suitability

Seven sites between Fort Patrick Henry Reservoir and South Holston Dam were tested for fecal coliform bacteria in 1993. South Fork Holston River met bacteriological water quality criteria for water contact recreation, and was only slightly impacted by the two tributaries tested. Thomas and Beidleman Creeks did not meet criteria.

A five fish composite each of carp, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. All analytes were not detected or found in low concentrations except slightly elevated levels of mercury in largemouth (0.5 μg/g), PCBs in carp (0.6 μg/g), and chlordane in channel catfish (0.08 μg/g).

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TENNESSEE VALLEY RESERVOIR AND STREAM QUALITY - 1993

SUMMARY OF VITAL SIGNS AND USE SUITABILITY MONITORING

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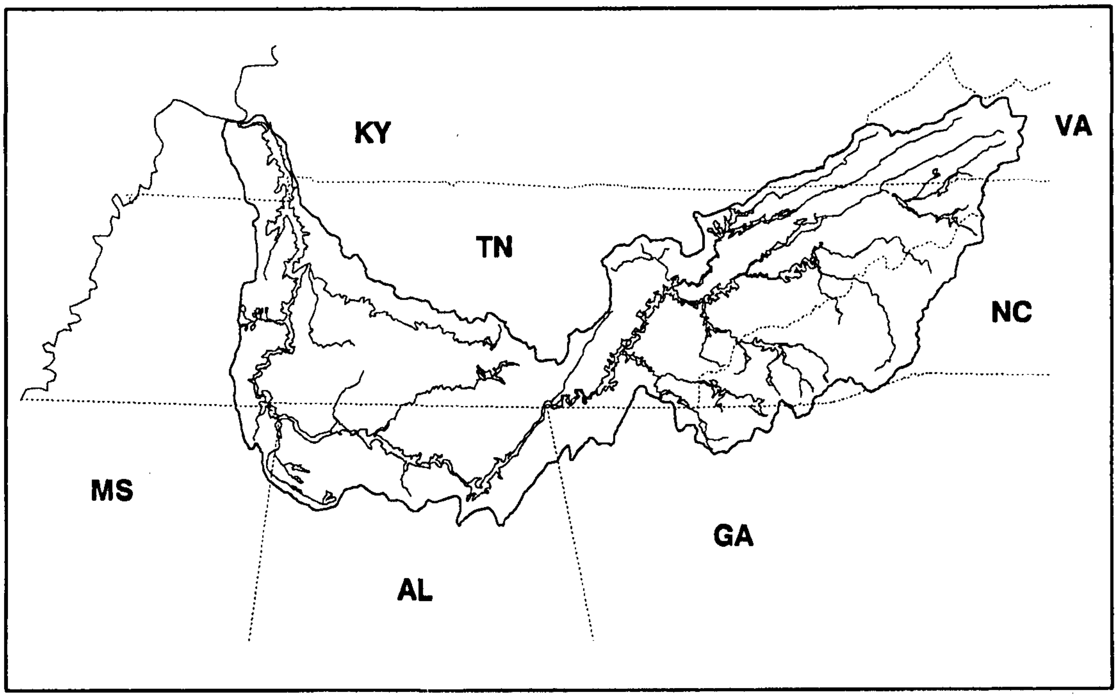

CLEAN WATER INITIATIVE

TENNESSEE VALLEY AUTHORITY
Resource Group
Water Management

TENNESSEE VALLEY RESERVOIR AND STREAM QUALITY - 1993
SUMMARY OF VITAL SIGNS AND USE SUITABILITY MONITORING

Volume II

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INTRODUCTION

The Tennessee Valley Authority (TVA) initiated a systematic, Valley-wide water quality and aquatic ecological monitoring program in 1986. The program started with a stream component and a reservoir component was added in 1990. The two primary objectives of these monitoring efforts are to evaluate the ecological health (Vital Signs Monitoring) of major streams and reservoirs in the Tennessee Valley and to examine how well these water resources meet the swimmable and fishable goals of the Clean Water Act (Use Suitability Monitoring).

Vital Signs Monitoring

Stream monitoring has been conducted on 12 large tributaries since 1986. Beginning in 1994, six additional tributaries will be monitored; all with watersheds of at least 500 square miles. Reservoir monitoring started with 12 reservoirs (mostly mainstream reservoirs) in 1990 and has expanded progressively to the full complement of 30 reservoirs in 1993. No further expansion of either stream or reservoir monitoring is planned. This report summarizes results of these monitoring efforts in 1993. Volume I is the main body of the report and Volume II is a data summary by sampling location within watershed areas.

Until 1991, the ecological health evaluations were based on subjective evaluation of the data. A weight-or-evidence approach was used— a stream or reservoir was deemed healthy if most of the physical, chemical, and biological components appeared healthy. Beginning with the 1991 results, a more quantitative approach was developed that has been used the last three years. This approach integrates information on important indicators of ecological health. For reservoirs, five indicators are used— dissolved oxygen, chlorophyll *a*, sediment quality, benthic macroinvertebrates, and fishes. Stream evaluations are similar except dissolved oxygen is not rated and nutrient concentrations are substituted for chlorophyll *a* concentrations. For each indicator (or metric), scoring criteria are developed that assign a score ranging form 1 to 5 representing very poor to excellent conditions. Scores for all indicators at a location are summed. For streams and smaller reservoirs, only one site is monitored. For larger reservoirs, multiple sites are monitored, and the overall reservoir score is achieved by totaling scores for all locations. The resulting total is divided by the maximum possible score. Thus, the possible range of scores is from 20 percent (all metrics very poor) to 100 percent (all metrics excellent). Hence, an overall ecological health rating of good, fair, or poor is obtained for each stream site or reservoir. A health rating border-line between two of these categories is considered poor-fair or fair-good. Each year , the most recent information is evaluated with the same basic approach, modified to incorporate improvements based on comments from reviewers and additional data.

Stream monitoring results for 1993 indicated seven streams rated good (three of these with perfect scores), three streams rated fair to good, and one stream rated poor. Full evaluation was not possible for one stream because only three of the four indicators were monitored in 1993. The only stream to receive a poor rating was the French Broad River. This overall rating was caused by poor scores for nutrients and fishes, a fair score for benthos, and a good score for sediment quality.

Reservoirs are stratified into two groups for evaluation: run-of -the-river reservoirs and deep storage reservoirs. Separate scoring criteria are used for the two categories. Overall ratings for the 11 run-of-the-river reservoirs in 1993 ranged from 58 to 88 percent. Four reservoirs rated good (74 to 88 percent), three rated fair to good (71 to 73 percent), three rated fair (63 to 68 percent), and one rated poor to fair (58 percent). Overall ratings for the 19 storage reservoirs ranged from 52 to 72 percent. Two reservoirs rated fair to good (both 72 percent), fourteen rated fair (58 to 67 percent), and three rated poor (52 to 56 percent).

Results did not yield any "big surprises"— most streams and reservoirs fell within expected categories. Similar results were observed in both 1991 and 1992, primarily due to similar meteorological conditions and reservoir flows during the period. Generally poorer ratings observed in storage reservoirs were primarily because of low dissolved oxygen in the hypolimnion. This is an ecologically undesirable condition that is mostly due to strong thermal stratification that occurs in deep reservoirs.

Use Suitability Monitoring

Use Suitability Monitoring provides screening level information on the suitability of selected areas within TVA reservoirs for water contact activities (swimmable) as determined by bacteriological studies and suitability of fish from TVA reservoirs for human consumption (fishable) as determined by fish tissue studies.

Bacteriological Studies

Bacteriological samples are collected at over 200 sites in the Tennessee Valley: designated swimming areas, canoe access sites, highly used recreational areas, and selected non-recreation sites that provide information on pollution sources or inflow stream quality. Not all sites are sampled each year. Beginning in 1993, each recreation site will be revisited at least every other year.

In 1993, bacteriological sampling at recreation sites was conducted at 71 swimming areas and 14 canoe access points. All but two swimming areas met the regulatory criterion to be considered safe. Even those two sites met the criterion if samples collected after heavy rains were excluded. Four canoe access points (all on the Duck River) exceeded the criterion, in dry or wet weather.

Bacteriological sampling at non-recreation areas was conducted at 35 sites in 1993. Only one reservoir site and two stream sites failed to meet recreation criteria.

The results of studies summarized above are consistent with previous surveys. Fecal coliform concentrations were generally lower in 1993 due to lower than normal summer rainfall. Bacteriological water quality is most areas of TVA reservoirs is good. In streams it is much poorer, especially after rainfall.

Fish Tissue Studies

Fish tissues studies examine fillets from important fish species for selected metals, pesticides, and polychlorinated biphenyls (PCBs) on the U.S. Environmental Protection Agency's list of priority pollutants. Resulting data are provided to appropriate state agencies to determine the need for further study and possible issuance of fish consumption advisories. Fish tissue data reported here represent autumn 1992 collections. Results for fish collected in autumn 1993 were not available at the time this report was prepared due to the time required for laboratory analysis.

Results of screening studies in 1992 did not reveal any new areas in need of intensive investigations. Concentrations of at least one contaminant were high enough to warrant sampling again at the screening level in 1993. Results of intensive studies (i.e., in-depth studies where there are know or suspected problems) did not indicate substantial changes from previous years.

KENTUCKY RESERVOIR WATERSHED

Kentucky Reservoir

Summary of 1993 Conditions - Ecological Health

Water—During the summer of 1993 (April-September), the coolest surface water temperatures in Kentucky Reservoir were in April and the warmest in July. Surface temperatures ranged from a minimum of 13.6°C to a maximum of 31.5°C at the forebay; from 15.8°C to 31.6°C at the transition zone; and from 16.1°C to 30.9°C at the sampling location in Big Sandy embayment. The State of Tennessee's maximum water temperature criteria for the protection of fish and aquatic life is 30.5°C.

Dissolved oxygen (DO) concentrations at the 1.5m depth ranged from a low of 6.2 mg/l in July to a high of 10.4 mg/l in April at the forebay; from 5.8 mg/l in August to 10.1 mg/l in June at the transition zone; and from 6.2 mg/l in July to 10.3 mg/l in April at the sampling location in Big Sandy embayment. At the inflow sampling site (i.e. the tailrace of Pickwick Dam) a minimum DO of 4.2 mg/l was recorded in July. The State of Tennessee's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5m depth.

The temperature and DO data depict a seasonal warming and very weak thermal stratification of Kentucky Reservoir in June-July 1993. The greatest surface-to-bottom temperature differential (ΔT) was only about 3°C in June and July at the forebay and about 4½°C in Big Sandy embayment in June. However, during July, a rather strong oxycline developed at Kentucky forebay and in the Big Sandy embayment due to the drought like conditions and low flows through Kentucky Reservoir and the Tennessee River system (see discussion in Section 4.0, Hydrologic Overview of 1993). In late July, forebay dissolved oxygen ranged from surface concentrations of about 8-9 mg/l to bottom concentrations approaching 0 mg/l. (The minimum DO observed in Kentucky Reservoir in 1993 was 0.1 mg/l in July at the bottom of the reservoir in the forebay.) Similar conditions were found in Big Sandy embayment, although near bottom DO concentrations were never actually measured below 1 mg/l. The transition zone DO concentrations were much more uniform and well mixed with the minimum bottom DO being 3.6 mg/l in July.

For the overall reservoir ecological health evaluation for Kentucky Reservoir, DO rated excellent at the transition zone; good to excellent in Big Sandy embayment; and good at the forebay and inflow (i.e., Pickwick Dam tailrace). The good rating at the forebay would have rated higher had it not been for the anoxic conditions which were found to exist for a short time (i.e. July) in the hypolimnion near Kentucky dam. Likewise, the good rating at the inflow would also have been higher if oxygen levels had not fallen below 5 mg/l in the releases from Pickwick dam (i.e. DO concentrations less than State of Tennessee's 5 mg/l criteria, measured at the 1.5m depth).

In 1993, values of pH ranged from 6.7 to 9.2 on Kentucky Reservoir. Near surface values exceeding 8.5 were observed at the forebay in July and in Big Sandy embayment in June and August. These high pH's were coincident with high DO saturation values (exceeding 100 percent) and elevated chlorophyll *a* concentrations, indicative of significant photosynthetic activity. The State of Tennessee's maximum pH criteria for the protection of fish and aquatic life is 8.5.

Average total phosphorus (0.073 mg/l) and dissolved ortho phosphorus (0.029 mg/l) concentrations at the transition zone were higher than at all other monitoring locations on the Tennessee River, an effect of the upstream inflows from the Duck River with naturally high concentrations of phosphorus (median total phosphorus concentrations of about 0.24 mg/l). Total phosphorus concentrations in the Tennessee River are approximately doubled by the inflows from the Duck River (annual mean daily flow of approximately 4,100 cfs), and gradually decline downstream. The Duck River joins with the Tennessee River at TRM 110.7, about 25 river miles upstream from the Kentucky Reservoir transition zone sampling site. (For additional information see Section 5.0, Duck River Watershed.) Because of high phosphorus concentrations, TN/TP ratios for samples collected at both the forebay and transition zone were quite low ranging from 5 to 13, indicating very little nutrient limitation and conditions highly supportive of primary productivity.

Chlorophyll *a* concentrations averaged 10.4 µg/l at the forebay, 9.2 µg/l at the transition zone, and 18.0 µg/l in Big Sandy embayment during the summer of 1993. In addition, high chlorophyll *a* concentrations were measured in August (31 µg/l) and September (35 µg/l) in Big Sandy embayment, indicative of nuisance level algal blooms. [It is also interesting to note that the Big Sandy embayment had among the highest organic nitrogen (= 0.51 mg/l), organic carbon (= 4.2 mg/l), and color (= 19 PCU) concentrations measured at any Vital Signs reservoir monitoring location in 1993.] Chlorophyll *a* values which average greater than 10 µg/l are generally indicative of eutrophic conditions while values greater than 15 µg/l are often indicative of hyper-eutrophic conditions. Consequently, the chlorophyll *a* ratings used in the 1993 ecological health evaluation for Kentucky Reservoir were fair at the forebay, good at the transition zone, and poor in the Big Sandy embayment.

Sediment Quality—Chemical analyses of sediments in Kentucky Reservoir in 1993 did not reveal any metal or organic analyte to be a concern in the two sample locations (i.e. forebay and transition zone) in the main reservoir. However, high levels of un-ionized ammonia were measured (510 µg/l) in the Big Sandy embayment. Toxicity tests detected no acute toxicity in the main reservoir, however, acute toxicity to both daphnids (15 percent survival) and rotifers (20 percent survival) was detected in the Big Sandy embayment. Particle size analysis showed sediments from the forebay and the Big Sandy embayment to be almost entirely silt and clay (99 percent at each site), while those from the transition zone were 65 percent silt and clay, 35 percent sand.

Sediment quality ratings used in the overall Kentucky Reservoir ecological health evaluation for 1993 were excellent at the forebay and transition zone, and poor in the Big Sandy embayment (due to the presence of ammonia and toxicity to the test organisms).

Benthic Macroinvertebrates—The benthic communities were excellent in the forebay and transition zone, fair in the inflow, and good in the Big Sandy embayment. The forebay had a total of 26 taxa with 1,658 organisms/m^2. The dominant taxa at the forebay were Tubificidae (18%), Corbicula sp (17 percent), and Musculium sp (17 percent). The transition zone represented a more diverse (33 taxa) but less abundant (1,307 organisms/m^2) community than the forebay with Tubificidae as the dominant taxa (22 percent), followed closely by Hexagenia limbata (22 percent). The inflow site had 25 taxa and a total of 234 organisms/m^2 with Cheumatopsyche sp (32 percent) and Corbicula sp (29 percent) as the dominant taxa. The Big Sandy embayment site had 20 taxa and 1,683 organisms/m^2 with Chironomus sp (37 percent), and Coelotanypus tricolor (33 percent) as the principal taxa.

The forebay and transition zone sites on Kentucky Reservoir rated excellent primarily because of the abundance of long-lived species such as Corbicula sp and Hexagenia sp, and because of a diverse and balanced benthic community. The inflow rated only fair, in spite of an abundance of Corbicula sp, because of reduced diversity and EPT (Ephemeroptera, Plecoptera, and Trichoptera) taxa. The Big Sandy embayment received a good rating due to the diversity of organisms present and the evenness of dominant organisms. An abundance of chironomids resulted in this site receiving a good rating instead of an excellent rating.

Though not included in the overall health survey, the Kentucky tailwater benthic community was also sampled. Diversity and a good EPT community, as well as low numbers of chironomids and tubificids, allowed this site to obtain an excellent rating.

Aquatic Macrophytes—Aquatic plants increased from 2,616 acres in 1992 to 3,465 acres in 1993. Kentucky Reservoir had the third largest amount of aquatic vegetation within the TVA system. Aquatic macrophytes peaked at about 7,100 acres in 1987. Significant declines in spinyleaf and southern naiad populations have occurred in recent years. Eurasian watermilfoil was the dominant macrophyte on Kentucky Reservoir and generally occurred in monospecific stands. However, it was sometimes mixed with coontail and naiads. Aquatic vegetation on Kentucky Reservoir was primarily found from TRM 107 downstream to near the vicinity of Kentucky Dam.

Fish Assemblage—Fish data collection at near shore (45 electrofishing transects) and offshore bottom areas (26 net-nights) showed a diverse fish assemblage of 46 species dominated in numbers by gizzard shad (64 percent). Other abundant species included emerald shiners (5.6 percent), bluegill (4.8 percent), and largemouth bass (2 percent). Electrofishing results indicated total numbers of fish were approximately the same in the forebay (1,634) and transition zones (1,762) with considerably lower numbers in the inflow zone (405). Gill netting fish abundance was also highest in the forebay (696) and transition (494) areas. Abundance at the inflow zone (69) was not comparable because of reduced effort. Gizzard shad made up 36 percent of the total fish collected in gill net samples followed by yellow bass (15.7 percent), skipjack herring (9.9 percent), and channel catfish (6.0 percent).

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) fair in the forebay (RFAI=32), transition (RFAI=34), and inflow (RFAI=40) zones of Kentucky Reservoir. The lower scores in transition and forebay zones were influenced by low numbers of sucker species, a high percentage of tolerant species and omnivorous individuals, and high percentage of dominance by a single species. The gill netting RFAI rated the transition zone excellent (RFAI=56) and the forebay good (RFAI=42). Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples. The excellent score of 56 in the transition was the highest ever observed and resulted from maximum scores in all metrics except number of sucker species and percent tolerant species.

Combined electrofishing and gill netting RFAI scores for the forebay (RFAI=37) and the electrofishing RFAI for the inflow (RFAI=40) were rated fair. The combined transition RFAI (RFAI=45) ranked good exhibiting the second highest score of all run-of-the-river transition zones, due primarily to the excellent gill netting results noted above.

Combined fish samples in shoreline electrofishing (15 transects) and offshore gill netting (24 net-nights) produced a total of 1,587 individuals including 27 species in the Big Sandy River embayment. There were four times as many fish collected by electrofishing as gill netting, largely attributed to high numbers of gizzard shad which made up 71 percent of the total sample.

The electrofishing RFAI score of 32 rated fair. The gill netting RFAI of 22 was the lowest recorded for any of the embayment study sites in 1993, and resulted from minimum scores for eight of the twelve metrics. The combined RFAI scores (RFAI=27) rated the Big Sandy embayment poor.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Fourteen swimming beaches and one informal swimming area were tested for fecal coliform bacteria in 1993. Bacteria concentrations were generally low at all 15 sites. The highest geometric mean at any site was 47 colonies per 100 milliliters (47/100 ml), well below the recreation criterion of 200/100 ml. No site had more than one sample exceed 400/100 ml, so EPA's guideline of no more than 10 percent of all samples exceeding 400/100 ml was also met. Two sites, Eva Park and Greenhead Recreation Area, each had one sample exceed the Tennessee single sample criterion of 1,000/100 ml. The geometric mean of all samples at these two sites were 14 and 15/100 ml. The six monthly Vital Signs samples collected at the forebay and transition zones were all at or below the detection limit of 10/100 ml.

Fish Tissue—Channel catfish composites were collected in 1992 from generally the same locations (except TRM 85 was sampled instead of TRM 100 to coincide with the transition zone location) as in previous years. As in past years, concentrations of all analytes were low. One analyte of interest was lead with a concentration of 0.6 μg/g at TRM 85. Similar levels have occurred sporadically with no pattern in locations over the five years screening samples have been collected from Kentucky Reservoir.

Beech Reservoir

Summary of 1993 Conditions - Ecological Conditions

Water—Beech Reservoir is the smallest and shallowest of the monitored reservoirs. The average flow through the reservoir in 1993 was only 64 percent of normal, making the average residence time over 600 days. The maximum temperature difference in the water column was 9.2°C in July, and had disappeared by September. The maximum surface temperature was 29.7°C in July. The extent of the area of depleted DO gave Beech Reservoir a poor DO rating for the reservoir ecological health index. DO depletion (<1.0 mg/l) began at the bottom of the water column in May and expanded to within four meters of the surface in June and July. As the reservoir destratified the bottom waters became re-aerated, although there was some low DO (2.2 mg/l) at the bottom in October.

Conductivities were generally in the 31 to 45 µmhos/cm range, but were much higher at the bottom during times of DO depletion, reaching a maximum of 141 µmhos/cm in August. Only in April and June did pH exceed 8.0, and the maximum was only 8.3. The minimum pH was 6.6 and occurred at greater depths during DO depletion.

Virtually all of the nitrogen was in the form of organic nitrogen. Total nitrogen increased slightly from 0.42 mg/l in April to 0.51 mg/l in August. Total and dissolved ortho phosphorus concentrations dropped from 0.04 and 0.01 mg/l in April to 0.02 and 0.002 mg/l in August, respectively. The TN/TP ratio thus increased from 11 to 26.5 from April to August. Secchi depths varied only from 1.0m in April and September to 1.5m in May and June, the second lowest water clarity of the 19 tributary reservoir forebays in 1993. Chlorophyll *a* concentrations were 3 µg/l in April, 6 µg/l in May, and varied from 9 to 14 µg/l for the rest of the sampling period. The average chlorophyll *a* concentration was 9.0 µg/l, in the good range (near the upper end) for the reservoir ecological health index. Total organic carbon dropped from 5.4 mg/l in April to 3.3 mg/l in August. Total phosphorus and total organic carbon concentrations were the second lowest concentrations of the 19 tributary reservoir forebays in 1993.

Sediment—Chemical analyses of sediments in the forebay of Beech Reservoir in 1993 did not reveal any metal or organic analyte to be a concern. Toxicity tests detected no acute toxicity to the two organisms tested; however, survival of daphnids (68 percent survival) was reduced. Particle size analysis showed sediments in the forebay were 97 percent silt and clay.

Because of the slightly reduced survival of daphnids, the forebay sediment quality rating used in the 1993 Beech Reservoir ecological health evaluation was good.

Benthic Macroinvertebrates—The forebay on Beech Reservoir supported a fair benthic community. There were 24 taxa and 1,417 organisms/m^2, with Einfeldia sp (39 percent of the total) and Chironomus sp (35 percent of the total) as the dominant species. This site had 2 metrics which rated good: diversity and proportion of the sample composed of tubificids. Fair representations of EPT and long-lived taxa were observed. An abundance chironomids negatively impacted the benthic community rating.

Fish Assemblage—No fish assemblage information was collected in autumn 1993 because water levels prevented access to the lake.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No bacteriological studies were conducted in 1993.

Fish Tissue—TVA has not conducted fish tissue studies on Beech Reservoir.

DUCK RIVER WATERSHED

Normandy Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average residence time in Normandy Reservoir was 201 days in 1993 as flows were 91 percent of normal. The maximum temperature difference in the water column was 23°C in July. The maximum surface temperature was 32.3°C in July, the only month when the maximum temperature exceeded 30.5°C, Tennessee's criteria for aquatic life. Metalimnetic and near-bottom oxygen depletion began in June. By August, DO was below 0.1 mg/l from the bottom to six meters from the surface. Surface temperatures had cooled enough to mix with the metalimnion in October, increasing the depth of aerated water to 10m. The extent of the area of depleted DO gave Normandy a poor DO rating for the reservoir ecological health index. Surface DO reached saturation levels of 120 percent or more on each sample date from May through July.

Conductivities were about 100 μmhos/cm early in the year, began increasing at the bottom in June and reached about 160 μmhos/cm in September and October. Normandy had slightly basic water (pH from 7.5 to 8.3) in April. Surface pH was over 9 from May through July, with a maximum pH of 9.5 in May. Bottom pH dropped slightly during the summer to a minimum of 6.6 in September.

Total nitrogen concentration dropped from 0.72 mg/l in April to 0.46 mg/l in August. The decline was due to the elimination of nitrates, 0.25 mg/l in April and <0.01 mg/l in August. Total phosphorus and dissolved ortho-phosphorus concentrations were 0.04 and 0.004 mg/l in April and 0.01 and <0.002 mg/l in August, respectively. The TN/TP ratio went from 18 in April to 46 in August. Secchi depths generally increased through the sampling period from 1.1m in April to 3.0m in October. Chlorophyll *a* was 10 μg/l in April, increased to 12 μg/l in May and July, and then dropped to 5 μg/l in August as available nutrients were depleted. The average chlorophyll *a* concentration was 8.9 μg/l, in the good range (near the upper end) for the reservoir ecological health index. Total organic carbon varied little from 3.6 mg/l in April to 4.2 mg/l in August. Total phosphorus and total organic carbon concentrations in the forebay were the third highest concentrations of the 19 tributary reservoir forebays in 1993.

Sediment Quality—Chemical analyses of sediments in the forebay of Normandy Reservoir in 1993 indicated very high levels of un-ionized ammonia (720 μg/l). Toxicity tests detected acute toxicity to daphnids (60 percent survival) in the forebay sediment. Particle size analysis showed sediments in the forebay were 99 percent silt and clay.

Because of the acute toxicity of the forebay sediment to daphnids and the high concentrations of ammonia, a poor sediment quality rating was used in the 1993 Normandy Reservoir ecological health evaluation.

Benthic Macroinvertebrates—The Normandy forebay received a poor rating for its benthic community. There were 198 organisms/m^2 representing only 6 taxa; the dominant organisms were Tubificidae, Limnodrilus sp, and Chironomus sp, which comprised 38, 35, and 24 percent of the total, respectively. The low diversity, paucity of EPT and long-lived taxa, and the abundance of tubificids all negatively impacted the benthic community rating at the Normandy forebay.

Fish Assemblage—Only the forebay zone was sampled on Normandy in fall 1993. Shoreline electrofishing (15 transects) and offshore experimental gill netting (12 net-nights) yielded 1,307 individuals with 29 species represented. Sixty-four percent of the total catch consisted of the sunfish species (rock bass, warmouth, redbreast, green, bluegill, and longear).

The Reservoir Fish Assemblage Index (RFAI) rated the Normandy Reservoir forebay fish community excellent, as determined by both electrofishing (RFAI=52) and gill netting (RFAI=54). The electrofishing and gill netting RFAI's, as well as the combined scores (RFAI=53), were the highest recorded for tributary forebays. Normandy received midrange or maximum scores in most metrics for both gear types; the only minimum score was percent anomalies in the electrofishing sample.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Two swimming beaches were tested for fecal coliform bacteria in 1993. The geometric mean of bacteria concentrations were relatively high, 146 and 174/100 ml, but within criterion for water contact recreation. At both sites, geometric means after rainfall were over 200/100 ml, and both sites had three of twelve samples exceed 400/100 ml. EPA recommends that not more than 10 percent of samples exceed 400/100 ml. Both sites had large flocks of resident geese which were the probable cause of the high fecal coliform concentrations.

Fish Tissue—Because of the small size of Normandy Reservoir, only the forebay was sampled for fish tissue screening. Five channel catfish were collected in autumn 1992. Fillets were composited and analyzed for selected metals, pesticides, and PCBs. Of the five metal analytes, only lead and mercury were detected, both at low levels. The only organic analyte detected was chlordane, also at a low level.

Duck River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Duck River is moderately hard (average hardness of 130 mg/l) and alkaline (average total alkalinity of 118 mg/l). The median pH for the stream monitoring site was 7.7. The river was well oxygenated with dissolved oxygen levels of 82 to 115 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the Duck River ranked among the highest in average concentrations of organic nitrogen (0.421 mg/l), total phosphorus (0.617 mg/l), and dissolved orthophosphate (0.177 mg/l). The average concentrations of ammonia nitrogen (0.027 mg/l) and nitrate+nitrite-nitrogen (0.48 mg/l) were near median for all sites. The high total phosphorus concentration yielded a poor rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, and zinc and total copper and zinc) were performed bi-monthly. Dissolved cadmium (4 of 6 samples) and total zinc (2 of 6 samples) were detected but neither exceeded the EPA guidelines for protection of aquatic life and human health.

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines. This is an improvement over 1992 when sediment quality rated fair.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate results rated good with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 47, with 105 taxa and 3,789 organisms/m^2. Conditions in 1992 rated fair (MBIBI score 34) with 61 taxa and 528 organisms/m^2. The benthic fauna improved one classification since 1992. Dominant organisms in 1993 were dipteran midge larvae (62 percent), mayflies (20 percent), and caddisflies (7 percent). Dipteran midge larvae were also the dominant organism in 1992 (26 percent), followed by coleopteran riffle beetles (22 percent) and caddisflies (17 percent). Excessive nutrients, streambank erosion, and substrate instability are a continuous problem at this site.

Fish Community Assessment—The fish community rated fair with an Index of Biotic Integrity (IBI) score of 46 and showed little improvement since it rated fair (IBI = 42) in 1992. Improvement in 1993 was seen mostly in increased fish density and absence of hybrid fish. Problems persisted in species composition and trophic structure indicating less than optimum conditions. Diversity was low for darter, sunfish, and intolerant species, and the proportion of tolerant fish was abnormally high. Fish most dependent on a diverse and stable aquatic macroinvertebrate community were out-numbered by fish that live by a more flexible feeding strategies, and the proportion of piscivorous fish was abnormally low. Adverse conditions observed were extensive bank erosion and the predominance of unstable substrate.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Five sites on the Duck River from 1.7 miles downstream of Normandy Dam to Shelbyville were tested for fecal coliform bacteria. At the first site downstream of Normandy Dam, the geometric mean of all fecal coliform samples was 104/100 ml. At the other four sites from 1.8 to 5.4 miles further downstream, the geometric mean ranged from 1100 to 2150/100 ml. There were several rainstorms during the sampling period, and concentrations were much higher after rainfall. If all samples within 24-hours of rainfall are excluded, the geometric mean of the four most downstream site range from 510 to 960/100 ml. These are among the highest concentrations found anywhere in the Tennessee Valley during the five years of sampling under the current program. The probable cause of the high concentrations are dairies.

Fish Tissue—A five-fish composite each of carp, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. Lead and mercury were detected in all samples but at low concentrations. Chlordane was detected in one sample and PCBs in two, again at only low concentrations.

PICKWICK RESERVOIR - WILSON RESERVOIR WATERSHED

Pickwick Reservoir

Summary of 1993 Conditions - Ecological Health

Water—During the summer of 1993 (April-September), coolest surface water temperatures in Pickwick Reservoir were in April and the warmest in July. Surface temperatures ranged from a minimum of 18.4°C to a maximum of 30.5°C at the forebay; from 16.2°C to 29.1°C at the transition zone; and from 22.8°C (in May-no samples in April) to 29.6°C in Bear Creek embayment. The State of Alabama's maximum water temperature criteria for the protection of fish and aquatic life is 30.0°C.

Dissolved oxygen (DO) concentrations at the 1.5m depth ranged from a low of 6.6 mg/l in August to a high of 12.0 mg/l in April at the forebay; from 6.6 mg/l in August to 11.6 mg/l in June at the transition zone; and from 6.7 mg/l in September to 10.1 mg/l in August at the sampling location in Bear Creek embayment. At the inflow sampling site (i.e. the tailrace of Wilson dam) a minimum DO of 3.1 mg/l was recorded in July. The State of Alabama's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth.

Temperature data depict a seasonal warming and very weak, transient thermal stratification of Pickwick Reservoir. The maximum observed surface to bottom temperature differential (ΔT), in Pickwick Reservoir in 1993 was 4.7°C at the forebay in June. However, there was a rather strong oxycline at all three sampling locations in June and July when differences between surface and bottom DO's were about 7 to 9 mg/l at the forebay, transition zone, and in Bear Creek embayment. In July 1993, a minimum DO of less than 0.1 mg/l was measured on the bottom at all three sampling locations (the forebay, transition zone, and Bear Creek embayment) in Pickwick Reservoir. Due to the drought like conditions and low flows into and through Pickwick Reservoir (see discussion in Section 4.0, Hydrologic Overview of 1993) sediment oxygen demands were consuming oxygen at a rate greater than it was being replenished by inflowing water. Flows increased to normal levels in August and September, resulting in less stratification and higher near bottom DO levels.

DO ratings used in the overall reservoir ecological health evaluation for Pickwick Reservoir were good at the forebay and transition zone; fair to good in Bear Creek embayment; and fair at the inflow. The forebay, transition zone, and Bear Creek embayment would all have rated higher had it not been for the very low near bottom oxygen concentrations which existed in July. The fair rating at the inflow sampling site on Pickwick Reservoir was a result of oxygen levels being measured approximately 2 mg/l below the Alabama criteria in the releases from Wilson dam in the summer of 1993 as mentioned above.

Values of pH ranged from 6.8 to 9.0 on Pickwick Reservoir in 1993. Near surface pH values exceeding 8.5 (and DO saturation values exceeding 100 percent) were observed at all three sampling locations. Many of these periods of high pH and high oxygen saturations were also coincident with high chlorophyll *a* concentrations, indicative of periods of high photosynthetic activity. The State of Alabama's maximum pH criteria for the protection of fish and aquatic life is 8.5.

In 1993, all three sampling locations on Pickwick Reservoir also had fairly high chlorophyll *a* concentrations averaging 15 µg/l, 12 µg/l, and 16.8 µg/l, respectively, at the forebay, transition zone, and Bear Creek embayment. The chlorophyll *a* concentrations measured in Pickwick Reservoir were among the highest measured in the Tennessee River reservoirs in 1993, indicative of eutrophic conditions.

Consequently, the chlorophyll *a* ratings used in the 1993 ecological health evaluation for Pickwick Reservoir were only fair at the forebay and transition zone, and poor in Bear Creek embayment.

Sediment—Although mercury has been found in sediment in Pickwick Reservoir at levels of concern in past years, levels in 1993 were lower and not above sediment quality guidelines for mercury (i.e., 1.0 mg/kg). Mercury levels in 1993 were 0.47 mg/kg at the forebay and 0.62 mg/kg at the transition zone sampling sites. Un-ionized ammonia was detected at levels of concern (220 µg/l) in one of the two forebay samples. Although no acute toxicity was detected in the main reservoir, acute toxicity to both daphnids (30 percent survival) and rotifers (45 percent survival) was detected in the Bear Creek embayment. Tests in 1991 and 1992 showed a potential for toxicity with MicrotoxR at the forebay. Particle size analysis showed sediments from the forebay were about 66 percent silt and clay, 34 percent sand; from the transition zone were 47 percent silt and clay, 53 percent sand; and from Bear Creek embayment were 99 percent silt and clay.

Sediment quality ratings used in the overall Pickwick Reservoir ecological health evaluation for 1993 were good at the forebay (presence of ammonia); excellent at the transition zone; and, fair in the Bear Creek embayment (toxicity to the test organisms).

Benthic Macroinvertebrates—The benthic communities at the forebay and inflow sites were excellent, the transition zone was good, and the Bear Creek embayment rated fair. The forebay site had 23 taxa and 533 organisms/m^2 with Coelotanypus sp (26 percent), Corbicula fluminea (20 percent), and Hydrobiidae (15 percent) as the dominant taxa. The transition zone had a slightly more diverse fauna than the forebay, with 25 taxa and 745 organisms/m^2. Corbicula fluminea (23 percent) and Hexagenia sp (21 percent) were the most abundant taxa. The inflow had the greatest diversity and of all sites sampled, with 42 taxa and 699 organisms/m^2. The benthic community there was dominated by Corbicula fluminea (65 percent).

Bear Creek embayment, a major component of Pickwick Reservoir, was also sampled and received a fair rating. It had a total of 1,188 organisms/m^2 and 15 taxa. Tubificidae (33 percent), Einfeldia (25 percent) and Coelotanypus tricolor (21 percent) were the dominant taxa. Although this site had a good diversity of benthic organisms and an evenness of dominant taxa, the abundance of chironomids and the paucity of EPT taxa contributed to this site only receiving a fair rating.

Aquatic Macrophytes—There were an estimated 105 acres of submersed plants on Pickwick Reservoir in 1993, primarily in the upstream portion of Yellow Creek embayment. Historically, most of the aquatic vegetation on Pickwick Reservoir has been in the Yellow Creek embayment, and in 1993 naiads and muskgrass were the most abundant macrophytes.

Fish Assemblage—Fish collections at near shore areas (45 electrofishing transects) and offshore bottom areas (30 net-nights) from the three zones of Pickwick Reservoir resulted in the collection of 2,526 fish including 42 species. Three non-game species, including skipjack herring, gizzard shad, and brook silverside, comprised 50 percent of all fish collected. Other dominant species groups were the sunfishes (green, bluegill, longear, and redear), catfishes (blue, channel, and flathead), and black basses (smallmouth, spotted, and largemouth), which made up 12, 7, and 6 percent of the total sample, respectively. Fish abundance was greatest in the forebay zone (1,563) followed by the transition (659), and inflow zones (304). Total catch was significantly higher in the forebay than the other two zones with both gear types (even considering reduced netting effort in the inflow).

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) good in all three zones of the reservoir (forebay RFAI=46, transition RFAI=42, and inflow RFAI=46). The Pickwick forebay score of 46 was, along with Wilson forebay, the highest recorded in run-of-the-river reservoirs in 1993. The slightly lower transition score was influenced by lesser numbers of piscivorous and sunfish species. The gill netting RFAI rated the transition (RFAI=46) and forebay (RFAI=42) good. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs. Combined electrofishing and gill netting RFAI scores for the forebay (RFAI=44), transition (RFAI=44), and the electrofishing RFAI for the inflow (RFAI=46) rated all areas as good.

Fish samples taken in the shoreline areas (15 electrofishing transects) and offshore/deep areas (12 net-nights) in Bear Creek embayment produced a total of 975 individuals represented by 36 species. By far the two most dominant species were gizzard shad (35 percent) and skipjack herring (22 percent). No other species were captured in significant numbers. Number of individuals captured was similar with both gear types.

Both electrofishing (RFAI=42) and gill netting (RFAI=46) RFAI's rated the Bear Creek embayment good, ranking it the highest of the four embayment study sites. Both gear types received the highest score for five of the twelve metrics.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Four swimming beaches and six informal swimming areas were tested for fecal coliform bacteria in 1993. Bacteria concentrations at all ten sites were very low (geometric mean <20/100 ml). There were no significant rainfall events during the survey. This may have contributed to the very low concentrations at some sites. Monthly sampling at the three Vital Signs locations (forebay, transition zone, and Bear Creek Embayment) produced equally low fecal coliform concentrations.

Fish Tissue—One composite sample of five channel catfish was collected at the forebay, transition zone, and inflow in autumn 1992. Concentrations of all metals were low. Mercury was detected in most samples but at relatively low concentrations (maximum of 0.24 μg/g). Pesticides and PCBs were generally low. The exception was DDTr, which was relatively high at the inflow (2.4 μg/g) yet not detected at the other two locations. This is not thought to represent a problem because concentrations of this magnitude have not been observed in previous years of screening. It is possible that one of the catfish in the composite was from Wheeler Reservoir where there is a problem with DDT contamination in one area resulting in high concentrations in fish. Relatively high concentrations of chlordane in 1990 were not found in 1991 or 1992. PCBs were detected in all samples (range 0.2 to 0.7 μg/g) with concentrations tending to be higher at the inflow. Samples were recollected at the inflow site in autumn 1993 to ensure that a possible problem with DDTr, chlordane, or PCBs is not overlooked; results were not available at the time this report was prepared.

Wilson Reservoir

Summary of 1993 Conditions - Ecological Health

Water—During the summer of 1993 (April-September), surface water temperatures ranged from 13.7°C in April to 31.6°C in July at the forebay sampling location. Temperatures above 30.0°C exceed State of Alabama water quality criteria for fish and aquatic life. Values for DO at the 1.5m depth ranged from a high of 13.8 mg/l in May (during a large algal bloom) to a low of 5.7 mg/l in September at the forebay. At the Wheeler dam tailrace a minimum DO of 4.3 mg/l was recorded in July. The State of Alabama's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth.

Temperature and DO data show seasonal warming and both thermal and oxygen stratification in the forebay from May through August. The greatest degree of thermal stratification was observed in July, as might be expected, during the period of high temperatures and low flows (see discussion in Section 3.0, Hydrologic Overview of 1993). In July, temperatures at the forebay ranged from 31.6°C (surface) to 21.5°C (bottom), a differential of 10.1°C.

Periods of strong DO stratification, with surface to bottom DO differentials ranging from about 7 to 12 mg/l, were also observed during these four months, May through August. For example, in June, surface DO concentrations of about 12 mg/l (during a large algal bloom) were contrasted with near bottom DO concentrations of about 0 mg/l. The depth of Wilson Reservoir (approximately 100 feet at the dam) and the unseasonably low flows during the summer of 1993 combined to have a pronounced effect on hypolimnetic DO in Wilson forebay. Bottom DO concentrations were at or near 0 mg/l for approximately three months (June, July, and August), and the volume of hypolimnetic anoxia was greater in the summer of 1993 than has been observed in the prior three years of Vital Signs monitoring (1992 to 1990). For the summer, DO concentrations in Wilson forebay averaged only 5.9 mg/l, lower than at any other Vital Signs monitoring location on run-of-the-river reservoirs.

Consequently, the forebay DO rating used in the overall ecological health rating of Wilson for 1993 was very poor. A good rating for DO was assigned to the Wilson reservoir inflow sampling site (i.e., Wheeler dam tailrace) because oxygen levels fell only slightly below 5 mg/l in releases from Wheeler dam during the summer of 1993 (i.e. DO's less than State of Alabama's 5 mg/l criteria, measured at the 1.5 meter depth).

Values of pH ranged from 6.7 to 9.1. In May and June near-surface values of pH were measured greater than 9.0. These high pH values coincided with periods of high photosynthetic activity, high temperatures, high dissolved oxygen measurements (percent oxygen saturation values exceeding 150%), and high chlorophyll a concentrations. The State of Alabama's maximum pH criteria for the protection of fish and aquatic life is 8.5.

Summer chlorophyll *a* concentrations in Wilson forebay averaged about 10.2 µg/l in 1993, slightly higher than preferred, but much better than in 1992 when a massive algal bloom (chlorophyll *a* concentrations of 146 µg/l) occurred in May on Wilson reservoir. A forebay chlorophyll *a* rating of fair was used in the ecological health evaluation of Wilson Reservoir in 1993.

Historically, the water in the forebay of Wilson is quite clear relative to the other Tennessee River reservoirs. In the summer of 1993, Secchi depths averaged over 1.7 meters and suspended solids (TSS) averaged only about 3.2 mg/l, among the highest Secchi's and lowest TSS's measured on the run-of-the-river reservoirs.

Sediment—Chemical analyses of sediment did not reveal any metal or organic analyte to be a concern. Toxicity tests detected no acute toxicity to either species tested; however, reduced survival of rotifers (65 and 85 percent survival) was seen in samples from the forebay. Toxicity to rotifers was detected in 1991. Particle size analysis showed sediments from the forebay were about 99 percent silt and clay.

The forebay sediment quality rating used in the overall Wilson Reservoir ecological health evaluation for 1993 was very good, instead of excellent, due to the slightly reduced survival of rotifers.

Benthic Macroinvertebrates—Wilson forebay and inflow sites showed improvements in their benthic communities. The forebay improved from poor to fair, and the inflow from good to excellent. The forebay had 803 organisms/m^2 representing 22 taxa with Chironomus sp (42 percent) as the dominant organism. The inflow site had 683 organisms/m^2 representing 48 taxa with Corbicula sp (41 percent) as the dominant organism.

The Wilson forebay scored as high as possible on three metrics: taxa richness, percentage of the community comprised of tubificids, and the evenness of dominant organisms. The two metrics that brought down the overall benthic score were the high numbers of chironomids present and the low number of EPT taxa present. These factors resulted in a fair rating for the forebay site. The inflow site received a perfect score for every metric and received an excellent rating. This epitomizes a healthy benthic community: high diversity, the presence of a good EPT community, an abundance of long-lived organisms, low numbers of tubificids and chironomids, and an evenness of dominant organisms.

Aquatic Macrophytes—There were 54 acres of aquatic plants on Wilson Reservoir in 1993. Muskgrass was the dominant species and colonized shallow water sloughs. Eurasian watermilfoil historically occurred as localized populations on Wilson Reservoir, but has not been observed on Wilson in several years.

Fish Assemblage—Shoreline electrofishing (30 transects) and offshore gill netting (19 net-nights) at the forebay and inflow of Wilson Reservoir produced 3,567 individuals of 38 species, and showed fish were most abundant in the inflow (69 percent of the total fish collected). Species representing the largest portion of the Wilson fish assemblage included emerald shiners (25 percent), brook silversides (22 percent), gizzard shad (19 percent), and bluegill (11 percent). Most of the inflow electrofishing catch (66 percent) consisted of emerald shiners and gizzard shad. There were also moderate numbers (CPUE= 234 per transect) of young-of-year (YOY) threadfin shad in the inflow area.

The 12 electrofishing RFAI metrics described the littoral fish community of both the inflow (RFAI=42) and the forebay (RFAI=46) zones as good. The Wilson and Pickwick forebay ratings of 46 were the highest recorded in run-of-the-river reservoirs in 1993. The 1993 forebay (RFAI=46) rating also represented an increase over the 1992 RFAI score of 38. The forebay scores were the same or higher for all metrics with exception of the average number of individuals (i.e., average catch per transect). The gill netting RFAI rated the forebay (38) fair. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples. Combined electrofishing and gill netting RFAI scores rated the forebay (RFAI=42) and the electrofishing RFAI for the inflow (RFAI=42) good.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—The boat ramps at Fleet Hollow and Lock Six were tested for fecal coliform bacteria in 1993. Bacteria concentrations were very low (geometric mean <20/100 ml). The monthly Vital Signs samples collected in the forebay were all less than 10/100 ml.

Fish Tissue—Composited channel catfish samples were collected from the forebay and inflow areas in autumn 1992. All analytes were low or not detected. PCB concentrations have been relatively high in occasional samples during past years. Interestingly, 1992 samples from both locations were below the detection limit.

Bear Creek Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average flow in 1993 was about 89 percent of normal. Even with the relatively short average residence time, 14.4 days, the maximum temperature difference in the forebay water column was 14.6°C in July. The maximum surface temperature was 31.3°C in July. The Alabama maximum water temperature criterion for fish and wildlife is 32.2°C (90 F). Depleted DO conditions began at the bottom in May and by June 21 the area of DO <2.0 mg/l extended to within four meters of the surface, resulting in a poor DO rating in the reservoir's ecological health index. The cooling surface temperatures in September allowed surface mixing with the metalimnion, extending the depth with DO >2.0 mg/l to seven meters.

Conductivities in April were about 50 µmhos/cm. Conductivities in the DO depleted zone rose throughout the summer reaching 182 µmhos/cm in September. The maximum pH was about 8.5 at the surface in July. The minimum pH was about 6.1 in the upper portion of the depleted DO zone in August and September.

The total nitrogen concentration was 0.79 mg/l in April, about 60 percent as nitrates. By August, nitrates had disappeared, reducing the total nitrogen concentration to 0.37 mg/l. Total phosphorus and dissolved ortho phosphorus concentrations were 0.02 and 0.002 mg/l in April, and 0.01 and <0.002 in August, respectively. The TN/TP ratio was between 37 and 40 in both surveys. Secchi depths were the lowest of the 19 tributary reservoir forebays, ranging from 0.75 to 1.75 meters. Chlorophyll *a* concentrations were the highest of the 33 tributary stations, ranging from 8 to 17 µg/l. The average chlorophyll *a* concentration of 12.3 µg/l gave Bear Creek a fair rating for chlorophyll in the reservoir's ecological health index. Total organic carbon concentrations were 2.5 and 2.8 mg/l in April and August, respectively.

Sediment Quality—Chemical analyses of sediments in the forebay of Bear Creek Reservoir in 1993 indicated elevated levels of un-ionized ammonia (280 µg/l). Toxicity tests detected acute toxicity to daphnids (0 percent survival) and rotifers (65 percent survival) in the forebay sediment. Particle size analysis showed sediments in the forebay were 94 percent silt and clay.

Because of the acute toxicity of the forebay sediment to daphnids and rotifers and the presence of ammonia, a very poor sediment quality rating was used in the overall 1993 Bear Creek Reservoir ecological health evaluation.

Benthic Macroinvertebrates—Bear Creek forebay, the only site sampled on the reservoir, had 18 taxa and 216 organisms/m^2. Procladius sp accounted for 37 percent of the total. Bear Creek forebay supported an excellent benthic community in 1993, with 5 of the 6 metrics receiving a good score. The proportion of the sample comprised by chironomids was the only metric to receive a poor score.

Fish Assemblage—Only the forebay zone was sampled on Bear Creek Reservoir in fall 1993. Electrofishing samples (15 transects) in shoreline areas and experimental gill netting samples (12 net-nights) offshore collected 1,632 individuals with 28 species represented. Bluegill was the most abundant taxon in Bear Creek Reservoir (28 percent of total fish sampled). Green sunfish (14 percent), gizzard shad

(7 percent), spotted bass (7 percent), and longear sunfish (6 percent) followed in order of density. Species diversity was much higher in electrofishing samples (24 species) than in gill netting efforts (14 species).

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) excellent (RFAI=52) and received maximum scores in all metrics except percent tolerant species, average number of individuals, and percent anomalies. Fifty-two was the highest RFAI recorded in all TVA tributary reservoir forebays (Normandy Reservoir forebay also scored 52). The gill netting RFAI of 40 was rated fair. The combined electrofishing and gill netting RFAI of 46 rated Bear Creek forebay good.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—The swimming beaches at Piney Point and Horseshoe Bend were tested for fecal coliform bacteria in 1993. Bacteria concentrations were very low (geometric mean <20/100 ml) except for one sample at Horseshoe Bend (4800/100 ml).

Fish Tissue—A five fish composite of channel catfish was collected from the forebay during autumn 1992. There were no pesticides or PCBs detected in the sample. Of the five metals examined, only mercury was found above the detection limit. The concentration (0.45 μg/g) was relatively high, although far below the concentration of 1.0 μg/g used by the U.S. Food and Drug Administration to remove products from commerce. Another sample of channel catfish was collected from the same area in autumn 1993 to further evaluate this result.

Little Bear Creek Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average flow through the reservoir in 1993 was about 89 percent of normal, with an average residence time of 254 days. The reservoir was thermally stratified throughout the sampling period with a maximum temperature difference in the water column of 20.5°C in July. The maximum surface temperature of 31.1°C in July was less than the Alabama water quality criterion for fish and wildlife of 32.2°C (90 F). The area of DO depletion (DO < 2.0 mg/l) began at the bottom in June, extended to within 8 meters of the surface in July and August, and still comprised over one-half the water column in October. This resulted in a poor DO rating in the reservoir ecological health index. During June, very high DO concentrations and corresponding high pH values occurred in the metalimnion. DO was 16.2 mg/l and pH was 9.4 at the six meter depth; a DO saturation of 172 percent. This was below the area at which the composited surface sample was collected, thus the chlorophyll concentration in June was probably much higher than the measured 5 µg/l.

Surface pH varied from 8.0 to 8.9 from April to August. The minimum pH was 6.7 near the bottom in September. Conductivities throughout the water column were slightly over 100 µmhos/cm until DO was depleted at the bottom. Then bottom conductivities rose continually to a maximum of 167 µmhos/cm in October.

Organic nitrogen concentrations were constant, 0.28 mg/l in April and 0.29 mg/l in August, while nitrates dropped from 0.2 mg/l in April to <0.01 mg/l in August. Total and dissolved ortho phosphorus concentrations were 0.02 and 0.002 mg/l in April and 0.008 and <0.002 mg/l in August. Total organic carbon concentrations were 2.3 mg/l in April and 2.9 mg/l in August. The water was relatively clear, with Secchi depths ranging from 2.0 meters in April to 4.0 meters in August. Productivity was relatively low—the chlorophyll concentration averaged 3.8 µg/l with a maximum of 7 µg/l in August. These chlorophyll concentrations are in the range considered good in the reservoir ecological health index.

Sediment Quality—Chemical analyses of sediments in the forebay of Little Bear Creek Reservoir in 1993 did not reveal any metal or organic analyte to be a concern. Toxicity tests detected acute toxicity to daphnids (45 percent survival) in the forebay sediment. This resulted in a fair rating for sediments in the ecological health index. Particle size analysis showed sediments in the forebay were 94 percent silt and clay.

Benthic Macroinvertebrates—The Little Bear Creek forebay site had a fair benthic community, with high densities and low diversity. There were 3,898 organisms/m^2 representing only 11 taxa, primarily Tubificidae (96 percent of the total). The abundance of Tubificidae, essentially a tolerant family, had the largest negative impact on the benthic community. The metrics of number of EPT taxa, number of long-lived taxa, and diversity all received fair scores. The only metric to receive a good score was the low proportion of the sample comprised of chironomids.

Fish Assemblage—Only the forebay was sampled on Little Bear Creek Reservoir in fall 1993. Shoreline electrofishing (15 transects) and offshore experimental gill netting (10 net-nights) yielded 2,946 individuals represented by 27 species. Thirty-eight percent of the total catch consisted of bluntnose minnows, followed by bluegill (21 percent), largemouth bass (6 percent), and green sunfish (5 percent). The primary forage base in Little Bear Creek Reservoir was comprised mainly of sunfish and minnows, as shad were collected in very low numbers in both electrofishing and gill netting samples.

Fish assemblage rated good for both electrofishing (RFAI=46) and gill netting (RFAI=50) in the forebay. Scores for the electrofishing sample were midrange or maximum for all metrics except number of piscivore species and percent omnivores. Scores in the gill netting samples were midrange or maximum for all metrics. The overall RFAI (combining electrofishing and gill netting results) rated Little Bear Creek forebay as good.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—The swimming beaches at Eliott Branch and Williams Hollow were tested for fecal coliform bacteria in 1993. Bacteria concentrations were very low (geometric mean <20/100 ml).

Fish Tissue—A five-fish composite of channel catfish was collected from the forebay in autumn 1992. There were no pesticides or PCBs detected in the sample. Mercury was the only metal analyte found; arsenic, cadmium, lead, and selenium were not detected. The mercury concentration (0.56 μg/g) was high enough to warrant further examination in autumn 1993 but not high enough to warrant a detailed study. The 1993 results were not available at the time this report was prepared.

Cedar Creek Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average flow was about 90 percent of normal. The average residence time was about 186 days, and thermal stratification was moderate to strong. The maximum temperature difference in the water column was 17.9°C in July. The maximum temperature was 30.9°C in July, less than the Alabama water quality criterion for fish and wildlife of 32.2°C (90 F). DO depletion (DO < 2.0 mg/l) began at the bottom in May, extended to within 7 meters of the surface in August, and remained depleted at the bottom in October. This resulted in a poor rating for DO in the reservoir ecological health index. Conductivities in Cedar Creek were the third highest of the 19 tributary reservoirs, averaging about 240 µmhos/cm in the water column in April, and increasing in the anoxic zone throughout the summer to a maximum of 295 µmhos/cm at the bottom in October. Surface pH was over 8.0 from April through September, with a maximum of 8.6 in May. Cedar Creek water is slightly basic, the minimum bottom pH was 7.1 in September.

Both organic and nitrate nitrogen concentrations decreased sharply from April to August. Organic nitrogen concentrations were 0.41 and 0.11 mg/l, while nitrate concentrations were 0.17 and <0.01 mg/l, respectively. Total and dissolved ortho phosphorus concentrations were 0.02 and 0.004 mg/l in April, and 0.004 and <0.002 mg/l in August. Total organic carbon concentrations were 2.9 and 2.7 mg/l in April and August, respectively. Water clarity was low to moderate, Secchi depths varied from 1.0 meter in April to 2.75 meters in June. Chlorophyll *a* concentrations were low, averaging 2.8 µg/l with a maximum of 5 µg/l in May. These low chlorophyll concentrations gave Cedar Creek Reservoir a fair chlorophyll rating in the reservoir ecological health index.

Sediment Quality—Chemical analyses of sediments in the forebay of Little Bear Creek Reservoir in 1993 did not reveal any metal or organic analyte to be a concern. Toxicity tests detected acute toxicity to daphnids (45 percent survival) in the forebay sediment. Particle size analysis showed sediments in the forebay were 94 percent silt and clay.

Because of the acute toxicity of the forebay sediment to daphnids, a fair sediment quality rating was used in the overall 1993 ecological health evaluation.

Benthic Macroinvertebrates—The Cedar Creek forebay supported a fair benthic community with 387 organisms/m^2 representing 10 species. Chironomus sp and Tubificidae were the dominant taxa, comprising 42 and 40 percent of the total, respectively. All 6 metrics received a fair score.

Fish Assemblage—Only the forebay zone was sampled on Cedar Creek Reservoir in fall 1993. Shoreline electrofishing (15 transects) and offshore experimental gill netting (12 net-nights) yielded 662 individuals represented by 18 species (second lowest diversity in all TVA reservoirs). Thirty-eight percent of the total catch consisted of brook silversides, followed by gizzard shad (20 percent), spotted bass (13 percent), and spotted suckers (11 percent).

The Reservoir Fish Assemblage Index (RFAI) rated the forebay of Cedar Creek Reservoir fair (RFAI=32) as determined by electrofishing samples and good (RFAI=46) as determined by gill netting. The low electrofishing rating could be attributed to low diversity, and low catch. Combined electrofishing and gill netting ratings (RFAI=38) determined the reservoir fish community to be fair.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—The swimming beach at Slickrock Ford was tested for fecal coliform bacteria in 1993. Bacteria concentrations were very low (geometric mean <20/100 ml).

Fish Tissue—Five channel catfish were collected from the Cedar Creek forebay in autumn 1992. Composited fillets were analyzed for pesticides, PCBs, and selected metals. All pesticides and PCBs were below detection limits. Of the five metal analytes, only mercury was detected - at a relatively low concentration of 0.21 μg/g.

Bear Creek Stream Monitoring Site

Summary of 1993 conditions - Ecological Health

Water— The water of Bear Creek is soft (average hardness of 50 mg/l) and moderately alkaline (average total alkalinity of 50 mg/l). The median pH for the stream monitoring site was 7.6 . The river is well oxygenated with dissolved oxygen levels ranging from 80 to 94 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, Bear Creek ranked among the lowest in average concentrations of nitrate+nitrite-nitrogen (0.24 mg/l) and dissolved orthophosphate (0.005 mg/l). It was among the highest stations with average ammonia nitrogen and organic nitrogen concentrations of 0.044 mg/l and 0.332 mg/l. The average total phosphorus concentration of 0.065 mg/l was near the median for all stations. The fair total phosphorus and acceptable nitrate+nitrite-nitrogen concentrations yielded a fair rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total and dissolved copper and zinc) were performed bi-monthly. Dissolved cadmium (6 of 6 samples), dissolved nickel (2 of 6 samples), and dissolved zinc (1 of 6 samples) were detected, but at levels within the EPA guideline for protection of human health and aquatic life. Dissolved lead in one of six samples exceeded the EPA guideline for chronic toxicity to aquatic life.

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines. This is an improvement over 1992 when sediment quality rated fair.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate results rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 40, with 91 taxa and 1,697 organisms/m^2. Conditions in 1992 also rated fair (MBIBI score 38) with 74 taxa and 2,044 organisms/m^2. The number of taxa was greater in 1993 but densities were lower. The benthic fauna in 1993 was composed mostly of dipteran midge larvae (31 percent), the Asian clam Corbicula (22 percent), and river snails (21 percent). Dipteran midge larvae were also dominant in 1992 (52 percent), followed by Asian clams (17 percent) and nutrient-tolerant oligochaeta worms (12 percent). Streambank erosion and unstable substrates are a continuing problem affecting benthic organisms at this site.

Fish Community Assessment—The fish community rated fair with an Index of Biotic Integrity (IBI) score of 40), deteriorating considerably from the good (IBI = 48) rating in 1992. Fish sampled in 1993 included fewer native species and fewer intolerant species. A decrease was also seen in the proportion of specialized insectivores, fish that depend most on a diverse and stable macroinvertebrate community. Fish density changed most drastically, declining by approximately 50 percent since 1992. Adverse conditions observed at this station include extensive bank erosion and a predominance of shifting gravel substrate.

Summary of 1993 conditions - Use Suitability

There were no bacteriological samples or fish tissue samples collected from the Bear Creek stream site in 1993.

WHEELER RESERVOIR - ELK RIVER WATERSHED

Wheeler Reservoir

Summary of 1993 Conditions - Ecological Health

Water—Wheeler Reservoir was generally well mixed and lacked persistent thermal stratification in 1993. During the April-September monitoring period, coolest surface water temperatures in Wheeler Reservoir were in April and the warmest in July. Surface temperatures ranged from a minimum of 17.3°C to a maximum of 31.9°C at the forebay; from 15.4°C to 29.6°C at the transition zone; and from 18.7°C to 31.2°C in the Elk River embayment. The 31.9°C temperature in the forebay of Wheeler Reservoir was the warmest Tennessee River temperature measured as part of the Vital Signs monitoring program (1990-1993), and is evidence of the effect the very warm meteorological conditions had on surface water temperatures in July of 1993. (See discussion in Section 4.0, Hydrologic Overview of 1993). Temperatures above 30.0°C exceed the State of Alabama's water quality criteria for fish and aquatic life.

Dissolved oxygen (DO) concentrations at the 1.5m depth ranged from a low of 6.6 mg/l in September to a high of 11.6 mg/l in April at the forebay; from 6.2 mg/l in August to 9.4 mg/l in April at the transition zone; and from 6.1 mg/l in September to 14.1 mg/l in April at the sampling location in the Elk River embayment. At the inflow sampling station site (i.e. the tailrace of Guntersville dam) a minimum DO of 5.4 mg/l was recorded in July. The State of Alabama's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth.

Temperature data give evidence of the seasonal warming and a weak thermal stratification in the downstream portion of Wheeler Reservoir (i.e. at the forebay and Elk River embayment). The maximum surface to bottom temperature differential (ΔT) occurred in June and was 5.8°C at the forebay and 7.0°C in the Elk River embayment. The transition zone was well mixed throughout the summer with ΔT's almost never exceeding 1.0°C.

As was the case for several other Tennessee River reservoirs, during the drought like conditions of the summer of 1993, a strong oxycline developed in June, July, and August in the downstream portions of Wheeler Reservoir. At the forebay, surface to bottom DO differentials (DO) were 9.7, 9.5, and 7.1 mg/l, respectively, in June, July, and August. In the Elk River embayment DO's of 11.0, 10.4, and 11.4 mg/l were measured in June, July, and August, respectively. As streamflows decreased and water temperatures increased, naturally occurring decomposition processes at the bottom of the reservoir used available oxygen at a rate faster than it was replenished by inflows. DO's at or near 0 mg/l occurred at the bottom in the forebay in July; and in the Elk River embayment in June, July, and August. However, in contrast, the transition zone was well mixed and lacked any DO stratification (DO differentials never exceeded 1 mg/l and minimum DO's were never less than 6 mg/l). In addition, DO's were never observed to fall below 5 mg/l at the inflow sampling site (i.e. the tailrace of Guntersville dam).

Based on the above information, the DO component of the overall reservoir ecological health evaluation for Wheeler Reservoir rated poor at the forebay and Elk River embayment; and excellent at the transition zone and inflow. The forebay and Elk River embayment rated poor because of the near bottom anoxia and the duration and volume of water with oxygen concentrations less than 2 mg/l.

Values of pH ranged from 6.7 to 9.1 in Wheeler Reservoir during the summer of 1993. Near surface values of pH equal to or greater than 8.5 were observed in April, June, July, and August at the forebay and in the Elk River embayment; but no pH's were ever less than 7.2 nor greater than 7.8 at the transition zone. Coincident with these pH's greater than 8.5 (particularly in the Elk River embayment) were oxygen saturation values ranging from 120% to 175% and high chlorophyll *a* concentrations, evidence of very high photosynthetic activity.

Ammonia nitrogen concentrations measured in Wheeler Reservoir, at both the forebay and the transition zone, were relatively high. As has been the case in previous years (1990-1992), ammonia nitrogen concentrations measured in 1993 were higher than at any other Vital Signs Monitoring location on the Tennessee River and averaged approximately 0.07 mg/l at the forebay and 0.11 mg/l at the transition zone. Given the volume of flow of the Tennessee River through Wheeler Reservoir and the lack extended periods of anoxia, the high ammonia concentrations could be indicative of large point and non-point waste discharge(s) to Wheeler Reservoir.

Historically (1990-1992), the forebay of Wheeler Reservoir has the highest total organic carbon (TOC) and organic nitrogen concentrations of any Vital Signs sampling site on the Tennessee River. In 1993, TOC averaged 2.6 mg/l (one of the highest TOC concentrations) and organic nitrogen averaged 0.32 mg/l (highest organic nitrogen concentration among the Tennessee River sampling sites) at the forebay. These data and other water quality characteristics (total phosphorus, total nitrogen, and chlorophyll *a*,) show substantial increases in concentration between the transition zone sampling site at Tennessee River Mile (TRM) 295.9 and the forebay sampling site at TRM 277.0. These data suggest a dramatic increase in primary productivity between the two sampling sites, likely stimulated by the input of large amounts of nutrients from the Elk River which joins Wheeler Reservoir about seven miles upstream of the forebay at TRM 284.3. The Elk River has a median total phosphorus and total nitrogen concentration of about 0.18 mg/l and 1.10 mg/l, respectively, and an annual mean daily flow of about 3050 cfs. (For additional information see discussion below on the Elk River embayment.)

The dramatic increase in primary productivity in Wheeler Reservoir between the transition zone and the forebay is reflected in the chlorophyll *a* results. During the summer of 1993, chlorophyll *a* concentrations measured at the forebay were as high as 24 μg/l in April and August, and averaged about 13.5 μg/l. This is over a 300% increase in chlorophyll *a* concentrations from those measured at the transition zone, where chlorophyll *a* concentrations averaged only about 4 μg/l during the summer of 1993.

Water quality in the Elk River embayment was unique in several aspects, largely reflecting the natural characteristics of the Elk River. During the summer of 1993, concentrations of several water quality parameters were higher in the Elk River embayment than at any other embayment or run-of-the-river sampling site. For example, total nitrogen and ammonia nitrogen averaged 0.72 mg/l and 0.11 mg/l, respectively. Total phosphorus and dissolved ortho phosphorus averaged 0.175 mg/l and 0.067 mg/l, respectively. Consequently, as might be expected, chlorophyll *a* concentrations were very high, averaging 23 μg/l and with concentrations as high as 39 μg/l measured during massive algal blooms. These chlorophyll *a* concentrations measured in the Elk River embayment were higher than at any of the other Vital Signs monitoring locations during 1993.

The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Wheeler Reservoir were fair at the forebay (average exceeding 10 μg/l), good at the transition zone, and poor in the Elk River embayment (average exceeding 15 μg/l and large algal blooms).

Finally, true color values in the forebay of Wheeler Reservoir are among the highest measured on the Tennessee River and show a relatively large increase between the transition zone and the forebay. The

1990-1992 average for true color was 15.4 and 11.8 PCU's at the forebay and transition zone, respectively. During the summer of 1993, true color values averaged 12.5 PCU's at the forebay (the highest among the Tennessee River sampling sites in 1993) and 7.0 PCU's at the transition zone (one of the lowest of the Tennessee River sampling sites in 1993). These summer color values at the forebay are even higher than those measured throughout the year in the Elk River, which averaged about 12 PCU's, from 1986-1991. These data suggest that even though some color is added to the Tennessee River by inflows from the Elk River, there are other additional sources of color to Wheeler Reservoir between the transition zone and the forebay.

Sediment Quality—Chemical analyses of sediment in Wheeler Reservoir in 1993 indicated elevated levels of un-ionized ammonia (340 μg/l) from the Elk River embayment. Toxicity tests did not reveal acute toxicity to daphnids or rotifers from the three sites tested. Particle size analysis showed sediments from the forebay were 98 percent silt and clay; from the transition zone were 25 percent silt and clay, 75 percent sand; and from the Elk River embayment were 73 percent silt and clay, 27 percent sand.

Sediment quality ratings used in the overall Wheeler Reservoir ecological health evaluation for 1993 were excellent at the forebay and transition zone; and slightly lower, i.e. good, in the Elk River embayment due to the presence of ammonia.

Benthic Macroinvertebrates—The benthos rated fair at the forebay in 1993, same as in 1992. The transition zone improved from fair in 1992 to good in 1993, and the inflow improved from good in 1992 to excellent in 1993. A major are of Wheeler Reservoir, the Elk River embayment, was sampled for the first time in 1993 and received a poor rating. The forebay location had 14 taxa and 633 organisms/m^2, dominated by the chironomid Coelotanypus (71 percent). The transition zone had 32 taxa and 870 organisms/m^2, with Hexagenia limbata as the dominant taxon comprising 38 percent of the total. The inflow site had 30 taxa present and 651 organisms/m^2 with Corbicula fluminea as the dominant organism present (61 percent). The Elk River embayment had 25 taxa and 1,488 organisms/m^2 with Tubificidae (37 percent) and Coelotanypus sp (16 percent) as the two dominant taxa.

Wheeler forebay received a fair rating; this is partially due to the high numbers of chironomids and low EPT taxa present at the site. Interestingly, tubificids made up only a small portion of the sample, and this boosted the rating slightly. The other metrics, taxa richness and abundance of long-lived species, were mediocre. At the transition site, a good rating was attained because of good diversity, EPT taxa richness, and low numbers of chironomids and tubificids. The only metric that brought the rating down was the evenness of dominant organisms; in this case one organism comprised an inordinate amount of the total organisms present. The inflow site on Wheeler received a perfect score due to its taxa richness, presence of a good EPT community, presence of several long-lived taxa, evenness of dominant organisms, and low numbers of tubificids and chironomids. Elk River embayment did not fare as well as the rest of the sites on Wheeler, primarily because it had large numbers of chironomids and tubificids, and very few EPT taxa and long-lived organisms. A perfect score on the taxa richness metric kept this site from receiving a very poor rating.

Aquatic Macrophytes—Aquatic plants increased from 4,412 acres in 1992 to 6,597 acres in 1993. Wheeler Reservoir had the second largest amount of aquatic vegetation within the TVA system. Dominant submersed species were Eurasian watermilfoil and spinyleaf naiad. These were most abundant in shallow overbank habitats from TRM 296 upstream to TRM 309. Wheeler Reservoir also had large populations (1,431 acres) of American lotus concentrated in Flint Creek embayment, overbank sloughs upstream of Flint Creek, and in Swan Creek embayment.

Fish Assemblage—Fish data collected in near shore and offshore bottom areas showed that 3,211 individuals of 47 species were recorded in both electrofishing (45 transects) and gill netting (26 net-nights) samples. Electrofishing results indicated total numbers of fish captured were higher in the inflow (1,277) than in the transition (934) or forebay (473) zones of the reservoir. Gizzard shad (32 percent) comprised the majority of the total individuals collected, followed by emerald shiners (18 percent), bluegill (8 percent), and skipjack herring (7 percent). Threadfin shad numbers were moderate in the transition (catch per unit effort, CPUE=271 per 300m transect) and high in the forebay (CPUE=851 per 300m transect) of Wheeler Reservoir. Gill netting catch rates were slightly higher in the forebay (CPUE=30 per net night) than the transition (CPUE=11 per net night) or the inflow (CPUE=14), due to much higher numbers of skipjack herring in the forebay.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on electrofishing results) good in the forebay (RFAI=44) and inflow (RFAI=44) and fair in the transition (RFAI=40). A high percentage of tolerant individuals (75 percent) and a lower average number of individuals (62) influenced the fair rating in the transition. Indices, determined by gill netting, for the transition and forebay zones of Wheeler Reservoir were 42 (good) and 40 (fair), respectively. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples.

Combined electrofishing and gill netting RFAI scores for the forebay (RFAI=42) and the electrofishing RFAI for the inflow (RFAI=44) were rated good. The combined transition RFAI (RFAI=41) ranked fair.

Electrofishing (15 transects) and gill netting (12 net-nights) results from the Elk River embayment yielded 5,126 individuals of 30 species. Gizzard shad were the most abundant species, comprising 78 percent of the total number of fish sampled. Other species of interest were bluegill (8 percent) and largemouth bass (2 percent). High numbers of gizzard shad accounted for the wide margin in catch rates for both gear types (4,776 individuals in electrofishing and 350 for gill netting). Unusually high numbers of young-of-year threadfin shad (3,356 per transect) were also observed in the electrofishing sample.

The Reservoir Fish Assemblage Index (RFAI) rated the quality of the littoral community (as determined by electrofishing samples) good in the Elk River embayment (RFAI=42). Metrics receiving high scores were number of species, and number of piscivorous, intolerant, and lithophilic spawning species. The gill netting RFAI of 34 rated fair with metric values being somewhat evenly distributed throughout the range of possible scores. The combined electrofishing and gill netting RFAI of 34 rated the Elk River embayment of Wheeler Reservoir as fair.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No bacteriological studies were conducted at recreation sites in Wheeler Reservoir in 1993. Fecal coliform bacteria concentrations at the monthly Vital Signs locations, the forebay, transition zone, and Elk River Embayment, were very low (geometric mean <20/100 ml). The highest concentration for any sample was 219/100 ml in the transition zone in September.

Fish Tissue—Composite catfish samples for screening purposes were collected from the forebay, transition zone, and inflow in autumn 1992. Intensive studies were also conducted during this same time period to examine DDTr concentrations in a 20 mile stretch of Wheeler Reservoir near the Indian Creek embayment, located between the inflow and the transition zone. Three five-fish composites of channel catfish, largemouth bass, and smallmouth buffalo were collected from four locations for the intensive study.

Samples for screening purposes indicated all metals were low or not detected. DDTr was the only pesticide detected with a range of 1.0 to 1.6 μg/g. Relatively high PCB concentrations reported for 1990 (maximum 1.4 μg/g) were again found in 1991 (maximum 1.3 μg/g) but generally lower levels were found in 1992 (maximum 0.8 μg/g). PCB concentrations during all years were higher at upstream locations.

Samples from the intensive study in 1991 found quite high concentrations of DDTr. At least one sample of one test species exceeded 5 μg/g at all four sites. Highest concentrations were in smallmouth buffalo (maximum 43 μg/g) from near the mouth of Indian Creek with lower concentrations at the upstream location and the location at the downstream end of the study reach. Largemouth bass tended to have lower concentrations than the other two species. Samples for the intensive study in autumn 1992 (samples actually collected in January 1993) had substantially reduced concentrations. Only two samples exceed 5 μg/g whereas 15 from 1991 exceeded that concentration. Also, the geographical pattern was not distinct in these samples. Because of the discrepancy between the two years, the intensive study was repeated in autumn 1993 but results were not available at the time this report was prepared.

Tims Ford Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average flow through Tims Ford Reservoir in 1993 was about 86 percent of normal, making the average residence time about 329 days. The reservoir was strongly stratified with a maximum temperature difference of 22.9°C in the water column at the forebay in July. Tennessee's maximum temperature criterion for aquatic life is 30.5°C. July surface temperatures were 31.3°C at the forebay and 31.5°C at the mid-reservoir station, the only time the temperature criterion was exceeded. DO depletion (DO <2.0 mg/l) began in May at the bottom of the water column at mid-reservoir, and in June in the metalimnion at mid-reservoir and in the forebay in both the metalimnion and at the bottom. The two areas of depleted DO expanded and met in July at mid-reservoir and September at the forebay. The extensive area of depleted DO resulted in a poor DO rating for Tims Ford in the reservoir ecological health index. As surface temperatures cooled in the early fall, the area of depleted DO declined as metalimnetic water mixed with surface water. Some extremely high DO concentrations occurred at the forebay in the upper part of the metalimnion. Both June and July DO concentrations exceeded 15 mg/l.

Conductivities in Tims Ford Reservoir were the fifth highest of the 19 tributary reservoirs. Conductivities were about 180 μmhos/cm in April, increased throughout the year in the DO depleted bottom waters to a maximum of 242 and 285 μmhos/cm in October at the forebay and mid-reservoir, respectively. Conductivities declined in the DO supersaturated surface water in the summer to a minimum of 145 μmhos/cm at the forebay in July and 136 μmhos/cm in June at mid-reservoir. The waters in Tims Ford are somewhat basic, as the minimum pH in April was 7.6 in the mid-reservoir. In June, surface pH was over 9.0 in both the forebay and mid-reservoir. The minimum pH was 6.8 at the bottom of the water column in September in mid-reservoir.

Organic nitrogen concentrations in June were 0.30 and 0.38 mg/l at the forebay and mid-reservoir, respectively, and 0.22 and 0.43 mg/l in August. Nitrates were 0.30 and 0.76 mg/l in April, declining to <0.01 at both locations in August. Total nitrogen concentrations at mid-reservoir in 1993 was the second highest concentration of the 33 tributary reservoir stations. Total phosphorus concentrations were 0.01 mg/l during both surveys at the forebay, and 0.02 and 0.005 mg/l at mid-reservoir in April and August, respectively. The TN/TP ratios were very high, ranging from 24 at the forebay to 90 at mid-reservoir, both in August. Dissolved ortho phosphorus concentrations were <0.002 mg/l at both stations during both surveys. Average total organic carbon concentrations in Tims Ford Reservoir were the fifth highest of the 19 tributary reservoirs. The minimum total organic carbon concentration was 2.6 mg/l in April, the maximum was 3.2 mg/l in August, both at mid-reservoir.

Chlorophyll *a* concentrations averaged 5.4 μg/l at mid-reservoir and 4.3 μg/l at the forebay. Some of the highest DO concentrations were below the depth at which the chlorophyll composite was collected in the forebay, thus the average sampled forebay concentration may be a little lower than actual values. The chlorophyll concentrations rated good in the reservoir ecological health index. Secchi depths varied from 1.3 meters in April to 5.5 meters in May at the forebay, and 1.3 meters in April to 8.0 meters in September at mid-reservoir.

Sediment Quality—Chemical analyses of sediments in Tims Ford Reservoir in 1993 indicated high levels of nickel in the forebay (51 mg/kg). Elevated levels of un-ionized ammonia were also found in both the forebay (230 µg/l) and mid-reservoir (410 µg/l) sediment samples. Toxicity tests detected acute toxicity to daphnids (5 percent survival) and rotifers (65 percent survival) in the mid-reservoir. Particle size analysis showed sediments in the forebay were 99 percent silt and clay; and in the mid-reservoir were 55 percent silt and clay, and 45 percent sand.

Sediment quality ratings used in the overall Tims Ford Reservoir ecological health evaluation for 1993 were good at the forebay sampling site, rather than excellent due to nickel and ammonia; and poor at the mid-reservoir sampling site (because of acute toxicity to daphnids and rotifers and presence of ammonia).

Benthic Macroinvertebrates—Two sites were chosen for sampling the first year on Tims Ford Reservoir, a forebay site and a mid-reservoir site of the Elk River arm. The forebay location had only 2 taxa and 122 organisms/m^2. Tubificidae accounted for 90 percent of the total. The inflow site had 108 organisms/m^2 representing 12 species and was dominated by Chironomus sp (32 percent) and Branchiura sowerbyi (27 percent). The forebay had a very poor benthic community, and scored poor on 5 of the 6 metrics: diversity, number of long-lived species, number of EPT species, proportion of the sample as tubificids, and unevenness of the dominant species. The only metric to get a good score was the proportion of the sample represented by chironomids. The inflow site rated only a little better than the forebay with a poor benthic community. Low diversity, absence of long-lived species, and a disproportionate number of the dominant taxa accounted for this site rating poor.

Fish Assemblage—Shoreline electrofishing (30 transects) and offshore experimental gill netting (24 net-nights) yielded 2,726 individuals with 32 species represented. The dominant species by number included bluegill (50 percent), green sunfish (8 percent), spotfin shiners (7 percent), and brook silversides (6 percent). Catch rates for most species (except for bluegill and green sunfish), utilizing both gear types, were higher at the transition zone than the forebay.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on electrofishing results) fair in the forebay zone (RFAI=40) and good in the transition (RFAI=46) of Tims Ford Reservoir. The transition received midrange to maximum scores for all metrics, except average number of individuals per transect, resulting in a slightly higher rating than the forebay. Identical gill netting scores for ten of the twelve metrics resulted in a good rating (RFAI=44) at both reservoir sample zones. Combined electrofishing and gill netting RFAI scores rated both the forebay (RFAI=42) and the transition (RFAI=45) zone good.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—The swimming area on Dry Creek and an area in Estill Springs Park were tested for fecal coliform bacteria in 1993. Bacteria concentrations were low at Estill Springs Park, geometric mean of 38/100 ml for all samples. In Dry Fork, bacteria concentrations were high in samples collected within 24-hours of rainfall, geometric mean of 389/100 ml, but were within Tennessee criteria if the rainfall samples were excluded, geometric mean of 151/100 ml.

Fish Tissue—Channel catfish composites collected from the forebay and transition zone in autumn 1992 were screened for pesticides, PCBs, and selected metals. All analytes were either not detected or found in only low concentrations. One point of interest was absence of PCBs in these samples because previous screening studies had typically found PCBs, sometimes at slightly elevated levels.

Elk River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Elk River is moderately hard (average hardness of 130 mg/l) and moderately alkaline (average total alkalinity of 103 mg/l). The median pH for the stream monitoring site was 7.7. The river was generally well oxygenated with dissolved oxygen levels ranging from 54 to 108 percent of saturation. Five of the six dissolved oxygen levels were above 85 percent of saturation. At the lowest dissolved oxygen saturation level, the dissolved oxygen concentration was 5.4 mg/l.

Of the 12 streams monitored across the Tennessee Valley, the Elk River ranked among the highest in average concentrations of total phosphorus (0.374 mg/l), dissolved orthophosphate (0.173 mg/l), nitrate+nitrite-nitrogen (0.68 mg/l), ammonia nitrogen (0.042 mg/l). The high total phosphorus and nitrate+nitrite-nitrogen concentrations yielded a poor rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total and dissolved copper and zinc) were performed bi-monthly. Dissolved cadmium (5 of 6 samples) and total zinc (2 of 6 samples) were detected but neither exceeded EPA guidelines for the protection of aquatic life or human health.

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines. This is an improvement over 1992 when the sediment quality rated only fair.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate results rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 39, with 73 taxa and 2,384 organisms/m^2. Conditions in 1992 rated poor (MBIBI score 27) with 52 taxa and 2,454 organisms/m^2. The benthic fauna improved one classification since 1992. Dominant organisms in 1993 were dipteran midge larvae (69 percent), coleopteran riffle beetles (8 percent), and caddisflies (7 percent). Dipteran midge larvae were also the most dominant organism in 1992 (70 percent), followed by nutrient tolerant oligochaeta worms (18 percent) and coleopteran riffle beetles (5 percent). Siltation from agricultural land usage along the river and unstable substrates are a serious problem affecting benthic organisms at this site.

Fish Community Assessment—Fish community was not evaluated in the Elk River in 1993.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—The canoe access location at Garner Ford on the Elk River, about one and one-half miles downstream of Tims Ford Dam, was tested for fecal coliform bacteria in 1993. Five of the 12 samples were collected within 48-hours of rainfall of at least one-half inch. Bacteriological water quality for samples collected more than 24-hours after rainfall easily met the Tennessee water quality criterion for recreation, but rainfall samples greatly exceeded criterion.

Fish Tissue—Smallmouth Buffalo, channel catfish, and spotted bass were collected in summer 1992. One five fillet of each species was analyzed for selected metals, pesticides, and PCBs. All analytes were either not detected or found in low concentrations.

GUNTERSVILLE RESERVOIR - SEQUATCHIE RIVER WATERSHED

Guntersville Reservoir

Summary of 1993 Conditions - Ecological Health

Water—During the summer of 1993, Guntersville Reservoir was well mixed and exhibited only weak thermal stratification. Surface water temperatures ranged from 16.2°C in April to 30.5°C in July at the forebay and from 15.1°C to 30.9°C for the same months at the transition zone. Temperatures above 30.0°C exceed the state of Alabama's water quality criteria for fish and aquatic life.

Values for DO at the 1.5m depth ranged from 10.1 mg/l in April to 6.5 mg/l in September at the forebay and from 9.3 mg/l in April to 5.6 mg/l in August at the transition zone. At the inflow sampling station site (i.e. the tailrace of Nickajack Dam) a minimum DO of 1.8 mg/l was recorded in July. The State of Alabama's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth.

Summer (April-September) temperature data for the forebay depict weak thermal stratification in the downstream portion of Guntersville Reservoir in 1993. Maximum surface to bottom temperature differentials
(ΔT's = 3.3°C) occurred at the forebay in May and June. However, June and July showed the development of a oxycline in the forebay, with surface DO's being 5.5 and 6.3 mg/l, respectively, greater than bottom DO's. The minimum DO measured in Guntersville reservoir in 1993 was 0.6 mg/l at the bottom in July in the forebay; however, this apparently persisted for only a short period of time and by August bottom DO's were back up to 5 mg/l.

The transition zone was well mixed throughout the summer with maximum ΔT's (2.2°C) and ΔDO's (3.4 mg/l) occurring in June. One interesting observation was the very warm temperatures which existed throughout the water column at the transition zone in July, when surface temperatures were 30.9°C and bottom temperatures were 30.0C. The minimum DO measured at the transition zone was 5.5 mg/l at the bottom in July.

The very low DO concentration of 1.8 mg/l, measured in July in the tailrace below Nickajack Dam (i.e., the inflow site), was the lowest ever recorded in the releases from Nickajack Dam. In addition, releases of water from Nickajack Dam were consistently below Alabama's DO water quality criteria for the protection of fish and aquatic life of 5.0 mg/l (at the 1.5 meter depth) in July, potentially impacting the ecological health of the inflow site on Guntersville Reservoir.

These data resulted in DO ratings used in the overall reservoir ecological health evaluation for Guntersville Reservoir to be good at the forebay (minor hypolimnetic anoxia); excellent at the transition zone; and very poor at the inflow (due to low DO's in the releases from Nickajack dam).

Values of pH ranged from 6.9 to 8.3. Surface water pH values in excess of 8.5 (Alabama's pH water quality criteria for the protection of fish and aquatic life of 8.5) were not observed in Guntersville Reservoir in the summer of 1993.

At the forebay, the highest chlorophyll *a* concentration of 9 µg/l was measured in July (average summer chlorophyll *a* concentration was 5-6 µg/l in 1993). At the transition zone chlorophyll *a* concentrations were lower, averaging about 4 µg/l. TN/TP ratios frequently exceeded 20 at both the forebay and transition zone, indicating conditions when phosphorus concentrations may have limited photosynthesis.

The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Guntersville Reservoir were good at both the forebay and the transition zone (i.e., average concentrations between 3 and 10 µg/l).

Historically, water clarity on Guntersville Reservoir has been among the highest of the mainstem Tennessee River reservoirs. In 1993, at the forebay and transition zone, respectively, average Secchi depth was 1.8 and 1.6 meters; total suspended solids was 3.7 and 3.2 mg/l; and true color was 8.3 and 7.1 PCU.

Sediment—Chemical analyses of sediment in Guntersville Reservoir in 1993 indicated the presence of chlordane (15 µg/g) in samples collected at the forebay. Toxicity tests did not reveal acute toxicity to daphnids or rotifers from the two sites tested (i.e. forebay and transition zone). Particle size analysis showed sediments from the forebay were 98 percent silt and clay; and from the transition zone were 39 percent silt and clay, 61 percent sand.

Sediment quality ratings used in the overall Guntersville Reservoir ecological health evaluation for 1993 were good at the forebay (presence of chlordane); and excellent at the transition zone.

Benthic Macroinvertebrates—The forebay site had a good benthic macroinvertebrate community, the transition zone had an excellent benthic community, and the inflow had a fair benthic community. The forebay had 20 taxa and 772 organisms/m^2 with Coelotanypus tricolor (27 percent) and Corbicula fluminea (18 percent) as the dominant taxa. The transition zone had 1340 organisms/m^2 representing 38 taxa; the dominant taxa were Corbicula fluminea (26 percent) and Coelotanypus tricolor (17 percent). The inflow site had 35 taxa and 672 organisms/m^2 with Corbicula fluminea (39 percent) and Tubificidae (24 percent) as the dominant taxa.

The forebay site fell short of an excellent rating primarily because high numbers of chironomids and a mediocre EPT community. All other metrics were excellent. The transition zone scored excellent, and fell just short of perfect because the percentage of the community made of chironomids was slightly elevated. The absence of adequate long-lived taxa, depressed diversity and EPT taxa, and unevenness of the dominant organisms all contributed to the inflow site receiving a fair rating. Metrics which rated food at the inflow were (due to their relatively low numbers) were tubificids and chironomids.

Aquatic Macrophytes—Aquatic macrophytes on Guntersville Reservoir increased from 5,993 acres in 1992 to 7,613 acres in 1993. The reservoir had the largest acreage of aquatic plants in the TVA system. About 99 percent of the total amount of vegetation was upstream of TRM 363 and primarily confined to shallow embayments and overbank areas adjacent to the river channel. Eurasian watermilfoil was the dominant submersed macrophyte species and colonized about 6,500 acres in 1993. About three acres of "topped out" hydrilla occurred on Guntersville Reservoir in 1993 compared to about 2,900 acres in 1988 when aquatic vegetation coverage peaked at about 20,200 acres. In 1990, the reservoir was stocked with 100,000 triploid grass carp for aquatic vegetation control.

Fish Assemblage—Shoreline electrofishing (45 transects) and offshore gill netting (29 net-nights) produced 8,441 fish representing 41 species. Both sampling techniques indicated higher catch rates in the forebay than the other two zones of the reservoir. Gizzard shad (19 percent) was the dominant species, followed by bluegill (17 percent), and emerald shiners (14 percent). Results indicated that largemouth bass

(4.3 percent) was the only major sport fish species to comprise more that one percent of the electrofishing sample. As in previous years, largemouth bass were five times more abundant in the transition zone than either of the other two zones.

Electrofishing RFAI analysis determined that fish communities in both the inflow (RFAI=30) and transition zone (RFAI=28) rated poor, while that present in the forebay zone (RFAI=38) rated fair. Compared to other mainstream reservoirs, the Guntersville inflow and transition zones were in the lower third and the forebay zone the upper third. The poor designation of the transition also represented a significant decrease from the good rating in 1992. Metrics contributing to the poor designation for the inflow and transition areas were low numbers of sucker and intolerant species, depressed fish abundance, and high percentages of anomalies. Gill netting results showed both zones to be fair (transition RFAI=34 and forebay RFAI=38). Transition zone scores were midrange (most metrics received a score of three), while forebay scores tended to be very low or very high (metrics received a score of one or five) for most metrics. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples.

Combined electrofishing and gill netting RFAI values for both the forebay (RFAI=38) and transition (RFAI=31) were classified as fair, followed by the electrofishing RFAI for the inflow (RFAI=30) which was poor.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Two swimming beaches, one boat ramp, the middle of the channel under five causeways, both Vital Signs locations, and an area downstream of Guntersville sewage treatment plant were each tested twelve times in 1993 for fecal coliform bacteria. No samples were collected within 48-hours of a rainfall of one-half inch or greater. The sampled swimming beaches were the Camp Barber Boy Scout Camp, and the Camp Trico Girl Scout Camp.

The 1993 survey at the causeways was intended to identify the watersheds having the most potential for affecting the bacteriological water quality in the main channel of Guntersville Reservoir. The other sites were selected to determine the impacts discharges or runoff from urban areas have on Guntersville Reservoir. At all but two sites, the bacteria concentrations were very low (geometric means <20/100 ml). At the Polecat Creek Causeway and at the Crow Creek boat ramp the fecal coliform bacteria samples had geometric mean concentrations of 69 and 67/100 ml, respectively. The lack of rainfall during the sampling period may have resulted in lower concentrations at some sites. For the regular monthly Vital Signs sampling, all fecal coliform concentrations were very low.

Fish Tissue—Composite catfish samples were collected from the forebay, transition zone, and near the inflow in autumn 1992. One reason for resampling was that relatively high PCB concentrations of chlordane and PCBs had been found in 1990 (chlordane levels at the forebay were 0.10 µg/g and those from near the inflow were 0.11 µg/g; whereas, PCB concentrations at these two locations were 1.2 and 1.3 µg/g, respectively). Chlordane was not detected in any of the 1992 samples and PCB concentrations decreased progressively from year to year (maximum 0.9 µg/g in 1991 and 0.4 µg/g in 1992). Other pesticides and metals were relatively low during all years at all locations.

Sequatchie River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Sequatchie River is moderately hard (average hardness of 90 mg/l) and moderately alkaline (average total alkalinity of 74 mg/l). The median pH for the stream monitoring site was 7.4. The river was well oxygenated with dissolved oxygen levels ranging from 72 to 93 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the Sequatchie River ranked among the highest in average concentrations of organic nitrogen (0.372 mg/l) and ammonia nitrogen (0.090 mg/l). It was among the lowest in average total phosphorus with a concentration of 0.022 mg/l. The average nitrate+nitrite-nitrogen (0.42 mg/l) and average dissolved orthophosphate (0.009 mg/l) concentrations ranked mid-way of all station medians. The low average total phosphorus and acceptable nitrate+nitrite-nitrogen concentrations yielded a good rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total and dissolved copper and zinc) were performed bi-monthly. Dissolved cadmium was detected in 4 of 5 samples. However, the concentrations did not exceed the EPA guideline for the protection of aquatic life or human health. Additional metals analyses included total and dissolved forms of iron and manganese. Total iron (2 of 6 samples) and total manganese (1 of 6 samples) exceeded the EPA guideline for combined consumption of fish and water.

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines. The sediment quality also rated good in 1992.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate results were rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 44, with 80 taxa and 3,951 organisms/m^2. Conditions in 1992 also rated fair (MBIBI score 41) with 93 taxa and 2,096 organisms/m^2. Dominant organisms in 1993 were dipteran midge larvae (38 percent), caddisflies (27 percent), and mayflies (12 percent). Nutrient tolerant oligochaete worms were the dominant group in 1992 (22 percent), followed by dipteran midge larvae (20 percent) and caddisflies (16 percent). Conditions have improved between sampling years. The fair rating (score 44) given for 1993 is borderline good for this site; however, siltation from agricultural land use along the river and coal mining in the Sequatchie watershed continues to impact benthic communities in the river.

Fish Community Assessment—No change was seen as the fish community rated fair with an Index of Biotic Integrity (IBI) score of 42 during both 1993 and 1992. Problems continued to occur in species richness and composition and in fish density. Forty-six to 69 native fish species were expected at this station, but only 38 were found. This loss of diversity was most noticeable among darters and intolerant species. Fish density was one of the lowest found at the 11 stations sampled in 1993. Poor conditions observed at this station were sedimentation of shoreline habitats and occasional bank erosion.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Four canoe access sites on the Sequatchie River from river mile 35.6 to 51.3 were tested for fecal coliform bacteria twelve times each in 1993. Two samples were collected within 48-hours of a rainfall greater than one-half inch. The geometric mean of fecal coliform bacteria concentrations for all samples at the four sites ranged from 43 to 103/100 ml, all well within the Tennessee bacteriological criterion for recreation. Concentrations were higher in the two rainfall samples.

Fish Tissue—Five freshwater drum, channel catfish, and largemouth bass were collected from the Sequatchie River during summer 1992. Composited fillets for each species were analyzed for selected metals, pesticides, and PCBs. Most analytes were not detected. Those that were had low concentrations.

NICKAJACK RESERVOIR - CHICKAMAUGA RESERVOIR WATERSHED

Nickajack Reservoir

Summary of 1993 Conditions - Ecological Health

Water—Surface water temperatures during the April to September monitoring period ranged from a 17.6°C in April to 29.2°C in July at the forebay; and DO at the 1.5m depth ranged from 5.6 mg/l in August to 10.2 mg/l in April at the forebay. At the inflow sampling station site (i.e., the tailrace of Chickamauga dam) a minimum DO of 2.2 mg/l was recorded in July. Tennessee's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth.

The riverine character of Nickajack Reservoir, with an average hydraulic residence time of only three to four days, results in it being the best mixed of any of the Vital Signs reservoirs. Temperature data reflect a lack of thermal stratification in Nickajack Reservoir in 1993. A maximum surface to bottom temperature differential of 1.8°C was measured at the forebay in May. However, summer DO data reflect a small oxycline in the forebay of Nickajack Reservoir when surface to bottom DO differentials were 3.0, 3.1, 4.8, and 2.1 mg/l, respectively, from May through August. The drought like conditions and low flows also depressed concentrations of oxygen. For example, minimum oxygen concentrations measured at the bottom in the forebay of Nickajack Reservoir were 4.6, 4.7, and 5.0 mg/l, respectively, for 1990, 1991, and 1992. However, in 1993, minimum DO concentrations at the bottom in the forebay of Nickajack Reservoir were 3.0 mg/l. In addition, in late July (between the mid-July and mid-August field surveys), releases from Nickajack Dam were recorded as low as 1.8 mg/l, indicating a short period when DO concentrations in the hypolimnion of the forebay were less than 2 mg/l. Also in July, DO's as low as 2.2 mg/l and frequently in the mid-3's mg/l were measured in the releases from Chickamauga dam (i.e., the inflow to Nickajack Reservoir).

Because DO concentrations were frequently below Tennessee's minimum dissolved oxygen criteria for the protection of fish and aquatic life (5.0 mg/l at the 1.5 meter depth), the DO rated poor at inflow sampling site in the overall ecological health evaluation of Nickajack Reservoir. Based on no DO's actually being measured in the hypolimnion of the forebay of Nickajack Reservoir below 2 mg/l, the forebay sampling site's DO rating was excellent.

Values of pH varied over a rather narrow range, from 7.0-8.0 during the summer of 1993. At the forebay, the highest chlorophyll *a* concentration of about 10 µg/l was measured in May and averaged about 6 µg/l in the summer of 1993. Consequently, the chlorophyll *a* rating used in the 1993 ecological health evaluation for Nickajack Reservoir was good (i.e., average concentration between 3 and 10 µg/l).

Sediment—Chemical analyses of sediments in Nickajack Reservoir in 1993 indicated the presence of chlordane (21 µg/g) from the forebay. Toxicity tests did not reveal acute toxicity to daphnids or rotifers from the forebay. Particle size analysis showed sediments from the forebay about 92 percent silt and clay.

The sediment quality rating used in the overall Nickajack Reservoir ecological health evaluation for 1993 was good (rather than excellent because chlordane was detected.

Benthic Macroinvertebrates—Both the forebay and inflow sites on Nickajack had excellent benthic macroinvertebrate communities, an improvement from the previous years. The forebay site had 21 taxa and 535 organisms/m^2 with Hexagenia limbata comprising 30 percent of the total. The inflow site had 38 taxa and 1458 organisms/m^2; Cheumatopsyche sp and Tubificidae were dominant, comprising 22 and 19 percent of the total organisms present, respectively.

The forebay site fell short of a perfect score due to a slightly elevated chironomid community, but still received an excellent rating. All other metrics were perfect. The inflow site scored perfect for each metric evaluated, resulting in an excellent benthic community evaluation.

Aquatic Macrophytes—Aquatic plants on Nickajack Reservoir increased from 583 acres in 1992 to 1,000 acres in 1993. Eurasian watermilfoil and spinyleaf naiad were the dominant species and occurred in mixed colonies or occasionally with other species such as American pondweed and southern naiad. Aquatic macrophytes were most abundant from TRM 425 upstream to TRM 440.

Fish Assemblage—Fish collections in the littoral (30 electrofishing transects) and offshore/benthic areas (16 net-nights) of Nickajack Reservoir found fish to be more concentrated in the inflow zone (2,181) than the forebay (1,337) particularly as indicated by electrofishing results. Although gill netting effort was reduced in the inflow, catch per unit effort (CPUE) was similar between forebay and inflow zones. Bluegill was the most abundant species (29 percent), followed by emerald shiners (20 percent). The majority of the forage base in the Nickajack sample was comprised of several shiner species (golden, emerald, spotfin, and steelcolor) instead of shad, which is unusual for run-of-the-river reservoirs.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish (based on electrofishing results) excellent in the inflow (RFAI=52) and fair in the forebay (RFAI=40) zones of Nickajack Reservoir. The inflow index of 52 was the highest score observed for run-of-the-river reservoir inflows and received maximum scores for all metrics except number of piscivorous, sucker, and intolerant species, and percent anomalies. The gill netting RFAI rated the forebay good (RFAI=48). Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples.

The combined electrofishing and gill netting RFAI score for the forebay (RFAI=44) was determined to be good. The electrofishing RFAI for the inflow (RFAI=52) was rated excellent. High inflow RFAI indices in 1992 and 1993 indicate Nickajack to have possibly the best fish community among run-of-the-river inflows.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Four swimming beaches and a boat ramp near Nickajack Dam, and one boat ramp and two informal swimming areas in the North Chickamauga Creek Embayment were tested for fecal coliform bacteria twelve times each in 1993. Two samples at each site were collected within 48-hours of a rainfall of at least one-half inch. The geometric mean of the bacteria concentrations were very low (<20/100 ml) at five of the eight sites. The geometric means at one formal and one informal swimming area was 49 and 31/100 ml, well within Tennessee water quality criterion for recreation. At Smith's Camp-On-The-Lake boat ramp, the geometric mean was 657/100 ml. All the Vital Signs monthly samples at the forebay were 10/100 ml or less.

Fish Tissue—The PCB concentration in channel catfish has averaged about 1.0 μg/g over the last three years. The TDEC has issued a precautionary advisory due to PCB contamination in catfish from

Nickajack Reservoir. This means that children, pregnant women, and nursing mothers should not consume catfish, and all others should limit consumption to 1.2 pounds per month.

Fish tissue studies conducted in autumn 1992 were aimed at examining the long-term trend of PCB concentrations in channel catfish and developing a data base for carp. Ten individuals of both species were collected at two sites, one near the forebay, and the other in the upper end of the reservoir about 13 miles downstream of the inflow. The 1992 study also included collection of striped bass (including hybrid striped bass x white bass) from just downstream of Chickamauga Dam. PCB concentrations in the catfish and carp were substantially reduced (about half) from those previously found. The average for channel catfish was 0.4 and 0.5 µg/g (maximum 0.8 µg/g) at the forebay and upper location, respectively. Concentrations in carp were similar to those in catfish. Highest concentrations were found in striped bass (average 0.8 µg/g and maximum 1.1 µg/g). The reduced concentrations in catfish and carp need to be verified, so these species, along with striped bass, were resampled in autumn 1993. Results were not available at the time this report was prepared.

Chickamauga Reservoir

Summary of 1993 Conditions - Ecological Health

Water—During the April-September 1993 monitoring period, coolest surface water temperatures in Chickamauga Reservoir were in April and the warmest in July. Surface temperatures ranged from a minimum of 17.0°C to a maximum of 31.7°C at the forebay; from 16.2°C to 30.1°C at the transition zone; and from 19.1°C to 28.8°C in the Hiwassee River embayment. Tennessee's maximum water temperature criteria for the protection of fish and aquatic life is 30.5°C.

Dissolved oxygen (DO) concentrations at the 1.5m depth ranged from a low of 6.9 mg/l in September to a high of 11.4 mg/l in April at the forebay; from 5.7 mg/l in September to 10.3 mg/l in April at the transition zone; and from 7.3 mg/l in August to 9.9 mg/l in April at the sampling location in the Hiwassee River embayment. At the inflow sampling site (i.e., the tailrace of Watts Bar dam) a minimum DO of 3.7 mg/l was recorded in August. Tennessee's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth.

Temperature data depict seasonal warming and weak thermal stratification in Chickamauga Reservoir from May through July. The maximum observed surface to bottom temperature differentials (ΔT's), occurred in July. ΔT's were 5.5°C at the forebay, 3.2°C at the transition zone, and 4.1°C in the Hiwassee River embayment. There was also an oxycline at the forebay and transition zone in June and July when differences between surface and bottom DO's (DO's) were about 6 to 9 mg/l at the forebay and transition zone. In July 1993, a minimum DO of less than 0.1 mg/l was measured on the bottom at the forebay and a minimum of 1.6 mg/l was measured on the bottom at the transition zone. Better DO conditions were observed in the Hiwassee River embayment portion of Chickamauga Reservoir, where maximum DO's were only 1.7 mg/l and near bottom DO's only slightly below 6 mg/l.

DO ratings used in the overall reservoir ecological health evaluation for Chickamauga Reservoir were good at the forebay; good to excellent at the transition zone; excellent in Hiwassee River embayment; and fair at the inflow. The forebay would have rated higher had it not been for the low near bottom oxygen concentrations which existed in July. The fair rating at the inflow sampling site on Chickamauga Reservoir was a result of oxygen levels being measured about 1.5 mg/l below the Tennessee criteria (5 mg/l, at the 1.5 meter depth) in the releases from Watts Bar dam.

Values of pH ranged from 6.8 to 8.8 on Chickamauga Reservoir, in 1993. Near surface pH values exceeding 8.5 (and DO saturation values exceeding 100 percent) were observed on only two occasions (April and July), both at the forebay. Both of these periods of high pH and high oxygen saturations were also coincident with high chlorophyll *a* concentrations, indicative of periods of high photosynthetic activity. Tennessee's maximum pH criteria for the protection of fish and aquatic life is 8.5.

Total nitrogen (TN), total phosphorus (TP), and dissolved ortho phosphorus (DOP) were low in the Tennessee River portion of Chickamauga Reservoir in 1993. TN averaged only 0.37 mg/l at the forebay, the lowest TN concentration measured at any of the Tennessee River sampling sites in 1993. At both the forebay and the transition zone, TP and DOP concentrations averaged only about 0.026 mg/l and 0.005 mg/l, respectively, and were among the lowest TP and DOP concentrations measured at any of the Tennessee River sampling sites in 1993. Because of these low concentrations (and because TN/TP ratios often exceeded 20), periods of phosphorus limitation on algal productivity were likely to have occurred.

In 1993, Chickamauga Reservoir chlorophyll *a* concentrations averaged 8.5 µg/l, 7.8 µg/l, and 5.5 µg/l, respectively, at the forebay, transition zone, and Hiwassee River embayment. Consequently, the chlorophyll *a* ratings used in the 1993 ecological health evaluation for Chickamauga Reservoir were good (i.e., falling in the 3 to 10 µg/l range) at all three locations.

Sediment Quality—As in 1990, 1991, and 1992, chemical analyses of sediments from Chickamauga Reservoir in 1993 found high levels of copper (64 mg/kg) and zinc (320 mg/kg) in the forebay. High levels of copper (50 mg/kg) were also found in the Hiwassee River embayment, which was sampled for the first time in 1993. Chlordane was also detected in the forebay (16 µg/g) and the transition zone (15 µg/g). Toxicity tests indicated no acute toxicity to either species from the three sites tested, but survival of rotifers (75 percent survival) was reduced in the transition zone. Toxicity to rotifers was detected in both forebay and transition zone samples in 1992. Particle size analysis showed sediments from the forebay were 97 percent silt and clay; from the transition zone were 86 percent silt and clay, 14 percent sand; and from the Hiwassee River embayment were 63 percent silt and clay, 37 percent sand.

Sediment quality ratings used in the overall Chickamauga Reservoir ecological health evaluation for 1993 were fair at the forebay (presence of copper, zinc and chlordane); fair at the transition zone (presence of chlordane and reduced survival of rotifers); and, good in the Hiwassee River embayment (presence of copper).

Benthic Macroinvertebrates—The forebay and transition zone sites had excellent benthic communities, and the inflow site was fair. The Hiwassee embayment, a major component of Chickamauga Reservoir, was also included in the ecological health rating. It was shown to support a good benthic community. The forebay site had 19 taxa and 847 organisms/m^2. The most numerous taxa collected were the chironomid Coelotanypus sp (29 percent), the mayfly Hexagenia limbata (20 percent), the asiatic clam Corbicula fluminea (19 percent) and Tubificidae (17 percent). The transition zone was represented by 25 taxa and 897 organisms/m^2 with Hexagenia limbata comprising 26 percent of the total organisms and Tubificidae comprising 18 percent of the total organisms. The inflow had 21 taxa and 845 organisms/m^2. Gammarus fasciatus, an amphipod, was the dominant species present comprising 36 percent of the total organisms. The Hiwassee embayment had the greatest diversity and abundance of organisms than any other site on Chickamauga Reservoir. It had 2312 organisms/m^2 representing 49 species; Tubificidae were the dominant taxa collected (36 percent) followed by the snail Musculium transversum (17 percent).

The forebay on Chickamauga supported an excellent benthic community, however, the overall benthic score was lowered due to an elevated chironomid community and lowered EPT community. The transition zone also received an excellent rating but fell short of perfect because of an elevated chironomid community and lowered numbers of long-lived taxa. The inflow site rated fair primarily because of an absence of long-lived organisms such as Corbicula sp and Hexagenia sp, and because of reduced diversity and EPT taxa present. The Hiwassee embayment supported a good benthic community in 1993 because of an excellent EPT representation, diversity, low numbers of Chironomids, and evenness of the dominant species. An abundance of tubificids and a lack of long-lived species contributed to this site receiving a good rating instead of an excellent rating.

Aquatic Macrophytes—Coverage of aquatic macrophytes increased from 387 acres in 1992 to 1,185 acres in 1993. Most macrophytes were in Dallas Bay embayment and in small embayments and overbank habitat upstream of TRM 499. Aquatic macrophytes on Chickamauga Reservoir peaked at about 7,500 acres in 1988 and continuously declined until 1993 when coverage increased. Spinyleaf and southern naiad were the dominant species in 1993 although small colonies of Eurasian watermilfoil, American pondweed, and American lotus also were present.

Fish Assemblage—Fish data collected in littoral (45 electrofishing transects) and offshore zones (28 net-nights) of the forebay resulted in the collection of 44 species (6,994 individuals). Emerald shiner was the most abundant species (collected at the rate of 56 per 300 meter electrofishing transect), accounting for 36 percent of the total number of fish collected. Gizzard shad comprised 16 percent of the sample, followed closely by bluegill at 14 percent. Electrofishing results showed approximately twice as many individuals in the inflow (2,624) and transition (2,300) zones as the forebay (1,229), due to numbers of gizzard shad and bluegill in the sample. Numbers of YOY threadfin shad followed a similar pattern with high catch rates in the forebay (CPUE=810 per 300m transect) and transition (CPUE=1,707 per 300m transect) and very high catch rates in the inflow zone (CPUE=3,559 per 300m transect). Gill netting fish abundance was higher in the transition (454) than the forebay (229); although abundance at the inflow zone (158) was lower because of reduced effort, catch rate was similar to the transition zone.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) fair in the forebay (RFAI=32), good in the transition (RFAI=46), and excellent in the inflow (RFAI=52) zones of Chickamauga Reservoir. The inflow index of 52 was the highest score observed for run-of-the-river reservoir inflows and received maximum scores for all metrics except number of sucker and tolerant species, dominance by a single specie, and percent anomalies. In 1992 the inflow rated only fair (RFAI=34).

The gill netting RFAI rated the transition zone excellent (RFAI=52) and the forebay fair (RFAI=36). The excellent score of 52 in the transition zone was the second highest ever observed for run-of-the-river reservoirs and resulted from maximum scores for all metrics except number of sucker, intolerant, and lithophilic spawning species, and percent insectivores. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples.

The combined electrofishing and gill netting RFAI score for the transition (RFAI=49) and forebay (RFAI=34) were rated good and fair, respectively. The electrofishing RFAI for the inflow (RFAI=52) zone received an excellent rating, which was one of the highest scores for all inflows sampled in 1993.

Combined fish samples in shoreline electrofishing (15 transects) and offshore gill netting (12 net-nights) produced a total of 2263 individuals including 31 species in the Hiwassee River embayment of Chickamauga Reservoir. The three most abundant species were redear sunfish (29 percent), gizzard shad (19 percent), and bluegill (16 percent). There were six times as many fish collected by electrofishing as gill netting, largely attributed to high numbers of sunfishes inhabiting shoreline areas.

The electrofishing RFAI score of 36 rated the embayment community as fair and gill netting results indicated good (RFAI=50) fish community conditions. Combining RFAI scores (RFAI=43) rated the Hiwassee River embayment good (scoring criteria for run-of-the-river transition was used to obtain RFAI ratings). Metrics for both electrofishing and gill netting that influenced the high scoring included low percent dominance by a single species, low percent omnivores, and high numbers of lithophilic spawning species.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No bacteriological studies were conducted at recreation sites in Chickamauga Reservoir in 1993. Fecal coliform bacteria concentrations at the monthly Vital Signs locations, the forebay, transition zone, and Hiwassee River Embayment, were all 10/100 ml or less except for one sample. The April sample in the Hiwassee River Embayment had a concentration of 300/100 ml.

Fish Tissue—There are no fish tissue consumption advisories in effect for Chickamauga Reservoir. Samples for screening studies were conducted in autumn 1991 and 1992. Fillets from five channel catfish were collected from the inflow, transition zone, and forebay, composited by site, and examined for a broad array of analyses (selected metals, pesticides, and PCBs on the EPA priority pollutant list). Results from samples collected from all locations in 1991 had low or nondetectable levels of metals and pesticides. PCB concentrations were 0.4, 0.7, and 1.2 μg/g at the forebay, transition zone, and inflow, respectively. This general trend had been documented in several previous studies but not always as pronounced as in the 1991 results. Such was the case for 1992 results - PCB concentrations were 0.6, 0.7, and 0.7 μg/g at the forebay, transition zone, and forebay, respectively. All other analytes were not detected or found in low concentrations in the 1992 fish samples.

HIWASSEE RIVER WATERSHED

Hiwassee Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average flow through Hiwassee Reservoir was about 107 percent of normal and the average residence time was about 99 days. The reservoir was strongly stratified with a maximum temperature difference in the water column at the forebay of 20.9°C in July. The maximum surface temperature was 28.7°C in July, both at the forebay and mid-reservoir. North Carolina's standard for maximum temperature of Class C waters is 29°C. Low DO water (DO <5.0 mg/l) first appeared at mid-reservoir in June and at the forebay in July at the bottom of the water column at both locations. Depleted DO water (DO < 2.0 mg/l) occurred at both locations at the bottom of the water column in August and September. The limited area of DO depletion provided ratings for the reservoir ecological health index of fair at the forebay and good at mid-reservoir.

Conductivities averaged about 30 µmhos/cm in April, increased slightly in the DO-depleted area to a maximum of 40 and 38 µmhos/cm at the forebay and mid-reservoir, respectively. The average conductivity in Hiwassee Reservoir was the fourth lowest of the 19 tributary reservoirs. Only in June, July, and August did pH reach or exceed 8.4, and only in the four to eight meter depth. Summer DO concentrations were normally higher at these depths.

The organic nitrogen concentration, in April and August respectively, was 0.12 and 0.26 mg/l at the forebay, and 0.14 and 0.09 mg/l at mid-reservoir. The April nitrate-nitrogen concentration was 0.12 and 0.10 mg/l at the forebay and mid-reservoir, respectively. The August concentrations were <0.01 mg/ at both locations. Total phosphorus concentrations were 0.007 mg/l in April and 0.002 mg/l in August at both locations. Dissolved ortho phosphorus concentration was 0.01 mg/l in April at mid-reservoir, and otherwise <0.002 mg/l.

These low concentrations of nutrients resulted in low concentrations of total organic carbon and chlorophyll and high water clarity. Total organic carbon concentrations were 0.9 mg/l in April and approximately double that in August at both locations. Chlorophyll *a* concentrations averaged 2.2 µg/l at the forebay (third lowest of 19 tributary reservoir forebays) and 3.7 µg/l at mid-reservoir. The chlorophyll concentrations rated fair at the forebay and good (near the low end of the range) at mid-reservoir for the reservoir ecological health index. Hiwassee Reservoir water clarity was the third highest of the tributary reservoir forebays, and the highest of all tributary mid-reservoir stations. Secchi depths varied from 2.4 m at both locations in April, to 5.1 m at mid-reservoir and 5.6 m at the forebay in July.

Sediment Quality—Chemical analyses of sediments in Hiwassee Reservoir in 1993 indicated the presence of chlordane in the forebay (15 µg/g) and mid-reservoir (16 µg/g). Toxicity tests detected acute toxicity to daphnids in both forebay (15 percent survival) and mid-reservoir (10 percent survival) samples. Toxicity to rotifers was also detected in the mid-reservoir (65 percent survival). Particle size analysis showed sediments in the forebay were 99 percent silt and clay, and in the mid-reservoir were 90 percent silt and clay.

Sediment quality ratings used in the overall Hiwassee Reservoir ecological health evaluation for 1993 were poor at the forebay (due to toxicity to daphnids and presence of chlordane) and poor at the mid-reservoir site (due to toxicity to daphnids and rotifers and presence of chlordane).

Benthic Macroinvertebrates—Until 1993, no TVA data on the benthic macroinvertebrate community in Hiwassee Reservoir existed. Sampling revealed that the forebay and mid-reservoir sites had poor benthic communities, and the inflow had a fair benthic community. The forebay site had 5 taxa and 127 organisms/m^2 and was dominated by Tubificidae (86 percent). The mid-reservoir site had 11 taxa and 2,111 organisms/m^2 with Tubificidae as the dominant taxon comprising 86 percent of the total. The Hiwassee inflow had the greatest number of taxa (16) and had 1,605 organisms/m^2. Tubificidae (61 percent) was the dominant taxon followed by Procladius sp (21 percent).

The Hiwassee forebay and mid-reservoir benthic samples rated poor due to low diversity, an absence of EPT and long-lived taxa, and an abundance of tubificids. The inflow fared better than the previous sites, but still rated only fair.

Fish Assemblage—Shoreline electrofishing (45 transects) and offshore gill netting (36 net-nights) from the three zones of Hiwassee Reservoir resulted in the collection of 2,958 fish including 27 species. When green sunfish (39 percent of total catch) were disregarded, the dominant taxa by number in the remaining sample were bluegill (43 percent), gizzard shad (9 percent), smallmouth bass (8 percent), white bass (7 percent), and black crappie (6 percent). Electrofishing results indicated total numbers of fish were approximately the same in the forebay (952) and transition (931) zones with considerably lower numbers in the inflow (326) zone.

The Reservoir Fish Assemblage Index (RFAI) showed the littoral fish community (based on results of electrofishing samples) to be poor in all three sample zones of Hiwassee Reservoir (forebay RFAI=28, transition RFAI=26, and inflow RFAI=28). Gill netting RFAI results rated all three zones good (forebay RFAI=50, transition RFAI=46, and inflow RFAI=42).

The trophic composition metric group showed maximum scores for both gear types; all other metric group scores generally reflected the total RFAI score. Combined electrofishing and gill netting RFAI scores for the forebay (RFAI=39), transition (RFAI=36) and inflow (RFAI=35)zones were rated fair.

Summary of 1993 Conditions - Use Suitability

There were no bacteriological studies conducted on Hiwassee Reservoir in 1993. Although fish tissue samples were collected in autumn 1993, results were not available at the time this report was prepared.

Chatuge Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average flow through Chatuge Reservoir in 1993 was about 88 percent of normal. The average residence time was 291 days. The reservoir was strongly stratified, with a maximum temperature difference of 19.1°C in the water column at the forebay in July. The maximum surface temperature was 29.0°C at the forebay and 28.6°C in Shooting Creek Embayment, both measurements in July. North Carolina's standard for maximum temperature of Class °C waters is 29°C. At both locations, low DO (<5.0 mg/l) conditions began developing at the bottom of the water column in July, and depleted DO (<2.0 mg/l) conditions occurred from August through October. Depleted DO conditions also occurred in the metalimnion at the forebay in September. The limited extent of the area of DO depletion gave the forebay a good rating and Shooting Creek Embayment a fair rating in the reservoir ecological health index.

Conductivities were the fourth lowest of the 19 tributary reservoirs, averaging about 25 μmhos/cm in April. Conductivities decreased slightly in the photic zone (supersaturated with DO) in the summer and increased to a maximum of 45 μmhos/cm at the bottom of the water column at the forebay in September. The only time pH exceeded 8.0 was in June and July from the four to eight meter depth. The minimum pH was 5.8 at the forebay and 5.9 in Shooting Creek Embayment, both in September.

Organic nitrogen concentrations increased from April to August at both locations, 0.04 and 0.23 mg/l at the forebay and 0.09 and 0.30 mg/l in Shooting Creek Embayment. Nitrate concentrations dropped from 0.09 to <0.01 mg/l at both locations. Total phosphorus concentrations at the two sites tied for the third lowest concentrations of the 33 tributary reservoir stations. The maximum concentration was 0.004 mg/l in Shooting Creek Embayment in April. Consequently, TN/TP ratios were very high, ranging from 47 at the forebay in April to 160 in Shooting Creek Embayment in August. Total organic carbon concentrations were low, 0.8 and 0.7 mg/l in April, and 1.5 and 1.8 mg/l in August at the forebay and Shooting Creek Embayment, respectively. Chlorophyll *a* concentrations averaged 2.8 μg/l at both locations. This concentration is in the range considered fair in the reservoir ecological health index. Chatuge had the fourth clearest water of the tributary reservoirs. Secchi depths varied from 2.4 m in August to 4.6 m in July in Shooting Creek Embayment, and from 3.1 m in April and August to 4.4 m in July at the forebay.

Sediment Quality—Chemical analyses of sediments in 1993 indicated high levels of chromium (89 mg/kg), copper (56 mg/kg) and nickel (48 mg/kg) in the Shooting Creek forebay area of Chatuge Reservoir. Toxicity tests detected acute toxicity to daphnids (55 percent survival) in the Hiwassee River forebay. Toxicity to daphnids (50 percent survival) was also detected in the water column in this forebay. Reduced survival of daphnids was also detected (60 percent survival) in the Shooting Creek forebay water column. Particle size analysis showed sediments in the forebay were about 75 percent silt and clay, 25 percent sand. In the Shooting Creek forebay sediments were 99 percent silt and clay.

Sediment quality ratings used in the overall Chatuge Reservoir ecological health evaluation for 1993 were fair at the Hiwassee River forebay sampling site (toxicity to daphnids in both water and sediment); and also fair at the Shooting Creek forebay sampling site (presence of chromium, copper, and nickel and reduced survival of daphnids).

Benthic Macroinvertebrates—The first year that the benthic macroinvertebrate community was evaluated on Chatuge Reservoir was 1993. Two forebay sites were chosen on Chatuge, and both had good benthic communities. The first forebay site, at HiRM 122.0, had 1,431 organisms/m^2 representing 22 taxa; Tubificidae was the dominant taxon comprising 52 percent of the total. The other site, at Shooting Creek mile 1.5, had 23 taxa and 1,065 organisms/m^2 with Tubificidae (37 percent) and the chironomid Zalutschia zalutschicola (19 percent) as the dominant taxon.

Both forebay sites had excellent diversity and excellent EPT representations, and an average amount of long-lived organisms in the community. The Shooting Creek site suffered slightly from an above average density of tubificids, and the HiRM 122 site was slightly impacted from an above average density of chironomids.

Fish Assemblage—Electrofishing samples (30 transects) in shoreline areas and experimental gill netting samples (24 net-nights) offshore collected 1,999 individuals with 20 species represented. Bluegill was the most abundant taxon in Chatuge Reservoir (47 percent of total fish sampled). Redbreast sunfish (19 percent), spotted bass (7 percent), white bass (5 percent), and gizzard shad (5 percent) followed in order of density. Note: Three percent of the total sample was comprised of snail bullheads which is the first documentation of this species in a TVA reservoir. Electrofishing catch rates were much higher in the forebay zone (78 per 300m transect) than the Shooting Creek arm (32 per 300m transect). However, gill netting catch rates were similar between the two stations.

The Reservoir Fish Assemblage Index (RFAI) rated both the forebay and Shooting Creek sites fair for electrofishing (Forebay RFAI=36 and Shooting Creek RFAI=32) and gill netting (forebay RFAI=34 and Shooting Creek RFAI=32) samples. The only metric grouping with consistently high scores was trophic composition (percent omnivores and insectivores) in the electrofishing sample. Combined electrofishing and gill netting RFAI's rated both areas fair.

Summary of 1993 Conditions - Use Suitability

There were no bacteriological studies conducted on Chatuge Reservoir in 1993. Although fish tissue samples were collected in autumn 1993, results were not available at the time this report was prepared.

Nottely Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The average flow through Nottely Reservoir in 1993 was about 90 percent of normal, with an average residence time of 228 days. The reservoir was stratified from April through September, with a maximum temperature difference in the water column at the forebay of 18.9°C in July. The maximum surface temperature was 29.3°C at both the forebay and mid-reservoir in July. Georgia's standard for maximum temperature for protection of aquatic life is 30°C. In June, low DO (<5.0 mg/l) conditions began developing in the forebay bottom waters, while depleted DO (<2.0 mg/l) conditions had already developed at mid-reservoir. An area of depleted DO developed at the forebay in July, and remained at both locations through September. The extensive areas of depleted DO gave both locations poor ratings for DO in the reservoir ecological health index. The vertical mixing of the reservoir in October eliminated areas of low DO. The area of DO depletion extended to within 7 meters of the surface in July at mid-reservoir.

Conductivities were the fifth lowest of the 19 tributary reservoirs, with an average of about 30 µmhos/cm in April, decreased slightly in the supersaturated (DO) photic zone in the summer and increased to a maximum of 49 and 79 µmhos/cm in September at the bottom of the water column at the forebay and mid-reservoir, respectively. The only time pH exceeded 8.0 was in June and July. The highest values at the forebay were from the 4 to 7 m depth, and from the 3 to 5 m depth at mid-reservoir. The maximum pH was 8.8 at both locations. The minimum pH was 5.9 in the depths at both locations from July to September.

Organic nitrogen concentrations were 0.14 mg/l in April at both locations, and 0.17 and 0.13 mg/l in August at the forebay and mid-reservoir, respectively. Nitrate-nitrogen concentrations were 0.12 and 0.15 mg/l in April at the forebay and midreservoir, respectively, dropping in <0.01 mg/l in August at both locations. Total phosphorus concentrations at both locations were 0.02 mg/l in April, dropping to 0.005 and 0.008 mg/l in August at the forebay mid-reservoir, respectively. Dissolved ortho phosphorus ranged from a maximum concentration of 0.004 mg/l in April at mid-reservoir to a minimum of 0.002 mg/l at both locations in August. Total organic carbon concentrations varied from a low of 1.2 mg/l in April to a maximum of 2.2 mg/l in August, both at mid-reservoir. Chlorophyll *a* concentrations averaged 3.4 µg/l at the forebay and 5.0 µg/l at mid-reservoir. These concentrations are in the range considered good in the reservoir ecological health index. Secchi depths varied from 1.4 m in April at both locations, to 4.2 and 2.4 m in June at the forebay and mid-reservoir, respectively.

Sediment Quality—Chemical analyses of sediments in Nottely Reservoir in 1993 did not reveal any metal or organic analytes to be of concern. Toxicity tests detected acute toxicity to daphnids (70 percent survival) and rotifers (60 percent survival) in the forebay. Particle size analysis showed sediments in the forebay were 89 percent silt and clay, 11 percent sand; and in the mid-reservoir were about 100 percent silt and clay.

Sediment quality ratings used in the overall Nottely Reservoir ecological health evaluation for 1993 were fair at the forebay sampling site (toxicity to daphnids and rotifers); and excellent at the mid-reservoir sampling site.

Benthic Macroinvertebrates—The first year that the benthic macroinvertebrate community was evaluated on Nottely Reservoir was 1993. The forebay site, which had a poor benthic community, had 11 taxa, 452 organisms/m^2, and was dominated by Tubificidae (50 percent) and Chironomus sp (29 percent). The inflow site had a good benthic community. There were more taxa (20) and a greater density (933 organisms/m^2) than at the forebay site. Tubificidae (34 percent), Chironomus sp (26 percent), and Procladius sp (23 percent) dominated the benthic community.

A deficiency of EPT taxa and long-lived organisms were the two primary contributing factors for the poor benthic community at the forebay. Elevated numbers of chironomids and tubificids also contributed to the poor rating. At the inflow, an opposite scenario surfaced: EPT and long-lived taxa had an excellent representation, and the tubificid metric was excellent, therefore contributing to a good benthic community structure.

Fish Assemblage—Only the forebay of Nottely Reservoir was sampled in fall 1992. However, in 1993 a transition zone sample was added to better assess the quality of the fish community. Shoreline electrofishing (30 transects) in the littoral zone and experimental gill netting (24 net-nights) in the offshore/deeper areas collected 2,275 individuals with 20 species represented. The four most abundant species represented in the samples were bluegill (63 percent), black crappie (6 percent), green sunfish (5 percent), and carp (5 percent). Electrofishing results indicated the primary forage available in Nottely consisted of sunfish species (69 percent of total catch) instead of shad, as is usually the case.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) fair in the transition zone (RFAI=36) and poor in the forebay (RFAI=30) of Nottely Reservoir. Generally low metric scores in both zones were directly related to low species diversity. Both areas (transition RFAI=32, and forebay RFAI=34) of Nottely were rated fair by gill netting RFAI analysis. When electrofishing and gill netting RFAI scores are combined both forebay (RFAI=32) and transition (RFAI=34) zones rated fair.

Summary of 1993 Conditions - Use Suitability

There were no bacteriological studies conducted on Nottely Reservoir in 1993. Although fish tissue samples were collected in autumn 1993, results were not available at the time this report was prepared.

Blue Ridge Reservoir

Summary of 1993 Conditions - Ecological Health

Water—The flow through Blue Ridge Reservoir in 1993 was about normal, with an average residence time of about 156 days. The reservoir was thermally stratified from April through September; there was no sampling in October. The maximum temperature difference in the water column was 17.7°C, and the maximum surface temperature was 29.8°C, both in July. Georgia's standard for maximum temperature for protection of aquatic life is 30°C. Low DO (<5.0 mg/l) conditions developed in August; the lowest DO measured was 3.4 mg/l in September. The absence of an area of depleted DO gave Blue Ridge a good rating for DO in the reservoir ecological health index.

Conductivities averaged about 20 μmhos/cm, the lowest of the 19 tributary reservoirs, and showed little stratification. The maximum pH was 8.8 at the 7 m depth in July. The minimum pH was 5.6 at the 20 m depth in September.

Organic nitrogen concentrations were 0.04 and 0.08 mg/l in April and August, respectively. Nitrate-nitrogen concentrations decreased from 0.06 to <0.01 mg/l from April to August. Total and dissolved ortho phosphorus concentrations were 0.003 for both in April, and 0.004 and <0.002 in August. Total organic carbon concentrations went from 0.7 mg/l in April to 1.5 mg/l in August, tied for the second lowest concentrations in the tributary reservoirs. Chlorophyll *a* concentrations were the second lowest of the 33 tributary reservoir stations, averaging 1.8 μg/l. This concentration is in the fair range in the reservoir ecological health index. Water clarity was the second highest of the tributary reservoir forebays, with Secchi depths varying from 3.4 meters in April to 5.4 meters in June.

Sediment Quality—Chemical analyses of sediments in Blue Ridge Reservoir in 1993 did not reveal any metals or organic analytes to be a concern. Toxicity tests detected acute toxicity to daphnids (20 percent survival) in the forebay. Particle size analysis showed sediments in the forebay were 95 percent silt and clay.

Because of the toxicity of the forebay sediment to daphnids, a fair sediment quality rating was used in the overall 1993 Blue Ridge Reservoir ecological health evaluation.

Benthic Macroinvertebrates—The first year that the benthic macroinvertebrate community was evaluated on Blue Ridge Reservoir was 1993. The forebay, the only sample location, had an excellent benthic fauna, with 1,308 organisms/m^2 representing 23 taxa. The dominant taxa were Pisidium sp (33 percent), Procladius sp (21 percent), Spirosperma nikolskyi (18 percent), and Tubificidae (17 percent). This site received good scores for five of the six metrics: diversity, number of EPT taxa, number of chironomids, number of tubificids, and evenness of dominant species. Depressed numbers of long-lived taxa was the only metric that rated fair.

Fish Assemblage—Only the forebay of Blue Ridge Reservoir was sampled in fall 1993. Electrofishing samples (15 transects) in shoreline areas and experimental gill netting samples (12 net-nights) offshore collected 856 individuals with 15 species represented. By far the predominant species captured was bluegill (59 percent) followed distantly by white bass (10 percent), smallmouth bass

(8 percent), and redbreast sunfish (5 percent). There were three times as many fish collected by electrofishing as gill netting, largely attributed to high numbers of bluegill inhabiting shoreline areas.

The electrofishing RFAI score of 28 rated poor and gill netting results indicated fair (RFAI=34) fish community conditions. The combined RFAI scores (RFAI=31) rated the Blue Ridge forebay fair. Scoring for both electrofishing and gill netting RFAI metrics was influenced by low diversity, low catch, and dominance by a single species (bluegill).

Summary of 1993 Conditions - Use Suitability

There were no bacteriological studies conducted on Blue Ridge Reservoir in 1993. Although fish tissue samples were collected in autumn 1993, results were not available at the time this report was prepared.

Ocoee Reservoir No. 1 (Parksville Reservoir)

Summary of 1993 Conditions - Ecological Health

Water—The average flow in 1993 was about 91 percent of normal. The high elevation outlet at the dam allows the hypolimnetic water to remain in place all spring and summer. In October, the bottom temperature was 7.7°C. The very cold bottom temperatures mean that the reservoir was strongly stratified; there was a temperature difference in the water column of 21.4°C in July. The maximum surface temperature was 28.7°C in July. Tennessee's maximum temperature criterion for aquatic life is 30.5°C. Very little DO depletion occurs in the reservoir; the minimum DO during the survey was 5.8 mg/l at the bottom in October. The maximum DO saturation was 108 percent at the surface in May. The lack of low DO in the reservoir resulted in a good rating for DO in the reservoir ecological health index.

Conductivities were low, usually between 50 and 60 µmhos/cm with little stratification. The lack of DO depletion and low primary productivity resulted in little variation in pH, which varied from 7.5 to 6.3.

Concentrations of total nitrogen, total phosphorus, total organic carbon, and chlorophyll were all among the lowest six of the 33 tributary reservoir stations. Organic- and nitrate-nitrogen concentrations were 0.03 and 0.09 mg/l in April, and 0.06 and 0.04 mg/l in August. Total and dissolved ortho phosphorus concentrations were 0.005 and 0.003 mg/l in April, and 0.002 and <0.002 mg/l in August. Total organic carbon concentrations were very low, 0.8 and 1.4 mg/l in April and August, respectively. Chlorophyll *a* concentrations averaged 2.5 µg/l. This chlorophyll concentration is considered fair in the reservoir ecological health index. Secchi depths varied from 1.6 m in April to 3.6 m in July, September, and October.

Sediment Quality—Chemical analysis of sediments in Parksville Reservoir in 1993 indicated extremely high levels of copper (1,500 mg/kg), lead (1,300 mg/kg) and zinc (1,500 mg/kg) in the forebay sediment. Toxicity tests detected acute toxicity to daphnids (0 percent survival) and rotifers (10 percent survival) at an upper reservoir site sampled only for sediments (not included in the overall ecological health score). Acute toxicity to daphnids and rotifers was also detected in near bottom water collected at the forebay (0 and 20 percent survival, respectively); and at the upper reservoir sampling site (0 percent survival for both species). Particle size analysis showed sediments in the forebay were 99 percent silt and clay. No chemical analyses or particle size analyses were conducted for the upper reservoir sediment sample.

Because of the acute toxicity of the forebay bottom water to daphnids and rotifers and the very high concentrations of copper, lead, and zinc found in the forebay sediment, a poor sediment quality rating was used in the overall 1993 Parksville Reservoir ecological health evaluation.

Benthic Macroinvertebrates—Only one site was chosen for sampling the first year on Ocoee No. 1, located in the forebay. The benthic community there was poor, with only 10 taxa, 372 organisms/m^2, and dominated by Tubificidae (65 percent) and Limnodrilus hoffmeisteri (27 percent). This site rated poor on 3 of the 5 metrics: number of EPT taxa, number of long-lived taxa, and proportion of tubificids. It received a good score only on the proportion of chironomids metric, and diversity was fair.

Fish Community—Only the forebay of Parksville Reservoir was sampled in fall 1993. Shoreline electrofishing (15 transects) and offshore netting (12 net-nights) produced a total of 524 individuals including 15 species. Bluegill and largemouth bass were the most abundant species collected, comprising 76 and 7 percent of the total sample, respectively. Channel catfish (4 percent) and yellow perch (3 percent) were also frequently encountered.

The electrofishing Reservoir Fish Assemblage Index (RFAI) rated the Parksville littoral fish community as poor (RFAI=28) and the gill netting RFAI rated the limnetic bottom fish community as very poor (RFAI=20).

Overall RFAI analysis (combined electrofishing and gill netting) determined that the quality of the reservoir fish community was poor. The Parksville Reservoir forebay RFAI of 24 was the lowest recorded for storage reservoir forebays, receiving minimum scores for seven of the twelve metrics utilized for the electrofishing RFAI analysis, and ten of the twelve metrics analyzed for gill netting.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No bacteriological studies were conducted in 1993.

Fish Tissue—There are no fish consumption advisories on Parksville Reservoir. However, screening studies conducted 1987 through 1991 consistently found relatively high PCB concentrations (about 1.0 μg/g) and higher than expected selenium concentrations (about 1.0 μg/g) at the forebay. Because of the consistently elevated PCB concentrations, TVA, TDEC, and TWRA designed and conducted a more intensive effort on Parksville Reservoir for autumn 1992. The study included individual analyses on channel catfish and largemouth bass from the forebay and upper reservoir area and composite analysis of bluegill sunfish from both areas and rainbow trout from the lower portion of the reservoir. PCBs, chlordane, selenium, and mercury were the analytes of interest. Results generally fell along expected lines. PCB concentrations in channel catfish were relatively high (averages 1.5 and 1.0 μg/g and maxima 3.0 and 1.9 μg/g at the forebay and upper locations, respectively). PCB concentrations in largemouth bass were not as high (averages 0.6 and 0.7 μg/g and maxima 1.7 and 2.0 μg/g at the forebay and upper location, respectively). PCB concentrations in the bluegill and trout composites were only slightly above detection limits. Chlordane and mercury concentrations were low or not detected in all samples. Selenium concentrations fell generally as expected (around 1.0 μg/g). At the time this report was prepared, no action had been taken on these results. Additional composite samples of channel catfish from the forebay and inflow areas were collected in autumn 1993, but results were not available at the time this report was prepared.

Hiwassee River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Hiwassee River is soft (average hardness of 15 mg/l) and slightly alkaline (average total alkalinity of 16 mg/l). The median pH for the stream monitoring site was 7.2. The river was well oxygenated with dissolved oxygen levels remaining around 100 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the Hiwassee River ranked among the lowest average concentrations of organic nitrogen (0.089 mg/l), nitrate+nitrite-nitrogen (0.16 mg/l), and total phosphorus (0.025 mg/l). It ranked near the middle in average ammonia nitrogen (0.030 mg/l) and dissolved orthophosphate (0.007 mg/l) concentrations. The low total phosphorus and nitrate+nitrite-nitrogen concentrations yielded a good rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total and dissolved copper and zinc) were performed bi-monthly. Dissolved cadmium was detected in 5 of 6 samples. One sample exceeded the EPA guidelines for both chronic and acute toxicity to aquatic life. Another sample exceeded the guideline only for chronic toxicity to aquatic life.

Sediment— Sediment quality rated good in 1993 with no acute toxicity observed. No PCBs or pesticides exceeded the EPA guidelines; however, nickel exceeded the EPA guidelines. This is an improvement over 1992 when the sediment quality rated fair.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate results rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 38, with 81 taxa and 828 organisms/m^2. Conditions in 1992 also rated fair (MBIBI score 34) with 65 taxa and 953 organisms/m^2; however, the MBIBI score of 34 was very close to a poor rating. Dominant organisms in 1993 were dipteran midge larvae (33 percent), caddisflies (18 percent), and mayflies (13 percent). Dipteran midge larvae was the most dominant organism in 1992 (28 percent), followed by the Asian clam Corbicula (20 percent) and caddisflies (14 percent). Regulated stream flows and cold water releases from Appalachia Powerhouse stress warmwater benthic communities in the river.

Fish Community Assessment—No meaningful change was seen in the fish community as ratings for both 1993 and 1992 were good with Index of Biotic Integrity (IBI) score 48 each year. Limited deficiencies in number of native species, numbers of darter and sunfish species, proportion of fish as specialized insectivores, and fish density indicated less than optimum conditions. Problems found in the fish community may be partially attributed to altered flows due to releases from Apalachia Powerhouse.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No fecal coliform bacteria samples were collected in 1993.

Fish Tissue—A five-fish composite each of carp, channel catfish, and largemouth was collected during summer and analyzed for selected metals, pesticides, and PCBs. All analytes were either not detected or found in low concentrations. The only analyte high enough to be noteworthy was PCBs in carp with a slightly elevated concentration of 0.6 µg/g.

WATTS BAR RESERVOIR, FORT LOUDOUN RESERVOIR, AND MELTON HILL RESERVOIR WATERSHED

Watts Bar Reservoir

Summary of 1993 Conditions - Ecological Health

Water—During the April-September 1993 monitoring period, surface water temperatures ranged from a minimum of 18.3°C in April to a maximum of 30.2°C in July in the forebay; and from 16.7°C to 29.8°C (for the same months) at the transition zone. The State of Tennessee's maximum water temperature criteria for the protection of fish and aquatic life is 30.5°C.

Values for DO at the 1.5m depth ranged from a low of 6.5 mg/l in September to a high of 12.6 mg/l in April at the forebay, and from 7.1 mg/l to 11.3 mg/l (for the same months) at the transition zone. At the inflow sampling site on the Tennessee River arm of Watts Bar Reservoir (i.e. the tailrace of Fort Loudoun dam) a minimum DO of 3.9 mg/l was recorded in September. At the inflow sampling site on the Clinch River arm of Watts Bar Reservoir (i.e., the tailrace of Melton Hill dam) a minimum DO of 6.3 mg/l was recorded in March. Tennessee's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5.0 mg/l, measured at the 1.5 meter depth.

Temperature and dissolved oxygen data show that Watts Bar Reservoir developed a moderate degree of both thermal and oxygen stratification throughout most of the summer of 1993. For the period April through August, monthly surface to bottom temperature differentials (ΔT's) were: 5.2°C, 5.5°C, 7.4° C, 7.3°C, and 4.0°C at the forebay; and 2.3°C, 2.6°C, 3.9°C, 6.2°C, and 2.2°C at the transition zone.

DO versus depth data show that a rather strong oxycline also developed in Watts Bar Reservoir, particularly from June through August. During these three months, surface to bottom differences in DO were: 9.2 mg/l, 9.2 mg/l, and 5.8 mg/l at the forebay; and 7.2 mg/l, 5.8 mg/l, and 3.1 mg/l at the transition zone. At the forebay, near bottom DO concentrations in the hypolimnion were less than 2 mg/l in June and July. In addition, the proportion of the hypolimnion with low DO's (i.e. less than 2 mg/l) averaged about 13 percent of the total cross sectional area, higher than in any other Tennessee River reservoir. The minimum observed DO concentration in Watts Bar Reservoir in 1993 was 0.6 mg/l at the bottom of the forebay in July, but DO's were never less than 4 mg/l at the transition zone.

DO ratings used in the overall reservoir ecological health evaluation for Watts Bar Reservoir were poor at the forebay; excellent at the transition zone and at the inflow sampling site on the Clinch River; and fair at the inflow site on the Tennessee River. The low forebay rating was due to the large proportion of the forebay hypolimnion with low DO concentrations (i.e., less than 2 mg/l). The fair rating at the inflow sampling site on the Tennessee River arm of Watts Bar Reservoir was a result of oxygen levels being measured about 1 mg/l, below the Tennessee criteria (5 mg/l, at the 1.5 meter depth) in the releases from Fort Loudoun dam.

Historically, the pH's of water in Watts Bar Reservoir has been higher than other Tennessee River sampling site. This is due to the addition of the cool, clear, well oxygenated, nitrate rich, and hard water of the Clinch River which combines with the Tennessee River (and Watts Bar Reservoir) at TRM 567.9, about seven miles upstream from the transition zone sampling site. In the summer of 1993, values of pH ranged from 6.8 to 9.0 on Watts Bar Reservoir. During much of the April-September sample period, near surface values of pH frequently exceeded 8.5 at both the forebay and the transition zone, with DO saturation values commonly exceeding 100 percent, indicating high rates of photosynthesis. Tennessee's maximum pH criteria for the protection of fish and aquatic life is 8.5.

The average total phosphorus concentrations observed in Watts Bar Reservoir (0.029 mg/l at the forebay and 0.035 mg/l at the transition zone) were among the lowest of the Tennessee River Vital Signs Monitoring locations in 1993. In addition, the average dissolved ortho phosphorus concentrations of 0.007 mg/l and 0.004 mg/l, respectively, at the forebay and transition zones were also among the lowest observed at any of the Tennessee River Vital Signs Monitoring locations in 1993. TN/TP ratios on Watts Bar Reservoir are higher than on any other Tennessee River reservoir. The low phosphorus concentrations in combination with the relatively high nitrogen concentrations (supplied by both the Clinch and Tennessee River inflows) results in the high TN/TP ratios in Watts Bar (particularly at the transition zone) and suggest periods of phosphorus limitation on primary productivity.

The highest chlorophyll *a* concentrations were measured in August at the forebay (10 μg/l) and in May at the transition zone (11 μg/l). Surface concentrations of chlorophyll *a* averaged about 7 μg/l at the forebay and about 8 μg/l at the transition zone in 1993. Consequently, the chlorophyll *a* ratings used in the 1993 ecological health evaluation for Watts Bar Reservoir were good (i.e., falling in the 3 to 10 μg/l range) at both locations.

Forebay Secchi depth and suspended solids measurements averaged 1.5 m and 6.3 mg/l, respectively. These values indicate the light transparency of Watts Bar Reservoir forebay to be relatively high compared with other mainstem Tennessee River reservoirs in 1993.

Sediment—Chemical analyses of sediments in Watts Bar Reservoir in 1993 indicated elevated levels of un-ionized ammonia (240 μg/l) in the forebay, and the presence of chlordane (18 μg/kg) in the transition zone. Mercury was also detected at the transition zone at a slightly elevated level (0.72 mg/kg), but at a level below sediment quality guidelines for mercury (i.e. 1.0 mg/kg). Toxicity tests detected acute toxicity to daphnids and rotifers (40 percent survival each) in the forebay. The forebay was also toxic to rotifers in 1992. Particle size analysis showed sediments from the forebay were near 100 percent silt and clay; and 98 percent silt and clay from the transition zone.

Sediment quality ratings used in the overall Watts Bar Reservoir ecological health evaluation for 1993 were "poor" at the forebay (acute toxicity to test animals and presence of ammonia); and "good" at the transition zone (presence of chlordane).

Benthic Macroinvertebrates—The forebay site had a good benthic macroinvertebrate community, the transition zone fair, and both the Tennessee River and Clinch River inflow sites had poor benthic communities. The forebay on Watts Bar had 805 organisms/m^2 representing 18 taxa; the dominant species were the chironomids Chironomus sp (32 percent) and Coelotanypus tricolor (16 percent). The transition zone had 14 taxa and 1,280 organisms/2 with the snail Musculium transversum (34 percent), the mayfly Hexagenia limbata (27 percent) and the chironomid Chironomus sp (17 percent) as the dominant species present. The Tennessee River inflow site had 314 organisms/m^2 representing 20 taxa; Corbicula fluminea was the dominant species comprising 71 percent of the total organisms. The Clinch River inflow site had 145 organisms/m^2 made up of 16 taxa; Corbicula fluminea (49 percent), Pseudochironomus sp (18 percent) and Tubificidae (18 percent), were the dominant taxa.

The Watts Bar forebay scored well on all metrics except for the paucity of EPT taxa and the preponderance of chironomids. Those two factors kept this site from obtaining an excellent rating. The transition zone exhibited a fair community. Reduced diversity, minimal numbers of long-lived species, above average numbers of chironomids, and unevenness associated with the dominant species all contributed to the fair rating this site received. The Tennessee River and Clinch River inflow sites both had a poor benthic communities because of the lack of diversity, EPT taxa, and long-lived species. The unevenness of dominant taxa also negatively impacted these benthic communities. Interestingly, the percent of the total organisms comprised of tubificids and chironomids, normally considered tolerant organisms, was relatively low at both inflows.

Aquatic Macrophytes—Aquatic plants have declined from about 700 acres in the late 1980's to an estimated 10 acres in 1993. Eurasian watermilfoil and spinyleaf naiad were the dominant species prior to the recent decline.

Fish Community—Shoreline electrofishing (60 transects) and offshore gill netting (39 net-nights) sampled a total of 5,174 fish represented by 50 species. Three species made up the majority of the overall sample: gizzard shad (37 percent), bluegill (13 percent), and emerald shiners (12 percent). Electrofishing results showed catch rates to be similar in the Clinch River inflow (CPUE=51 per 300m transect), Tennessee River inflow (CPUE=53 per 300m transect), and forebay (CPUE=56 per 300m transect) but much higher at the transition zone (CPUE=129 per 300m transect). The higher catch rate in the transition was attributed mainly to abundance of emerald shiners and bluegill. Threadfin shad YOY catch rates were moderate in all sample zones except the Tennessee River inflow which was considered high. Gill netting catch rates were much the same in all four sample areas.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) good in the transition (RFAI=48), fair in the forebay (RFAI=34) and Tennessee River inflow (RFAI=34), and poor in the Clinch River inflow (RFAI=30). The lower Clinch River inflow rating (compared to the Tennessee River inflow) resulted from slightly fewer numbers of sunfish and intolerant species. The gill netting RFAI rated both the transition zone (RFAI=38) and forebay (RFAI=32) fair. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples.

Combined electrofishing and gill netting RFAI scores for the forebay (RFAI=33) received a fair rating, followed by the transition (RFAI=43) zones which was rated good. Electrofishing RFAI scores for the Tennessee (RFAI=34) and Clinch River (RFAI=30) inflow zones were rated fair and poor, respectively.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Fourteen swimming areas were tested for fecal coliform bacteria 12 times each in 1993. Only one sample at each site was collected within 48 hours of a rainfall of at least one-half inch. Bacteria concentrations were generally higher after rainfall. If the one rainfall sample is excluded, all sites met Tennessee's water quality criteria for geometric mean concentration. However, four sites had one or more concentrations to exceed 1000/100 ml, Tennessee's maximum concentration for one sample. Only three of the fourteen areas had very low geometric mean concentrations for all samples (<20/100 ml), a much lower ratio than the other Tennessee River Reservoirs. All monthly fecal coliform bacteria samples taken at the two Vital Signs locations were <10/100 ml.

Fish Tissue—Fish from Watts Bar Reservoir have been under intensive investigation for several years because of PCB contamination. TDEC has issued an advisory warning the public to avoid eating certain species and to limit consumption of other species. Four of these species (channel catfish, striped bass including striped bass/white bass hybrids, sauger, and white bass) were reexamined in autumn in 1992. Average PCB concentrations among sample sites ranged from 0.4 to 1.9 μg/g for channel catfish (five sites), 1.0 to 1.1 μg/g for striped bass (two sites), 0.2 to 0.6 μg/g for sauger (three sites), and the average for white bass at the single location was 0.7 μg/g. Additional data for channel catfish and striped bass collected in autumn 1992 will be available in the future from studies conducted for DOE study. This is also true for additional fish collected for TVA studies in autumn 1993.

Fort Loudoun Reservoir

Summary of 1993 Conditions - Ecological Health

Water—Temperature and dissolved oxygen (DO) data show the establishment of stratification (both a thermocline and oxycline) in Fort Loudoun Reservoir which persisted throughout most of the summer (April through September) of 1993. Summer surface water temperatures were warmest in July and coolest in April. They ranged from a maximum of 29.3°C to a minimum of 15.8°C at the forebay; and from 30.4°C to 15.5°C at the transition zone. Surface to bottom temperatures differentials (ΔT's) exceeded 5°C each month from April through August at the forebay and from May through July at the transition zone. Maximum thermal stratification occurred in July when ΔT's were 9.6°C at the forebay, and 10.2°C at the transition zone.

In Fort Loudoun Reservoir in 1993, DO at the 1.5m depth ranged from a high of 14.5 mg/l in May (algal bloom) to a low of 5.4 mg/l in September at the forebay; and from 12.6 mg/l to 5.4 mg/l (for the same months) at the transition zone. The minimum DO observed in Fort Loudoun Reservoir in 1993 was 2.5 mg/l at the bottom of the forebay during September. Maximum surface to bottom dissolved oxygen differentials (DO's) exceeded 5 mg/l each month, May through August, at the forebay; and, exceeded 4 mg/l April through June at the transition zone, with a minimum bottom DO of 4.9 mg/l in September. DO ratings used in the overall reservoir ecological health evaluation for Fort Loudoun Reservoir were excellent at both the forebay and the transition zone.

Summer values of pH ranged from 6.9 to 9.4 in Fort Loudoun Reservoir in 1993. At the forebay, near surface pH values exceeding 8.5 (ranged from 8.8 to 9.3), and DO saturation values exceeding 120 percent (ranged from 121% to 163%) were measured each month from April through August indicating substantial photosynthetic activity. During May, June, and July, a similar pattern of high pH's (range 8.6 to 9.4) and high DO saturations (range 132% to 161%) was observed at the transition zone. Tennessee's maximum pH criteria for the protection of fish and aquatic life is 8.5.

Conductivity ranged from 107 to 221 µmhos/cm, averaging about 185 µmhos/cm at the forebay and 200 µmhos/cm at the transition zone. The slightly lower conductivities measured at the forebay were caused by the mixing of the soft water inflows from the Little Tennessee River, via the Tellico Reservoir canal with the harder water of the Tennessee River. During the summer, the water in the forebay of Tellico Reservoir is often cooler (1993 average summer forebay temperature was 16.5C) than the water in the forebay of Fort Loudoun Reservoir (1993 average summer forebay temperature was 20.6C). During hydro-electric power generation, water from Tellico Reservoir forebay is pulled into Ft Loudoun forebay and being cooler (higher density) flows under the warmer water of Fort Loudoun Reservoir. For example, in Fort Loudoun forebay in September 1993, surface conductivity was approximately 200 µmhos/cm and near bottom conductivity was about 115 µmhos/cm (i.e. lower conductivity because of the addition of cooler, lower conductivity water from Tellico Reservoir). At the same time, this cooler, epilimnetic water from Tellico Reservoir has higher DO's than the bottom water in the forebay of Fort Loudoun Reservoir, resulting in improved hypolimnetic DO's in Fort Loudoun's forebay, and improved DO's in the releases from Fort Loudoun dam.

Nutrient concentrations (total nitrogen and total phosphorus) have historically (1990-1993) been high at both the forebay and the transition zone. The average nitrite plus nitrate-nitrogen concentrations of

0.34 mg/l (forebay) and 0.43 mg/l (transition zone); and the average total nitrogen concentrations of 0.60 mg/l (forebay) and 0.71 mg/l (transition zone) were the highest average concentrations of these nutrients measured in 1993 at any of the Tennessee River Vital Signs Monitoring locations. These high concentrations of nitrogen are due to a combination of the effect of wastewater discharges in the Knoxville metropolitan area and the inflows to Fort Loudoun Reservoir from the Holston and French Broad Rivers, which have relatively high nitrogen concentrations.

The transition zone area of Fort Loudoun Reservoir has historically had lower water clarity than any of the other Tennessee River Vital Signs sampling sites. In 1993, total suspended solids (TSS) averaged 13.4 mg/l, while Secchi depths averaged less than 1 meter. One final interesting piece of data was the high fecal coliform concentrations, with no antecedent rainfall, measured at both the forebay and transition zone sampling sites in April (greater than 600 fecal coliform (FC) colonies per 100 ml of water), which may indicate municipal wastewater treatment interruptions in the Knoxville area. On no other occasion throughout the summer did fecal coliform concentrations exceed 5 F°C colonies/100 ml.

The highest chlorophyll *a* concentrations in the forebay occurred in April (24 μg/l) and in the transition zone in May (19 μg/l). Surface concentrations of chlorophyll *a* averaged about 14.7 μg/l and 13.7 μg/l, at the forebay and transition zone, respectively, among the highest measured at Tennessee River sampling sites in 1993. The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Fort Loudoun Reservoir were fair (i.e., falling in the 10 to 15 μg/l range), at both locations; just below the level considered poor (i.e. greater than 15 μg/l).

Sediment—As 1990-1992, chemical analyses of sediments in 1993 from Fort Loudoun Reservoir indicated high levels of zinc (300 mg/kg) in both forebay and in transition zone samples. Chlordane was also detected in sediment at both the forebay (12 μg/kg) and the transition zone (27 μg/kg). Toxicity tests detected acute toxicity to daphnids (55 percent survival) in the forebay. Particle size analysis showed sediments from the forebay and the transition zone were 99 percent silt and clay.

Sediment quality ratings used in the overall Fort Loudoun Reservoir ecological health evaluation for 1993 were poor at the forebay (acute toxicity to test animals and presence of chlordane and zinc); and good at the transition zone (presence of chlordane and zinc).

Benthic Macroinvertebrates—In 1993, the benthic macroinvertebrate sampling showed fair communities in the forebay and transition zone, and a very poor community in the inflow. The forebay benthic community improved and the inflow benthic community declined from 1992. The forebay site on Fort Loudoun had 1,178 organisms/m^2 representing 15 taxa; Chironomus (45 percent) and Tubificidae (26 percent) were the dominant organisms. The transition zone had fewer total organisms (987 organisms/m^2) but greater taxa richness (22 total taxa) than the forebay site. The transition zone benthic community this year was more diverse and abundant than the 1992 community. Tubificidae (27 percent) and the chironomids Chironomus sp (23 percent) and Procladius sp (24 percent) were the most abundant taxa. The inflow macroinvertebrate community had 747 organisms/m^2 and 18 taxa. Polypedilum sp comprised 31 percent of the sample, and Tubificidae and Corbicula fluminea comprised 24 percent of the total each.

The Fort Loudoun forebay benthic community rating was negatively impacted by the abundance of chironomids and the lack of EPT taxa. This was balanced by the positive influence of a diverse assemblage with evenness among the dominant taxa, allowing this site to achieve an overall fair rating. The benthic community at the transition zone was negatively impacted by the shortage of long-lived taxa and the abundance of chironomids. This was off-set by the taxa richness and evenness of dominant species observed at the site, resulting in a fair rating. The inflow site on Fort Loudoun had a very poor benthic community in 1993 because of low diversity, a shortage of EPT and long-lived taxa, and an overabundance of the dominant species.

Aquatic Macrophytes—Aquatic plants on Ft. Loudoun Reservoir were primarily upstream of TRM 635. An estimated 25 acres of aquatic plants were present in 1993. Coverage over the past decade has ranged from 25 to 140 acres, and Eurasian watermilfoil has been the dominant species.

Fish Community—Fish samples from the littoral (45 electrofishing transects) and profundal areas (34 net-nights) of Fort Loudoun Reservoir produced 3,211 individuals, representing 40 species. The most abundant taxa was gizzard shad which accounted for 42 percent of the total number collected. Other abundant species included bluegill (11 percent), yellow bass (10 percent), largemouth bass (9 percent), and carp (7 percent). Electrofishing results indicated total numbers of fish were approximately the same in the forebay (907) and transition zones (1,027). Considerably lower numbers in the inflow zone (420) were due to reduced catch of gizzard shad, bluegill, and largemouth bass. Very high numbers of YOY threadfin shad were collected by electrofishing in both the transition (CPUE=7,775 per 300m transect) and forebay (CPUE=7,953 per 300m transect) zones of Fort Loudoun Reservoir. Gill netting catch rate decreased from 37 fish per net night in the forebay to 30 and 6 in the transition and inflow zones, respectively.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) very poor in the transition zone (RFAI=14) and poor in the forebay (RFAI=24) and inflow zones (RFAI=26). The transition RFAI of 14, which was the lowest score ever observed in TVA reservoirs, resulted from the lowest possible score for all metrics except percent anomalies. The gill netting RFAI rated the transition (RFAI=36) and forebay (RFAI=36) both fair. High metric scores were observed at both areas for percent of tolerant and omnivorous species, and percent anomalies, with low scores for intolerant and lithophilic spawning species. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples. Combined electrofishing and gill netting RFAI scores for the forebay (RFAI=30) and transition (RFAI=25) zones and the electrofishing RFAI for the inflow (RFAI=26) were all rated poor, resulting in the poorest fish community conditions in TVA run-of-the-river reservoirs.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—One boat ramp was tested for fecal coliform bacteria in 1993. Fecal coliform concentrations met Tennessee's bacteriological criteria for water contact recreation. The only fecal coliform bacteria concentrations in the monthly Vital Signs monitoring >10/100 ml were the April samples. Concentrations were >600/100 ml at both stations.

Fish Tissue—The sample site for the PCB trend study is near the transition zone at TRM 625. Ten channel catfish were collected there in autumn 1992. Concentrations in 1992 were higher than had been found in 1990 (average of 1.0 g/g and range of 0.3 to 1.9 g/g) but lower than in 1991 (average of 2.5 g/g and range 1.4 to 4.6 g/g). The 1992 samples had an average of 1.8 g/g and ranged from <0.1 to 4.2 g/g).

Melton Hill Reservoir

Summary of 1993 Conditions - Ecological Health

Water—In the summer of 1993, thermal stratification began to develop in May and persisted through September at both the forebay and the transition zone in Melton Hill Reservoir. Temperature differentials (ΔT's) exceeding 10°C between the water surface and the bottom were found each month at the forebay from May through August; and each month at the transition zone from May through July. This fairly strong thermal stratification of Melton Hill Reservoir is enhanced by the upstream release of cool water from Norris Dam, which during the summer flows along the bottom of Melton Hill Reservoir. Surface water temperatures were warmest in July and coolest in April. They ranged from a high of 29.7°C to a low of 11.5°C at the forebay; and from 28.8°C to 10.9°C at the transition zone. In the late summer the release of cool water from Norris Dam into the upstream end of Melton Hill Reservoir and the solar warming as the water moves downstream into the forebay often results in water surface temperatures being 4-5°C cooler at the transition zone than at the forebay. In 1993, the average summer water temperatures in Melton Hill Reservoir (16.7°C at the forebay and 16.5°C at the transition zone) were lower than all other run-of-the-river sampling sites except at Tellico Reservoir forebay.

In spite of the thermal stratification, little oxygen stratification and no hypolimnetic anoxia were found in Melton Hill Reservoir in 1993. Minimum DO's measured in the summer of 1993 were 4.3 mg/l on the bottom at the forebay in July; and 6.5 mg/l on the bottom at the transition zone in September. DO's at the 1.5m depth in Melton Hill Reservoir in the summer of 1993, ranged from a high of 11.5 mg/l in May and June to a low of 9.3 mg/l in September at the forebay; and from 10.8 mg/l in April to 7.6 mg/l in September at the transition zone. Average summer DO's (= 9.1 mg/l) and percent oxygen saturation values (= 92 percent) were higher at the Melton Hill transition zone than any other reservoir Vital Signs sampling site in 1993. DO ratings used in the overall reservoir ecological health evaluation for Melton Hill Reservoir were excellent at both the forebay and the transition zone.

The Clinch River flows through the Valley and Ridge physiographic province, a region underlain by large amounts of limestone and dolomite. Consequently, Melton Hill Reservoir has relatively high pH and conductance; in fact, the highest among the run-of-the-river reservoirs. In the summer of 1993, pH ranged from 7.3 to 8.8 and conductivity ranged from 223 to 272 µmhos/cm and averaged about 255 µmhos/cm in Melton Hill Reservoir. At the forebay, near surface water pH's exceeded 8.5 each month from May through August, coincident with DO super-saturation values (>110%), and indicative of photosynthetic activity. Tennessee's maximum pH criteria for the protection of fish and aquatic life is 8.5.

Average nitrite plus nitrate-nitrogen concentrations were quite high in Melton Hill Reservoir. As in past years, the 1993 average concentration at the transition zone (0.56 mg/l) was the highest nitrite plus nitrate-nitrogen among all Vital Signs locations sampled.

Dissolved ortho phosphorus concentrations (the only form of phosphorus assimilated by algal cells) averaged only about 0.003-0.004 mg/l at the forebay and transition zone, respectively, among the lowest measured at run-of-the-river sampling sites in 1993. Further, TN/TP ratios were often high (>50) indicating frequent episodes of phosphorus limitation to algal productivity in Melton Hill Reservoir. Consequently, average summer chlorophyll *a* concentrations of 5.3 µg/l at the forebay and 4 µg/l at the transition zone, may reflect a limiting nutrient effect. The highest chlorophyll *a* concentrations measured were 6-7 µg/l at both the transition zone and the forebay. The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Melton Hill Reservoir were "good" (i.e., falling in the 3 to 10 µg/l range), at both locations; just above the level considered fair (i.e., less than 3 µg/l).

The water clarity (Secchi depth, suspended solids, color, etc.) of Melton Hill Reservoir was comparatively high and measurements were generally stable throughout the year, being largely influenced by discharges from Norris Dam rather than localized rainfall runoff events.

Sediment—Chemical analyses of sediments in Melton Hill Reservoir in 1993 indicated the presence of chlordane in one of two forebay samples (25 µg/kg) and also in the transition zone (32 µg/kg) sample. Toxicity tests detected no acute toxicity to the two organisms tested. Particle size analysis showed sediment in the forebay were 99 percent silt and clay and from the transition zone were 90 percent silt and clay.

Sediment quality ratings used in the overall Melton Hill Reservoir ecological health evaluation for 1993 were "good" at both the forebay and the transition zone (presence of chlordane).

Benthic Macroinvertebrates—The 1993 benthic communities at all three sites on Melton Hill declined from 1992. The forebay and inflow had a poor benthic macroinvertebrate community and the transition zone had a very poor benthic community. Melton Hill forebay had 16 taxa and 363 organisms/m^2, a decrease in both diversity and dominance from 1992. The benthic community was dominated by Chironomus sp (49 percent) and Tubificidae 17 percent. The transition zone had 362 organisms/m^2 representing 21 taxa, predominately Tubificidae (36 percent) and Chironomus (27 percent). The inflow location had the greatest abundance (1,649 organisms/m^2) and diversity (29 taxa) of all locations sampled on Melton Hill. There was a substantial increase in diversity and density in the inflow compared to the previous year. Tubificidae (49 percent) and Paratendipes (17 percent) were the dominant organisms at this site.

Several factors contributed to the poor benthic communities found on Melton Hill Reservoir. Three factors that negatively impacted all three locations were a preponderance of chironomids, and low numbers of EPT and long-lived taxa. The problems were further compounded at the transition and inflow sites because of decreased diversity and inflated numbers of tubificids.

Aquatic Macrophytes—An estimated 240 acres of aquatic macrophytes occurred on Melton Hill Reservoir in 1993. Eurasian watermilfoil was the dominant aquatic plant and was most abundant from CRM 24 to 51. Coverage over the past decade has generally ranged from about 100 to 250 acres.

Fish Community—Electrofishing (45 transects) and gill netting efforts (34 net-nights) on Melton Hill Reservoir produced a total of 2,437 fish representing 42 species. Gizzard shad was the most numerous species (56 percent of the total number of fish sampled), followed in abundance by yellow bass (8 percent), largemouth bass (5 percent), carp (5 percent), and bluegill (4 percent). The threadfin shad YOY catch rate (CPUE=335 per 300m electrofishing transect) was moderate in the forebay zone of Melton Hill Reservoir and insignificant in the transition and inflow areas. Overall fish abundance was much the same in the forebay (1,172) and transition (1,108) zones but substantially less in the inflow (157). Fewer species were also collected from the inflow zone (16) than the forebay (28) or transition zone (36).

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) fair in the transition (RFAI=32), poor in the inflow (RFAI=22), and very poor in the forebay (RFAI=18) zones of Melton Hill Reservoir. The very poor rating in the forebay, which represented the lowest RFAI score for all run-of-the-river forebays, resulted from minimum scores for all metrics except number of sucker and intolerant species. The gill netting RFAI rated both the forebay (RFAI=38) and transition (RFAI=40) zones fair. The only extreme difference between the two zones in metric scoring resulted from higher numbers of lithophilic spawning species in the transition. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples.

Combined electrofishing and gill netting RFAI scores rated the transition zone (RFAI=36) fair. The poor RFAI's of 28 and 22 in the forebay and inflow zones, respectively, were the lowest recorded for comparable zones of run-of-the-river reservoirs in 1993. (Note: Results from biomonitoring on Melton Hill Reservoir like Tellico, were compared to results from mainstream reservoirs due to similar operational characteristics. These reservoirs lack deep drawdown which occurs in storage impoundments and have a navigation lock.)

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No bacteriological studies were conducted at recreation areas in 1993. The April fecal coliform bacteria concentrations at the Vital Signs locations were 113 and 191/100 ml at the forebay and transition zone, respectively. All other concentrations were <20/100 ml.

Fish Tissue—PCB contamination in catfish from Melton Hill Reservoir has been under study for several years. Because of this contamination, the TDEC has advised the public not to eat these catfish. TVA participates on a study team with TDEC, TWRA, and ORNL to investigate PCBs and other contaminants in fish from east Tennessee Reservoirs. In 1992 ORNL collected and analyzed channel catfish from the forebay, while channel catfish from near the transition zone and inflow were collected and analyzed by TVA. Average PCB concentrations from these same locations were 0.8, 1.0, and 0.5 μg/g, respectively, and average chlordane concentrations were 0.07, 0.10, and 0.05 μg/g, respectively.

Emory River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Emory River is soft (average hardness of 24 mg/l) and slightly alkaline (average total alkalinity of 16 mg/l). The median pH for the stream monitoring site was 7.5. The river was well oxygenated with dissolved oxygen levels ranging from 88 to 102 percent of saturation.

Of the 12 stations monitored in the Tennessee Valley, the Emory River had the lowest concentrations of nitrate+nitrite-nitrogen (0.10 mg/l), total phosphorus (0.020 mg/l), and dissolved orthophosphate (0.002 mg/l). The low organic nitrogen (0.195 mg/l) and ammonia nitrogen (0.002 mg/l) concentrations were in the lower third of all stations. The good total phosphorus and nitrate+nitrite-nitrogen concentrations, in particular, contributed to a good nutrient rating for the station.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total copper and zinc) were performed bi-monthly. Dissolved cadmium (5 of 6 samples), dissolved nickel (2 of 6 samples) and zinc were detected. All were within EPA guidelines for the protection of aquatic life and human health.

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines. This is a significant improvement over 1992 when sediment quality rated poor.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate community rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 39, with 102 taxa and 4,308 organisms/m^2. Conditions in 1992 also rated fair (MBIBI score 38) with 77 taxa and 3,137 organisms/m^2. Benthic organisms have essentially remained unchanged between sampling years with the exception of a 25 percent increase in total taxa reported in the qualitative sample. Dominant organisms in 1993 were dipteran midge larvae (62 percent), coleopteran riffle beetles (13 percent), and caddisflies (10 percent). Dipteran midge larvae was also the most dominant organism in 1992 (56 percent), followed by caddisflies (14 percent) and mayflies (12 percent). Siltation from coal mining practices in the Emory River watershed are a continuing problem for benthic organisms at this site.

Fish Community Assessment—The fish community rated good with an Index of Biotic Integrity (IBI) score of 52, improving from the borderline good (IBI = 46) rated in 1992. The 1993 fish sample contained no hybrids and fewer diseased fish, and had a slightly increased fish density suggesting less stressful conditions for fish since 1992. Minor problems, however, continued to be seen in species composition and trophic structure. A contributing factor of stress on fish at this station is naturally-occurring low flow (usually less than 50 cfs) during mid to late summer. Low flow reduces fish habitat, reduces the river's ability to assimilate pollutants, and generally makes the aquatic fauna more vulnerable to environmental degradation.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—There were no bacteriological studies conducted on the Emory River in 1993.

Fish Tissue—A five fish composite each of carp, channel catfish, and largemouth were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. Mercury was detected in all three samples but at concentrations which would not be considered elevated. Chlordane was detected at low concentrations in two samples, and PCBs were found in all samples (carp 0.4 μg/g; channel catfish 1.2 μg/g; and largemouth bass 0.6 μg/g). Additional catfish and largemouth bass were collected in summer 1993, but results were not available at the time this report was prepared.

CLINCH RIVER AND POWELL RIVER WATERSHED

Norris Reservoir

Summary of 1993 Conditions - Ecological Health

Water—Surface water temperature ranged, for the months it was measured (April-October), from 12.6°C in April to 29.8°C in July in the forebay, from 14.9°C to 30.0°C for the same months at the Clinch mid-reservoir sampling location, and from 14.6°C to 30.1°C for the same months at the Powell mid-reservoir sampling location. Thermal stratification was evident in Norris Reservoir in 1993. While this stratification was evident in April, when the first measurements for the year were made, it became much stronger beginning in May, due to drastically decreased streamflow combined with solar heating. Maximum surface to bottom water column temperature differentials occurred in July, when the surface temperatures were about 22°C warmer than bottom temperatures in the forebay, and about 19°C at the mid-reservoir sampling locations. The strong thermal stratification in Norris Reservoir persisted through October for the forebay, and through September for the mid-reservoir locations.

Dissolved oxygen at the 1.5m depth ranged from 9.7 mg/l in May to 7.4 mg/l in September at the forebay, from 10.8 mg/l in April to 7.0 mg/l in August at the Clinch mid-reservoir sampling location, and from 10.2 mg/l in May to 6.7 mg/l in October at the Powell mid-reservoir sampling location. During the summer of 1993, (as in past summers) anoxic conditions developed at all three sampling locations on Norris Reservoir. At the mid-reservoir sampling locations, dissolved oxygen concentrations near the bottom were approximately 0 mg/l in July, August, and September. Further, in August this anoxia development resulted in hypolimnetic dissolved oxygen concentrations being less than 1 mg/l over approximately two-thirds of the water column depths in the mid-reservoir sampling locations. For the forebay, anoxic conditions existed at the bottom in September and October.

DO ratings used in the overall reservoir ecological health evaluation for Norris Reservoir were poor at the forebay and very poor at the mid-reservoir sampling locations. The forebay DO rating was poor because approximately 10 percent of the cross-sectional area (six-month summertime average) of the forebay had a dissolved oxygen concentration less than 2.0 mg/l; anoxic bottom conditions existed; and, over 20% of this site's cross-sectional bottom length (six-month summertime average) had a dissolved oxygen concentration less than 2.0 mg/l. The mid-reservoir sites both received very poor ratings for dissolved oxygen because of even poorer DO conditions. At both sites over 20 percent of the cross-sectional areas (six-month summertime average) had a dissolved oxygen concentration less than 2.0 mg/l; both had anoxic bottom conditions; and both had over 50 percent of each site's cross-sectional bottom length (six-month summertime average) with dissolved oxygen concentrations less than 2.0 mg/l.

In 1993, values of pH in Norris Reservoir ranged from 7.0 to 8.7 for the three monitoring locations. Surface water pH values slightly exceeded 8.5 (Tennessee's maximum pH criteria for the protection of fish and aquatic life is 8.5) at the forebay in August, at the Clinch mid-reservoir location in June, and at the Powell mid-reservoir location in May and June. In each of these cases, dissolved oxygen saturation concentrations were high (>100 percent), which indicates substantial photosynthetic activity. The conductivity of the water in Norris Reservoir is among the highest of all the reservoirs in the Tennessee River drainage. Reservoir-wide, conductivities ranged from 172 to 382 μmhos/cm. They averaged 244 μmhos/cm at the forebay, 277 μmhos/cm at the Clinch mid-reservoir sampling location, and 295 μmhos/cm at the Powell mid-reservoir sampling location.

Concentrations of nutrients were very low, which is typical for Norris Reservoir. Average total phosphorus (TP) and dissolved ortho phosphorus (DOP) were especially low reservoir-wide. At the forebay, both TP and DOP averaged less than 0.002 mg/l and were among the lowest average total phosphorus concentrations measured in 1993. Further, TN/TP ratios for individual samples often exceeded 100 at all Norris sampling sites, which indicates extremely limiting phosphorus conditions on algal productivity in the reservoir.

Concentrations of chlorophyll *a* averaged only 1.7 μg/l at the forebay, 4.1 μg/l at the Clinch mid-reservoir sampling location, and 3.6 μg/l at the Powell location. The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Norris Reservoir were fair at the forebay (i.e. less than 3 μg/l) and good (i.e. falling in the 3 to 10 μg/l range), at both mid-reservoir locations; just above the level considered fair (i.e. less than 3 μg/l).

The water of Norris Reservoir, especially in the forebay area has historically been quite clear. However, Norris Reservoir forebay in 1993 was less clear than 1992 with an average Secchi depth of 2.5 meters. The Clinch mid-reservoir Secchi depth was slightly clearer than in 1992, averaging 2.5 meters, and the Powell was about the same, averaging 2.2 meters.

Sediment—As in 1990-92, chemical analyses of sediments in Norris Reservoir in 1993 found high levels of lead (76 mg/kg) in the forebay, and elevated levels of un-ionized ammonia in both the Clinch (375 μg/l) and Powell (370 μg/l) mid-reservoir regions. Toxicity tests detected no acute toxicity to the two organisms tested. Particle size analysis showed sediments from the forebay were about 100 percent silt and clay; from the Clinch mid-reservoir were about 95 percent silt and clay; and from the Powell mid-reservoir were 98 percent silt and clay.

Sediment quality ratings used in the overall Norris Reservoir ecological health evaluation for 1993 were good at the forebay (presence of lead); and good at both of the mid-reservoir sites (presence of ammonia).

Benthic Macroinvertebrates—Among the three reservoir monitoring locations on Norris Reservoir, the Powell River mid-reservoir site had the highest number of benthic taxa (23) and greatest density (1,887 organisms/m^2), and received the best overall benthic rating of good. The dominant taxa were Tubificidae (39 percent), Limnodrilus sp (21 percent) and Chironomus sp (22 percent). The forebay and Clinch River mid-reservoir site both had fair benthic communities. The forebay site had 16 taxa and 751 organisms/m^2; Tubificidae, the dominant taxon, comprised 56 percent of the total, followed by Corbicula fluminea (26 percent). The Clinch River mid-reservoir location had 1,214 organisms/m^2 representing 17 taxa and was dominated by Tubificidae (52 percent) and Chironomus sp (36 percent).

The Norris forebay could have achieved a good rating had it not been for the abundance of tubificids and the dearth of EPT taxa. These negative influences were offset by the abundance of long-lived taxa and low numbers of chironomids. The Powell River site, which received a good rating, scored well because of its diversity and evenness of the dominant taxa. All other metrics evaluated were fair. The Clinch River site had an average benthic community primarily because all metrics evaluated received only a fair score. The only metric that rated very low was the dominance metric; in this instance, Tubificidae comprised an overwhelmingly large percentage of the total organisms collected.

Fish Assemblage—The fish samples from the littoral (45 electrofishing transects) and profundal areas (36 net-nights) of Norris Reservoir produced a total of 1,602 individuals representing 29 species. Highest concentrations of fish were found in the Clinch River transition zone (43 percent of total fish sampled) due to the abundance of walleye in the gill netting sample (10 per net night) and black basses (smallmouth, spotted, and largemouth) in the electrofishing sample (9 per 300m transect). The forebay electrofishing catch rate (CPUE=15 per 300m transect) was the lowest recorded among all tributary reservoir forebays. The forebay gill netting catch rate (CPUE=7 per net night) was the second lowest recorded (Parksville forebay was the lowest). Twenty-five species were collected at both transition zones and 16 in the forebay.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on results of electrofishing samples) good in the Powell River transition (RFAI=46) zone and fair in both the Clinch River transition (RFAI=40) and forebay (RFAI=34) zones. The higher RFAI in the Powell River transition zone was influenced by maximum metric scores for diversity, number of piscivore, sucker, intolerant, and lithophilic spawning species, percent tolerant species and dominance by a single species. Both the Powell and Clinch rivers received gill netting RFAI values of 50 classifying them good. The forebay (RFAI=28) was poor; only one metric (percent anomalies) had a maximum score in the forebay of Norris; all other scores were either minimum or midrange. Combined electrofishing and gill netting RFAI scores for both the Clinch (RFAI=45) and Powell (RFAI=48) river transitions were rated good, followed by a fair rating in the forebay (RFAI=31).

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Two swimming beaches, one boat ramp, and one site upstream and another downstream of the Jacksboro sewage treatment plant were tested for fecal coliform bacteria twelve times each in 1993. Two samples at each site were collected within 48-hours of rainfall of at least one-half inch. Bacteria concentrations at all five sites were very low (geometric mean <20/100 ml).

Fish Tissue—Fish tissue samples for screening studies were collected on Norris Reservoir in autumn 1992. All analytes were low except for PCBs, which were highest at the forebay where the concentration was 0.9 μg/g. Concentrations at the other two locations were low. Screening samples were collected again in autumn 1993 to further evaluate PCB concentrations but results were not available at the time this report was prepared.

Clinch River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Clinch River is moderately hard (average hardness of 147 mg/l) and alkaline (average total alkalinity of 120 mg/l). The median pH for the stream monitoring site was 8.0. The river was well oxygenated with dissolved oxygen levels ranging from 81 to 106 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the Clinch River ranked among the lowest in average concentrations of ammonia nitrogen (0.015 mg/l) and dissolved orthophosphate (0.003 mg/l). It ranked just below the median in average concentrations of organic nitrogen (0.198 mg/l), nitrate+nitrite-nitrogen (0.30 mg/l), and total phosphorus (0.020 mg/l). The low concentrations of total phosphorus and nitrate+nitrite-nitrogen yielded a good nutrients rating for the station.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total copper and zinc) were performed bi-monthly. Dissolved cadmium was detected in 4 of 6 samples, but did not exceed the EPA guidelines for the protection of aquatic life and human health.

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines. This is an improvement over 1992 when sediment quality rated fair.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate results rated good with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 53, with 83 taxa and 2,726 organisms/m^2. Conditions in 1992 also rated good (MBIBI score 50) with 85 taxa and 3,326 organisms/m^2. The Clinch River is rated the best among the 12 stream monitoring sites. The benthic fauna in 1993 was composed mostly of river snails (33 percent), nutrient tolerant oligochaeta worms (16 percent), and mayflies (14 percent). Mayflies were the dominant organism in 1992 (46 percent), followed by river snails (13 percent) and coleopteran riffle beetles (9 percent). Overall, conditions remain unchanged between sampling years.

Fish Community Assessment—The fish community rated good with an Index of Biotic Integrity (IBI) of 50 in 1993, showing no change since 1992. Minor problems were seen in species composition, trophic structure, and fish condition. The fish assemblage was basically intact with a good number of native species and a healthy compliment of darter, sucker, and intolerant species. Trophic structure was good at the lower levels, as most fish found were specialized insectivores. Fish density was also at a normal level. Detrimental conditions observed at this station included occasional bank erosion and siltation.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—The weir downstream of Norris Dam and the canoe launch site downstream of the weir were tested for fecal coliform bacteria twelve times each in 1993. Two samples were collected within 48 hours of rainfall of at least one-half inch. The geometric mean of fecal coliform bacteria concentrations were very low (<20/100 ml)at both sites.

Fish Tissue—A five fish composite each of carp, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. All analytes were not detected or found in low concentrations.

Powell River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Powell River is moderately hard to hard (average hardness of 150 mg/l) and alkaline (average total alkalinity of 125 mg/l). The median pH for the stream monitoring site was 8.0. The river was well oxygenated with dissolved oxygen levels ranging from 88 to 105 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the Powell River ranked in the lower half in concentrations of nutrients. The average ammonia nitrogen concentration (0.013 mg/l) was the lowest for the network. The good average total phosphorus (0.035 mg/l) and nitrate+nitrite-nitrogen (0.47 mg/l), in particular, yielded a good rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total copper and zinc) were performed bi-monthly. Dissolved cadmium (5 of 6 samples) and dissolved nickel (1 of 6 samples) were detected. Neither metal exceeded the EPA guidelines for the protection of aquatic life or human health. Additional metals analyses included total and dissolved forms of iron and manganese. Total iron exceeded the EPA guideline for combined consumption of fish and water in one sample. Total manganese was detected in 4 of 6 samples, but none exceeded EPA guidelines.

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines. This is a significant improvement over 1992 when sediment quality rated poor.

Benthic Macroinvertebrates—In 1993, the benthic macroinvertebrate community rated good with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 47, with 94 taxa and 2,586 organisms/m^2. Conditions in 1992 rated fair (MBIBI score 42) with 66 taxa and 2,167 organisms/m^2. Dominant organisms in 1993 were dipteran midge larvae (27 percent), river snails (24 percent), and coleopteran riffle beetles (16 percent). River snails were the most dominant group in 1992 (43 percent), followed by dipteran midge larvae (24 percent) and the Asian clam Corbicula (10 percent). Overall, conditions improved from fair to good over the previous year.

Fish Community Assessment—Meaningful improvement was seen in the fish community in 1993. Ratings of good were found for both 1993 and 1992, however the Index of Biotic Integrity (IBI), on which the ratings are based, increased from 48 in 1992 to 56 in 1993 and was approaching an excellent rating. Improvement was seen in species richness and composition, trophic structure, and fish density. Only slight deficiencies in number of darter species and proportion of piscivorous fish prevented a higher rating. Accumulations of sand, coal, and gravel were observed in some pool areas, but apparently were not a major problem for the fish community.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No fecal coliform bacteria samples were collected and analyzed above the stream monitoring site.

Fish Tissue—A five fish composite each of freshwater drum, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. All analytes were not detected or found in low concentrations.

LITTLE TENNESSEE RIVER WATERSHED

Tellico Reservoir

Summary of 1993 Conditions - Ecological Health

Water—Fairly strong thermal stratification persisted from April through September 1993 at both the forebay and transition zone. From June through August, temperature differentials between the water surface and bottom equaled or exceeded 11°C at the forebay and 10°C at the transition zone. These differentials were due to a combination of atmospheric warming of surface water—intensified by the low streamflows in April and May and the intrusion of surface waters from Fort Loudoun forebay—contrasted with the inflow of cool bottom water from the releases of Chilhowee Dam upstream. Surface water temperatures ranged from lows in April to highs in July (i.e. from 16.1°C to 28.0°C at the forebay and from 16.3°C to 29.5°C at the transition zone). Water in Tellico Reservoir was relatively cool, particularly at the transition zone which was influenced by the releases from Chilhowee Dam. Summer temperatures averaged 16.5°C and 17.5°C at the forebay and transition zone, respectively, among the lowest temperatures for run-of-the-river Vital Signs sampling sites in 1993.

DO at the 1.5m depth ranged from a high of 11.4 mg/l in April to a low of 6.8 mg/l in September at the forebay; and from 10.6 mg/l to 8.1 mg/l (for the same months) at the transition zone. From June through September a persistent oxycline was present in the forebay. Differences between surface and bottom DO concentrations were 5 to 9 mg/l, and near bottom concentrations were less than 1 mg/l in August and September. This near bottom, cool, low DO water was very low in conductivity (<50 µmhos/cm). This suggests that cool water, which is fairly high in DO when it is released from Chilhowee Dam, becomes trapped in the hypolimnion of Tellico Reservoir and is slowly depleted of oxygen content during the summer. The minimum DO was 4.1 mg/l in July, on the bottom at the transition zone. DO ratings used in the overall reservoir ecological health evaluation for Tellico Reservoir were fair at the forebay (due to the hypolimnetic anoxia in August and September) and excellent at the transition zone.

The Little Tennessee River drains through the Blue Ridge physiographic province—a mountainous, largely forested region underlain, for the most part, by crystalline rocks. The upper slopes of the watershed have generally thin soils and weathered rock. In addition, the underlying rocks, broadly speaking are siliceous and not easily dissolved. Surface drainage is rapid, and consequently, the water of the Little Tennessee River (and Tellico Reservoir) are quite soft, low in pH and conductivity, and low in nutrients.

In 1993, Tellico Reservoir pH values ranged from 6.0 to 8.9. Near surface pH's exceeded 8.5 at the forebay in June and July and at the transition zone in July, coincident with DO super-saturation values indicative of photosynthetic activity. Values of pH in Tellico Reservoir were the lowest of any of the run-of-the-river Vital Signs reservoirs, averaging 7.0 at both the forebay and transition zone. Values of pH below the Tennessee minimum criterion of 6.5 for fish and aquatic life were observed in the hypolimnion of Tellico Reservoir at both the forebay and transition zone in 1993.

The conductivity of water in Tellico Reservoir was also quite low, averaging about 35 µmhos/cm at the transition zone and 65 µmhos/cm at the forebay. Mixing of forebay surface waters between Fort Loudoun and Tellico reservoirs via the inter-reservoir canal influences water quality and causes the higher measured conductivity at Tellico forebay compared with Tellico transition zone.

Total nitrogen concentrations were low and averaged only 0.33 mg/l at the forebay and 0.22 mg/l at the transition zone. Dissolved ortho phosphorus concentrations (the only form of phosphorus assimilated by algal cells) were also quite low, averaging only 0.003 mg/l at the forebay and transition zone. Together, these nutrient concentrations were among the lowest measured concentrations at Vital Signs Monitoring locations in 1993; and consequently, primary productivity could be expected to be limited much of the time.

Average summer chlorophyll *a* concentrations were 7 μg/l at the forebay and 3 μg/l at the transition zone. The highest single sample chlorophyll *a* concentrations measured in 1993 were 9 μg/l at the forebay and only 6 μg/l at the transition zone. The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Tellico Reservoir were good (i.e. falling in the 3 to 10 μg/l range), at both locations; just above the level considered fair (i.e. less than 3 μg/l).

Water clarity data (as measured by Secchi depth, suspended solids, color, etc.) was comparatively high with little relative variation throughout the year. This is because inflows to Tellico Reservoir are primarily a result of Chilhowee Dam discharges which are of high clarity and low color, rather than rainfall runoff events.

Sediment—Samples for toxicity testing and chemical analyses were collected at three sites in Tellico Reservoir in 1993: the forebay (LTRM 1.0); and two transition zone locations (LTRM 15.0, downstream of the confluence of the Tellico River, and LTRM 21.0, upstream of the confluence of the Tellico River). Chemical analyses of sediments in Tellico Reservoir in 1993 indicated the presence of chlordane in the forebay (21 μg/kg) and in one of two transition zone (LTRM 15.0) samples (16 μg/kg). Toxicity tests detected acute toxicity to daphnids (0 percent survival) at all sampling sites tested; however, for the first time since 1990, toxicity to rotifers was not detected. Particle size analysis showed sediments from the forebay were about 97 percent silt and clay; from LTRM 15.0 transition zone were 91 percent silt and clay; and from LTRM 21.0 transition zone were about 66 percent silt and clay, 34 percent sand.

Sediment quality ratings used in the overall Tellico Reservoir ecological health evaluation for 1993 were poor at the forebay (acute toxicity to test animals and presence of chlordane); poor at the transition zone site-LTRM 15.0 (acute toxicity to test animals and presence of chlordane). Information from the transition zone site at LTRM 21.0 was not included in the overall ecological health rating.

Benthic Macroinvertebrates—The benthic community in Tellico Reservoir in 1993 rated poor at both the forebay and transition zone. The forebay zone had 17 taxa and 433 organisms/m^2 dominated by Tubificidae (65 percent of the total), which is very similar to the benthic community observed the previous year. The transition zone had 13 taxa and 320 organisms/m^2. As in 1992, Tubificidae was the dominant taxon (28 percent) and the chironomid Zalutschia zalutschicoia was the second most abundant (18 percent).

Reduced diversity, few EPT taxa, and an abundance of tubificids resulted in the forebay and transition zone communities receiving poor ratings were . The transition zone was further impacted because relatively few long-lived taxa were present.

Aquatic Macrophytes—The 246 acres of aquatic macrophytes on Tellico Reservoir were most abundant in the Tellico River portion (between miles 1 and 13) of the reservoir and along the Little

Tennessee River portion from LTRM 9 to 15. Eurasian watermilfoil was the dominant submersed macrophyte on Tellico Reservoir.

Fish Assemblage—Electrofishing (30 transects) and gill netting samples (24 net-nights) in the transition zone and forebay produced 1,498 individuals of 36 species. More fish (66 percent) as well as more species (31 compared to 29) were found in the forebay than in the transition zone. Gizzard shad comprised 37 percent of the total sample, followed by spotfin shiners, bluegill, and the black basses (smallmouth, spotted, and largemouth) all at 9 percent. Electrofishing and gill netting results indicated most species were present in higher numbers in the forebay than the transition zone. Walleye and sauger were more numerous in 1993 than in previous years, which may be of interest to sport anglers in the future.

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on electrofishing results) fair in both the forebay (RFAI=34) and transition (RFAI=38) zones. All metric scores for both zones were identical with the exception of percent tolerant and omnivorous species which received higher scores in the transition. Gill netting RFAI's rated the forebay (RFAI=34) fair and the transition (RFAI=22) poor, due primarily to lower scores for the number of species, number of sucker, intolerant, lithophilic spawning species, and percent anomalies and dominance by a single species. Gill netting RFAI values were not calculated for inflow zones of run-of-the-river reservoirs due to low numbers of replicate samples.

Combined electrofishing and gill netting RFAI scores rated the forebay (RFAI=34) fair and the transition (RFAI=30) zone poor. The RFAI rating of poor in the transition resulted from a low gill netting RFAI (22) which was the lowest score observed for run-of-the-river reservoirs in 1993. (Note: Results from biomonitoring on Tellico Reservoir were compared to results from mainstream reservoirs because of the lack of a deep drawdown as occurs in storage impoundments and the presence of a navigation lock allowing recruitment of fish species.)

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No bacteriological studies were conducted at recreation sites in 1993. Fecal coliform bacteria concentrations were very low (geometric mean <20/100 ml) at the Vital Signs stations. The highest individual concentrations were April samples, 114 and 54/100 ml, at the forebay and transition zone, respectively.

Fish Tissue—An advisory not to eat catfish from Tellico Reservoir has been in effect for several years. Documentation of the PCB problem in what was thought to be a background study in 1985 came as a surprise because there was basically no industrial development in the watershed. Subsequently, more intensive studies supported the initial results and showed very little change in concentrations during the late 1980s. Several attempts at locating potential sources were fruitless and the source remains unknown. A less intensive sampling effort was begun in autumn 1990. Since then one composite of five channel catfish has been collected annually from the forebay and one from an area about 10 miles upstream (several miles downstream of the transition zone) to continue examination of the temporal trend in PCB concentrations.

Channel catfish samples collected in autumn 1992 had relatively high PCB concentrations - 2.7 µg/g at the forebay and 1.9 µg/g at the mid-reservoir location. Chlordane concentrations were also relatively high - 0.22 and 0.20 µg/g, respectively. Other organics were either not detected or found in very low concentrations. Arsenic, cadmium, lead, and selenium were not detected in either sample. Mercury concentrations were relatively high - 0.65 and 0.36 µg/g at the forebay and mid-reservoir locations. Due to these high concentrations of mercury, largemouth bass were collected along with channel catfish in autumn 1993; results were not available at the time this report was prepared.

Fontana Reservoir

Summary of Conditions in 1993 - Ecological Health

Water—Average flow through Fontana Reservoir in 1993 was about 107 percent of normal, with an average residence time of 174 days. Fontana Reservoir was strongly stratified, with a maximum temperature difference in the water column at the forebay of 21.8°C in July, and remaining 14.3°C in October. Due to the fall drawdown, the two mid-reservoir sampling locations were weakly stratified in September and mixed in October. Maximum surface temperatures were 27.8°C at the forebay, 29.8°C at the Little Tennessee River mid-reservoir station, and 29.0°C at the Tuckasegee River mid-reservoir station. The maximum temperatures were in July. North Carolina's standard for maximum temperature of Class°C waters is 29°C. Depleted DO (<2.0 mg/l) only developed at the forebay at depths of over 100 meters in September and October. Depleted DO conditions also occurred at the Tuckasegee River mid-reservoir station in August and September, but not in the Little Tennessee River mid-reservoir station. The DO rating in the reservoir ecological health index was good for the forebay and Little Tennessee River mid-reservoir sites and poor for the Tuckasegee site.

Conductivities were generally in the 20 to 30 μmhos/cm range, the second lowest of the tributary reservoirs, with little stratification except for late summer when a maximum conductivity of 39 μmhos/cm occurred. The minimum pH was 6.0 at all three sites, the maximum was 8.8 in June at the Little Tennessee River mid-reservoir station.

Total nitrogen concentrations at the three stations were the third, fourth, and fifth lowest concentrations of the 33 tributary reservoir stations. Total nitrogen concentrations at the three sites averaged 0.21 mg/l in April, mostly as nitrates, and 0.07 mg/l in August, mostly as organic nitrogen. Total phosphorus concentrations were 0.01 mg/l at both mid-reservoir locations and 0.003 mg/l at the forebay in April, and dropped to an average of 0.003 mg/l at the three locations in August. Total phosphorus concentrations at the forebay were the lowest concentrations of the tributary reservoir stations. Total organic carbon concentrations averaged 0.8 mg/l in April and 1.4 mg/l in August, with little variation between locations. Chlorophyll *a* concentrations averaged 1.4 μg/l at the forebay, and 2.7 and 2.4 μg/l at the Little Tennessee and Tuckasegee River mid-reservoir locations, respectively. These were the fourth, fifth, and sixth lowest concentrations of the tributary reservoir stations, and were within the range considered fair. Secchi depths at the mid-reservoir stations varied from 2.1 meters in April to 4.9 meters in June, both in the Tuckasegee River. The water at the forebay was the clearest of all tributary reservoir stations, ranging from 5.1 meters in September to 8.1 meters in June.

Sediment—Chemical analyses and toxicity testing of sediments were conducted on sediment samples collected at three locations in Fontana Reservoir in 1993: a forebay site (LTRM 62.0); a mid-reservoir site on the Tuckasegee River (TkRM 3.0) arm; and, a mid-reservoir site on the Little Tennessee River (LTRM 81.5) arm. The presence of chlordane was detected in the forebay (12 μg/kg) and in the Tuckasegee River mid-reservoir region (14 μg/kg). Toxicity tests detected acute toxicity to daphnids (60 percent survival) and rotifers (55 percent survival) in the forebay. Particle size analysis showed sediments in the forebay were 75 percent silt and clay, 25 percent sand; in the Little Tennessee River mid-reservoir were 94 percent silt and clay; and in the Tuckasegee River mid-reservoir were 76 percent silt and clay, 24 percent sand.

Sediment quality ratings used in the overall Fontana Reservoir ecological health evaluation for 1993 were poor at the forebay (presence of chlordane and toxicity to test animals); good at the Tuckasegee mid-reservoir site (presence of chlordane); and excellent at the Little Tennessee mid-reservoir site.

Benthic Macroinvertebrates—The first year that the benthic macroinvertebrate community was evaluated on Fontana Reservoir was 1993. The benthic community at the forebay site rated very poor, the Tuckasegee River mid-reservoir site rated poor, and the Little Tennessee River mid-reservoir site rated fair. The forebay had 1,040 organisms/m^2 representing 4 taxa. The Tuckasegee site had 15 taxa and by far the greatest density of all three sites sampled (6,328 organisms/m^2). The Little Tennessee mid-reservoir site had the greatest diversity of the three sites, with 23 taxa and 3,753 organisms/m^2. The dominant taxon at all three sites was Tubificidae, accounting for 90 percent of the total at the forebay and Tuskasegee inflow, and 77 percent of the total at the Little Tennessee River inflow.

The three sites sampled on Fontana Reservoir had several common problems: an absence of long-lived taxa, an absence of EPT taxa, and an abundance of tubificids. It is also worthy to note that a common observation at all three locations on Fontana was low numbers of chironomids. In addition to the above elements, the forebay benthic community was further impacted by very low diversity. The Little Tennessee mid-reservoir site had greater diversity and fewer tubificids than the other two sites which allowed it to receive the best overall benthic rating.

Fish Assemblage—Shoreline electrofishing (45 transects) and offshore experimental gill netting (36 net-nights) yielded 1782 individuals with 22 species represented. Green sunfish and smallmouth bass were the most abundant species collected, comprising 39 and 16 percent of the total sample, respectively. Bluegill (7 percent) and white bass (7 percent) were also frequently encountered. Catch rates for both gill netting and electrofishing were approximately the same for all three sample areas (forebay, Little Tennessee River transition, and the Tuckasegee River transition).

The Reservoir Fish Assemblage Index (RFAI) rated the littoral fish community (based on electrofishing results) poor in all three sample areas (forebay RFAI=28, Little Tennessee River transition RFAI=28, and Tuckasegee River transition RFAI=22) of Fontana Reservoir. All electrofishing metrics received low to moderate scores except for percent omnivores and insectivores. Gill netting RFAI results rated the forebay zone (RFAI=36) fair, and both the Little Tennessee River transition (RFAI=42) and the Tuckasegee River transition (RFAI=48) zones good. Combined electrofishing and gill netting RFAI scores rated all three zones of Fontana Reservoir fair.

Summary of Conditions in 1993 - Use Suitability

Fecal Coliform Bacteria—There were no bacteriological studies conducted on Fontana Reservoir in 1993.

Fish Tissue—Five channel catfish were collected in autumn 1992 from both the forebay and mid-reservoir site on the Little Tennessee River. Fillets were composited by area and analyzed for selected metals, pesticides, and PCBs on EPA's priority pollutant list. Most analytes were not detected or had low concentrations. Exceptions to this were mercury at both locations (0.40 μg/g at the forebay and 0.53 μg/g at the mid-reservoir site), and PCBs at the forebay (1.1 μg/g). PCBs were not detected in the sample from the mid-reservoir site. Channel catfish were collected again in 1993 from both locations and analyzed for the same analytes with close attention for PCBs at the forebay. Largemouth bass were also collected in autumn 1993 from both locations to further examine mercury concentrations. Results were not available at the time this report was prepared.

Little Tennessee River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Little Tennessee River is soft (average hardness of 7 mg/l) and slightly alkaline (average total alkalinity of 10 mg/l). The median pH for the stream monitoring site was 7.5. The river was well oxygenated with dissolved oxygen levels ranging from 95 to 110 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the Little Tennessee River ranked among the lowest in average concentrations of organic nitrogen (0.188 mg/l), nitrate+nitrite-nitrogen (0.14 mg/l), total phosphorus (0.030 mg/l), and dissolved orthophosphate (0.006 mg/l). The highest average concentration of ammonia nitrogen (0.138 mg/l) was found at this site. The good total phosphorus and nitrate+nitrite-nitrogen concentrations yielded a good rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total and dissolved copper and zinc) were performed bi-monthly. Dissolved cadmium was detected in 4 of 6 samples. Three of the samples exceeded the EPA guidelines for both chronic and acute toxicity to aquatic life. Another sample exceeded the guideline for chronic toxicity. Dissolved lead exceeded the guideline for chronic toxicity. (Chronic toxicity bioassays are not routinely performed at stream monitoring sites. As seen below, there was no acute toxicity testing apparent in these samples.)

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrate results were rated good with a Modified Benthic Index of Biotic Integrity (MBIBI) of score 44, with 92 taxa and 11,086 organisms/m^2. Conditions in 1992 also rated good (MBIBI score 46) with 84 taxa and 9,079 organisms/m^2. Dominant organisms in 1993 were dipteran midge larvae (54 percent), nutrient tolerant oligochaete worms (15 percent), and caddisflies (9 percent). Mayflies were the most dominant group in 1992 (27 percent), followed by dipteran midge larvae (23 percent) and caddisflies (19 percent). Conditions have essentially remained unchanged between sampling years; however, an increase was noted in the numbers of silt and nutrient tolerant organisms.

Fish Community Assessment—The fish community rated excellent with an Index of Biotic Integrity (IBI) of 58 and showed little change since rating borderline good (IBI = 56) in 1992. With the exception of low fish density (catch rate), measures of the fish community indicated nearly optimum conditions. Siltation, however, was conspicuous and is suspected of effecting low fish density at this station.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No studies conducted in 1993.

Fish Tissue—A five fish composite each of river redhorse, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. All analytes were either not detected or found in low concentrations.

FRENCH BROAD RIVER WATERSHED

Douglas Reservoir

Summary of 1993 Conditions - Ecological Health

Water—During the summer of 1993, surface water temperatures ranged from 13.4°C in April to 28.5°C in July at the forebay, and from 15.4°C to 30.2°C (for the same months) at the mid-reservoir sampling location. Some thermal stratification was observed beginning in May at both the forebay and mid-reservoir locations, and was strongest in July when the temperature differentials between the bottom and the surface were 15.1°C at the forebay, and 12.1°C at the mid-reservoir location. This stratification existed through August at the mid-reservoir location, and through September at the forebay.

Dissolved oxygen at the 1.5m depth ranged from 12.5 mg/l in May to 4.6 mg/l in October at the forebay, and from 11.8 mg/l in May to 5.5 mg/l in September at the mid-reservoir location. (The State of Tennessee's minimum dissolved oxygen criteria for the protection of fish and aquatic life is 5 mg/l, at the 1.5m depth.) Anoxic conditions near the bottom existed from June through September at the forebay, and from June through August at mid-reservoir. This hypolimnetic anoxia peaked at the forebay in August and at the mid-reservoir in July. In each case, about two-thirds of the water column had dissolved oxygen concentrations of less than 1 mg/l. The forebay and mid-reservoir sampling sites had, respectively, about 30% and 20% of their cross-sectional areas (six-month summertime average) with dissolved oxygen concentration less than 2.0 mg/l; and, over 60% of each site's cross-sectional bottom length (six-month summertime average) had a dissolved oxygen concentration less than 2.0 mg/l. Because of the conditions described above (and the low surface concentration in October at the forebay, 4.6 mg/l), DO ratings used in the overall reservoir ecological health evaluation for Douglas Reservoir were very poor at both the forebay and at the mid-reservoir sampling locations.

Values of pH ranged from 6.6 to 9.4 for both locations in Douglas Reservoir in 1993. In April through August at the forebay, and May through August at the mid-reservoir location, near surface pH's equal to or exceeding 8.5 were observed. In almost all of these cases, when the pH was above 8.5, surface dissolved oxygen saturation values exceeded 100 percent, indicating high levels of photosynthesis.

In 1993, the average concentrations of total phosphorus (average 0.035 mg/l at the forebay and 0.040 mg/l at the mid-reservoir) were higher in Douglas Reservoir than any of the other tributary Vital Signs reservoirs; and, at the mid-reservoir sampling location the dissolved ortho phosphorus (average 0.013 mg/l) was also higher than any of the other tributary reservoirs. The Douglas mid-reservoir sampling site historically has had the lowest average TN/TP ratios of all the tributary reservoirs.

In 1993, concentrations of chlorophyll *a* averaged 6.6 μg/l at the forebay and 10.3 μg/l at the mid-reservoir site. These concentrations are somewhat lower than those measured in 1992, when they were among the highest of the Vital Signs reservoirs. The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Douglas Reservoir were good at the forebay (i.e. falling in the 3 to 10 μg/l range); and fair at the mid-reservoir location (i.e. falling in the 10 to 15 μg/l range).

The water of Douglas Reservoir, especially in the mid-reservoir area has historically had low water clarity. In 1993, the Secchi depth averaged only 1.2 m, the lowest of all the tributary reservoir sampling locations.

Sediment—Chemical analyses of sediments in Douglas Reservoir in 1993 indicated the presence of chlordane (18 µg/kg) at the mid-reservoir site. Toxicity tests detected acute toxicity to rotifers (55 percent survival) in the mid-reservoir. Particle size analysis showed sediments from the forebay were about 100 percent silt and clay and from the mid-reservoir were 83 percent silt and clay, 17 percent sand.

Sediment quality ratings used in the overall Douglas Reservoir ecological health evaluation for 1993 were excellent at the forebay; and poor at the mid-reservoir site (presence of chlordane and toxicity to rotifers).

Benthic Macroinvertebrates—The forebay on Douglas Reservoir did not change significantly from the previous year. Only 265 organisms/m^2 representing 6 taxa were found, similar to the number of taxa (7) and density (282 organisms/m^2) found in 1992. The dominant taxa were Chironomus (50 percent) and Tubificidae (31 percent). The benthic macroinvertebrate community at this site was poor primarily because of the absence of long-lived and EPT taxa, and because of the abundance of chironomids. The benthic community structure observed at the forebay is indicative of low near-bottom dissolved oxygen concentrations.

The inflow site on Douglas Reservoir was not evaluated in 1993 because it was determined that 90 percent of the samples taken at that site were above the average winter pool level.

Fish Assemblage—Shoreline electrofishing (30 transects) and offshore/deep netting (24 net-nights) samples collected 2,679 fish of 29 species. The most abundant species were gizzard shad (29 percent), followed by white bass (20 percent), and largemouth bass (13 percent). The crappie species (black and white) represented 10 percent of the total sample. Electrofishing results indicated fish abundance in the transition (1,075) was twice that of the forebay (533) due mainly to much higher numbers of white bass, largemouth bass, and white crappie. Gill netting efforts showed a similar pattern, with the transition catch (884) considerably higher than the forebay (187). The only species that were more abundant in the forebay samples were smallmouth buffalo and black crappie.

The Reservoir Fish Assemblage Index (RFAI) analysis of shoreline electrofishing data showed the forebay (RFAI=42) zone to be good and the transition (RFAI=36) fair. Maximum metric scores were recorded at both sample areas for species diversity, number of sucker species, and dominance by a single species, and minimum scores for percent insectivores. The gill netting RFAI rated the transition zone (RFAI=50) good and the forebay (RFAI=30) poor. Transition zone scores were midrange or maximum (3's or 5's) for all metrics except for number of intolerant species. Combined electrofishing and gill netting RFAI scores indicated good fish community conditions in the transition (RFAI=43) zone and fair in the forebay (RFAI=36).

Summary of Conditions in 1993 - Use Suitability

Fecal Coliform Bacteria—One swimming beach and two boat ramps were tested for fecal coliform bacteria twelve times in 1993. Two samples were collected within 48-hours of a rainfall of at least one-half inch. Fecal coliform bacteria concentrations were very low (geometric mean <20/100 ml) at every site.

Fish Tissue—TVA worked with the Tennessee Department of Environment and Conservation in 1992 to conduct fish tissue studies on Douglas Reservoir. TVA collected the fish samples and provided fillets to TDEC for analysis. Results were not available at the time this report was prepared.

French Broad River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the French Broad River is soft (average hardness of 18 mg/l) and only slightly alkaline (average total alkalinity of 20 mg/l), reflecting the underlying geology of the area. The median pH for the stream monitoring site was 7.4. The river was well oxygenated with dissolved oxygen levels ranging from 87 to 99 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the French Broad River station ranked among the highest in mean concentrations of total phosphorus (0.122 mg/l), dissolved orthophosphate (0.087 mg/l), and nitrate+nitrite-nitrogen (0.56 mg/l). Average concentrations of 0.220 mg/l and 0.030 mg/l for organic nitrogen and ammonia nitrogen placed the site near median for these variables. The high average total phosphorus concentration yielded a poor rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total copper and zinc) were performed bi-monthly. Dissolved cadmium was detected in 5 of 6 samples. Three of those exceeded the EPA criterion for chronic toxicity to freshwater aquatic life. (Chronic toxicity bioassays are not routinely performed at stream monitoring sites. However, the acute toxicity test data is consistent with the water chemistry. See "Sediment" for additional information on toxicity testing results.)

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines. This is an improvement over 1992 when sediment quality rated fair.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrates rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 36, with 77 taxa and 12,121 organisms/m^2. Conditions in 1992 also rated fair (MBIBI score 35) with 81 taxa and 10,961 organisms/m^2. Benthic organisms have essentially remained unchanged between sampling years. Dominant organisms in 1993 were dipteran midge larvae (67 percent), caddisflies (15 percent), and dipteran black-fly larvae (6 percent). Dipteran black-fly larvae was the most dominant organism in 1992 (49 percent), followed by dipteran midge larvae (36 percent) and caddisflies (5 percent). The French Broad River consistently ranks the poorest of the 12 stream monitoring sites. Siltation from agricultural land usage along the river severely affects benthic communities at this site.

Fish Community Assessment—The fish community continued to be depressed rating borderline poor with an Index of Biotic Integrity (IBI) score of 38 in 1993 and borderline poor (IBI = 36) in 1992. Serious problems were found in species richness and composition, and in fish density, indicating poor conditions. Forty to 60 native species were expected to occur at this station, but only 30 were found. Diversity was low among darters, sunfish, suckers, and intolerant species. The proportion of tolerant fish was excessive representing approximately 41 percent of the fish found, and fish density was among the lowest found at the 11 stations sampled in 1993. Turbidity, siltation, and nutrient enrichment were evident and probably played some part in the disorder exhibited by the fish community.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—No bacteriological studies were conducted in this watershed by TVA in 1993.

Fish Tissue—A five fish composite each of carp, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. All analytes were not detected or found in low concentrations.

Nolichucky River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Nolichucky River is moderately hard (average hardness of 79 mg/l) and moderately alkaline (average total alkalinity of 67 mg/l). The median pH for the stream monitoring site was 7.8. The river was well oxygenated with dissolved oxygen levels ranging from 87 to 100 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the Nolichucky River station ranked just above the median concentrations for average organic nitrogen (0.223 mg/l), nitrate+nitrite-nitrogen (0.56 mg/l), total phosphorus (0.075 mg/l), and dissolved orthophosphate (0.024 mg/l). An average concentration of ammonia nitrogen of 0.022 mg/l placed the site among the best for the variable. The moderately high average total phosphorus concentration yielded a fair rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total copper and zinc) were performed bi-monthly. Dissolved cadmium was detected in 5 of 6 samples. Dissolved lead was detected in 2 of 6 samples. Neither metal exceeded the EPA criteria for protection of aquatic life or human health. Additional metals analyses included both total and dissolved forms of manganese and iron. Total iron exceeded the chronic toxicity criterion for freshwater aquatic life in one sample and the criterion for combined consumption of fish and water in 4 samples. Total manganese was detected in 5 of 6 samples, although only one sample exceeded an EPA criterion value (for combined consumption of fish and water).

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed and no metals, PCBs, or pesticides exceeding the EPA guidelines. This is a significant improvement over 1992 when sediment quality rated poor.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrates rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) of score 39, with 81 taxa and 5,543 organisms/m^2. Conditions in 1992 were also rated fair (MBIBI score 39) with 91 taxa and 6,195 organisms/m^2. Dominant organisms in 1993 were dipteran midge larvae (32 percent), caddisflies (24 percent), and mayflies (19 percent). Dipteran midge larvae were also the most dominant group in 1992 (46 percent), followed by dipteran black-fly larvae (18 percent) and caddisflies (14 percent). Conditions have essentially remained unchanged between sampling years. Siltation from agricultural land usage along the river and mica and mica and feldspar mining in the watershed adversely affect benthic communities at this site.

Fish Community Assessment—The fish community rated good with an Index of Biotic Integrity (IBI) score of 48, improving considerably from the borderline fair (IBI = 38) rated in 1992. Improvement included a lower proportion of tolerant fish, a higher proportion of piscivorous fish, increased fish density, and absence of hybrids. Deficiencies in number of native species and in numbers of darter, sunfish, and intolerant species continued to indicate poor conditions. Excessive turbidity and heavy siltation have been observed at this station during all sampling trips, 1990-93.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Bacteriological studies were not conducted in this watershed by TVA in 1993.

Fish Tissue—A five fish composite each of carp, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. All analytes were not detected or found in low concentrations.

HOLSTON RIVER WATERSHED

Cherokee Reservoir

Summary of 1993 Conditions - Ecological Health

Water—Summer surface water temperatures ranged from 12.2°C in April to 29.8°C in July at the forebay, and from 14.4°C to 30.9°C for the same months at the mid-reservoir sampling location (Tennessee's maximum temperature criterion for the protection of fish and aquatic life is 30.5C). Thermal stratification was evident in Cherokee Reservoir in 1993. Stratification was strongest in June, when the temperature difference between the surface and the bottom of the reservoir was about 20°C at the forebay and about 18°C at the mid-reservoir location. Thermal stratification persisted through September at the forebay and through August at the mid-reservoir site.

Dissolved oxygen at the 1.5m depth ranged from 15.2 mg/l (algal bloom) in April to 5.2 mg/l in September at the forebay, and from 14.2 mg/l (algal bloom) in April to 5.6 mg/l in July at the mid-reservoir sampling location. Anoxic conditions in the hypolimnion developed in the forebay in July and existed through October. In July and August, dissolved oxygen concentrations were less than 1 mg/l for about three-fourths of the water column. Dissolved oxygen gradients (DO's) were high in the forebay (about 7 mg/l) in June, July, and August. The gradients were not as high in September and October because of the low surface dissolved oxygen. Similar conditions existed at the mid-reservoir sampling location where hypolimnetic anoxia existed near the bottom in July and August. In July in the mid-reservoir location, three-fourths of the water column contained less than 1 mg/l dissolved oxygen. Dissolved oxygen gradients of 9.4 mg/l and 7.6 mg/l were observed in June and August, respectively. Such a high gradient did not exist in July because of the low surface dissolved oxygen for that month. The forebay and mid-reservoir sampling sites both had over 20% of their cross-sectional areas (six-month summertime average) with dissolved oxygen concentration less than 2.0 mg/l; and, over 40 percent of each site's cross-sectional bottom length (six-month summertime average) had a dissolved oxygen concentration less than 2.0 mg/l. Because of the conditions described above, DO ratings used in the overall reservoir ecological health evaluation for Cherokee Reservoir were very poor at both the forebay and at the mid-reservoir sampling locations.

In 1993, values of pH in Cherokee Reservoir ranged from 6.9 to 8.8 for both monitoring locations. Surface water pH values slightly exceeded 8.5 (Tennessee's maximum pH criterion for the protection of fish and aquatic life is 8.5) at the forebay in April through August, and at the mid-reservoir location in May through August. In each of these cases, with the exception of July at the mid-reservoir section, high dissolved oxygen saturation values coincided with the high pH's, sometimes up to 140 percent, indicating substantial photosynthetic activity.

Historically, the mid-reservoir sampling site has had the highest nutrient concentrations among all reservoir Vital Signs sampling locations. Average nutrient concentrations at the mid-reservoir location in 1993 were observed to be only about half of 1992 concentrations. In 1993, the average total nitrogen concentration was 0.45 mg/l and the average total phosphorus concentration was 0.030 mg/l. Lower nutrient concentrations at the forebay as well as higher TN/TP ratios indicate a higher productivity potential at the mid-reservoir sampling site than at the forebay sampling site.

Concentrations of chlorophyll *a* support this hypothesis where chlorophyll *a* averaged 7.6 μg/l at the forebay and 9.4 μg/l at the mid-reservoir site. The chlorophyll *a* ratings used in the 1993 ecological health evaluation for Cherokee Reservoir were good (i.e. falling in the 3 to 10 μg/l range), at both the forebay and the mid-reservoir locations.

Sediment—Chemical analyses of sediments in Cherokee Reservoir in 1993 indicated high levels of copper (57 mg/kg) from the mid-reservoir and elevated levels of un-ionized ammonia from both the forebay (390 μg/l) and mid-reservoir (290 μg/l). Toxicity tests detected acute toxicity to rotifers (75 percent survival) in the mid-reservoir. Particle size analysis showed sediments from the forebay were about 100 percent silt and clay and from the mid-reservoir were 99 percent silt and clay.

Sediment quality ratings used in the overall Cherokee Reservoir ecological health evaluation for 1993 were good at the forebay (presence of ammonia); and poor at the mid-reservoir site (presence of copper and ammonia and toxicity to rotifers).

Benthic Macroinvertebrates—In 1993, the overall condition of the benthic macroinvertebrate community in the forebay of Cherokee Reservoir remained approximately the same as in 1992. However, there was a slight increase in taxa (14) and decrease in density (510 organisms/m^2). As in 1992, Tubificidae (45 percent) and Chironomus sp (26 percent) were the dominant taxa.

The forebay had a fair macroinvertebrate benthic community; problem characteristics were numbers of long-lived species and the abundance of chironomids. On a more positive note, this site exhibited excellent species diversity. The Cherokee inflow benthic macroinvertebrate community improved substantially since last year, resulting in an excellent rating. The only factor that kept this site from receiving a perfect score for the benthic component was a slightly elevated number of chironomids in the sample. The abundance of mayfly Hexagenia limbata, considered to be an intolerant, long-lived species, greatly improved the benthic community rating at the inflow.

Fish Assemblage—Fish sampling in shoreline (45 electrofishing transects) and offshore/deep areas (34 net-nights) of Cherokee Reservoir produced a total of 4,086 individuals including 33 species. The most numerous species was gizzard shad (35 percent), followed by bluegill (20 percent), and largemouth bass (14 percent). Species richness ranged from 24 in the transition , 25 in the forebay, to 27 in the inflow. Electrofishing results indicated higher abundance in the inflow (1,458), where gizzard shad and largemouth bass were most numerous, and in the forebay (1,104) where bluegill numbers were very high. Gill netting catch rates were progressively higher from inflow to forebay areas due largely to abundance of gizzard shad, quillback carpsuckers, and striped bass.

The Reservoir Fish Assemblage Index (RFAI) analysis of shoreline electrofishing data determined the quality of the littoral fish communities of the forebay (RFAI=32) and inflow (RFAI=34) zones to be fair and the transition (RFAI=30) to be poor. All three reservoir sample areas were rated fair based on gill netting RFAI's. Combined electrofishing and gill netting RFAI scores for the forebay (RFAI=36), transition (RFAI=34), and inflow (RFAI=35) zones of Cherokee Reservoir were all rated fair.

Summary of Conditions in 1993 - Use Suitability

Fecal Coliform Bacteria—One swimming beach, seven boat ramps, and the head of one small embayment were tested for fecal coliform bacteria twelve times in 1993. Two samples were collected within 48-hours of a rainfall of at least one-half inch. Fecal coliform bacteria concentrations were very low (geometric mean <20/100 ml) at the swimming beach and at six of the boat ramps. At the Malinda Bridge boat ramp and at the head of Spring Creek Embayment, the geometric mean fecal coliform concentrations were between 20 and 50/100 ml, well below the Tennessee criterion for recreation.

Fish Tissue—Channel catfish were collected from Cherokee Reservoir as part of screening studies in autumn 1992. Results indicated low or nondetectable concentrations of metals. Mercury, known to be a problem in the North Fork Holston River, was 0.29 μg/g at the forebay with lower concentrations at the other two locations. The only organics found were PCBs and chlordane. Chlordane concentrations were low (maximum 0.07 μg/g) and PCB concentrations were generally similar to those in past years - 0.8, 0.5, and 0.5 μg/g at the forebay, transition zone, and inflow, respectively.

Fort Patrick Henry Reservoir

Summary of Conditions in 1993 - Ecological Health

Water—Average flow through Fort Patrick Henry Reservoir in 1993 was about 91 percent of normal. It is only stratified due to the continual release of cold water from the three upstream dams. The maximum temperature difference in the water column was 12.5°C in July. The maximum surface temperature was 27.8°C in July, well below Tennessee's maximum temperature criterion for aquatic life of 30.5°C. Low DO (<5.0 mg/l) conditions developed in July, August, and October, but DO never dropped below 2.2 mg/l. Absence of DO <2.0 mg/l gave Fort Patrick Henry Reservoir a good rating for DO in the reservoir ecological health index.

Conductivities varied widely from month to month and in the water column, but averaged the fourth highest of the 19 tributary reservoirs. The minimum was 150 µmhos/cm at the bottom of the water column in May, and the maximum was 216 µmhos/cm in September, also at the bottom of the water column. Surface pH reached or exceeded 9.0 in July, August, and September, while bottom pH never fell below 7.1.

Relatively high nutrient concentrations were found: the total nitrogen concentration in April was 1.08 mg/l, 72 percent as nitrates, and 0.63 mg/l in August, 62 percent as organic nitrogen. Total phosphorus concentrations were 0.02 mg/l in both surveys. Total organic concentrations were 2.0 mg/l in April and 2.8 mg/l in August. Chlorophyll *a* concentrations tied for the fourth highest of the 33 tributary reservoir stations, averaging 10.3 µg/l. This chlorophyll concentration was considered fair in the reservoir ecological health index. Water clarity was low. Secchi depths ranged from 1.3 meters in September to 1.7 meters in July and August.

Sediment—Chemical analyses of sediments from the forebay of Fort Patrick Henry Reservoir in 1993 indicated slightly elevated levels of un-ionized ammonia (210 µg/l). Toxicity tests detected no toxicity to the two organisms tested. Particle size analysis showed sediments from the forebay were 99 percent silt and clay.

The sediment quality rating used in the overall Fort Patrick Henry Reservoir ecological health evaluation for 1993 was good at the forebay (presence of ammonia).

Benthic Macroinvertebrates—The first year that the benthic community in this tributary reservoir was evaluated was 1993. The forebay, the only sample location, had a fair benthic macroinvertebrate community with 11 taxa, 438 organisms/m^2, and Tubificidae as the dominant taxa (63 percent). The absence of EPT taxa and the abundance of tubificids negatively impacted the benthic community. An average representation of the long-lived species Corbicula fluminea, average taxa richness, and low numbers of chironomids were all positive attributes of the benthic community.

Fish Assemblage—Only the forebay zone was sampled on Fort Patrick Henry Reservoir in fall 1993. Shoreline electrofishing (15 transects) and offshore experimental gill netting (12 net-nights) yielded 1,251 individuals represented by 22 species. Fifty-one percent of the total catch consisted of spotfin shiners, followed by gizzard shad (23 percent), bluegill (7 percent), carp (6 percent), and largemouth bass (5 percent).

Fish community conditions were rated fair for both electrofishing (RFAI=38) and gill netting (RFAI=34) in the forebay zone of Fort Patrick Henry Reservoir. The overall RFAI of 36 also rated the reservoir forebay as fair.

Summary of Conditions in 1993 - Use Suitability

Fecal Coliform Bacteria—The boat ramp at Warriors Path State Park was tested for fecal coliform bacteria in 1993. The geometric mean concentration was 94/100 ml, well within Tennessee's Criterion for water contact recreation.

Fish Tissue—Autumn 1993 was the first time TVA had conducted fish tissue samples from Fort Patrick Henry Reservoir. Results were not available at the time this report was prepared.

Boone Reservoir

Summary of Conditions in 1993 - Ecological Health

Water—The average flow through Boone Reservoir in 1993 was about 97 percent of normal, with an average residence time of 38.5 days. Boone Reservoir has two large arms, the South Fork Holston River and Watauga River, their confluence is slightly more than one mile upstream of Boone Dam. Both arms receive cold water releases from the deep impoundments upstream. Consequently, Boone Reservoir remains stratified throughout the sampling period, with a maximum temperature difference in the water column at the forebay of 16.3°C in July. The maximum surface temperature was 28.9°C at the forebay in July, well below Tennessee's maximum temperature criterion for aquatic life of 30.5°C. DO depletion (DO <2.0 mg/l) at the forebay and in the South Fork Holston River arm was limited to the metalimnion from July through October. In the Watauga arm, DO depletion occurred at the bottom in September. The limited amount of DO depletion gave the forebay a good rating and both mid-reservoir stations fair ratings for DO in the reservoir ecological health index.

Conductivities varied widely by month and depth. In the Watauga arm, conductivities ranged from 74 µmhos/cm at the bottom in May to 236 µmhos/cm in the metalimnion in September. In the South Fork Holston River arm, conductivities varied from 177 µmhos/cm at the surface to 264 µmhos/cm in the metalimnion in July. Conductivities in the forebay reflected the mixing of these two rivers. The minimum pH was 6.7 in the Watauga arm in September, while pH reached 9.1 in both the forebay and Watauga arm in the summer.

Total nitrogen concentrations on South Fork Holston River were the third highest of the 33 tributary reservoir stations. Total nitrogen concentrations in April ranged from 0.76 mg/l on the Watauga River to 1.07 mg/l on South Fork Holston River. About 60 percent of the total nitrogen was nitrates at each site. Nitrate concentrations had dropped by August to 0.03 mg/l or less at each station, bringing the average total nitrogen concentration to 0.41 mg/l, slightly higher at the mid-reservoir stations than at the forebay. Total phosphorus concentrations were 0.01 mg/l on the Watauga River and 0.02 mg/l at the other two sites in April. Total phosphorus concentrations dropped at the forebay from April to August to 0.008 mg/l, remained constant in the South Fork Holston River, and increased in the Watauga River to 0.03 mg/l. Dissolved ortho phosphorus concentrations were 0.003 mg/l in the Watauga River both months and at the forebay in April, and <0.002 for the other three samples. The TN/TP ratios were high, 50:1 at the forebay and higher at the other two stations. Total organic carbon concentrations were high, ranging from 1.8 mg/l in the Watauga River to 2.7 mg/l in the forebay in April, and 3.8 mg/l at both mid-reservoir stations to 4.5 mg/l at the forebay in August. The forebay concentrations of total organic carbon were the fourth highest of the tributary reservoir locations.

The two mid-reservoir stations had the second and third highest chlorophyll concentrations of the tributary reservoir stations. Average chlorophyll *a* concentrations were 8.7 µg/l at the forebay, 11.9 µg/l in the South Fork Holston River, and 10.4 µg/l in the Watauga River. These concentrations are in the ranges considered good for the forebay and fair for the two mid-reservoir locations in the reservoir ecological health index. Water clarity was low at the mid-reservoir stations, Secchi depths varied from 1.0 meter in the South Fork Holston River in June to 1.5 meters at both stations in October. The South Fork Holston

River mid-reservoir station had the second lowest water clarity of the tributary reservoir stations. At the forebay, Secchi depths varied from 1.3 meters in May to 2.2 meters in October.

Sediment—Chemical analyses of sediments collected from three locations in Boone Reservoir in 1993 indicated very high levels of un-ionized ammonia at all three sites: 790 μg/l at the forebay sampling site; 660 μg/l at the South Fork Holston River (SFHR) mid-reservoir sampling site; and, 990 μg/l at the Watauga River (WR) mid-reservoir sampling site. Chlordane was also detected in sediment at all three sampling sites: 22 μg/kg at the forebay site; 35 μg/kg at the SFHR mid-reservoir site; and, 35 μg/kg at the WR mid-reservoir site. In addition, high levels of copper (58 mg/kg) and zinc (370 mg/kg) were found at the Watauga River mid-reservoir sampling site. However, no acute toxicity to daphnids nor rotifers was found at any of the three sampling sites. Particle size analysis showed sediments in the forebay were about 100 percent silt and clay; in the S. F. Holston River mid-reservoir were 99 percent silt and clay; and in the Watauga River mid-reservoir were 86 percent silt and clay, 14 percent sand.

Sediment quality ratings used in the overall Boone Reservoir ecological health evaluation for 1993 were good at the forebay as opposed to excellent because ammonia was elevated; good at the SFHR mid-reservoir site (presence of ammonia); and fair at the WR mid-reservoir site (presence of copper, zinc, and ammonia).

Benthic Macroinvertebrates—The first year that the benthic macroinvertebrate community was evaluated on Boone Reservoir was 1993. The forebay site had a poor benthic community, with 1,107 organisms representing a mere 10 taxa; Tubificidae (58 percent) and the tubificid <u>Limnodrilus</u> <u>hoffmeisteri</u> (38 percent) were the dominant taxa. The South Fork Holston River and the Watauga River mid-reservoir sites both had poor benthic communities. Both had only 11 taxa, but the South Fork Holston inflow had a lower density (615 organisms/m^2) than the Watauga inflow (267). The tubificids <u>Limnodrilus</u> sp and Tubificidae were the dominant taxa at both mid-reservoir sites comprising 91 percent of the total at the South Fork Holston site and 96 percent of the total at the Watauga site.

The forebay and both inflows were negatively impacted by the absence of long-lived and EPT taxa, and the abundance of tubificids. If not for the relatively low proportion of chironomids, all sites would have received a "very poor" benthic rating.

Fish Assemblage—Electrofishing (45 transects) and gill netting (34 net-nights) results from Boone Reservoir yielded 2,439 individuals of 23 species. Bluegill were the most abundant species, comprising 29 percent of the total number of fish sampled. Other species making up a significant portion of the reservoir sample included gizzard shad (21 percent), spotfin shiners (21 percent), and carp (9 percent). Fish abundance was greater in the Watauga River transition zone (1,414), followed by the South Fork Holston River transition (632) and the forebay (393). Both electrofishing and gill netting total catch rates followed the same pattern as abundance.

The Reservoir Fish Assemblage Index (RFAI) rated the quality of the littoral community (as determined by electrofishing samples) fair in the Holston River transition (RFAI=32) and poor in both the Watauga River transition (RFAI=28) and forebay zones (RFAI=26). Minimum metric scores for diversity, and number of intolerant and lithophilic spawning species were recorded for all stations. The gill netting RFAI followed the same pattern as electrofishing, rating the Holston River transition (RFAI=36) fair, and both the Watauga River transition (RFAI=28) and forebay (RFAI=26) zones poor. Scoring at all zones revealed scattered values for most metrics with the exception of maximum scores (5) for percent anomalies, and minimum scores (1) for percent tolerant and omnivorous species.

Combined electrofishing and gill netting RFAI scores for both the forebay (RFAI=26) and Watauga River transition (RFAI=28, which was the lowest tributary transition RFAI recorded in 1993) rated poor and the Holston River transition zone (RFAI=34) rated fair.

Summary of Conditions in 1993 - Use Suitability

Fecal Coliform Bacteria—Two swimming areas and four boat ramps were each tested for fecal coliform bacteria twelve times in 1993. No samples were collected within 48-hours of a rainfall of at least one-half inch. Bacteria concentrations were very low (geometric mean <20/100 ml) at the four boat ramps. The geometric mean fecal coliform concentration at the swimming beaches were 106 and 51/100 ml, well within Tennessee's criterion of 200/100 ml for water contact recreation. One sample at the Boone Dam recreation area exceeded Tennessee's maximum concentration criterion for one sample of 1000/100 ml.

Fish Tissue—Past studies conducted by the state of Tennessee found PCBs and chlordane in fish tissue, resulting in a state issued advisory that catfish and carp should not be eaten by children, pregnant women, and nursing mothers. Further, all other people should limit their consumption of these particular fish. Fish samples were collected by TVA in autumn 1993, but results were not available at the time this report was prepared.

South Holston Reservoir

Summary of Conditions in 1993 - Ecological Health

Water—The average flow through South Holston Reservoir in 1993 was near normal with an average residence time of about 341 days. The reservoir was strongly stratified, with a maximum temperature difference in the forebay water column of 21.9°C in July. The maximum surface temperature was 28.3°C at the forebay in July, well below Tennessee's maximum temperature criterion for aquatic life of 30.5°C. DO depletion (DO <2.0 mg/l) occurred in both the metalimnion and at the bottom of the water column. Areas of DO depletion began in July at mid-reservoir and August at mid-reservoir. Because the water was clearer at the forebay than at mid-reservoir and the photic zone was deeper, metalimnetic DO depletion occurred at deeper depths in the forebay than at mid-reservoir and the area of low DO was not mixed as the surface cooled in October as was the case at mid-reservoir. For the reservoir ecological health index, DO was considered fair at the forebay and poor at mid-reservoir.

Conductivities varied widely by month and depth, from a minimum of 72 μmhos/cm in May near the bottom at the forebay to 270 μmhos/cm at the mid-reservoir bottom in September. Surface pH was between 8.5 and 9.0 at both stations each month except for April at the forebay. The minimum pH was 7.1 at mid-reservoir in September.

Total nitrogen concentrations were 0.75 and 1.08 mg/l in April at the forebay and mid-reservoir, respectively, about three-fourths as nitrates. In August, the total nitrogen concentration had dropped to 0.36 mg/l at both stations, primarily due to a decline in nitrates. The mid-reservoir total nitrogen concentrations were the fourth highest of the 33 tributary reservoir stations. In April, total and dissolved ortho phosphorus concentrations were 0.01 and 0.003 mg/l at the forebay and 0.02 and 0.003 mg/l at mid-reservoir. In August, total phosphorus was <0.002 mg/l at the forebay and 0.003 at mid-reservoir. TN/TP ratios were very high, over 50 in April and over 100 in August. Total organic carbon concentrations varied only from 1.7 mg/l in April to 2.7 mg/l in August, both concentrations at mid-reservoir.

Average chlorophyll *a* concentrations were 3.4 μg/l at the forebay and 7.0 μg/l at mid-reservoir. These concentrations are in the range considered good in the reservoir ecological health index. Secchi depths varied from 1.6 m in April to 2.3 m in September and October at mid-reservoir and from 2.0 m in May to 5.75 m in June at the forebay. The forebay had the fourth clearest water of the 19 tributary reservoir forebays.

Sediment—Chemical analyses of sediments in South Holston Reservoir in 1993 indicated the presence of chlordane (12 μg/kg) and un-ionized ammonia (310 μg/l) in the mid-reservoir. Toxicity tests detected no acute toxicity to daphnids or rotifers, however survival of daphnids (75 percent survival) was reduced in the forebay. Particle size analysis showed sediment in the forebay were 99 percent silt and clay, and in the mid-reservoir were 98 percent silt and clay.

Sediment quality ratings used in the overall South Holston Reservoir ecological health evaluation for 1993 were good at the forebay as opposed to excellent due to reduced survival of daphnids) and good at the mid-reservoir site (presence of ammonia and chlordane).

Benthic Macroinvertebrates—The first year that the benthic macroinvertebrate community was evaluated on the South Holston Reservoir was 1993. The forebay site had a very poor community, with only 3 taxa, 98 organisms/m^2, and the tolerant Tubificidae comprising 97 percent of the total. The inflow site rated somewhat better with 13 taxa and 354 organisms/m^2, dominated by Tubificidae (69 percent).

The forebay site had very poor benthic community structure as indicated by low diversity, the absence of EPT and long-lived taxa, and the preponderance of tubificids; a low number of chironomids was the only metric that kept this site from receiving the lowest possible score. The inflow site had a fair benthic representation, but an absence of EPT taxa and an abundance of tubificids were negative attributes of the community. As was the case at the forebay, a low number of chironomids found at the site was a considered a positive indicator. Diversity and the presence of long-lived species allowed the inflow site to receive a better rating than the forebay site.

Fish Assemblage—Fish samples taken in the shoreline areas (30 electrofishing transects) and offshore/deep areas (24 net-nights) of South Holston Reservoir produced a total of 2,160 individuals represented by 27 species. Fish density and diversity was similar between the forebay (1,246 individuals of 20 taxa) and transition zone (914 individuals of 23 taxa). No inflow zone sample was collected from South Holston Reservoir. The three most abundant species were spotfin shiner (46 percent), gizzard shad (10 percent), and bluegill (8 percent). Other abundant species included black crappie and walleye at six percent, and white bass at five percent of the total catch. Gill netting results indicated an increase from 1992 estimates in black crappie numbers in both forebay and transition zones.

RFAI analysis of electrofishing data determined the quality of the littoral fish community in the transition zone (RFAI=40) and forebay (RFAI=38) to be fair. Gill netting RFAI rated the transition (RFAI=32) fair and forebay (RFAI=50) good. Forebay scores for all metrics were maximum except for number of sunfish and sucker species, and percent insectivores. The forebay score of 50 represented a substantial improvement from the previous sample season (1992 RFAI=28). Combined electrofishing and gill netting RFAI scores rated the forebay (RFAI=44) zone good and the transition (RFAI=36) fair.

Summary of Conditions in 1993 - Use Suitability

Fecal Coliform Bacteria—One informal swimming area and three boat ramps were each tested for fecal coliform bacteria twelve times in 1993. No samples were collected within 48-hours of a rainfall of at least one-half inch. Fecal coliform bacteria concentrations were very low (geometric mean concentration <20/100 ml) at all four sites.

Fish Tissue—There are no fish consumption advisories on South Holston Reservoir. The most recent TVA data for fish tissue samples are for fish collected in autumn 1991. The single composite of channel catfish from the forebay had low or nondetectable concentrations of all pesticides, PCBs, and metals (except mercury). The mercury concentration was 0.42 µg/g, just high enough to be of interest. Additional fish tissue samples were collected from the forebay in autumn 1993, but results were not available at the time this report was prepared.

Watauga Reservoir

Summary of Conditions in 1993 - Ecological Health

Water—The average flow through Watauga Reservoir in 1993 was near normal with an average residence time of about 404 days. Watauga Reservoir was strongly stratified with a maximum temperature difference in the forebay water column of 21.3°C in July. The maximum surface temperature was 28.8°C at mid-reservoir in July, less than Tennessee's maximum temperature criterion for aquatic life of 30.5°C. At the forebay, the area of DO depletion (DO < 2.0 mg/l) was limited to the bottom of the water column in October. At mid-reservoir, areas of DO depletion developed in both the metalimnion and at the bottom of the reservoir in September and October. The limited amount of DO depletion gave the forebay a rating of good and mid-reservoir a rating of fair for DO in the reservoir ecological health index.

The maximum conductivity was 101 μmhos/cm at the forebay and 96 μmhos/cm at mid-reservoir, both at the bottom of the water column in September. At both stations pH reached 9.0 near the surface, the minimum pH was 6.5 in the mid-reservoir metalimnion in September.

Total nitrogen concentrations in April were 0.80 mg/l at mid-reservoir and 0.61 mg/l at the forebay, about three-fourths of the total at each site as nitrates. The total nitrogen concentration in August was about half the April total with the reduction due to a decline in nitrate concentrations as organic nitrogen concentrations rose slightly. Total phosphorus concentrations in April were 0.02 mg/l at mid-reservoir and 0.01 mg/l at the forebay. August concentrations were about half of the April total. TN/TP ratios were 40 or higher for each sample. Dissolved ortho phosphorus concentrations were at or below the detection limit of 0.002 mg/l for all four samples. Total organic carbon concentrations at mid-reservoir were 1.8 and 3.2 mg/l in April and August, respectively, and 2.1 mg/l at the forebay in August.

The average chlorophyll *a* concentration was 4.1 μg/l at the forebay and 5.9 μg/l at mid-reservoir. These concentrations are in the good range for the reservoir ecological health index. Secchi depths varied at the forebay from 1.3 m in April to 3.9 m in May, and at mid-reservoir from 1.7 m in April to 4.2 m in September.

Sediment—Chemical analyses of sediments in Watauga Reservoir in 1993 indicated the presence of chlordane in both forebay (22 μg/kg) and in the mid-reservoir (36 μg/kg). Elevated levels of un-ionized ammonia (260 μg/l) were found in the forebay. Toxicity tests detected acute toxicity to daphnids (0 percent survival) and rotifers (5 percent survival) in the forebay. Particle size analysis showed sediments in the forebay were about 100 percent silt and clay, and in the mid-reservoir were 99 percent silt and clay.

Sediment quality ratings used in the overall Watauga Reservoir ecological health evaluation for 1993 were poor at the forebay (acute toxicity to daphnids and rotifers and presence of chlordane and ammonia); and good at the mid-reservoir site (presence of chlordane).

Benthic Macroinvertebrates—The first year that the benthic macroinvertebrate community was evaluated on Watauga Reservoir was 1993. The forebay and mid-reservoir sites both had very poor benthic communities with only 7 and 9 taxa, respectively, and 158 and 60 organisms/m^2, respectively. The forebay was dominated by Tubificidae (79 percent of the total) and the inflow was dominated by the chironomid Einfeldia sp (53 percent).

Scores at both sites were negatively influenced by three common factors: low diversity, the absence of EPT taxa, and the absence of long-lived taxa. An interesting difference was observed between the forebay and inflow sites on Watauga: the forebay site was overwhelmingly dominated by the tubificids which negatively impacted the community rating, but very few chironomids were found, whereas the inflow site was overwhelmingly dominated by chironomids which negatively impacted the rating at that site, but very few tubificids were found.

Fish Assemblage—Combined fish samples in shoreline electrofishing (30 transects) and offshore gill netting (24 net-nights) produced a total of 1,102 individuals including 20 species in the transition and forebay zones of Watauga Reservoir. No sampling was conducted in the inflow zone. Fish were more abundant in the transition zone (63 percent of total) but diversity was similar in both sample areas (14 taxa in the forebay and 17 in the transition). The three dominant species by number were bluegill (23 percent), gizzard shad (20 percent), and walleye (16 percent). Other common species were spotfin shiners (11 percent), and rockbass (9 percent).

Analysis of shoreline electrofishing data identified a very poor littoral fish community in the forebay zone (RFAI=20) of Watauga Reservoir. In fact, the forebay score of 20 was the lowest observed (in both 1992 and 1993) in comparable areas of other tributary reservoirs that were sampled. The low forebay RFAI resulted from minimum scores in eight of the twelve metrics used for evaluation. Although the transition zone (RFAI=40) fish community rated only fair, it did receive maximum scores in five of the twelve metrics. Gill netting RFAI evaluations rated the transition zone (RFAI=34) fair and forebay (RFAI=30) poor. The slightly lower forebay rating resulted from minimum scores for six of the twelve metrics.

Combined electrofishing and gill netting RFAI score of 25 indicated a poor rating for the forebay (only Parksville Reservoir had a lower forebay score). The transition zone (RFAI=37) rated fair.

Summary of Conditions in 1993 - Use Suitability

Fecal Coliform Bacteria—The swimming beach at Shook Branch Recreation Area and an informal swimming area at Watauga Point and three boat ramps were tested for fecal coliform bacteria twelve times each in 1993. No sample was collected within 48-hours of a rainfall of one-half inch or greater. Fecal coliform bacteria concentrations were very low (geometric mean concentration <20/100 ml) at all five sites.

Fish Tissue—There are no fish consumption advisories on Watauga Reservoir. The most recent fish tissue collections by TVA were made in autumn 1991. All pesticides, PCBs, and metals (except mercury) were low or not detected in the single channel catfish composite from the forebay. The mercury concentration was 0.53 μg/g. Additional fish tissue screening samples were collected in autumn 1993, but results were not available at the time this report was prepared.

Holston River Stream Monitoring Site

Summary of 1993 Conditions - Ecological Health

Water—The water of the Holston River is moderately hard (average hardness of 113 mg/l) and moderately alkaline (average total alkalinity of 94 mg/l). The median pH for the stream monitoring site was 8.0. The river was well oxygenated with dissolved oxygen levels ranging from 88 to 106 percent of saturation.

Of the 12 streams monitored across the Tennessee Valley, the Holston River station ranked among the highest in average nitrate+nitrite-nitrogen (0.67 mg/l) and just above the median for average total phosphorus (0.112 mg/l), dissolved orthophosphate (0.057 mg/l), and ammonia nitrogen (0.038 mg/l). The average concentration of organic nitrogen (0.185 mg/l) was among the lowest recorded. The high average total phosphorus and average nitrate+nitrite-nitrogen concentrations yielded a poor rating for nutrients at the site.

Seven analyses for priority pollutant metals (dissolved cadmium, lead, nickel, silver, and zinc and total copper and zinc) were performed bi-monthly. Dissolved cadmium was detected in 4 of 6 samples. Dissolved nickel was detected in 1 of 6 samples. Neither metal exceeded EPA criteria for protection of aquatic life or human health.

Sediment—Sediment quality rated good in 1993 with no acute toxicity observed. No PCBs or pesticides exceeding the EPA guidelines. However, copper was detected at a level slightly above the EPA guideline for copper in sediment. This was an improvement over 1992 when sediment quality rated fair.

Benthic Macroinvertebrates—In 1993, benthic macroinvertebrates rated fair with a Modified Benthic Index of Biotic Integrity (MBIBI) score of 36, with 59 taxa and 4,673 organisms/m^2. Conditions in 1992 also rated fair (MBIBI score 41) with 50 taxa and 3,311 organisms/m^2. Dominant organisms in 1993 were dipteran midge larvae (30 percent), dipteran black-fly larvae (25 percent), and river snails (10 percent). River snails were the most dominant group in 1992 (43 percent), followed by coleopteran riffle beetles (10 percent) and caddisflies (7 percent). Siltation from agricultural land usage along the river and pollution from industries located upstream have a major impact on benthic organisms at this site.

Fish Community Assessment—The fish community rated good with an Index of Biotic Integrity (IBI) score of 48, improving from a rating of fair (IBI = 44) in 1992. Improvement was seen mainly in decreased proportions of both tolerant fish and omnivorous fish suggesting some relief from chronic nutrient enrichment of the river. Other problems for the fish community continued to be reflected by low numbers of darter, sunfish, sucker, and other native species, and low proportions of piscivorous fish. Adverse conditions observed were nutrient enrichment (evident in the abundance of aquatic vegetation), and alteration of flow by releases from Fort Patrick Henry Dam.

Summary of 1993 Conditions - Use Suitability

Fecal Coliform Bacteria—Seven sites on South Fork Holston River were tested twelve times each for fecal coliform bacteria in 1993. No samples were collected within 48-hours of a rainfall of at least one-half inch. Six sites were located between South Holston Dam and Boone Reservoir. Thomas and Beidleman Creeks were sampled near their confluence with South Fork Holston River. The geometric mean concentration of fecal coliforms on both streams were about 250/100 ml, a little higher than Tennessee's water quality criterion for recreation of 200/100 ml. The other sites were on South Fork Holston River. The two sites between the South Holston Weir and the confluence with Thomas Creek and the site downstream of Thomas Creek but upstream of Beidleman Creek all had very low fecal coliform bacteria concentrations (geometric mean <20/100 ml). The site downstream of Beidleman Creek had a geometric mean concentration of 31/100 ml, and the site downstream of Boone Dam at Fordtown Bridge had a geometric mean concentration of 52/100 ml. Three sites on South Fork Holston River are boat launching sites. Samples at the other sites were taken from the middle of the stream off a bridge, including a footbridge at the most upstream site.

Fish Tissue—A five fish composite each of carp, channel catfish, and largemouth bass were collected during summer 1992 and analyzed for selected metals, pesticides, and PCBs. All analytes were not detected or found in low concentrations except slightly elevated levels of mercury in largemouth (0.57 μg/g), PCBs in carp (0.6 μg/g), and chlordane in channel catfish (0.08 μg/g).

CONTENTS - VOLUME I

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TENNESSEE VALLEY AUTHORITY
RESOURCE GROUP, ENGINEERING SERVICES
HYDRAULIC ENGINEERING

DISCHARGE TEMPERATURE LIMIT EVALUATION FOR

WATTS BAR NUCLEAR PLANT

Report No. **WR28-1-85-137**

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DISCHARGE TEMPERATURE LIMIT EVALUATION FOR WATTS BAR NUCLEAR PLANT

EXECUTIVE SUMMARY

The Tennessee Valley Authority (TVA) anticipates one unit at Watts Bar Nuclear Plant to begin operation in 199411995. Watts Bar Fossil Plant is currently mothballed with no present schedule for unit start up. Both the fossil and nuclear plants rely on the Tennessee River downstream of Watts Bar Hydro for dispersing thermal effluent from condenser cooling. Due to the uncertainty in Watts Bar Fossil Plant future operation, TVA has evaluated the thermal effects of operating the hydro, fossil, and nuclear plants under various operating scenarios. The goal is to ensure that operations do not violate the State of Tennessee instream water quality criteria for temperature.

Watts Bar Hydro Plant is generally operated to provide peaking power. The normal maximum duration of zero discharge is 15 hours, Historically, continuous zero releases associated with special operations or repairs have not exceeded 20 hours in duration.

Previous field studies showed a worst case maximum fossil plant-induced instream temperature rise of 3 F° (1.7 C°). This occurred after 12 hours of zero release from the hydro plant.

Water temperatures and flows, and meteorological records from 1976 to 1993, were used with a computer model to simulate Watts Bar Nuclear Plant operation with and without fossil plant operation. The results showed that under all simulated historical conditions the maximum downstream temperature (85.6°F, 29.8°C) was below 86.9°F (30.5°C), allowed by the State of Tennessee. The maximum nuclear plant-induced temperature rise (1.8 F°, 1.0 C°) was below both the State criteria for temperature rise of 5.4 F° (3.0 C°) and for rate of temperature change of 3.6 F°/hour (2.0 C°/hour). The combined worst-case temperature rise from both fossil and nuclear plant operation was 4.8 F° (2.7 C°). The maximum hourly nuclear plant discharge temperature, only dependent on meteorology, was 97.3°F (36.3°C). The worst case conditions evaluated at steady-state showed that even with a discharge of 100.9°F (38.3°C) the maximum downstream temperature was 86.4°F (30.2°C).

Based on the extensive simulations of historical conditions, the worst case steady-state results, and a small margin of safety, TVA proposes a daily average discharge limit of 95°F (35°C). The diffuser mixing zone remains (as previously permitted) 240 feet wide and extends 240 feet downstream. TVA also proposes a pond emergency overflow temperature limit of 104°F (40°C), which would be measured by grab sample once a day during overflow at the overflow weir. A proposed mixing zone for the overflow weir discharge should be 1,000 feet wide and extend 3,000 feet downstream. Due to the location and length of the diffuser (less than 1/4 of the river width) and small effect from surface overflow discharge, ample space exists for fish to pass by the plant during all operations.

The operation of Watts Bar Fossil and Nuclear Plants are not anticipated to cause problems with Sequoyah Nuclear Plant's ability to meet safety or environmental temperature limits. The combined effects of Watts Bar Fossil and Nuclear Plants on Sequoyah Nuclear Plant are expected to be small, with an average increase in bottom temperature of about 0.4 F° (0.2 C°) under low flow conditions.

Watts Bar Nuclear Plant has continuous discharge temperature and **flowrate** monitors. **TVA** proposes a daily average discharge temperature limit on the flow weighted average of hourly temperature values (based on the actual hours of discharge). **TVA** will calibrate the plant temperature sensors, **flowrate** monitors, and transfer electronics at least annually. **TVA** proposes to field survey thermal conditions in stages, as heated discharges are added at the Watts Bar site, to verify computer modeling assumptions.

I INTRODUCTION

The Tennessee Valley Authority is constructing a two-unit 2,540 Megawatt (MWe) nuclear plant in Rhea County, Tennessee, on the right bank of Chickamauga Reservoir at Tennessee River Mile (TRM) 528. One nuclear unit is anticipated to begin operation in 1994/1995. The location, shown in Figure A.1 (all figures have been placed in the Appendix), is adjacent to the Watts Bar Dam Reservation. Watts Bar Nuclear Plant is situated about two miles downstream of Watts Bar Hydro Plant (TRM 529.9) and about one mile downstream of the four-unit Watts Bar Fossil Plant, located on the right bank of Chickamauga Reservoir at TRM 529.

The State of Tennessee instream water quality criteria for temperature are a maximum downstream temperature of 86.9°F (30.5°C), a maximum temperature rise of 5.4 F° (3.0 C°), and a maximum rate of temperature change of 3.6 F°/hour (2.0 C°/hour). The standards are applicable at the edge of a mixing zone.

State-of-the-art mathematical models together with available data are used to simulate the environmental impact of plant operations from 1976 through 1993. The primary goal of the evaluation is to provide a maximum daily average discharge temperature for the nuclear plant that will ensure meeting the instream State of Tennessee temperature standards, yet provide flexibility for plant operation. Experience at other fossil and nuclear plants has shown that daily average limits provide plant operating flexibility without adverse effects on the water body. Combined fossil and nuclear plant operation was also evaluated.

This report provides details of the operating characteristics of each of the generating plants (hydro, fossil, and nuclear). Thermal characteristics for the fossil plant and the nuclear plant are presented. The hydro-thermal effects of worst case operation of the fossil plant are identified. Computer models of nuclear plant operation are used for various operating scenarios. A daily average discharge temperature and maximum pond overflow temperature are proposed, based on the findings. The "mixing zone" and "zone of passage" for nuclear plant thermal discharges are addressed. The combined effects of Watts Bar Fossil and Nuclear Plant operation on Sequoyah Nuclear Plant are evaluated. Finally, proposed limits, monitoring, reporting, and field verification for thermal compliance at Watts Bar Nuclear Plant are discussed.

II. PLANT OPERATING CHARACTERISTICS

A. Watts Bar Hydro Plant

Watts Bar Hydro Plant (WBH) has five units with a total capacity of 166.5 MWe. The hydro plant releases about 9,000 cubic feet per second (cfs) per unit and is normally used for peaking operations. Peaking operations entail storing water at night and releasing water during the day when there is the greatest demand for electricity.

Hourly WBH discharge records have been archived since January 1, 1976. The average discharge at the hydro plant has been 26,300 cubic feet per second (cfs), with about 24,200 cfs during the summer months and about 35,100 cfs during the winter months. The normal discharge through each of the five turbines at the hydro plant ranges from 7,500 to 10,000 cfs. The minimum flow at which the turbines can operate is 3,500 cfs; however, for maximum efficiency, the flow seldom falls below 8,000 cfs per unit.

WBH is operated to provide peaking power and the normal maximum duration of zero discharge is 15 hours. When special operations are planned, the period of zero discharge historically has not exceeded 20 hours. Tables 1 and 2 show low river flow (less than 3,500 cfs) occurrences and durations by month and by year. The low river flow occurrences were divided into periods of 5-hour duration. The longest period of low flow ever recorded was between 16-20 hours and the largest number of occurrences for this duration was nine, occurring in 1988. Within the 18 years, there were 1826 occurrences for the 6- to 10-hour duration, 1390 for the 1- to 5-hour duration, 396 for the 11- to 15-hour duration and 26 for the 16- to 20-hour duration.

Headwater elevation at Chickamauga Dam along with the discharge from WBH determines the water surface elevations downstream of WBH in the vicinity of the plant sites. Chickamauga Reservoir elevations vary from a normal maximum elevation of 683.0 feet in the summer months to a normal minimum elevation of 675.0 feet in the winter months. Table 3 shows the approximate stage-discharge relationship below WBH at minimum pool conditions in the winter.

B. Watts Bar Fossil Plant

Watts Bar Fossil Plant (WBF) is currently mothballed with no scheduled start-up date. When operated at full capacity, WBF generated 240 MWe, used a once-through cooling system requiring 626 cfs of cooling water, and elevated the cooling water temperatures up to 10 F° (5.6 C°). The fossil plant heated discharge was continuous regardless of WBH operation.

Ungate and Howerton (1977) described the plant water usage as follows. The once-through cooling water is supplied by gravity from WBH through a conduit system approximately 3,600 feet long. The centerline of the intake opening is located at elevation 716 feet and is contiguous with the upstream face of Watts Bar Dam at the right abutment of the dam. The

TABLE 1

Watts Bar Hydro Plant Releases (1976 - 1993[1])

Low River Flow Occurrence And Duration
Broken Down By Year For All Months

Number of times flows < 3,500 cfs persisted for indicated duration

Year	Total hours per year[2]	Duration (hours)				
		1-5	6-10	11-15	16-20	21+
1976	1422	134	112	8	1[3]	0
1977	1386	123	98	18	0	0
1978	1775	136	145	19	0	0
1979	448	58	29	1	0	0
1980	1548	98	145	9	0	0
1981	2520	176	238	14	0	0
1982	56	14	2	0	0	0
1983	6	3	0	0	0	0
1984	454	39	39	3	0	0
1985	1886	79	140	39	3	0
1986	2817	113	189	73	4	0
1987	2408	117	189	44	2	0
1988	2814	121	169	74	9	0
1989	540	25	50	5	0	0
1990	523	22	34	13	1	0
1991	551	24	47	9	0	0
1992	1119	53	78	20	5	0
1993	1763	55	122	47	1	0
Total Occurrences		1,390	1,826	396	26	0

Notes:
1. Does not include November 29 through December 31, 1993.
2. There are 8760 hours in a non-leap year.
3. For example, there was 1 occurrence in 1976 when the WBH release was less than 3,500 cfs for between 16 and 20 continuous hours.

TABLE 2

Watts Bar Hydro Plant Releases (1976 - 1993[1])

Low River Flow Occurrence And Duration
Broken down By Month For All Years

Number of times flows < 3,500 cfs persisted for indicated duration

Month	Total hours per year	Duration (hours)				
		1-5	6-10	11-15	16-20	21+
Jan	870	117	66	1	1[2]	0
Feb	800	128	53	1	0	0
Mar	1241	118	109	3	2	0
Apr	2266	147	196	16	3	0
May	3018	110	222	58	10	0
Jun	3952	68	175	106	4	0
Jul	2553	59	196	62	1	0
Aug	1947	80	148	39	2	0
Sep	2762	75	181	81	3	0
Oct	2465	143	239	17	0	0
Nov	1867	186	158	9	0	0
Dec	1195	159	83	3	0	0
Total Occurrences		1,390	1,826	396	26	0

Notes:
1. Does not include November 29 through December 31.
2. For example, there was 1 occurrence in all **Januarys,** 1976-1993, when WBH release was less than 3,500 cfs for between 16 and 20 continuous hours.

TABLE 3

Approximate Stage Discharge Relationship
Immediately Below Watts Bar Dam

(Ungate and Howerton, 1977)

Water Surface Elevation **(feet)**	Watts Bar Dam Discharge **(cfs)**
675	0
677	12,500
679	25,000
681	37,500
683	50,000
696	190,000

heated water from the condensers is discharged into the river through a rectangular culvert 7 feet wide and 10 feet deep. The top elevation of the culvert outlet is 675.0 feet, which coincides with the minimum pool level of **Chickamauga** Reservoir. Topography in the vicinity of the discharge is given in Figure A.2.

C. Watts Bar Nuclear Plant

Watts Bar Nuclear Plant (WBN) operates in closed-mode using one natural draft cooling tower per nuclear unit. The **blowdown** from closed-mode operation is discharged into the Tennessee River through a multiport diffuser system. WBN is designed to route the **blowdown** water either to the diffusers or to a yard holding pond. The current National Pollutant Discharge Elimination System **(NPDES)** Permit for WBN stipulates that the discharge diffusers may operate only when discharge from WBH is greater than 3,500 cfs.

1. Plant Design

WBN is a two-unit nuclear plant, with one unit nearing the end of construction. It is located on the right bank of the Tennessee River at TRM 528. When operated at full capacity, it will produce 2,540 **MWe** (1,270 **MWe** per unit) of electricity. WBN utilizes a closed-cycle heat dissipation system consisting of two natural draft cooling towers and a **blowdown** system. The water losses due to evaporation and **blowdown** are replenished with the makeup water which is supplied via an intake channel and pumping station at **TRM** 528.0. The average and maximum intake flow rates are 133 cfs and 143 cfs, with a dilution ratio of twice that of the blowdown.

2. Intake and Discharge Design

The cooling tower **blowdown** flow is directed through the **blowdown** diffuser system to the Tennessee River. The **blowdown** system consists of two multiport diffusers (at TRM 527.8) and the 190 acre-feet capacity yard holding pond. Presently, whenever less than 3,500 cfs is discharged from the WBH, the two diffuser legs are closed and **blowdown** flow is diverted to the holding pond for storage. An overflow weir on the south side of the pond allows discharge to the Tennessee River (TRM 527.2) should the pond capacity be exceeded in an emergency. The **blowdown** system is depicted in Figure A.3.

The diffuser system consists of two pipes branching from a central conduit at the right bank of Chickamauga Reservoir and extending in a direction perpendicular to Tennessee River flow. Each pipe is controlled by a 54-inch diameter **butterfly** valve located a short distance downstream of the central conduit wye. A physical description of the diffusers is given in Table 4 and depicted in Figure A.4.

TABLE 4

Dimensions of Constructed Diffusers
Watts Bar Nuclear Plant

		Upstream Leg	Downstream Leg	Total
DIFFUSER	Pipe Length (ft) (unpaved corrugated steel pipe)	80.0	160.0	240.0
	Pipe Diameter (ft)	3.5	4.5	
	Port Diameter (in)	1.0	1.0	
	Number of Port Per Corrugation	2	2	
	Port Spacing Normal to Corrugation (in)	3.0	3.0	
	Port Spacing Parallel to Corrugation (in)	3.0	3.0	
	Friction Factor	0.0948	0.0841	
APPROACH PIPE	Pipe Length (ft) (paved corrugated steel pipe)	447.0	297.0	744.0
	Pipe Diameter (ft)	3.5	4.5	
	Friction Factor	0.0191	0.0148	

The downstream leg is composed of two segments of 4.5-foot diameter pipe. The approach pipe is made of paved corrugated steel approximately 297 feet long, while the diffuser pipe is made of unpaved **corrugated** steel 160 feet long. The diffuser pipe section is half buried in the river bottom and has two 1-inch diameter ports per corrugation. The centerline of the ports is oriented at a **45°** angle from the horizontal in a downstream direction.

The upstream leg is composed of two segments of 3.5-foot diameter pipe. The approach pipe is made of paved corrugated steel approximately 447 feet long, while the diffuser pipe is made of unpaved corrugated steel 80 feet long. The upstream diffuser pipe section is half buried in the river bottom and extends its entire length of 80 feet beyond the dead end of the downstream diffuser pipe section. The port diameter, spacing, and orientation of the upstream leg is the same as that of the downstream leg.

The location of the diffuser system at TRM 527.8 is given in Figure A.5. Both the upstream and downstream legs are located beneath the navigation channel. For a detailed description of the diffuser design and operation see Ungate (1976). For results of hydrothermal model tests of the diffusers see Ungate (1977).

3. **Blowdown** Discharge Rates

To maintain the concentration of dissolved solids in the cooling tower basins at approximately twice that found in the Tennessee River, **blowdown** discharge from the cooling tower basins is between 44.6 cfs and 85.0 cfs. During periods of zero release from WBH, **blowdown** is routed into a yard holding pond of approximately 190 acre-feet capacity. When discharge from WBH is greater than 3,500 cfs, discharge of **blowdown** through the diffusers into the river is resumed. The yard holding pond discharge rate is between 60.2 and 85.0 cfs. Combined **blowdown** and holding pond discharge can range between 44.6 and 170 cfs.

4. Operating Characteristics of the Diffuser Legs

Table 5 contains the operating characteristics of the diffuser legs such as maximum and minimum flows, the average jet exit velocity, approach pipe velocity, and the required head. It shows that the average jet exit velocity varies from 6.8 to 17.3 feet per second **(fps)** for all operations.

TABLE 5

Design Characteristics of Blowdown Diffusers for Normal Operation

OPERATING PARAMETERS	Minimum	Maximum
Blowdown Discharge Rate	44.6 cfs 28.8 Mgld	170.0 cfs 109.9 Mgld
Port Velocity (fps)	6.8	17.3
Appeoach Pipe Velocity (fps)	2.3	5.9
Dead End Head (ft)	1.6	10.4
Diffuser Head Required (ft)	1.7	11.1
Total Head Required from Wye (ft)	1.8	12.1

III. HYDROTHERMAL ANALYSES

Due to the unique configuration of having a dam, a fossil plant, and a nuclear plant located in close proximity to each other, the effects of the individual and combined fossil and nuclear discharges on the river temperature (near-field) are evaluated.

A. Watts Bar Fossil Plant Thermal Discharge

1. Future Watts Bar Fossil Plant Operation

Currently Watts Bar Fossil Plant is mothballed. There are no schedules for unit start up. The units are being considered for a solid waste burning facility. However, the project is only in the initial exploration stage. A waste-fired plant is not anticipated to have a higher heat discharge than the previous coal-fired operation.

2. Watts Bar Fossil Plant 316a Variance

The Environmental Protection Agency granted TVA a 316a variance for WBF once-through cooling operation in 1975 (Zeller, 1975). The variance was based in part on water temperature surveys (Tennessee Valley Authority, 1974). The WBF NPDES permit issued in 1984 (with continued 316a variance) has a daily average discharge limit of 90°F (32.2°C).

3. Effects of Watts Bar Fossil Plant on Water Temperatures

Although WBF is not currently on-line, there is a possibility of some form of renewed operation in the future. Because the thermal discharge characteristics of any future fossil plant operation are unknown, predictive modeling efforts utilize the cooling water flow and temperature rise of the past operation. Thus, the discharge analyzed conforms to the previous full load fossil plant discharge of 626 cfs with a 10 F° (5.6 C°) temperature rise, which equates to adding 1.4×10^9 Btu/hr heat to the river.

4. River Temperature Analysis

Ungate and Howerton (1977) provide the most complete analysis of the fossil plant discharge together with field measurements. Using the surface jet model of Shirazi and Davis (1974), Ungate and Howerton analyzed the initial mixing zone of the discharge. The initial mixing zone extended between 300 and 800 ft downstream of the discharge depending on the ambient flowrate. At the edge of the initial mixing zone, calculated temperature rises for the plume centerline were between 1 and 5 F° (0.6 and 2.8 C°), and for the average of the whole plume were between 0.5 and 3 F° (0.3 and 1.7 C°).

At higher ambient flows and higher pool elevations, the calculated temperature rises were smaller. Temperatures beyond the initial mixing zone were not presented.

Additionally, Ungate and Howerton (1977) described field observations of the fossil plant discharge during and immediately following a prolonged **period** of zero river flow. Periods of zero flow can extend 12 hours or longer as WBH operates for peaking power purposes. Under zero flow conditions, the heated discharge is not advected downstream. The river in the fossil plant vicinity is gradually heated as the discharge re-entrains itself.

The field observations made on October 30, 1977, included studies of the river during and after a 12-hour flow shutdown, while all four WBF units were operating. The observed longitudinal excess water temperature is shown in Figure A.6, along with measurements made during a 6-hour shutdown on March 16, 1974. The effect of the extended duration is to increase the longitudinal extent, but not the maximum value, of the excess temperature of the warm water slug. The downstream edge of the warm water slug proceeded downstream as a stratified surface layer, causing less than a 1.0 F° (0.6 C°) temperature rise in the vicinity of the nuclear plant discharge at **TRM** 527.8. Upstream of the discharge, no significant difference in the excess temperature distribution was observable for the two shutdown durations. Apparently the excess temperature distribution upstream of the discharge attains a steady-state condition after six hours of zero river flow.

Once flow at WBH is resumed after a shutdown, the warm water slug is advected downstream. Figure A.7 shows field measurements and model predictions of the river temperature presented by Ungate and Howerton (1977) for resumed flow following the October 30, 1977, shutdown. The field survey and model predictions show that after an extended period of no flow (12 hours), the discharge from WBF caused a temperature rise of almost 3.0 F° (1.7 C°) at the WBN diffuser location. During the critical summer months the temperature rise would be less because the discharge is submerged and, in rising to the surface, the discharge entrains a greater volume of the ambient water.

5. Summary of Effects for Combined Evaluation

A conservative approach was taken to estimate the downstream impact of the discharge for the combined operation of the fossil and nuclear plants. A 3.0 F° (1.7 C°) temperature increase over the ambient was used to quantify the impact of the fossil operation at the nuclear diffuser. The 3.0 F° (1.7 C°) increase is greater than the observed increase after a 12-hour shutdown. In mid-summer, the increase should be less than 3.0 F° (1.7 C°) due to the higher pool and the associated discharge submergence which provides a greater available volume of water for dilution.

B. Watts Bar Nuclear Plant Thermal Discharge

1. Near-Field Effects of Diffuser Discharge on River Temperature

The thermal effects of the WBN discharge on Chickamauga Reservoir depend on the ambient river flow temperature and surface elevation and the discharge flow and temperature through the WBN diffusers. A computer model was used to simulate the thermal effects of WBN under several scenarios for WBF and WBN plant operations for the ambient river and atmospheric conditions of the period from January 1, 1976 through October 15, 1993. River flows and elevations, WBN discharge temperatures and flows, and the resulting downstream river temperatures were calculated for each hour of this period.

2. Computer Model Inputs

a. Meteorological Data

Hourly wet-bulb and dry-bulb temperatures were obtained from National Weather Service meteorological records at Chattanooga airport for January 1, 1976, through October 15, 1993. The Chattanooga airport is the closest airport south (conservative meteorology) of the Watts Bar site. The airport at Knoxville is closer to the Watts Bar site but is north of the site, and may be cooler.

b. Watts Bar and Chickamauga Hydro Releases and Chickamauga Headwater Elevation

Hourly releases from Watts Bar and Chickamauga Hydros, and the headwater elevation at Chickamauga Hydro, were obtained from TVA records for January 1, 1976 through October 15, 1993.

c. Reservoir Elevations at WBN Site

The discharge flowrate through the WBN diffusers depends on the difference in elevation between the river surface at WBN and the water surface in the WBN holding pond. During periods of discharge from WBH, the river elevation at WBN can be lower than WBH tailwater elevation (Figure A.8). Therefore, river flow and river elevations at WBN were calculated on an hourly basis using an explicit one-dimensional unsteady numerical flow routing model (Ferrick and Waldrop, 1977). Hourly discharges from WBH and Chickamauga Hydro and the headwater elevation at Chickamauga Hydro were used as boundary conditions. The model was calibrated using field measurements of river elevation at WBN for the month of August 1993 (Figure A.8).

d. River Temperatures Upstream of the Nuclear Plant Site

WBH release temperatures were generated by **TVA's** System Temperature (SYSTEMP) model (Alavian and **Ostrowski**, 1991) using the above meteorological data. The SYSTEMP model has previously been used to estimate probable extreme intake temperatures at WBN (Alavian and Potter, 1992). An example of computed versus measured WBH release temperatures from that study is shown in Figure A.9. The computed WBH release temperatures were used as the ambient river temperature at WBN for the scenarios with no **WBF** operation. For scenarios where WBF was assumed operational, these temperatures were incremented by the estimated maximum river temperature rise of 3.0 F° (1.7 C°) due to the WBF discharge (Section III.A.5).

e. WBN **Blowdown** Flow and Temperature

The diffuser discharge flow and temperature depend on the reactor power levels of each unit; the flowrates and temperatures of the condenser cooling water (CCW), essential raw cooling water (ERCW), and raw cooling water (RCW) systems; the surface elevations of the yard holding pond and Chickamauga Reservoir; the ambient wet-bulb and dry-bulb temperatures; and the intake temperature of the ERCW and RCW systems.

Hourly values of tower **blowdown** flow and temperature were computed using steam turbo-generator and cooling tower performance calculation methods **(Benton**, 1992). Two-unit WBN operation at full design load was assumed. In cases where the turbine backpressure limit of 5.5 inches of mercury would be exceeded, the unit loads were reduced to meet the backpressure limit. Cooling tower capabilities of 89 percent were assumed for both towers. Condenser cleanliness factors of 85 percent were assumed for both units.

ERCW pump flowrates were assumed to be 21.7 cfs (9,740 **gal/min)** per pump. RCW pump flowrates were assumed to be 10.3 cfs (4,610 **gal/min)** per pump. These flowrates assume 10 percent degradation from design capacity as indicated in the ERCW Design Criteria and RCW System Description (TVA Engineering Design, 1993; TVA Engineering Design, 1988). ERCW and RCW system intake temperatures were assumed equal to the ambient river temperature.

The diffuser discharge was computed with a pipe flow routing program which distributes the flow between diffuser legs by balancing the head between the pond and the river. The program simulates the operation of the yard holding pond in a manner such that flow conservation is maintained for all discharges entering the **blowdown** system from the cooling towers. It was assumed that both diffuser legs were operated whenever diffuser discharge was permitted.

Model Results

The heated effluent dilution caused by the interaction between **WBN** submerged diffusers and the river was computed using an analytical expression (Adams, 1972) described in Ungate and Howerton (1977). Two operational scenarios were investigated. For both scenarios, hourly **WBN** discharge temperature and flow, and downstream river temperature, temperature rise, and rate of change were calculated for the period from January 1, 1976 through October 15, 1993. Results of simulation for each scenario are given below:

a. Scenario 1 - Operation of **WBN** under the current discharge restrictions (no WBN diffuser discharge when **WBH** discharge is less than 3,500 cfs) and no **WBF** plant operation.

   In this scenario, **WBF** is not operating and no discharge from the **WBN** diffusers is allowed if the **WBH** discharge is less than 3,500 cfs (one-half unit operation). During periods when the WBH discharge is below this level, cooling tower **blowdown** flow is routed into the yard holding pond. The pond can accumulate **blowdown** water for approximately 30 hours before overtopping the overflow weir. The actual time available before overflow varies with plant pump operation, the percentage of cooling tower flow which is lost to evaporation, river elevation, and the initial level of water in the pond.

   The maximum pond elevation which occurred under this scenario was 708.05 feet on September 26, 1988 at 1200 hours, corresponding to an overflow weir discharge of 60 cfs (Figure A.lO). The maximum diffuser discharge of 165 cfs, a combination of 65 cfs **blowdown** from the towers and 100 cfs flow from the yard holding pond, occurred on September 26, 1988 at 1300 hours. The maximum total discharge from the plant occurred at the same time, with an additional 25 cfs being discharged from the overflow weir for a total discharge rate of 190 cfs (Figure A.11).

   The maximum upstream river temperature for this scenario was 82.5**°F** (28.1 C°) on July 29, 1993. The maximum downstream river temperature of **82.6°F** (28.1 C°) occurred on the same date (Figure A.12). The maximum downstream river temperature rise was 1.8 F° (1.0 C°) on February 3, 1986 (Figure A.13). The maximum diffuser discharge temperature was **97.3°F** (36.3 C°) on July 13, 1980 (Figure A.14). Minimum, average, and maximum monthly values for the downstream temperature rise, downstream temperature, and discharge temperature are shown in Table 6.

b. Scenario 2 - Operation of **WBN** under the current discharge restrictions (no **WBN** diffuser discharge when WBH discharge is less than 3,500 cfs) but with **WBF** plant operation.

TABLE 6

Summary of Results (Scenario 1)
Downstream Temperature, January 1, 1976 to October 15, 1993

Assumptions: No WBF operation, no WBN discharge when WBH release is < 3,500 cfs

Month	Temperature Rise F°			River Temperature °F			Discharge Temperature °F		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Jan	0.0	1.6	0.2	34.9	58.4	42.0	43.0	80.6	64.3
Feb	0.0	1.8	0.3	35.1	51.3	41.9	50.8	83.5	66.6
Mar	0.0	1.7	0.3	37.7	56.7	47.7	51.3	87.0	70.8
Apr	0.0	1.4	0.3	48.7	65.6	56.7	59.1	88.1	75.1
May	0.0	1.0	0.2	57.8	72.4	64.5	64.9	91.5	79.9
Jun	0.0	0.9	0.2	62.3	79.1	70.7	70.1	94.0	84.5
Jul	0.0	0.7	0.1	66.2	82.6	74.9	76.2	97.3	86.8
Aug	-0.1	0.4	0.1	70.8	81.8	76.5	74.5	95.4	86.0
Sep	-0.2	0.7	0.1	67.5	81.2	75.0	67.2	93.0	82.5
Oct	-0.3	0.9	0.1	58.2	76.8	68.0	59.1	90.3	75.5
Nov	-0.1	1.2	0.1	47.6	68.3	58.8	54.7	86.0	70.9
Dec	0.0	1.5	0.2	39.8	59.5	48.7	46.8	85.1	66.4

In this scenario, WBF is assumed to be operational, and the same restrictions on WBN diffuser discharge apply as in Section III.B.3.a. The upstream river temperature for this scenario, incremented by the estimated maximum river temperature rise due to WBF operation (3 F°, 1.7 C°), resulted in a maximum upstream river temperature of 85.5 °F (29.7 C°) on July 28, 1993. The maximum downstream river temperature of **85.6°F** (29.8 C°) occurred on the same date (Figure A.15).

The maximum downstream river temperature rise for this scenario was 1.7 F° (0.9 C°) on February 3, 1986 (Figure A.16). The discharge temperature from a closed cycle plant is primarily determined by air temperature and plant load, and is relatively independent of the intake water temperature. Thus, the maximum diffuser discharge temperature for this scenario was the same as Scenario 1 **(97.3°F,** 36.3 C°, on July 13, 1980). Minimum, average, and maximum monthly values for the downstream temperature rise, downstream temperature, and discharge temperature are shown in Table 7.

4. Worst Case Combination of Ambient River and Air Temperatures and WBN Diffuser **Operation**

The WBN diffuser operation was analyzed for the combined worst case ambient river, air, and yard holding pond temperatures. The maximum value of upstream river temperature for full load operation of WBF was used (85.5°**F, 29.7°C).** The air temperature values at the time of maximum discharge temperature in the previous runs were used **[dry**- and wet-bulb temperatures of 102°**F** (38.9 **°C)** and 85.O°F (29.4**°C)].** A yard holding pond temperature of **104°F** (40.0°C) was used (details are provided in Section III.B.6).

When WBN diffuser discharge is not permitted (WBH discharge is less than **3,500** cfs), the worst case discharge condition would occur at the beginning of a **3,500** cfs release from WBH after a period when the WBN pond has reached its maximum elevation. The resulting discharge from WBN was a combination of tower **blowdown** flow of 83.8 cfs at **97.3°F (36.3°C)** and flow from the pond through the diffusers of 98.6 cfs at 104°F (40.0°C). The diffuser discharge flow of 182.4 cfs at **100.9°F (38.3°C)** resulted in a river temperature rise of 0.9 F° (0.5 C°) and a downstream river temperature of **86.4°F (30.2°C)** (Table 8).

If the maximum WBN-induced temperature rise (1.8 F°, 1.0 C°) is added to the 3 F° (1.7 C°) increase from WBF operation after resumed releases from WBN, the combined worst case temperature rise is 4.8 F° (2.7 C°).

TABLE 7

Summary of Results (Scenario 2)
Downstream Temperatures, January 1 to October 1993

Assumptions: WBF operation, no WBN discharge when WBH release is < 3,500 cfs

Month	Temperature Rise F°			River Temperature °F			Discharge Temperature °F		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Jan	0.0	1.5	0.2	37.9	54.8	45.0	43.0	80.6	64.3
Feb	0.0	1.7	0.2	38.1	54.3	44.9	50.8	83.5	66.6
Mar	0.0	1.6	0.2	40.7	59.5	50.7	51.3	87.0	70.8
Apr	0.0	1.2	0.3	51.7	68.5	59.7	59.1	88.1	75.1
May	-0.1	0.9	0.2	60.8	75.3	67.5	64.9	91.5	79.9
Jun	-0.1	0.7	0.1	65.3	82.0	73.7	70.1	94.0	84.5
Jul	-0.1	0.6	0.1	69.2	85.6	77.9	76.2	97.3	86.8
Aug	-0.2	0.3	0.1	73.8	84.7	79.5	74.5	95.4	86.0
Sep	-0.3	0.6	0.1	70.4	84.2	78.0	67.2	93.0	82.5
Oct	-0.4	0.8	0.1	61.2	79.7	71.0	59.1	90.3	75.5
Nov	-0.2	1.0	0.1	50.6	71.2	61.8	54.7	86.0	70.9
Dec	0.0	1.4	0.1	42.8	62.5	51.7	46.8	85.1	66.4

TABLE 8

Summary of Results - Watts Bar Nuclear Plant Thermal Discharge
Worst Case Steady-State Conditions with Continuous Discharge

Assumptions: Worst case meteorology, upstream, and pond temperatures; Loads adjusted for 5.5 in.-Hg limit; Maximum diffuser discharge flow

	Unit 1	Unit 2	Units 1 & 2
River flow (cfs)	--	--	3500
Velocity (fps)	--	--	0.227
Elevation (ft)	--	--	680.0
Dry-bulb temperature (°F)	--	--	102.0
Wet-bulb temperature (°F)	--	--	85.0
Relative humidity (%)	--	--	50.3
Intake temperature (°F)	--	--	85.5
Condenser cleanliness (%)	95.0	95.0	95.0
Tower capabilities (%)	89.0	89.0	89.0
CCW pumps	4	4	8
ERCW pumps	2	2	4
ERCW bypass (cfs)	0.0	0.0	0.0
RCW pumps	3	3	6
Loads (MWe)	960	960	1920
CCW inlet temperature (°F)	98.0	98.0	98.0
CCW outlet temperature (°F)	130.2	130.2	130.2
Turbine backpressure (in.-Hg)	5.5	5.5	5.5
Tower flows (cfs)	935	935	1870
Tower blowdown flows (cfs)	41.9	41.9	83.8
Tower discharge temperature (°F)	97.3	97.3	97.3
Pond elevation (ft)	--	--	708.1
Pond temperature (°F)	--	--	104.0
Diffuser discharge temperature (°F)	--	--	100.9
Diffuser discharge (cfs)	70.1	112.3	182.4
Overflow weir discharge (cfs)	--	--	65.9
Upstream temperature (°F)	--	--	85.5
Downstream temperature (°F)	--	--	86.4
Temperature Rise (F°)	--	--	0.9

5. Daily Average Discharge Temperature Limit

Experience with thermal discharges at **TVA's** other nuclear and fossil plants has shown that a daily average limit offers plant flexibility without adversely affecting the receiving water body. Changes in plant operations, adverse short-term weather patterns, and other factors can often cause unexpected spikes in water temperatures. Such temperatures are not representative of the effect of the thermal discharge on the water environment. All of **TVA's** fossil plants in Tennessee have a daily average discharge limit.

The modeling discussed in the previous section showed that even a steady-state discharge (up to **100.9°F, 38.3°C)** under worst case conditions (worst meteorology on record, full load WBF Operation, and no WBH Operation) guarantees that the discharge after mixing will meet the State of Tennessee's thermal water quality criteria.

Table 9 shows the worst daily average discharge temperature in the two scenario simulations. Also shown is the maximum hourly discharge temperature. Based on these results and providing for a small margin of safety, TVA proposes a daily average discharge limit for WBN of 95°**F** (35°C).

6. Yard Holding Pond Temperature - Maximum Temperature Limit

During a period of zero discharge from the WBH, the **blowdown** is stored in the yard holding pond. The following assumptions were used to calculate the rise of pond water temperature:

a. zero discharge from WBH for 12 hours,
b. worst meteorological conditions (July **1952),**
c. pond surface elevation at 707.0 feet,
d. pond bottom elevation at 688.0 feet,
e. no advection to cool the water, and
f. maximum **blowdown** temperature of 97.3 °**F** (36.3°**C).**

The analysis results show that the pond water temperature could reach 104.0°F (40.0°C), and the water would discharge through the pond overflow weir if the pond elevation should reach above 707.0 feet (Figure A.17).

7. Thermal Impact of Yard Holding Pond **Overflow** on the River Temperature

CORMIX (Cornell Mixing Zone Expert System, NCASI, **1992),** was used to model the mixing of the pond discharge through the overflow weir into the river. The following assumptions were used:

TABLE 9

Effects of Watts Bar Nuclear Plant Operation on River Temperature
Summary Results of Scenario Simulations

Scenario	Scenario Characteristics	Maximum Upstream Temperature (°F)	Maximum Downstream Temperature (°F)	Maximum Temperature Rise* (F°)	Maximum Hourly Discharge Temperature (°F)	Maximum Daily Average Discharge Temperature (°F)
1	No WBF operation, no **WBN** discharge when WBH release < 3500 cfs	82.5	82.6	1.8	97.3	93.3
2	WBF operation, no WBN discharge when WBH release < 3500 cfs	85.5	85.6	1.7	97.3	93.3

* Temperature rise due only to WBN thermal discharge

a. river at summer pool elevation of 682.0 feet,
b. ambient temperature of 84.5°F (29.2°C),
c. river at the low flow of 0.3 feet per second velocity,
d. pond discharge temperature of 104.0°F (40.0°C), and
e. pond flow of 60 cfs.

The modeling results indicate that a steady state was reached at about 3,000 feet, fully laterally mixed to the depth of 1.2 feet. The temperature rise in the plume is 1.3 F° (0.7 C°) which is lower than the State criteria of 5.4 F° (3.0 C°).

8. Nuclear Plant Mixing Zones and Zone of Passage

The permitted diffuser mixing zone at WBN extends 240 feet downstream over the entire river depth and diffuser system width (240 feet) for all discharge operations (Ungate and Howerton, 1977). Figure A.5 (from Ungate and Howerton, 1977) shows the diffuser location. The width of the Tennessee River at the nuclear plant site is about 1,000 feet. Previous studies of diffuser mixing considered river flows as low as 3,500 cfs.

The diffuser mixing zone will be confirmed by field observations for one-unit operation and later for two-unit operation. As shown in Figure A.5, there should be ample area for fish movement on the left (looking downstream) side of the river under all operating conditions. The navigation lock is also located on the left side of the river for fish movement past the dam (see Figure A.1).

The discharge from overflowing the yard holding pond takes longer to mix than the diffuser discharge. The proposed mixing zone for the surface discharge is 1,000 feet wide and extends 3,000 feet downstream. Because of the surface discharge, there should be ample area for fish movement below the surface plume.

9. Summary of Watts Bar Nuclear Plant Thermal Effects

Table 9 summarizes the results of the two operational scenarios evaluated. The maximum hourly downstream temperature was 85.6°F (29.8°C) and the maximum temperature rise was 1.8 F° (1.0 C°). Because the maximum hourly temperature rise is below 3.6 F° (2.0 C°), the plant-induced rate of temperature change will always meet the State rate of temperature change criteria of 3.6 F°/hour (2.0 C°/hour). The maximum hourly discharge temperature (97.3 F°, 36.3 C°), only dependent on meteorology, was the same in both scenarios.

The worst case conditions evaluated at steady-state showed that, even with a discharge of 100.9°F (38.3°C), the maximum downstream temperature of 86.4°F (30.2°C) is below the State criteria of 86.9°F (30.5°C). Based on the worst case steady-state results, the maximum daily averages shown in Table 9, and a small margin of safety,

TVA proposes a daily average discharge limit of 95°F (35°C). **TVA** also proposes a pond overflow temperature limit of 104°F **(40°C),** which would be measured by grab sample once a day at the overflow weir during an emergency overflow.

The previously defined diffuser mixing zone is 240 feet wide and extends 240 feet downstream. Due to the location and width of the diffuser, ample space exists for fish to pass by the plant during all operations. The proposed mixing zone for the overflow discharge is **1,000** feet wide and extends **3,000** feet downstream. These evaluations will be confirmed by field investigations.

IV. THE COMBINED EFFECT OF WATTS BAR NUCLEAR AND FOSSIL PLANT DISCHARGES ON SEQUOYAH NUCLEAR PLANT

Sequoyah Nuclear Plant (SQN) is located about 45 river miles downstream of the Watts Bar facilities. A reservoir water quality model was used to determine the potential effects of the Watts Bar facilities on SQN intake temperatures and subsequent operation.

The impact of thermal discharges from WBN (TRM 527.8) and WBF (TRM 529.0) on SQN (TRM 484.5) operation was examined using the two-dimensional Chickamauga Box Exchange Transport Temperature and Ecology of a Reservoir (BETTER) model. The Chickamauga BETTER model was calibrated with three years of field surveys (1985, 1986, and 1987) and was verified using field data collected in 1988. A detailed description of the model and discussions on model calibration and verification can be found in Butkus, et al. (1990). The following worst case was selected to evaluate the effects of thermal discharges from WBN and WBF under 1986 (dry year) hydrology and meteorology, assuming the two units at SQN are in operation with a total condenser circulating water flow of about 3,000 cfs.

Both nuclear units were assumed in operation plus yard holding pond discharge at WBN and surface discharge at WBF. The maximum **blowdown** rate is about 85 cfs. Combined with the yard holding pond discharge, the maximum worst case total discharge amounts to 182.4 cfs (Table 8). The **blowdown** temperature is a function of the wet-bulb temperature and can be computed (from a curve fit of model results) as:

$$T_b = 17.1777 + 0.230339T_d - (0.463474\times10^{-2})T_d^2 + 0.250133T_w \\ - (0.127615\times10^{-2})T_w^2 + (0.94504\times10^{-2})T_dT_w$$

where $\mathbf{T_b}$ is the **blowdown** temperature in **°C,** $\mathbf{T_d}$ is the dry bulb temperature in **°C,** and $\mathbf{T_w}$ is the wet-bulb temperature in **°C.** No ambient heating or cooling is assumed for the yard holding pond discharge. The **blowdown** and the yard holding pond discharge enter the river via two multiport diffusers with a combined length of about 240 ft.

When WBF is operated at rated capacity, the plant requires 626 cfs of cooling water and raises the temperature of water withdrawn through Watts Bar Dam by up to 10 F° (5.6 C°) (Ungate and Howerton, 1977). Because the elevation of the centerline of the turbines (elevation 676 feet, approximately 60 feet deep) is 40 feet below the fossil plant intake, water temperatures entering the fossil plant could theoretically be higher than water temperatures entering the turbines. A study of withdrawal thickness at WBH indicates that water from all depths enter the turbines, even when a warm surface layer is present in the summer months (TVA, 1972). The temperature difference between the fossil plant intake and the turbine discharge is, therefore, not considered to be significant. In this study, the temperature of water entering the fossil plant is assumed equal to the release temperature at WBH.

The combined effects of WBN and WBF thermal discharges can be evaluated by comparing water temperatures at the SQN intake (TRM 483.7-484.8) against that of a base run which does not include thermal discharges from WBN and WBF. As shown in Figure A.18, below the **WBN** and **WBF** thermal discharges (TRM **527.4-529.0),** the average differences in the surface and bottom temperatures are about 1.3 F° (0.7 C°) and 0.5 F° (0.3 C°) even under extremely low flow conditions. A large increase in surface temperature of about 4.5 F° (2.5 C°) occurs in early July under reverse flow conditions. This reverse flow was computed based on the flat pool assumption and might not actually happen in the field. The temperature increase dissipates quickly as it flows downstream. At the SQN intake (Figure A.**19),** there is essentially no difference in the surface temperature, and the average difference in the bottom temperature is reduced to about 0.4 F° (0.2 C°). Immediately below the SQN diffuser **(TRM 483.0-483.7),** the average difference in the bottom temperature (Figure A.20) is reduced to about 0.2 F° (0.1 C°). With higher river flows, the combined impacts of WBN and WBF are expected to be less pronounced as the temperature increase would quickly dissipate due to dilution with larger flows. At Chickamauga Dam, the effect of WBN and WBF is almost indiscernible as demonstrated by the difference in release temperatures in Figure A.21.

The combined effects of WBN and **WBF** thermal discharges on SQN operation are expected to be small with an average increase in bottom temperature of about 0.4 F° (0.2 C°) under low river flow conditions. With higher river flows, the impact is expected to be less pronounced as the temperature increase would quickly dissipate due to dilution with larger flows. Therefore, operations of Watts Bar Fossil and Nuclear Plants are not anticipated to cause problems with **Sequoyah** Nuclear Plant's ability to meet safety or environmental temperature limits.

V. PROPOSED THERMAL LIMITS FOR WATTS BAR NUCLEAR PLANT

A. Proposed Diffuser Discharge and Overflow Pond Temperature Limits

TVA proposes a daily average thermal discharge limit of 95°F (35°C). TVA also proposes a pond overflow temperature limit of 104°F (40°C), measured at least once per day at the overflow weir. The 240-foot wide diffuser mixing zone extends 240 feet downstream. The proposed surface overflow mixing zone should be 1,000 feet wide and extend 3,000 feet downstream.

B. Monitoring and Reporting

WBN has continuous temperature and flowrate sensors to monitor the discharge before it enters the multiport diffusers. Plant instrumentation can record the hourly-averaged values of temperature and flowrate measurements. TVA proposes a daily average discharge temperature limit based on the flow-weighted average of the hourly temperature values measured during diffuser discharge. Flow weighting provides a true representation of the amount of heat being discharged. Daily reporting would include both average temperature and flowrate. Should the yard holding pond overflow, measurements of the discharge flowrate and temperature will be made by water level measurement and grab sample at least once per day at the overflow weir. Monthly Discharge Monitoring Reports would provide the maximum and mean daily average temperature and flowrate values.

TVA will calibrate the plant temperature sensors, flowrate monitors, and transfer electronics at least annually. Calibration records will be kept on-site for review.

C. Staged Field Verifications

TVA proposes to conduct field surveys of thermal conditions in stages as heated discharges are added at the Watts Bar site. Near-field surveys of one-unit WBN operation will be used to verify mathematical modeling assumptions used in this report. The near-field surveys will attempt to cover both worst-case summer (maximum downstream temperature) and winter (maximum temperature rise) conditions. Surveys will include steady one-unit releases (7,500 to 10,000 cfs) from WBH. Peaking operations will also be tested where WBH releases are curtailed at night for up to 16 hours, followed by one-unit hydro plant operation until steady-state conditions are reached. Appropriate conditions for these surveys may only be available during periods of normal to low rainfall. Heavy rainfall years may provide too much river flow in the system to schedule low WBH operations. TVA will attempt to finish the surveys within a year after full load operation.

The results of all field surveys will be sent to the State of Tennessee within six months of the survey. Reports will summarize the thermal surveys in tabular and visual formats. The surveys will be compared with mathematical model results to verify the assumptions used in this report. The surveys will also document the mixing zone and zone of passage.

Any field surveys that show exceptions to the assumptions used in this report will be documented. Revised mathematical models will then be used to re-create the evaluations in this report.

As units at WBF or the second unit at WBN are added, new near-field surveys of the combined thermal effects of plant operations will be made. Similar near-field surveys to those described above will be conducted during the summer and the winter of the first year of full load operation. Addition of other heat discharges will also be studied in a similar manner under worst-case summer and winter conditions.

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Zeller, H. D. (Environmental Protection Agency, Region IV) to P. **Krenkel** (TVA Environmental Planning) Letter "Regarding): Section **316(a)** requests for Allen, Browns Ferry, ... Watts Bar (fossil) and Widows Creek Steam Electric Generating Plants," February 28, 1975.

VII. APPENDIX

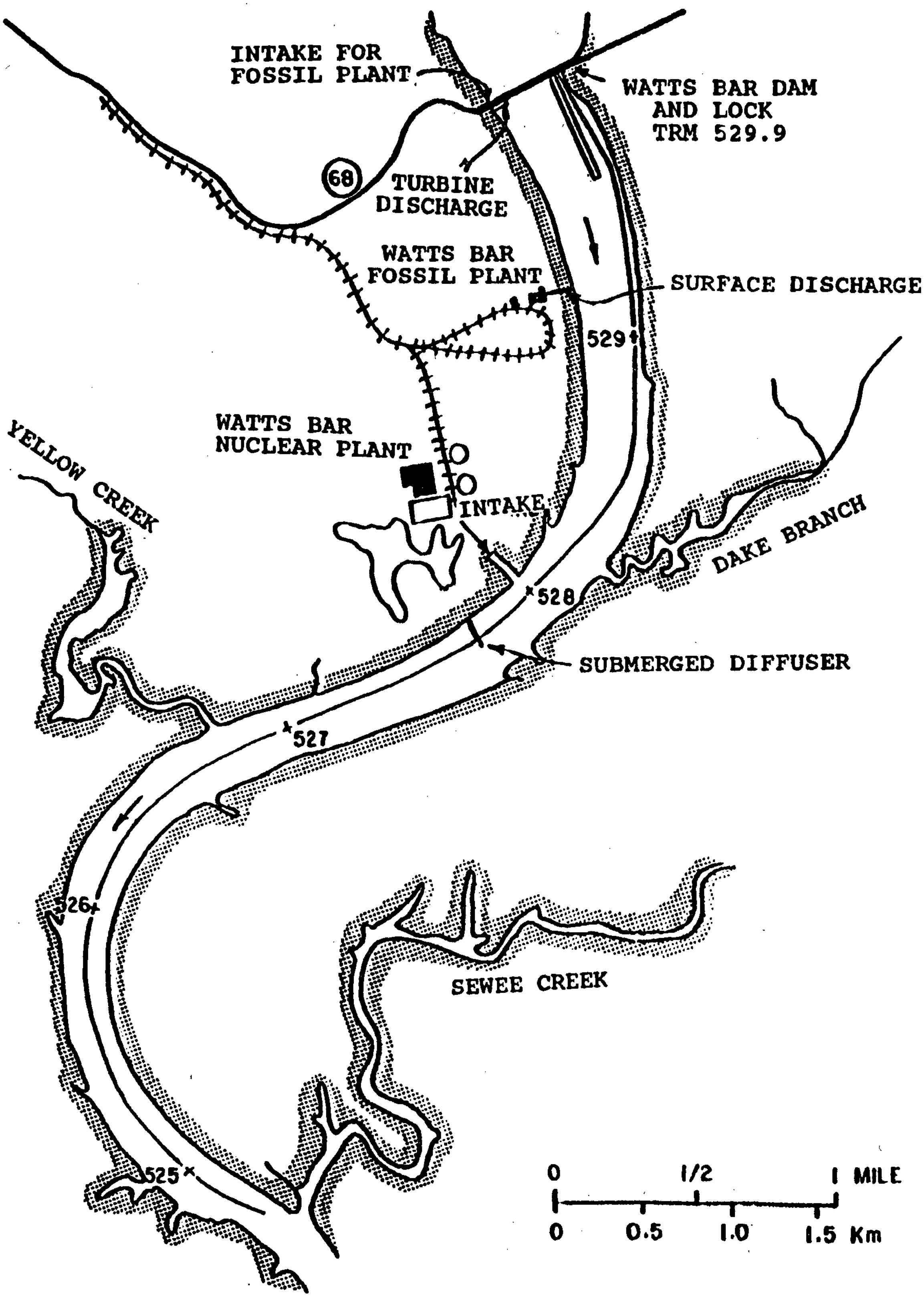

Figure A.1 Tennessee River Near Watts Bar Hydro Plant
(Ungate and Howerton, 1977)

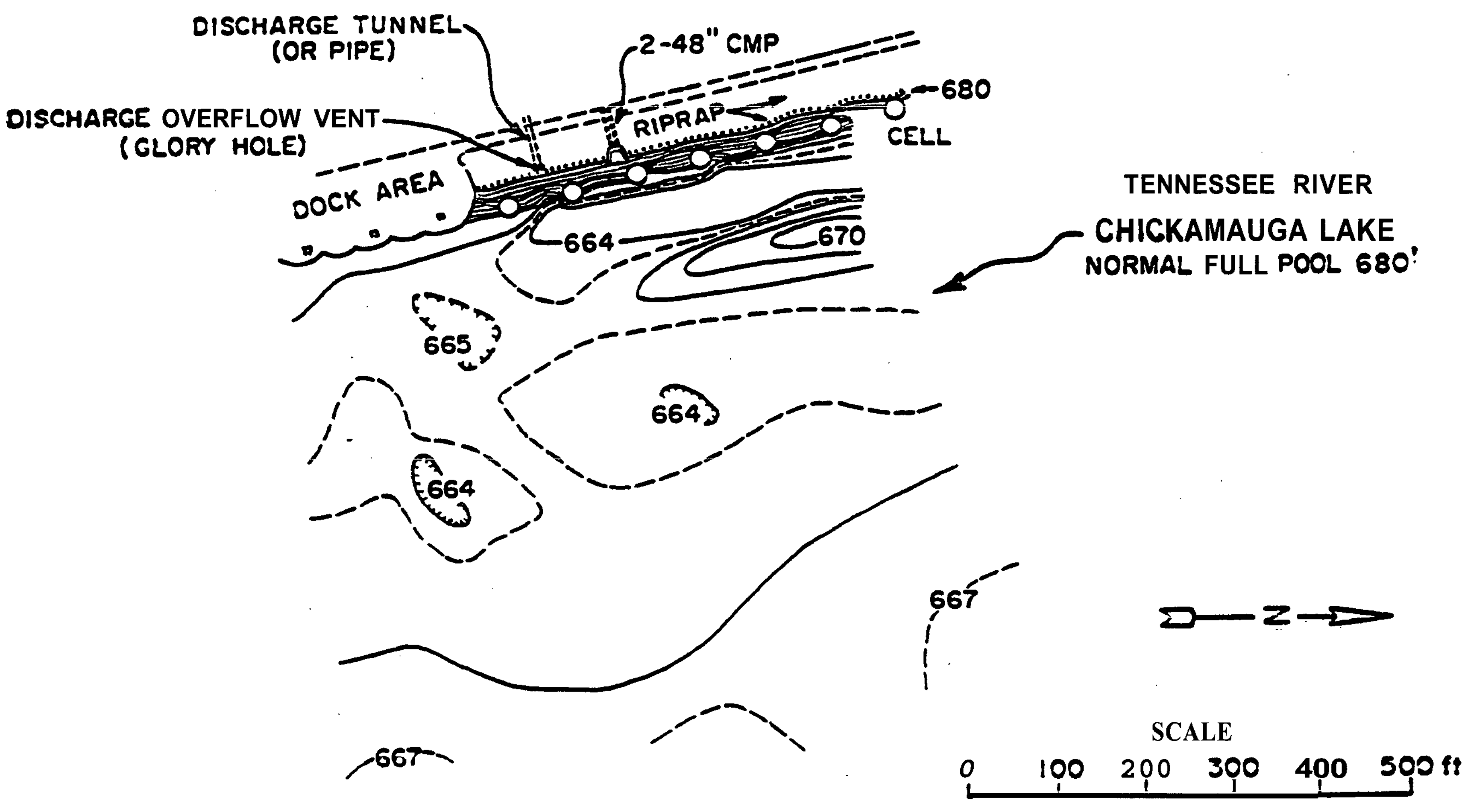

Figure A.2 WBF Condenser Water Discharge Area (Ungate and Howerton, 1977)

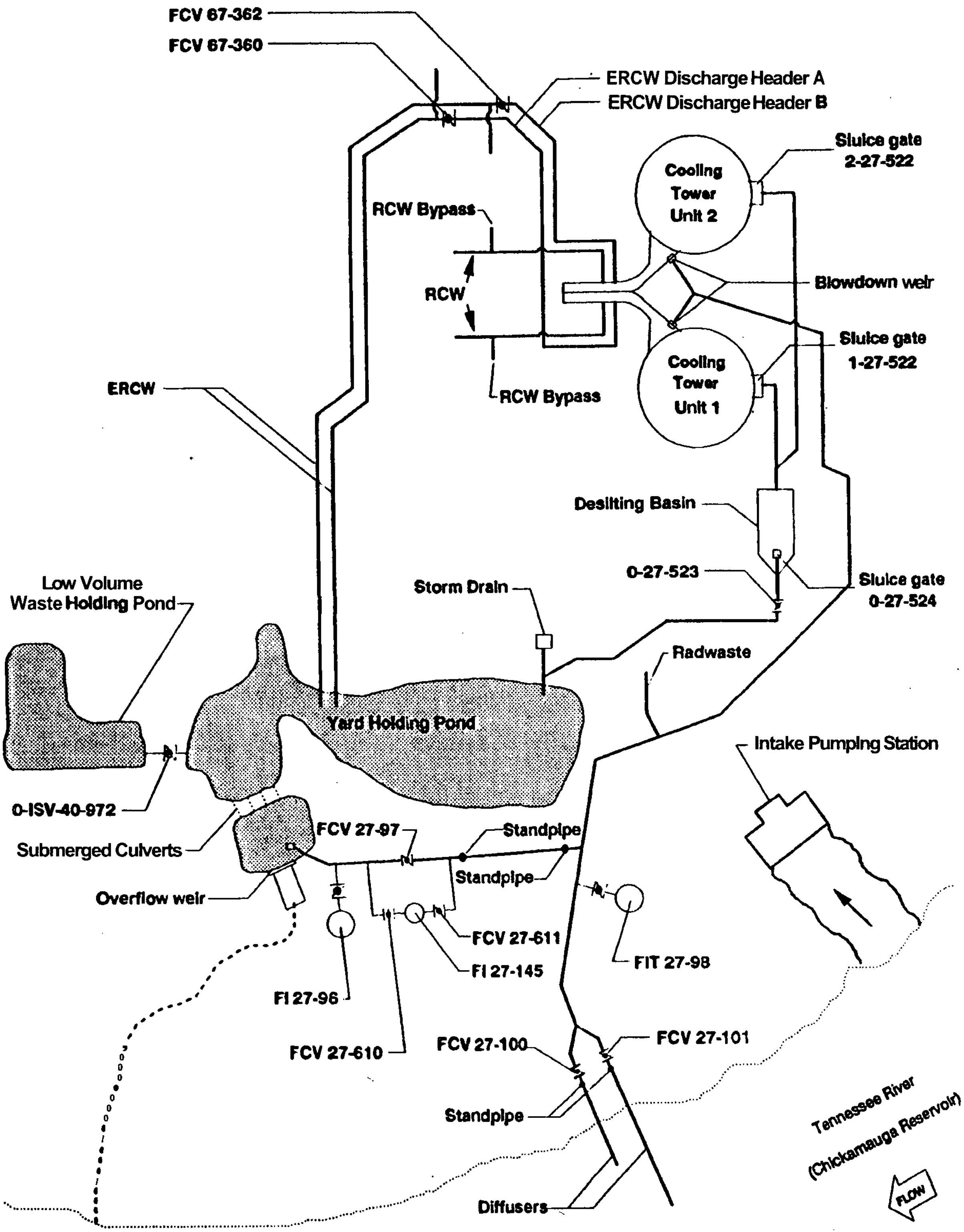

Figure A.3 WBN Cooling Tower Blowdown System

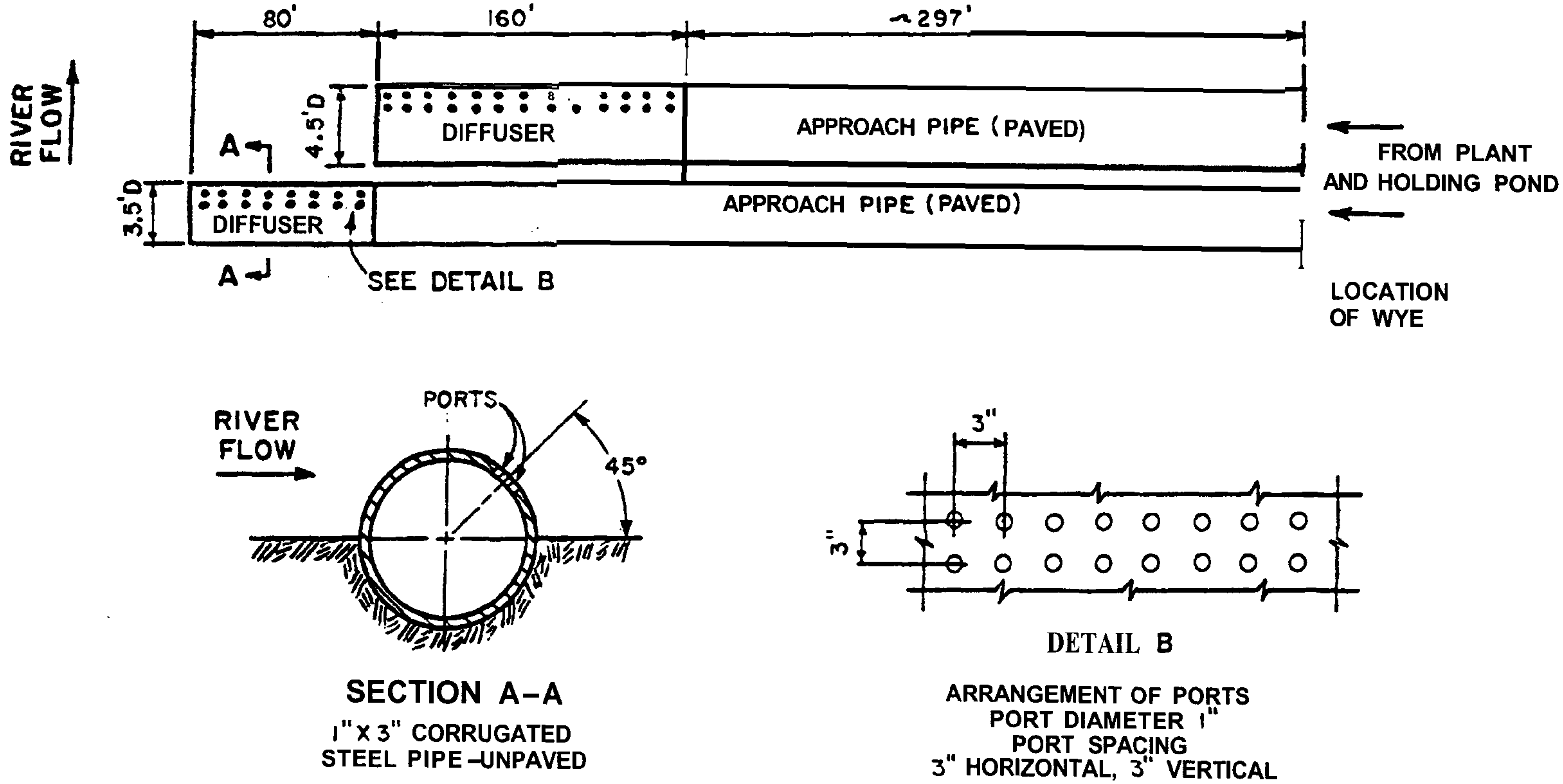

Figure A.4 Description of WBN Multiport Diffuser System (Ungate and Howerton, 1977)

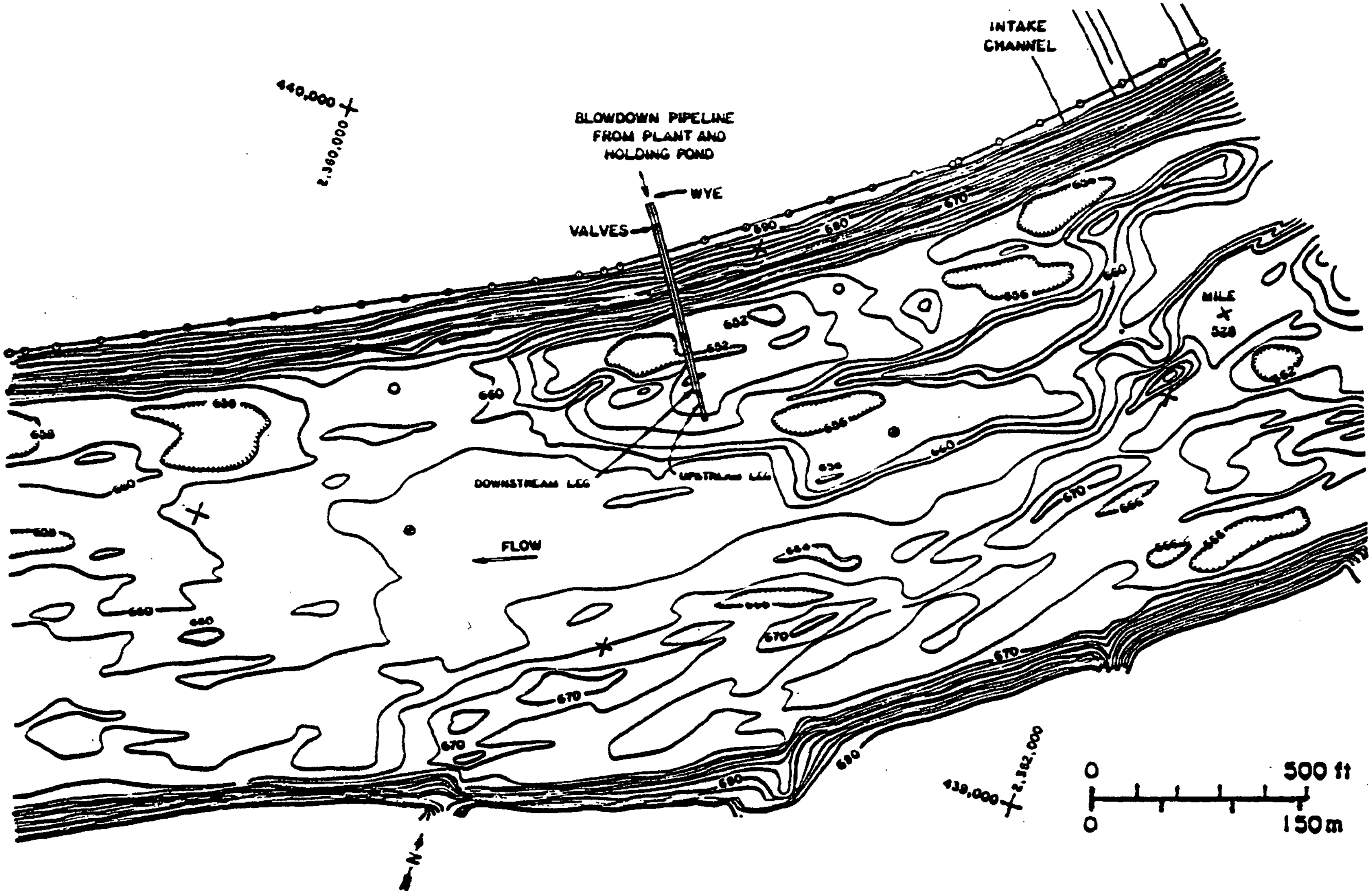

Figure A.5 Location of WBN Multiport Diffuser System, Tennessee River (Ungate and Howerton, 1977)

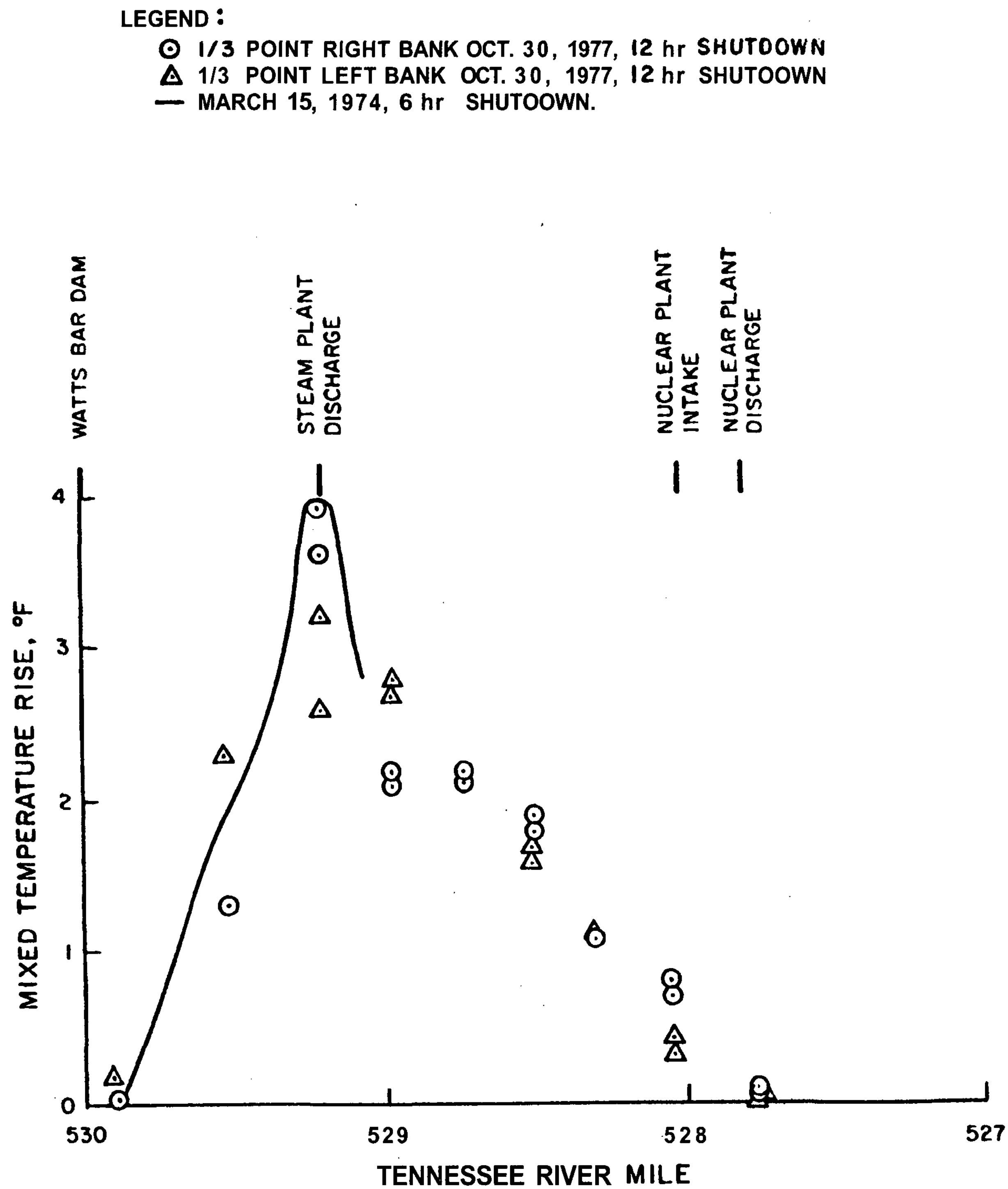

Figure A.6 Longitudinal Excess Temperature Distribution Below WBH After Periods of WBF Discharge and Zero River Flow (Ungate and Howerton, 1977)

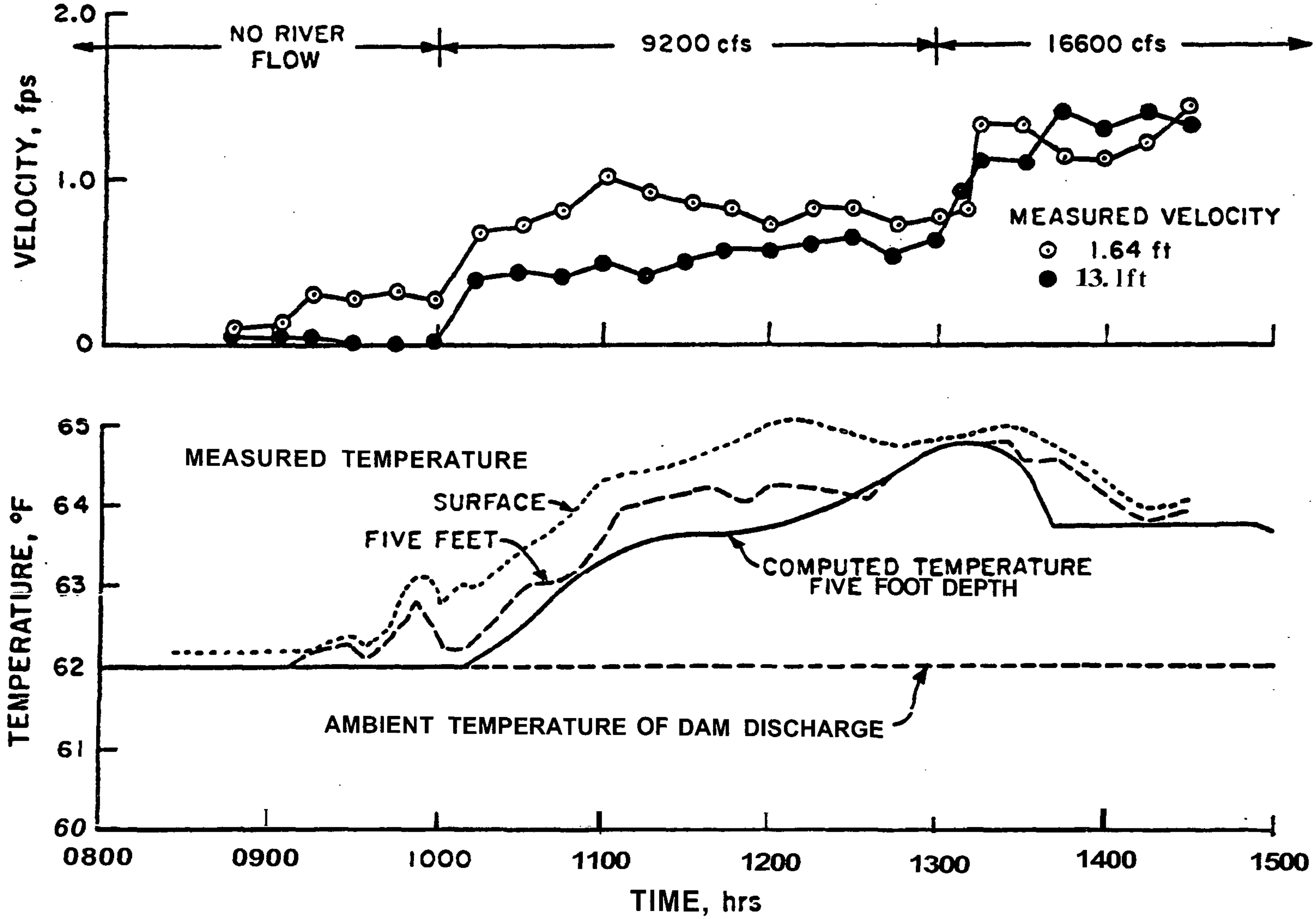

Figure A.7 Velocity and Temperature at TRM 527.8, October 30, 1977, After 12 Hours of Zero Flow from WBH (Ungate and Howerton, 1977)

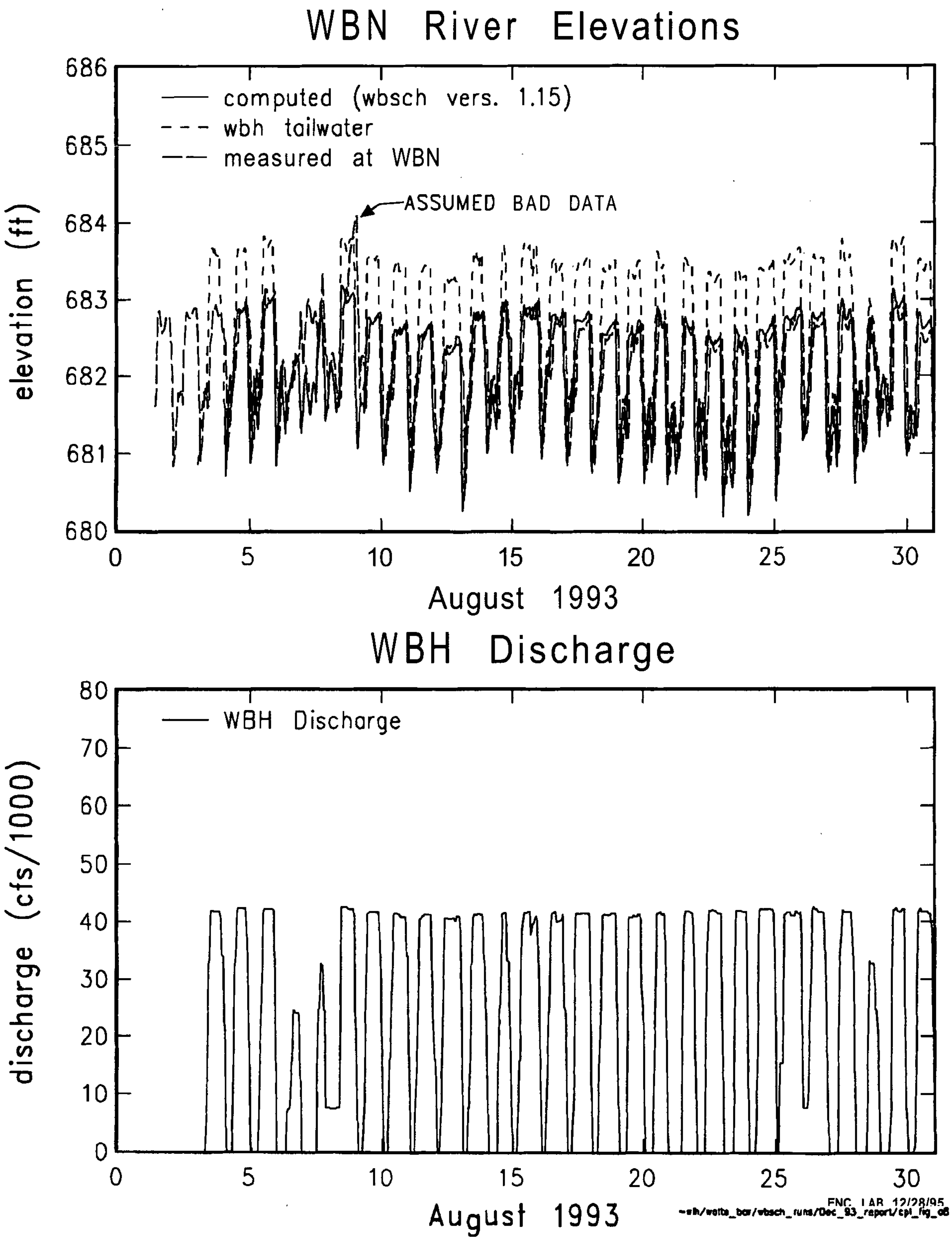

Figure A.8 Measured and Computed River Elevations in the Vicinity of WBN, and WBH Discharges During August 1993.

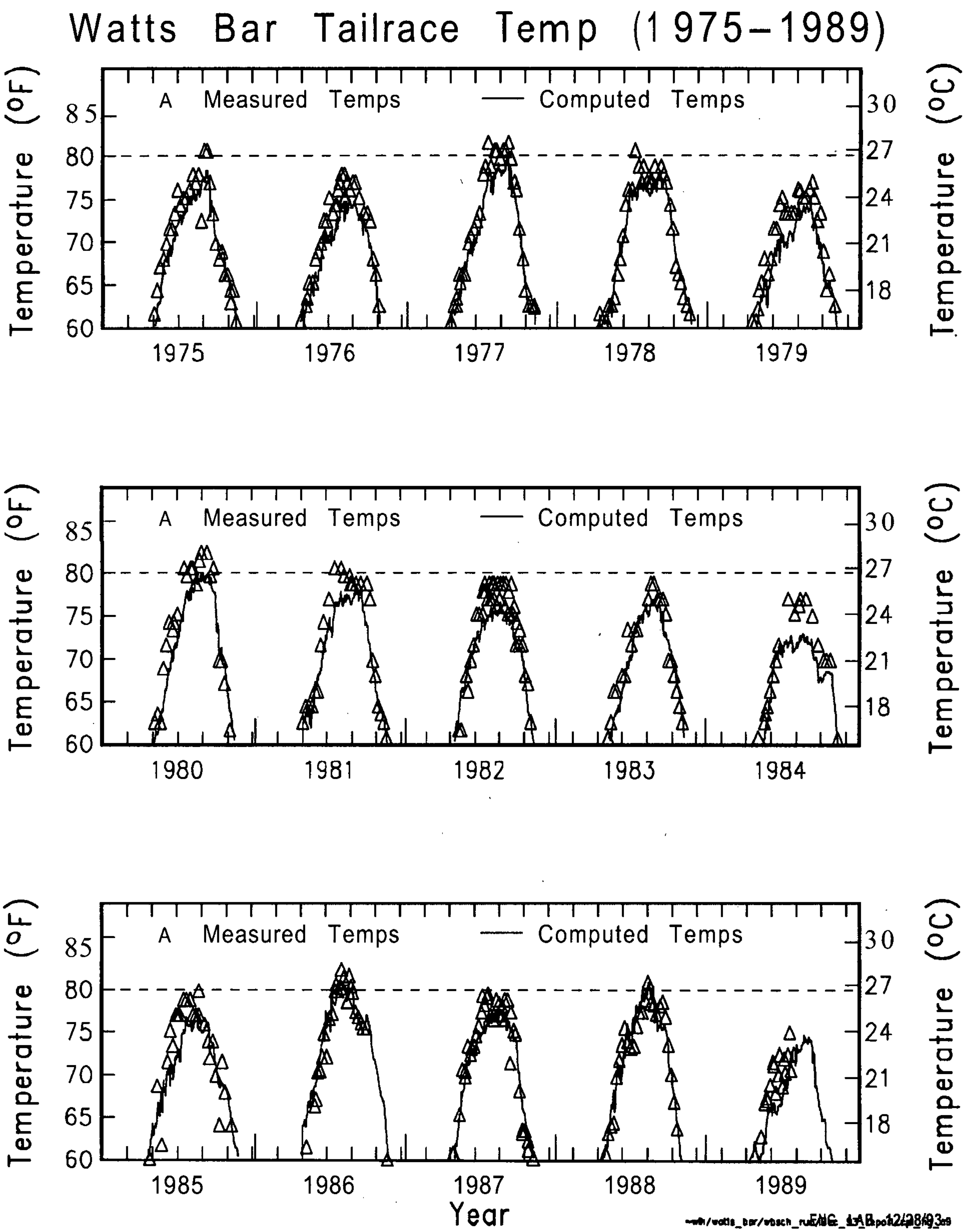

Figure A.9 Measured and Computed WBH Tailrace Temperatures, 1975-1989 (Alavian and Potter, 1992).

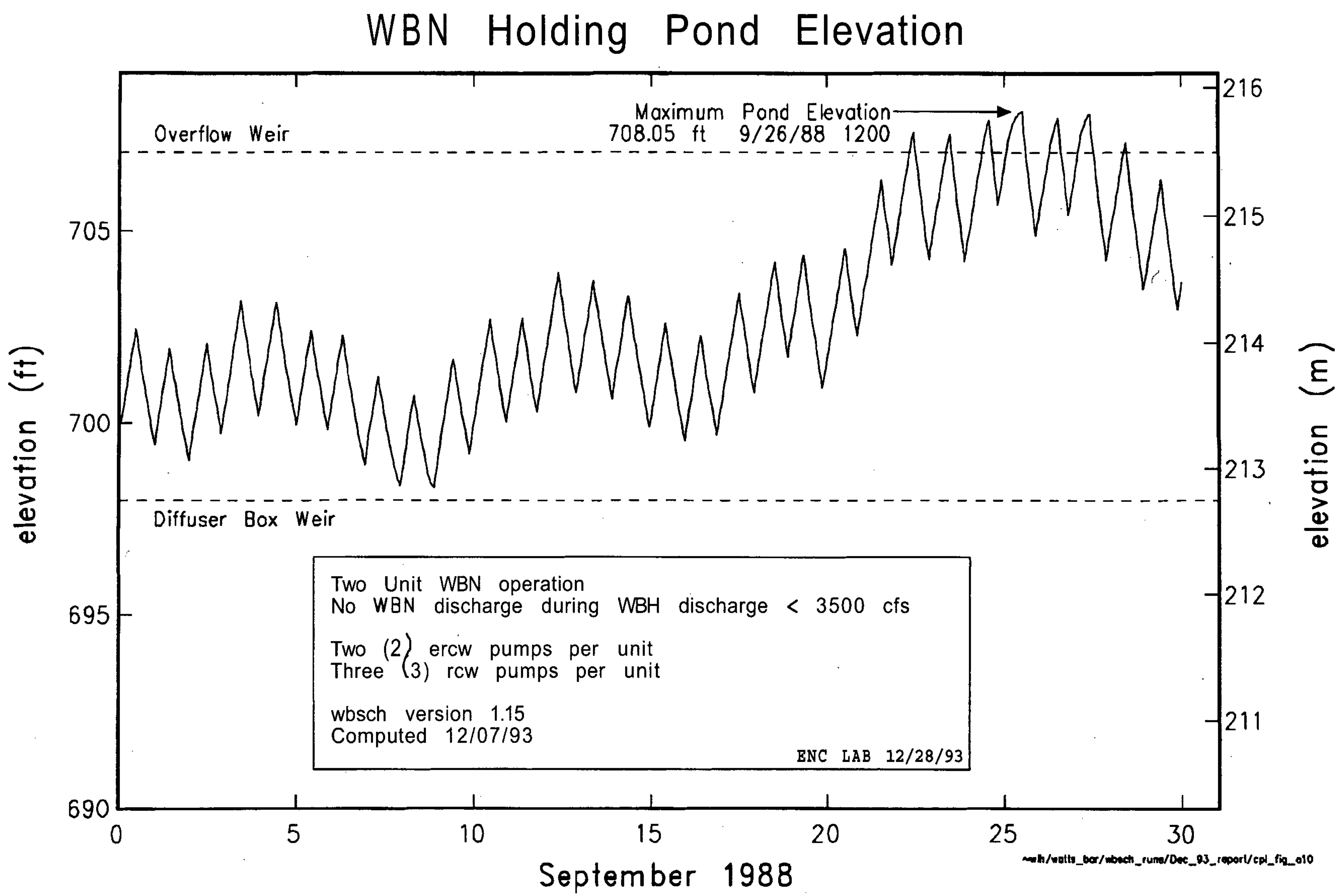

Figure A.10 WBN Yard Holding Pond Elevations During Month of Maximum Pond Elevation.

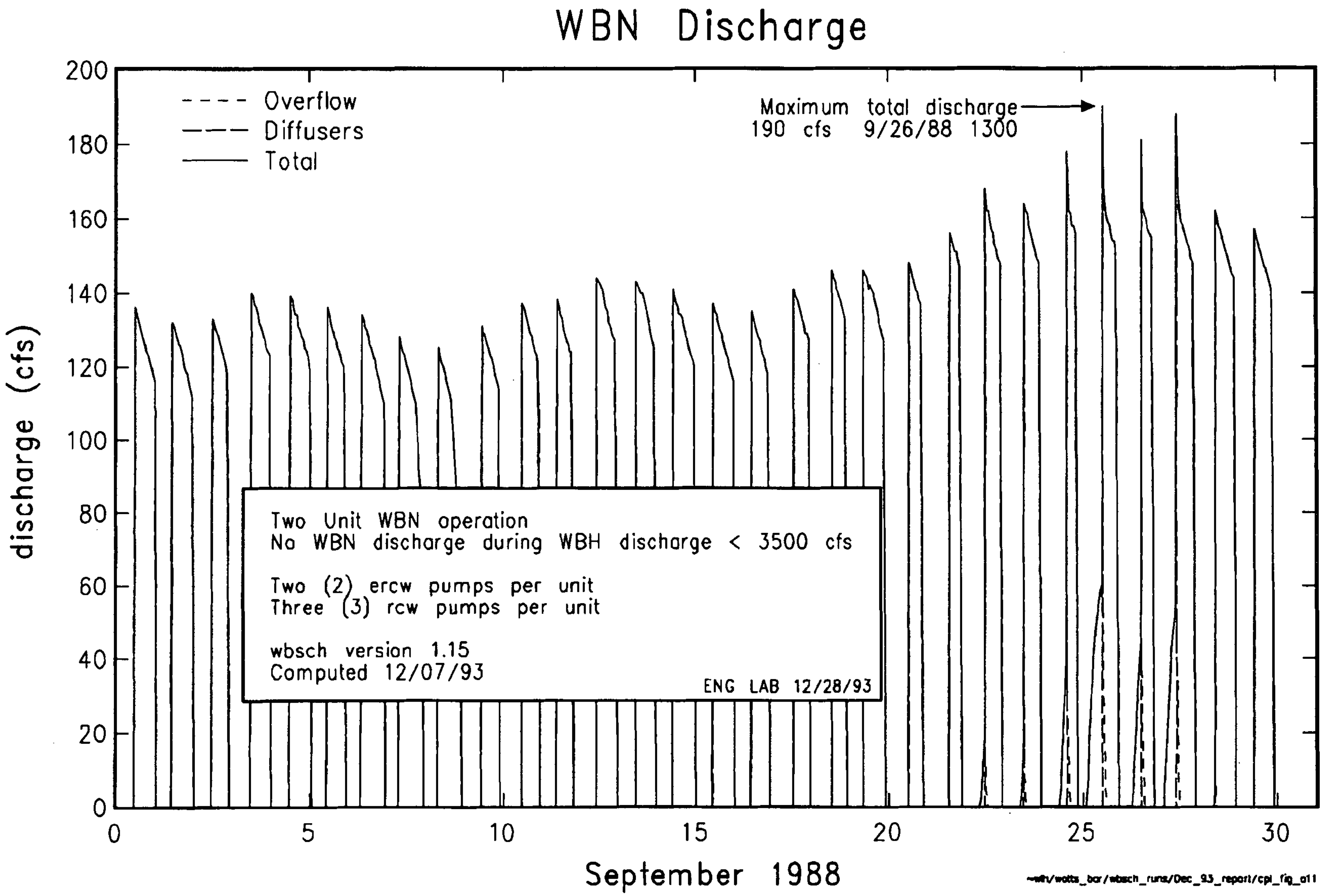

Figure A.11 WBN Thermal Discharge Flows During Month of Maximum Total Discharge With No WBN Discharge Permitted When WBH Release < 3500 cfs.

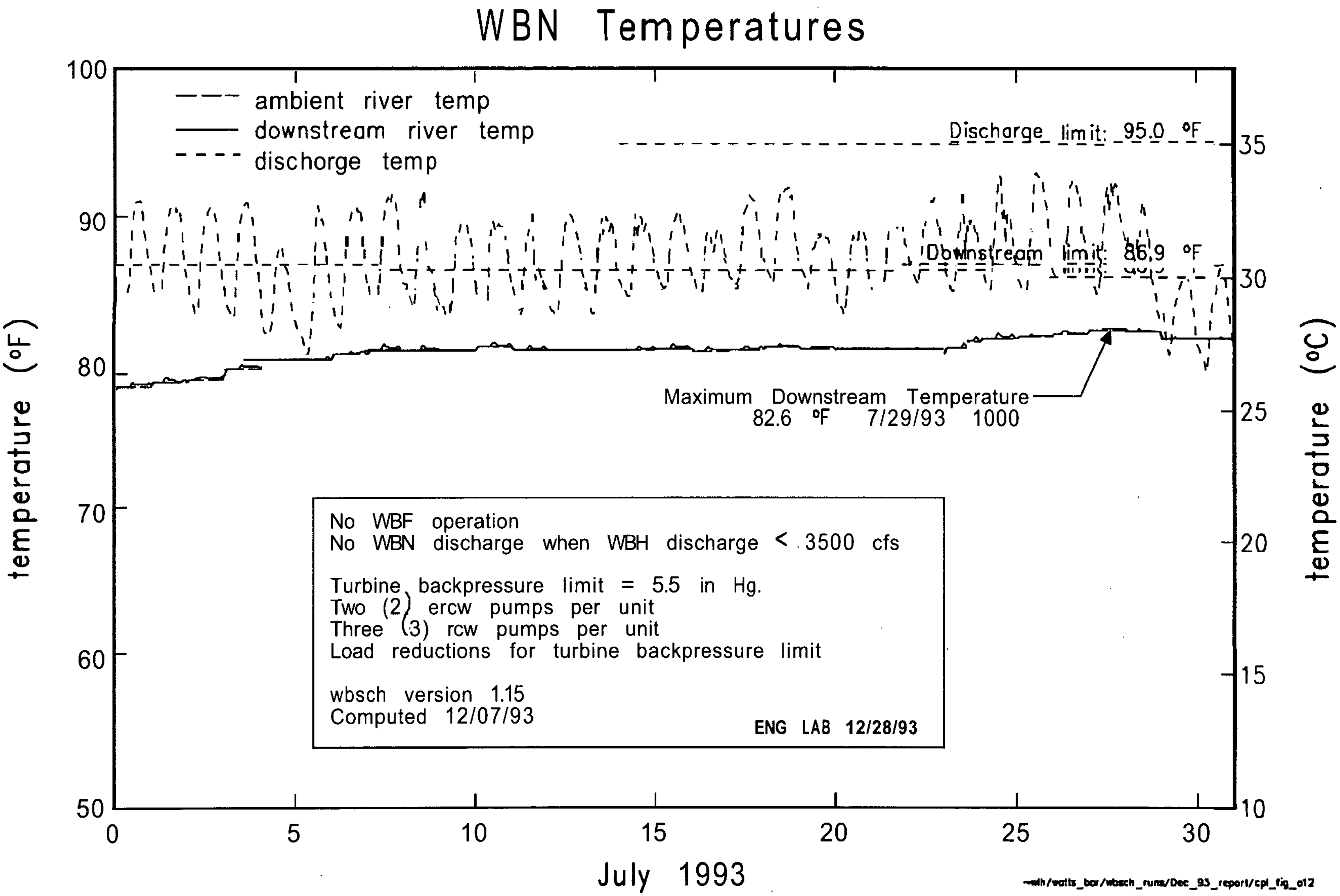

Figure A.12 WBN Temperatures During Month of Maximum Downstream Temperature With No WBF Operation and No WBN Discharge Permitted When WBH Release < 3500 cfs.

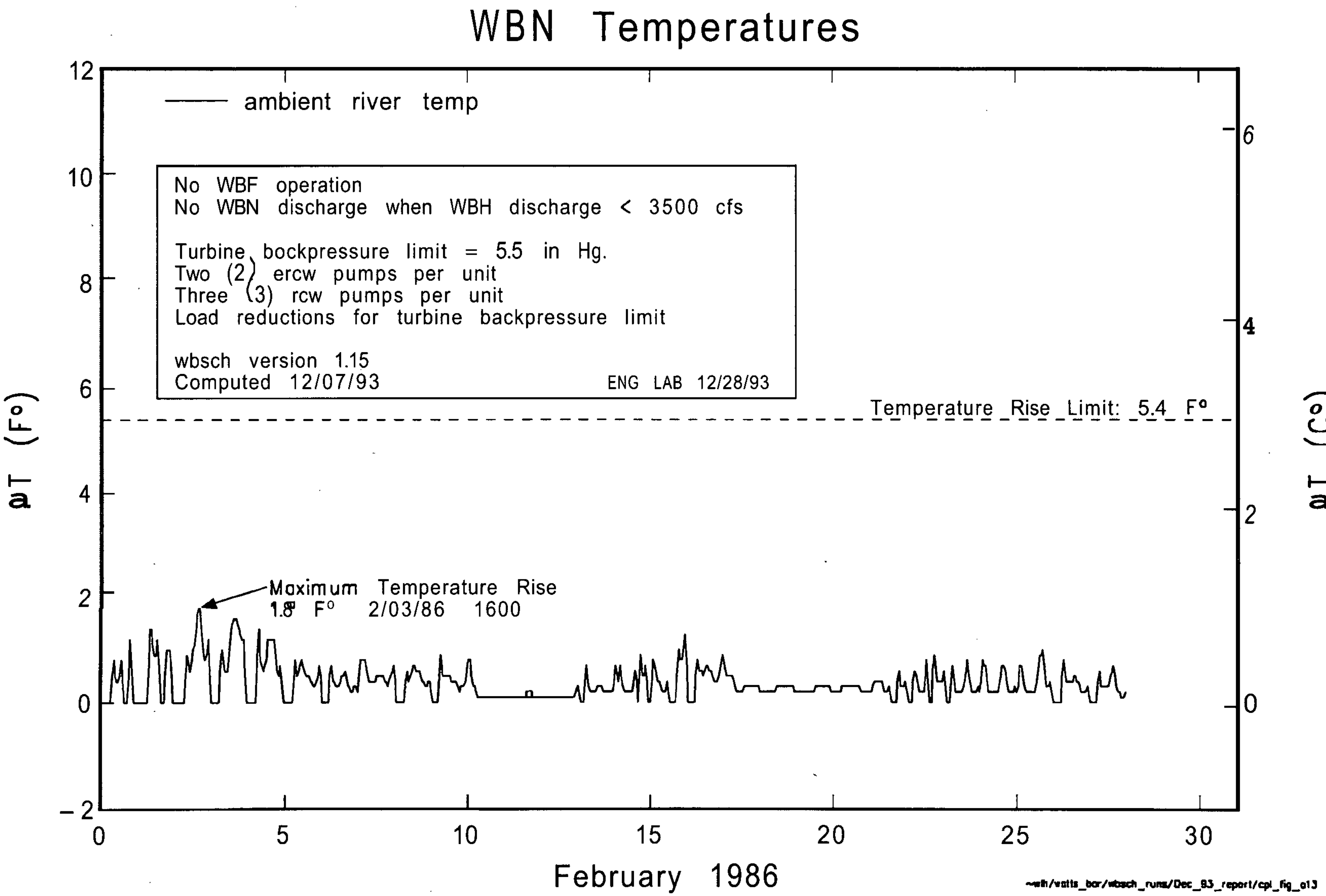

Figure A.13 WBN Downstream Temperature Rise During Month of Maximum Downstream Temperature Rise With No WBF Operation and No WBN Discharge Permitted When WBH Release < 3500 cfs.

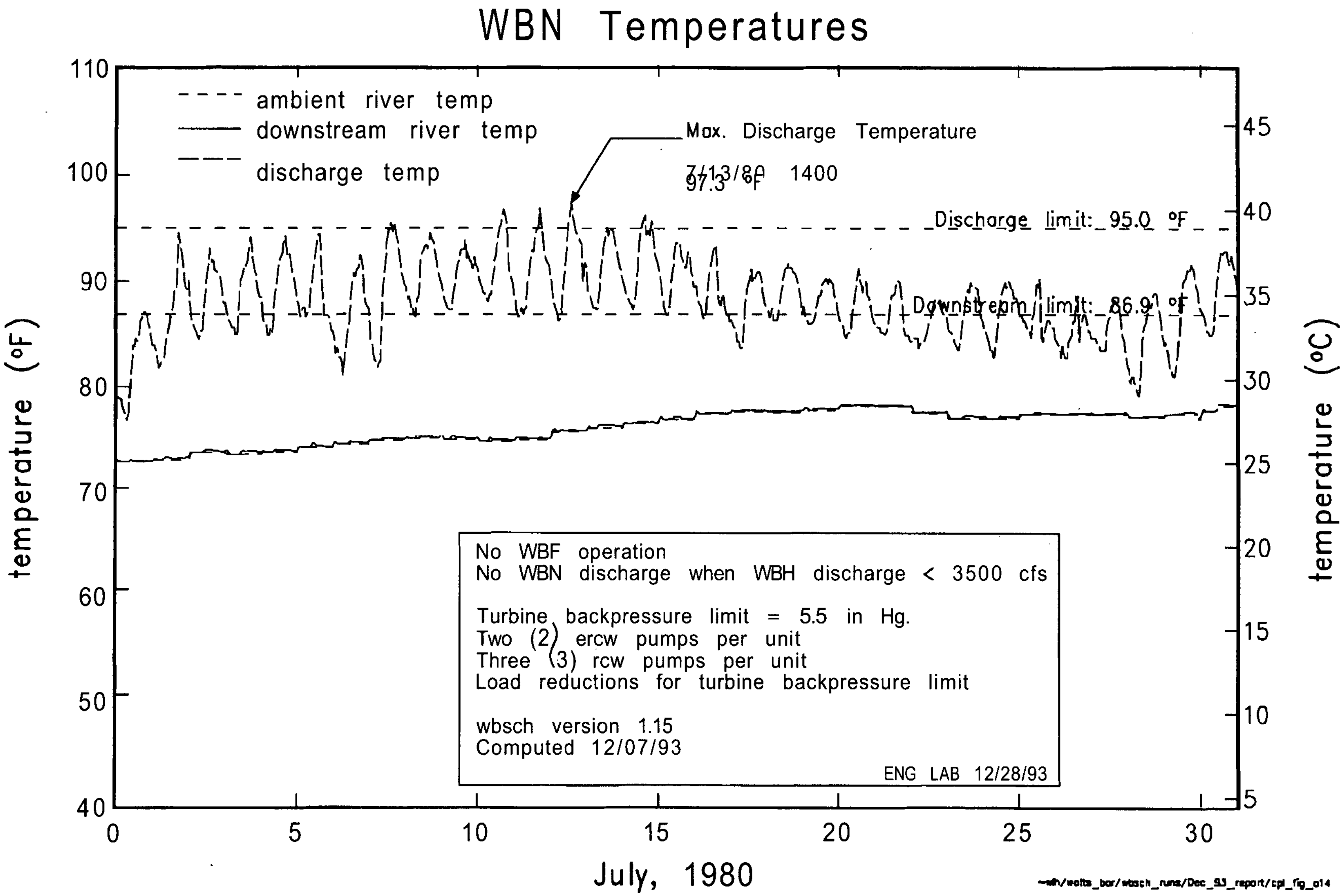

Figure A.14 **WBN Temperatures During Month of Maximum Discharge Temperature With No WBF Operation and No WBN Discharge Permitted When WBH Release < 3500 cfs.**

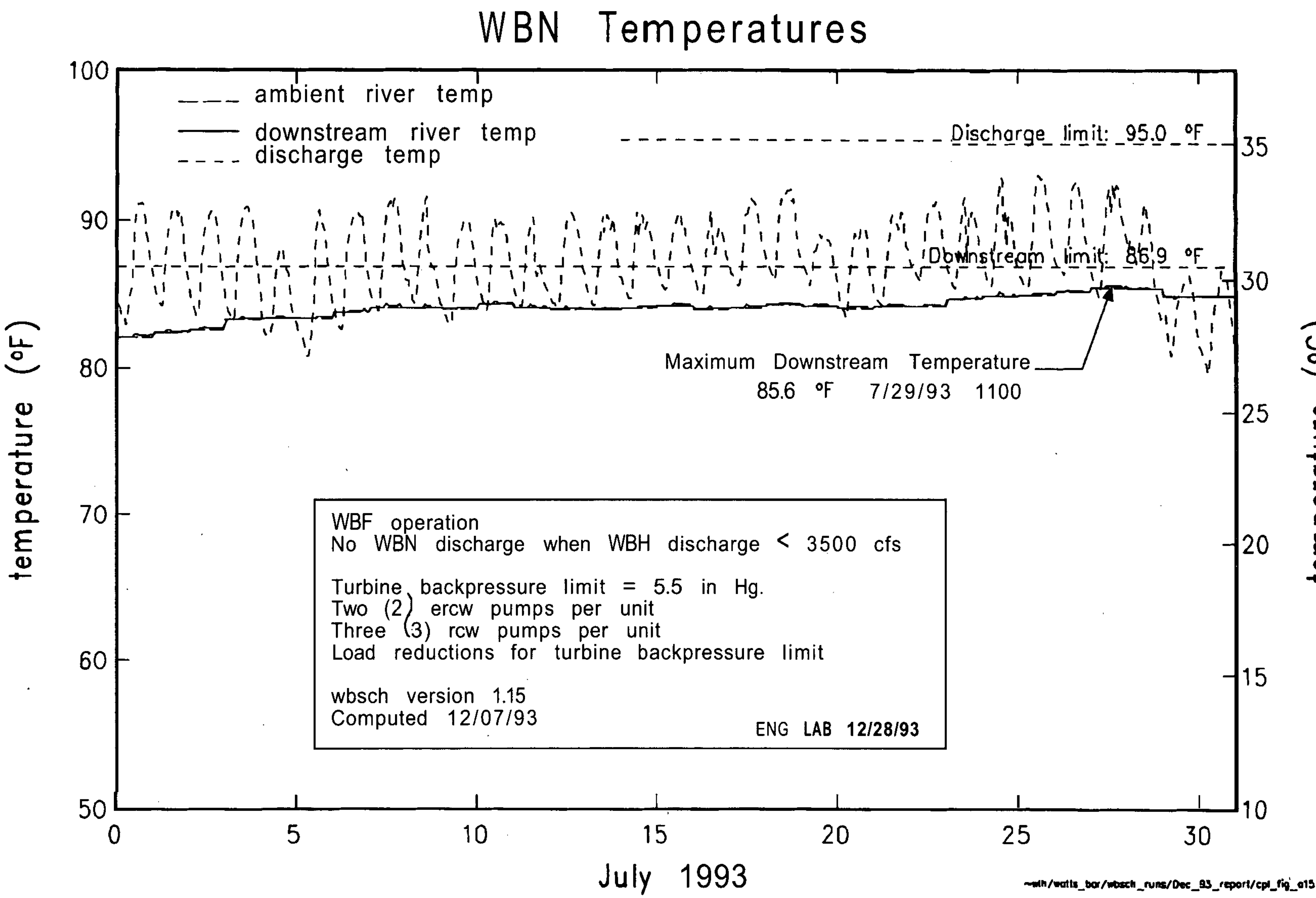

Figure A.15 WBN Temperatures During Month of Maximum Downstream Temperature With Full Load WBF Operation and No WBN Discharge Permitted When WBH Release < 3500 cfs.

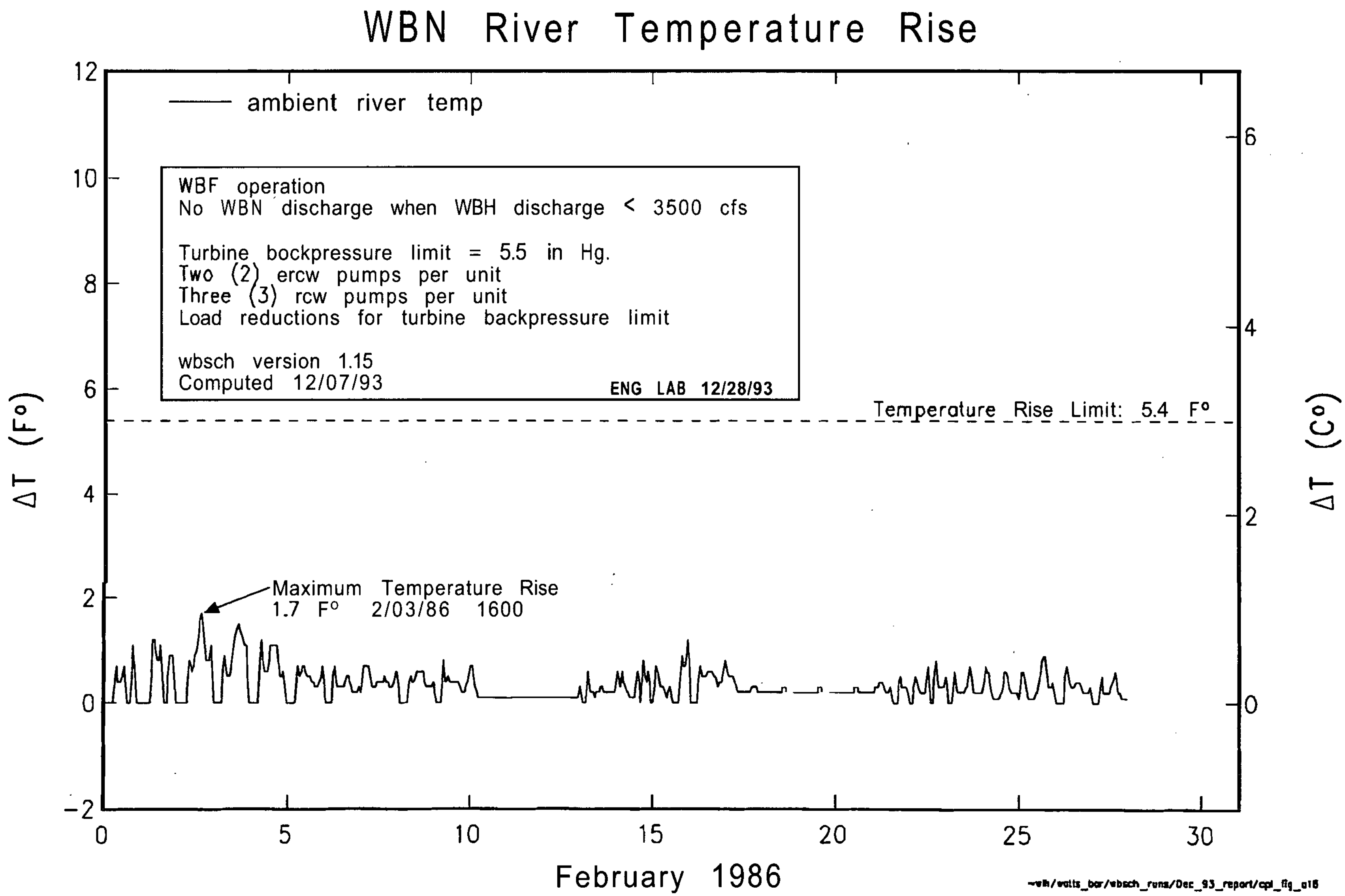

Figure A.16 WBN River Temperature Rises During Month of Maximum Temperature Rise With Full Load WBF Operation and No WBN Discharge Permitted When WBH Release < 3500 cfs.

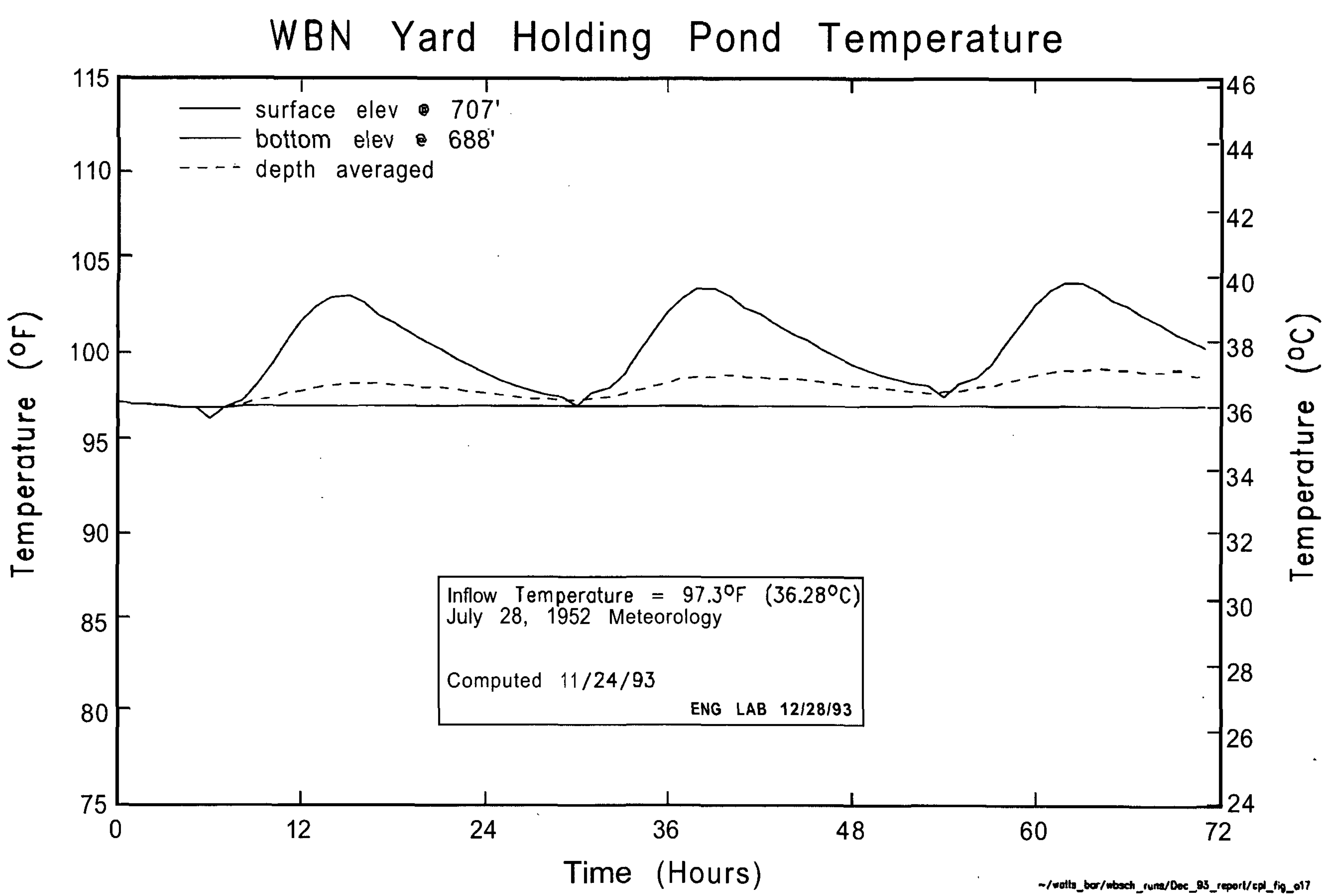

Figure A.17 WBN Yard Holding Pond Temperatures Using July 28, 1952 Meteorology

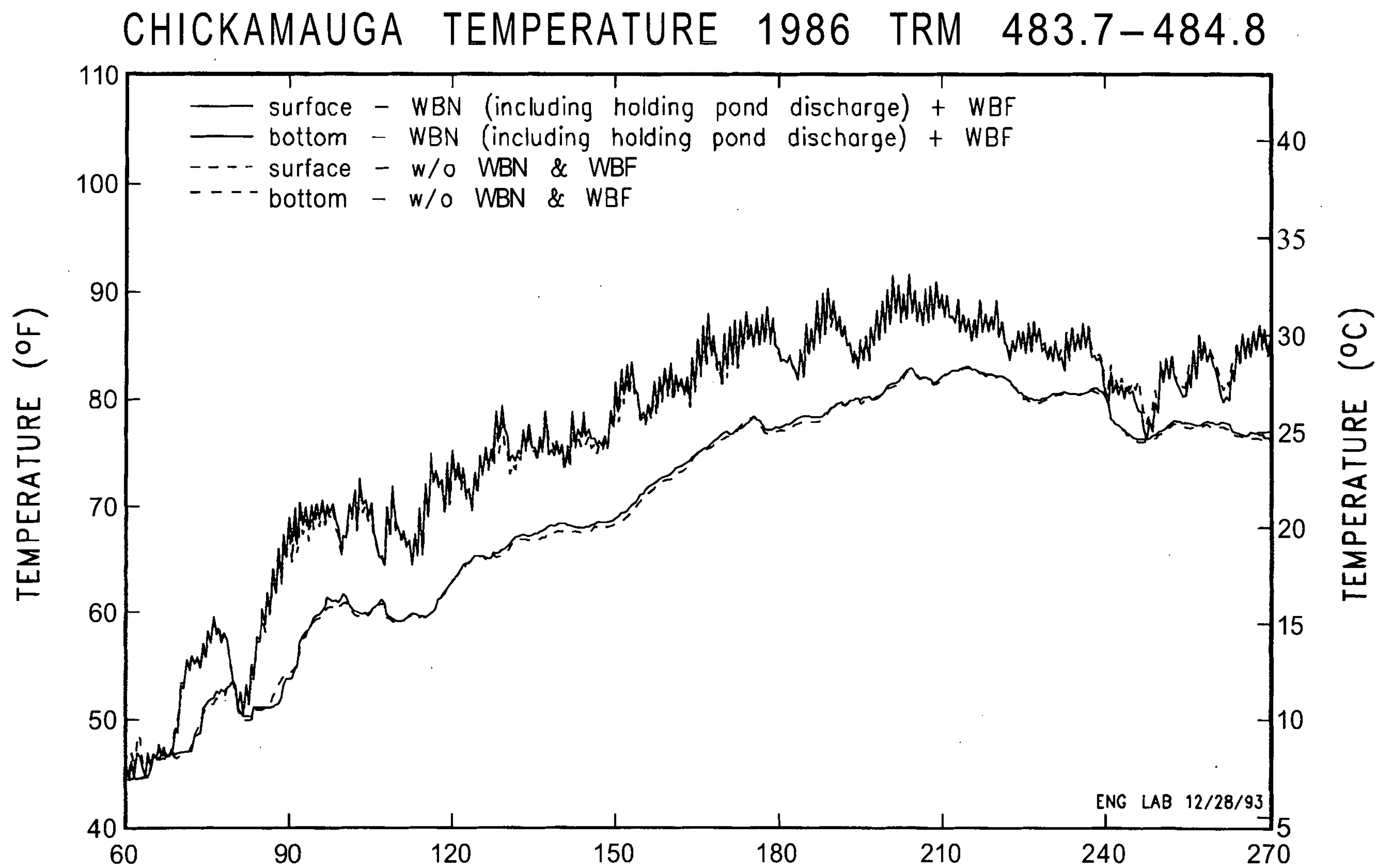

Figure A.18 Effects of WBN & WBF Thermal Discharges on Water Temperature Below WBH - 1986

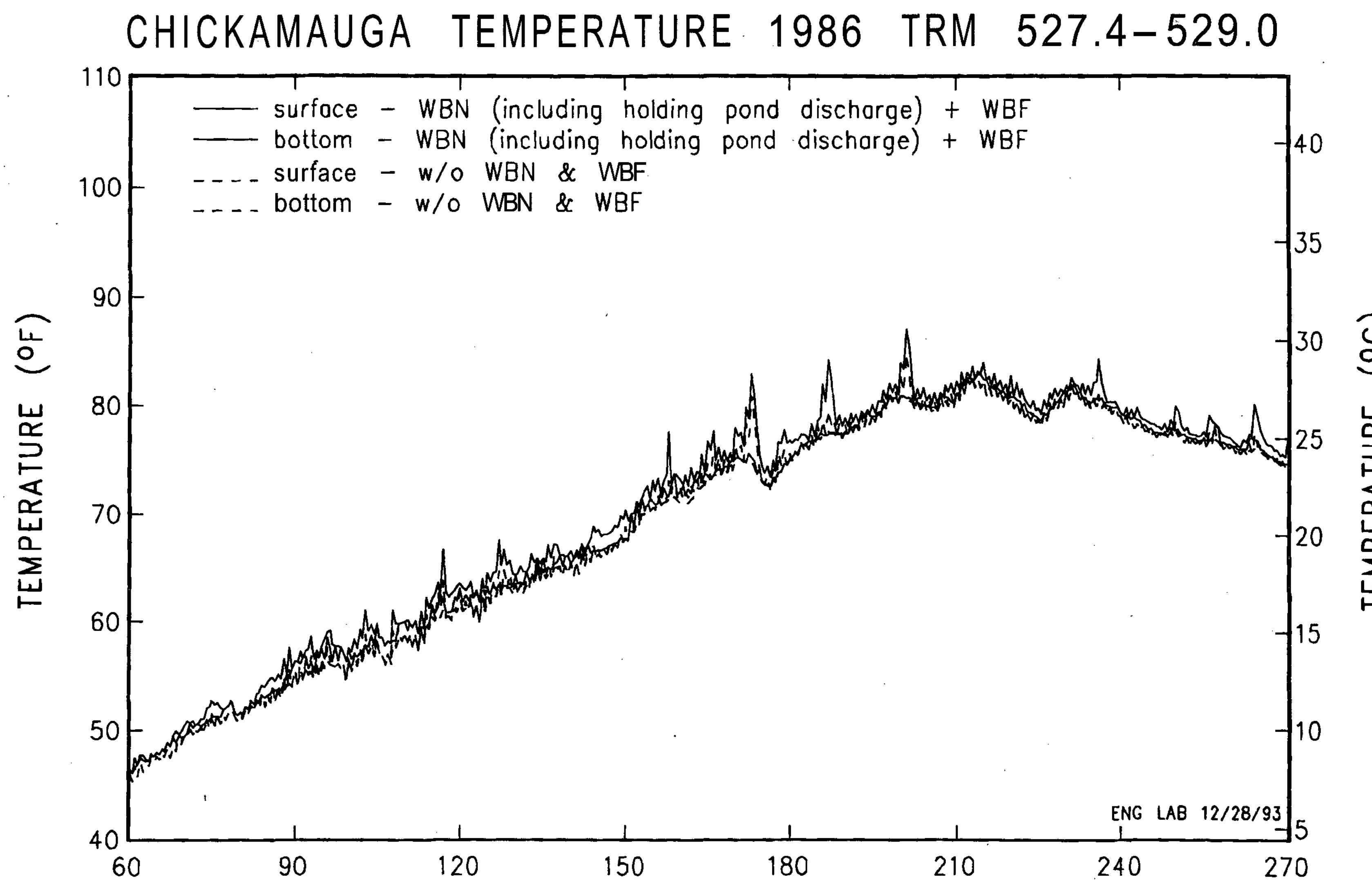

Figure A.19 Effects of WBN & WBF Thermal Discharges on Water Temperature at SQN Intake - 1986

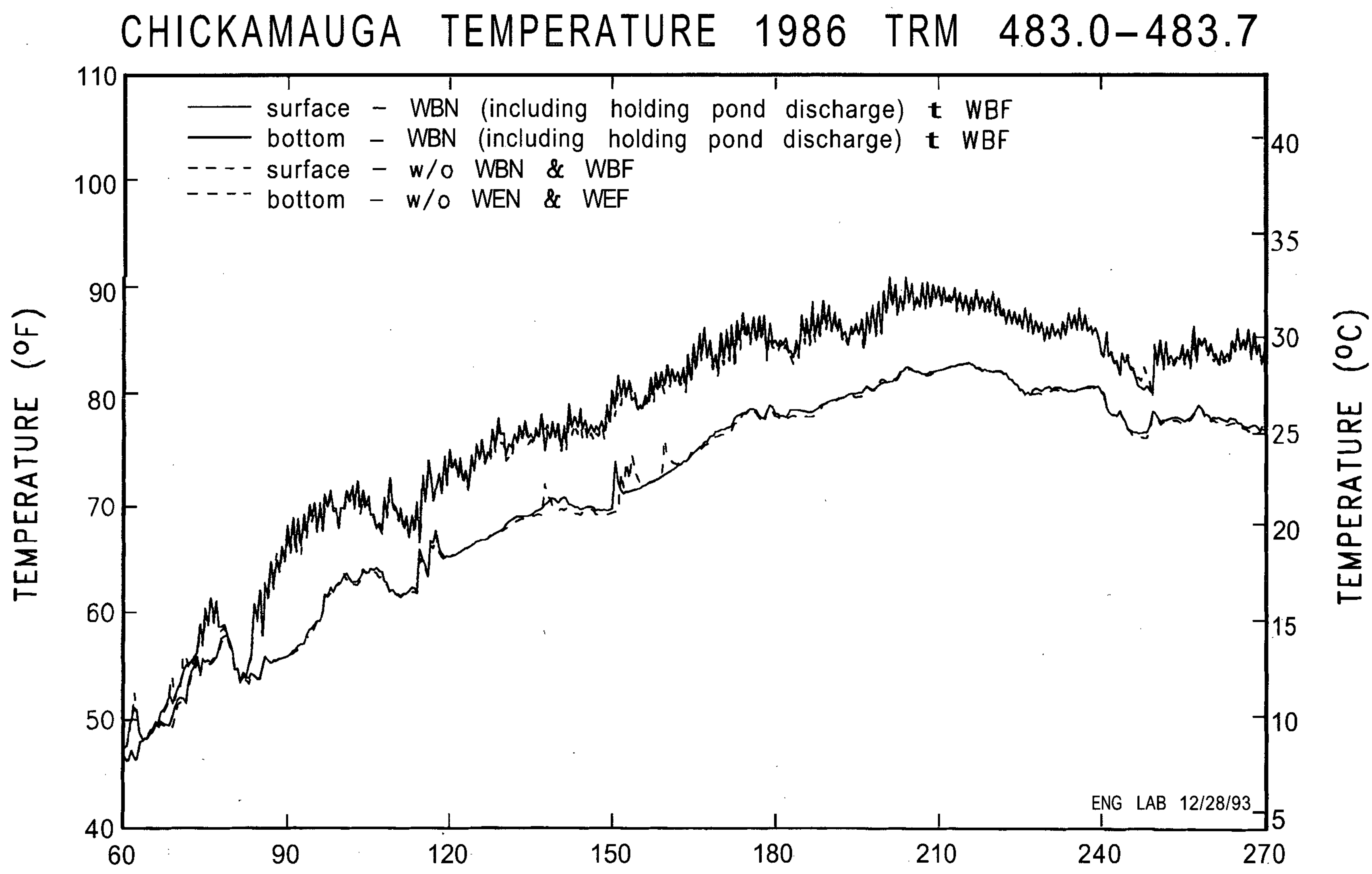

Figure A.20 Effects of WBN & WBF Thermal Discharges on Water Temperature Below the SQN Diffusers - 1986

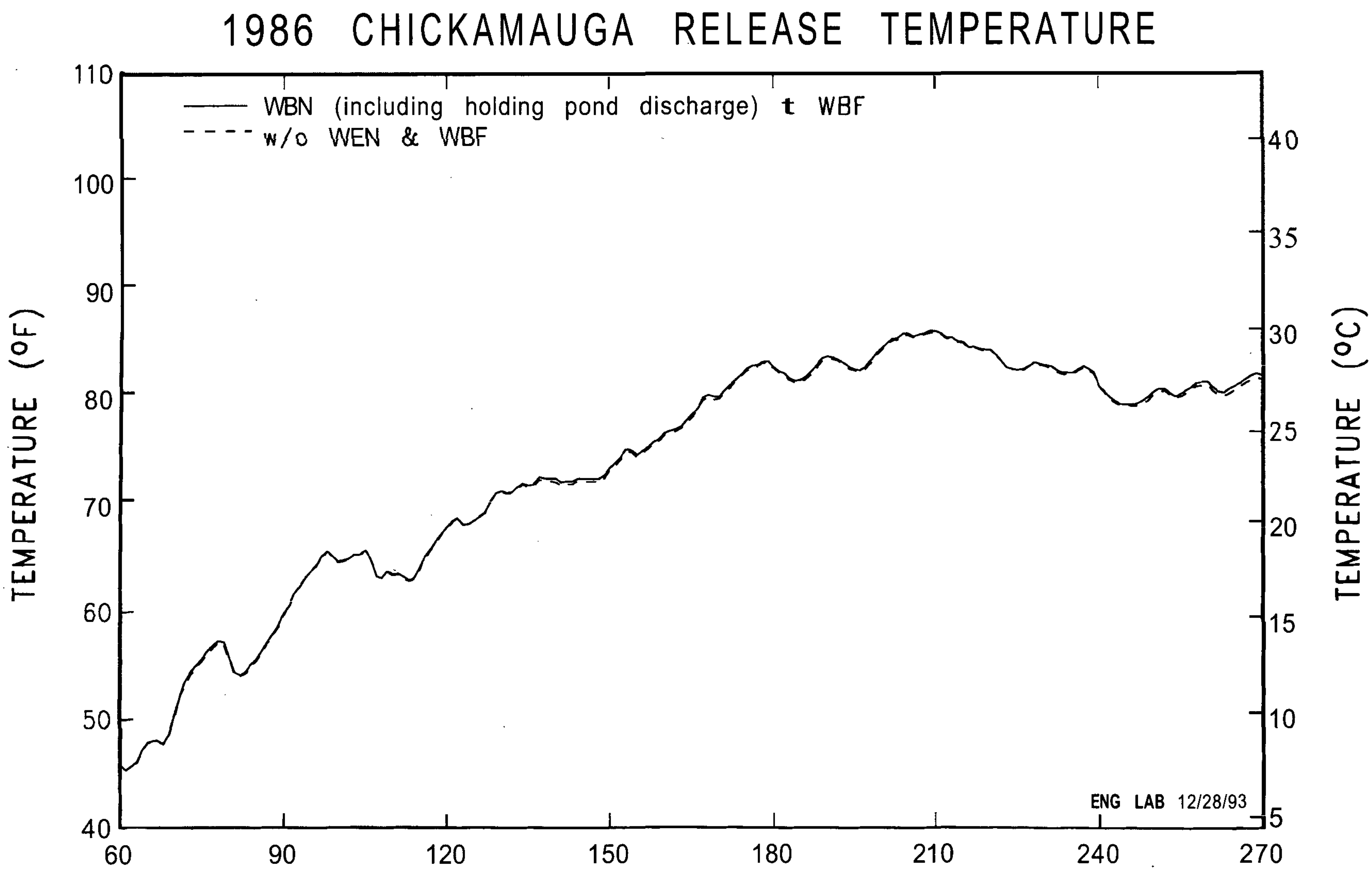

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Figure A.21 Effects of WBN & WBF Thermal Discharges on Chickamauga Release Temperature - 1986

TVA/RDG-RBO/EQS-89/__

TENNESEE VALLEY AUTHORITY

ENVIRONMENTAL ASSESSMENT

PROPOSED INCINERATOR
FOR BURNING LOW-LEVEL RADIOACTIVE WASTE

SCIENTIFIC ECOLOGY GROUP, INC.
CLINCH RIVER INDUSTRIAL PARK
OAK RIDGE, TENNESSEE

TRACT XWBR-688IE

Last Copy

Do Not Remove

JANUARY 1989

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5.1.1 Radioactive Emissions

5.1.2 Nonradioactive Emissions

5.1.3 Postulated Accidents

5.2 Water Quality

5.3 Aquatic Resources

5.4 Solid and Hazardous Waste

5.5 Socioeconomic

5.5.1 Transportation

5.5.2 Social

5.5.3 Economic

5.5.4 Land Use

5.5.5 Aesthetics

5.6 Vegetation

5.7 Wildlife and Threatened and Endangered Species

5.8 Floodplains and Wetlands

EXHIBITS

ATTACHMENTS

Attachment A	Tennessee Air Pollution Control Board Permit No. 996948I
Attachment B	Tennessee Department of Health and Environment - Division of Radiological Health - Radioactive Material License
Attachment C	United States Environmental Protection Agency - NESHAP Approval
Attachment D	City of Oak Ridge, Tennessee - Environmental Quality Advisory Board (EQUAB) Findings
Attachment E	Grant of Easement for TVA Tract No. XWBR-688IE, parcel 1
Attachment F	Grant of Easement for TVA Tract No. XWBR-688IE, parcel 2
Attachment G	SEG's Waste Characteristics and Release Rates
Attachment H	SEG's Oil Acceptance Criteria
Attachment I	SEG's Radiation Safety Guide
Attachment J	SEG's Oil Burning Procedure
Attachment K	Letter from the Tennessee State Planning Office - Intergovernmental Review

submitted to the State of Tennessee in December 1988. The thin film evaporator and ash vitrification system will be submitted in January of 1989.

SEG has advised TVA that they do not plan to burn any hazardous chemical wastes or hospital wastes. Therefore, no applications have been made for either a Part A or Part B Resource Conservation and Recovery Act (RCRA) permit nor a Toxic Substances Control Act (TSCA) permit.

Because the incinerator will be equipped to burn flammable fluids consisting primarily of low-level radioactively contaminated lubrication oil (waste oil) in addition to solids, EPA has required SEG to develop a spill control and countermeasure plan (SPCC). The present oil burning equipment previously approved by TVA will be removed from operation before the incinerator begins operation and disposed of as solid waste in accordance with SEG's existing RML.

SEG has held several local meetings with the public to discuss the proposed incinerator. They have cooperated with the city of Oak Ridge's EQUAB review of the proposal and the resulting approval was published in "The Oak Ridger" on Friday, August 5, 1988, page 3.

TVA has received a letter from the Tennessee State Planning Office indicating successful completion of intergovernmental review for this action under Executive Order No. 12372 (see Attachment K).

Approval of the incinerator by TVA will be withheld until or made conditional upon SEG obtaining all required permits and licenses.

2.0 Need for the Proposed Action

2.1 Need for the Proposed Facility

The SEG facility is currently licensed to process low-level radioactive waste (LLRW) by sorting, shredding, supercompaction, decontamination, solidification, and other miscellaneous processes. The SEG incinerator will greatly reduce the disposed volume of combustible LLRW generated by private, public, and institutional sources resulting in better conservation of burial space and improvement in waste form.

In addition, the incinerator will be equipped with a liquid waste injection system to dispose of waste oil and it will replace auxiliary burners now used to dispose of the waste oil.

The incinerator will allow SEG to offer a wider range of services at its existing location and it will work in conjunction with the existing CVRF facility to minimize requirements for burial space.

2.2 Need for the Proposed Site

The site is currently used by SEG for offices and their CVRF operation, and use of the incinerator here would promote logistical efficiency and convenient oversight. As indicated, SEG will obtain or has obtained a RML, APC permit, and NESHAP and EQUAB approval to permit incineration at this location. Also, the installation of a separate heat exchanger system with the incinerator will give SEG the capability of supplementing the heat for its offices and the CVRF during the winter. Finally, the SEG facility is within the Clinch River Industrial Park which was developed and zoned by the city of Oak Ridge for businesses that handle radioactive or hazardous materials. No other land outside the Clinch River Industrial Park in this vicinity is currently available for this type of industrial development.

3.0 Description of the Proposed Action

3.1 Proposed Facility - General Information

SEG's existing facilities consist of a 12,500-square-foot storage building located at the east end of the developed area, an adjacent connected 22,920-square-foot processing building and a separate 5,000-square-foot office building on the west side of the developed area.

SEG proposes to build a 13,000-square foot steel building positioned between the existing processing building and Bear Creek Road to house the incinerator.

The building will be erected on a concrete slab 200 feet long by 65 feet wide with an eave height of approximately 20 feet. The concrete slab will have a four-inch curb on the perimeter to retain any liquids released in the building. SEG states that the design criteria for the height of the curb was to provide a 5X safety factor for the largest tank in the building. The curb height was also designed to contain the water from four sprinkler heads running approximately 12 hours with a flow rate of 20 gallons per head, per hour. The incinerator room will occupy 7,500 square feet of the building and the remaining space will be used for offices, shops, and utility rooms. The floor of the building will be sealed with a special coating to make cleaning and ultimate decommissioning easier.

Ventilating and cooling air will be drawn into the building by an induction fan that will be separate from the incinerator air supply system. The flow rate through this system will be approximately 10,000 cubic feet per minute depending on the filter loadings. The fan system will be connected to the emergency power supply and will operate if commercial power is interrupted.

Incoming air will be drawn through a demister and, in cold months, as necessary, through an air exchanger heated by hot water from the boiler. All building ventilating and cooling air will be exhausted from the building through High Energy Particulate Air (HEPA) filters that are separate from the incinerator filtration system and discharged through a separate 40-foot stack located at the east end of the building. A negative air pressure will be maintained in the incinerator room and a positive pressure will be maintained in the office, shop, and utility spaces in the incinerator building. These spaces will be heated by the incinerator boiler air exchanger and will be cooled by a separate air conditioning system in addition to normal heating, ventilation, and air conditioning systems.

The building will be connected to the plant fire detection and protection system. This system consists of fire, smoke, and water flow detection devices with automatic local alarming and remote notification to the Oak Ridge Fire Department. Fire protection will be provided by an installed sprinkler system. Portable fire extinguishers are located throughout the facility according to fire code requirements. Any water discharged by the sprinkler system will be retained by the 4-inch curb on the perimeter of the building slab. An on-site diesel generator supplies emergency electrical power.

3.2 Proposed Incinerator - General Information

The proposed incinerator was designed by Fauholdt Engineering Company of Denmark based on the company's Envikraft incineration system and designated as Model No. EK980NC. It will be sold to SEG by Studsvic Nuclear, a Division of Studsvik AB of Sweden. The basic incinerator is a multi-chamber, computer controlled, centrally operated unit and is dimensioned to incinerate 800 to 1600 pounds of combustible waste per hour. This wide range of waste through-put is due to the different heating values of waste received. A liquid waste injection system in the secondary combustion chamber will be used to dispose of liquid materials such as waste oils at a rate of 30 gallons per hour. The present oil burning equipment will be removed from operation and disposed of after the incinerator begins operation.

The incineration process is supplemented by propane auxiliary burners that provide the necessary thermal input to combust hard-to-burn materials, such as water soaked rags. The incinerator will be relatively insensitive to the feed waste stream because of the auxiliary burners. It should be noted that the incinerator will have three burners, all being designated in incinerator terminology as "auxiliary burners." The primary fuel for all the burners is propane; however, the burner in the secondary combustion chamber is also engineered to burn waste oil.

Typical waste streams for this type of incinerator consist of paper, cloth, wood, and rubber with a fair amount of metal particles, glass, and plastics. The waste will have a typical heat content ranging from 6,500 to 13,000 Btu per pound. Waste entering the system should be reduced in volume by a factor of about 100 dependent upon the bulk density of the incoming waste. Ash removed from the system will be volume reduced by a factor of 2 to 5, for an overall volume reduction of 200 to 500. The incinerator will be equipped with an energy recovery system, which will provide hot water for the facility and is capable of being upgraded to deliver steam at 100 pounds per square inch (psi). About 75 percent of the waste to be incinerated will be from commercial nuclear power plants. Additional waste will come from other generators including private industries, nuclear fuel fabricators, and brokers.

The proposed system incorporates a number of safety features including:

- o negative pressure in the system to prevent the contents of the incinerator from escaping to the surrounding environment;
- o high operating temperatures and long secondary chamber residence time to assure complete burning;
- o instrumentation to provide system control and information;
- o redundancy and auxiliary electrical backup of critical components to maintain safe operation or shutdown in the event of a system failure; and
- o air pollution control systems, including parallel, redundant HEPA filters and a liquid scrubber, to minimize environmental impact.

3.3 Proposed Site and Vicinity

The proposed incinerator site is on SEG's CVRF facility located in Roane County in the city of Oak Ridge on a 35-acre tract of land in the Clinch River Industrial Park. This industrial park was established by the city of Oak Ridge as the preferred location for businesses which plan to handle either radioactive or hazardous materials. The park abuts property under the custody and control of TVA to the south and west and property under the custody and control of DOE on the other two sides except for an existing road. To date there are only two other facilities, both owned by International Technology Corporation (IT), in the park. At opposite ends of the park are IT's waste handling facility and its radiological laboratory. SEG is between these two facilities.

Figure 1 shows the location of the CVRF in relation to DOE facilities and the city of Oak Ridge. The site is 1 mile (1.6 kilometers) from the Oak Ridge Gaseous Diffusion Plant (ORGDP), 2 miles (about 3 kilometers) from the site of the former Clinch River Breeder Reactor (CRBR), 4 miles (about 6 kilometers) from Oak Ridge National Laboratory (ORNL), and approximately 11 miles (about 18 kilometers) from the center of Oak Ridge.

Access to the site is provided by two major highways, Highways 58 and 95. These highways connect to Interstate 40 at distances of 5 and 8 miles (8 and about 13 kilometers), respectively. Both of these highways provide very good access to I-40 without passing through highly populated areas.

The site is composed of parcels 1 and 2 of land designated by TVA as Tract XWBR-688IE. These two parcels consist of timbered land which gently slopes toward Grassy Creek. The large existing asphalt access and parking area, office, processing, and storage buildings are at an elevation of 780, which is 39 feet above the normal maximum pool level for Watts Bar Reservoir and 15 feet above the Clinch River maximum probable flood elevation at this location. The proposed incinerator building is to be built between the existing process building and Bear Creek Road with a floor slab elevation of 784.2.

Figure 3 shows the existing site in more detail. The site is surrounded by a seven-foot security fence approximately one mile long. The entrance gate is electrically operated. The site is serviced by city water, electric power, and a city sewer leading to a treatment plant nearby. The plant is largely obscured from the road by a buffer of uncleared timber and SEG is prohibited by covenants in the grant of easement from disturbing a habitat protection area in the vicinity of Grassy Creek. Consequently, the aesthetic quality of the area was preserved.

The permanent population within approximately 2 miles (3 kilometers) of the SEG site is all located in a southeast to southwest sector and consists of less than 100 people. The nearest potential resident is 1300 meters southwest of SEG, just across the Clinch River, and the nearest actual resident is 1800 meters in the same direction. See Figure 4 for an area map of population densities.

The DOE nuclear facilities on the reservation are the major industries within a 10-mile (16 kilometer) radius of SEG and employ approximately 15,000 people. SEG currently employs approximately 140 people at the site, and it projects that 200 people could be employed by 1989. IT has proposed construction of an Environmental Technology Development Center next to the SEG site that is expected to directly employ up to 110 people and will be home base for another 500 individuals who will be the operating personnel for transportable waste treatment and disposal technologies. IT currently employs 55 to 60 people at this location.

3.4 Waste Acceptance Plan

All wastes shipped to SEG must comply with applicable DOT packaging, shipping, and documentation regulations, including all waste certifications and descriptions. The wastes accepted for incineration at SEG include burnable dry active wastes and liquids generated at nuclear power plants, industrial facilities, and government facilities. Gas cylinders, and wastes containing large amounts of nonombustibles, such as metal, or glass are not accepted for incineration. Incidental quantities of metal, glass, and other noncombustibles are acceptable. If wastes with unacceptable physical characteristics are received, they will be removed during hand sorting operations. (See Section 3.6 and Attachment I, SEG's Radiation Safety Guide, for more details on the sorting process and worker protection.)

Since SEG is not a hazardous waste treatment, storage, or disposal (TSD) facility, waste will not be accepted from clients if it contains any listed or characteristic hazardous waste, as defined by applicable regulations. Explosives, whether or not regulated as a hazardous waste, are also not accepted. Oil and similar burnable liquids not regulated as hazardous waste are accepted. Certain SEG generated chemical wastes may be incinerated according to applicable regulations. However, at this time SEG does not generate any chemical wastes that would be considered a candidate for incineration, no do they anticipate any chemical wastes from current operations. Any chemical wastes burned by SEG will meet all Federal and State environmental laws and be in accordance with existing permits, licenses, and approvals.

The radiological characteristics of waste acceptable for incineration at SEG are mostly determined by the EPA airborne release restrictions. To a lesser extent, these characteristics are driven by operator exposure concerns, inventory buildup in ash (e.g., criticality considerations), and analytical complexity. The annual quantities and radionuclides (daughters implicitly included) generally acceptable for incineration at SEG are given in Table 3.4.1. These values were derived from the waste characteristic data in Attachment G. If all of these quantities are incinerated at SEG every year, the EPA exposure limits will still be met. SEG does not intend to incinerate special nuclear material (SNM) except as incidental quantities of much less than a few grams per year. Therefore, criticality will not be a concern. Since hospital wastes are excluded from the acceptance plan, the analytical difficulties of accounting for nuclides such as P-32, S-35, large quantities of H-3 and C-14, and other problem nuclides, will be minimized. Relatively small quantities of H-3, C-14, and pure beta emitters will be present in accepted wastes.

For radionuclides (other than daughters) not shown in Table 3.4.1, SEG will establish a Maximum Acceptable Quantity (MAQ) to be incinerated each year if that quantity is likely to exceed a trivial amount. The trivial amount of any unlisted radionuclide allowed to be incinerated without establishing an MAQ is defined as that quantity which will result in an annual calculated committed effective dose equivalent of 0.25 millirem, or a committed organ dose equivalent of 0.75 millirem (1 percent of the NESHAPS standards). To calculate the trivial amount of an unlisted radionuclide, SEG will perform a dose equivalent assessment for the radionuclide. SEG will perform this assessment, using the airdose calculation required by the EPA NESHAP permit, with the exception that the determination need only be performed at the previously established point of maximum impact and that the model used may be a desk-top computer version of AIRDOS-EPA.

If the radionuclide is expected to exceed the trivial amount, SEG will establish an MAQ such that the NESHAPS standards are met for the entire inventory of incinerated radionuclides.

Prior to incinerating a new radionuclide which exceeds the trivial amount, SEG will notify EPA, in writing, of its intent to incinerate a radionuclide not previously included in the application analysis. The notification will include the MAQ established for the new radionuclide, and the estimated annual dose resulting from incinerating this radionuclide, as well as all others.

Table 3.4.1 Maximum Annual Incinerated Radionuclide Quantities

Radionuclide	Quantity (Ci/yr)
Co-60	34.1629
Cs-137	14.6029
Co-58	12.5014
Cs-134	4.8108
I-131	0.0165
Mn-54	5.0769
Cr-51	1.6332
Ru-103	0.0362
Sb-125	0.2929
Nb-95	1.3870
Zr-95	0.9413
Ru-106	0.0089
Fe-59	0.7467
Ce-141	0.0021
Ce-144	0.0368
Sr-90	0.1001
Ni-63	4.8393
Fe-55	47.2951
Pu-241	0.0511
Co-57	0.0377
Ag-110H	0.0110
Sn-113	0.0017
Sc-90	0.0023
Sr-89	0.0572
H-3	2.5875
C-14	0.1431
Tc-99	0.5306
I-129	0.0225
U-238	2.0000

Prior to shipping waste to SEG, the client will characterize the waste physically, chemically, and radiologically. Knowledge of how the waste was produced may be used to determine characteristics. As appropriate, laboratory analyses may also be required. SEG will review this data, determine if the waste is acceptable for incineration, and possibly assist the client in shipping. When the previously approved waste is received at

SEG, SEG will review the shipment documentation for acceptability, physically inspect for compliance with shipping regulations, and do a radiological survey on the shipment. Prior to incineration, the waste will be opened and sorted to inspect for, and remove, any undesirable materials such as noncombustibles, hazardous or dangerous items, and anything else that should not be incinerated. If the stated physical, radiological, or chemical composition of a waste becomes doubtful during sorting, appropriate analyses and determinations will be done, and the unacceptable material removed for alternate disposal in accordance with SEG's existing RML. (See Section 3.4, Waste Acceptance Plan for more information on alternate disposal.).

Waste received from nuclear power plants is shipped with the weight and radionuclide content specified for each package. SEG and the NRC require the waste generators to have typical samples of their waste streams analyzed each two years or when the radionuclide distribution is believed to have changed. The analysis performed on the waste develops scaling factors which when used with contact radiation readings on the outer surface of the packages can be used to predict the amount of activity associated with each radionuclide. (SEG customers are required by NRC regulations to develop and evaluate scaling factors on a prescribed basis if the waste generator has more than one radionuclide. In general, SEG accepts the customer supplied scaling factor since they are generally done by independent labs.) Waste from other generators will be handled in a similar manner. When SEG receives the waste, they will verify the package radiation readings and package weight for 100 percent of the incoming packages of waste for burning. After the waste is sorted and the burnable waste packaged in waste containers designed for the incinerator, the dose of these containers will be measured and compared with the doses expected from the waste analysis provided by the customer. If there is good agreement, the waste will be burned. If the SEG reading does not correlate with the customer provided analysis, SEG will assign the correct value to the waste prior to burning.

SEG will also verify the composition of the radioactive material burned by sampling ash removed from the incinerator, analyzing the stack gases, and back calculating the amount of activity that would have been contained in the waste. The back calculation method should be an accurate way of verifying the actual radionuclide content of the incoming waste. SEG will maintain a record of all radioactive material received. The record will include at least: date shipped and received, radionuclides and quantities in shipment, verification and comparison of results, if conducted, and date of incineration. SEG will also keep records of the cumulative quantities of radionuclides charged to the incinerator and records of the radionuclide content in disposed ash.

3.5 Waste Oil Handling

All oil will be shipped directly from the waste generator in container systems providing at least double containment and these container systems will not be loaded, unloaded, or shifted en route. The double containment system used for shipping shall also be used for storage at SEG. These systems are expected to consist of sealed 55-gallon metal drums packed inside sealed metal containers of approximately 100 cubic feet (B-25 containers) or sealed 55-gallon metal drums packed inside Sealand Containers (these are larger metal boxes which open from the side and have a separate additional metal containment pan). The container systems will then be offloaded with fork-lifts and stored on the asphalt parking area adjacent to the process building and later transported by forklift to the storage building or the process building. No container system shall be opened until it is within the storage or process building which have diked areas protected from rainwater. Noncontaminated blending fuel will be stored outside the process building in a steel fuel tank surround by a dike to prevent the escape of the fuel in the event of a storage tank failure. SEG will be required, as a condition of TVA's approval, to ship and receive oil in these container systems until and unless SEG submits an adequate spill prevention control and countermeasure plan (SPCC) and obtains additional TVA approval for the alternate transportation proposal.

Waste oil will be prepared in several steps for burning. First, it will be analyzed and then pumped from the primary containment system (usually drums) into an oil processing tank located in the decontamination room of the existing process building. The waste oil will be analyzed in accordance with

SEG's existing oil burning procedure (see Attachment J) for viscosity, flammability, solids and water content, and radionuclide content. The waste oil in the processing tank will be filtered; water will be removed; and blending fuel will be added to assure that the prepared fuel will meet burner specification. Filter elements and sludges will be disposed of as radioactive waste in accordance with the Radioactive Material License. The used primary containment system will then be rinsed with kerosene at this location and the rinse added to the oil processing tank. These used containers may then be packed with other low level radioactive waste but in any case they will not be used for liquids and they will not leave the SEG facility except as radioactive waste processed in accordance with the radioactive material license.

Prepared fuel will be pumped through double-wall pipe to a holding tank located outside the process building in the same diked area as the blending fuel. Fuel will be piped from the prepared fuel tank to the incinerator using double-wall pipe. Double containment will be maintained throughout the fuel-handling process.

All fuel-handling facilities shall be installed to meet the requirements of the city of Oak Ridge Fire Department and the American Nuclear Insurance Company (which insures SEG).

Waste oil received from waste generators will be entered into the SEG waste tracking system and will be fully accounted for throughout the project. SEG will be required, as a condition of TVA's approval, to refuse receipt of any oils or other liquids contaminated with listed hazardous wastes or which have hazardous waste characteristics such that the oils or liquids would be regulated as hazardous wastes under Tennessee hazardous waste regulations or the Resource Conservation and Recovery Act. SEG will also be required to refuse receipt of any oils or liquids containing any detectable levels of polychlorinated biphenyls (PCBs) (i.e., 2 ppm PCBs or greater). (See Section 3.4, Waste Acceptance Plan, for waste verification information.)

Radioactive particles that may be carried over with flue gases are effectively filtered before the system is vented to the environment. The filtering is accomplished by cooling the flue gases in the boiler and then passing the gases through a baghouse, a HEPA filter bank, and a wet scrubber. The cooling process is accomplished in an energy recovery system, whereby hot water or steam may be produced. Initial plans are to operate the boiler in a hot water mode.

3.6 Sort and Feed Operation

SEG has stated that only hand sorted waste will be packaged for incineration. Waste will be sorted in the existing main process building near the present shredder system. The sorting facility is illustrated in Figure 10 and 11 and will replace

SEG's current sorting system. Waste received in boxes or "sealand containers" will be introduced into the vibratory hopper and fed in at a controlled rate from the hopper to the sorting wheel. Waste processing technicians will sort the waste into the following categories:

1. Burnable waste: This category of waste will include wood, plastic, paper, cloth, absorbed liquids, and animal carcases. Wastes which are not acceptable for burning will be eliminated from this class of waste. For example, plastic materials containing polyvinyl chloride (PVC) will be reduced to less than 5 percent.

   Waste generators will be required to limit the amounts of PVC shipped to SEG for incineration. SEG's acceptance criteria will specify that the incoming waste have a PVC content of less than five percent by weight. In addition, SEG will require the waste generators to procure PVC in a specific color for easy identification in its sorting process. SEG plans to monitor the procurement of PVC materials by its customers to assure the lowest possible PVC content in the waste. Compliance with SEG's acceptance criteria will be measured by the amount of sodium hydroxide consumed in the scrubber during the incineration of a particular customers waste. Customers with out-of-specification waste will be required to pay higher processing and disposal costs because SEG will only compact their out-of-specification waste. Customers with significant out-of-specification waste will be banned from the incinerator until they demonstrate compliance with SEG's PVC acceptance specification.

2. Waste for shredding: This category of waste includes waste that will be shredded prior to compaction. The primary reason for shredding will be to size reduce the waste to fit SEG's compactable boxes.

3. Waste for decontamination and release: This category of waste includes waste which can be decontaminated and released. Typical materials will include metals, some wood, or other materials which are lightly contaminated. SEG's original license and present license allows for the decontamination and release of any materials which have contamination levels below the values specified in that license. Normally, SEG only decontaminates and releases valuable equipment or metal which has a high value and which has a geometry that allows for complete and careful surveys. No material is decontamined or released which does not have a geometry that allows assurance that the decontaminated material is free of contamination.

4. Unallowable waste: This category of waste includes material that cannot be accepted at the burial site in its present condition. Waste in this category must be treated to make it acceptable for burial. For example, lead shielding would be removed from the waste to comply with the ban on burying lead sheet.

Waste may also be sorted by radionuclide concentration, particularly where I-129 and Tc-99 are present. SEG states that wastes which contain high concentrations or other radionuclides (such as H-3 and C-14) that could cause releases to exceed release limits will not be burned. This means that a majority of the medical and research waste now being processed by SEG will not be burned in the incinerator. Waste of this type will continue to be compacted and buried as the preferred method of disposal in accordance with SEG's existing radiological material license (not a part of this assessment).

After the waste is sorted, the burnable fraction will be packaged in wheeled containers that hold 50 cubic feet (about 300 pounds) of waste.

The incinerator system is equipped with a magazine capable of accepting 22 wheeled containers. This number of containers approximates the amount of waste that can be processed in an eight-hour shift. Waste is delivered to the incinerator automatically as the control system determines when new waste can optimally be fed to the primary combustion chamber. The waste feed system is shown in Figure 12.

A container placed in the container magazine will approach the incinerator on a chain conveyor until the container arrives at the sluice charging trolley, where it is automatically attached. When the incinerator is ready for charging, the container rides up the vertically inclined trolley to the waste charging sluice. This charging cycle will be repeated between 3 and 5 times per hour, depending upon the heat content and bulk density of the waste.

The waste container trolley consists of a vertical rail system constructed of heavy channel steel. Waste containers are automatically connected to the hoisting mechanism, which is constructed of heavy steel and equipped with travelling and guiding wheels that run in the rail channels. When the waste container arrives at the top of the rail system, the container is rotated to a near-vertical position over the waste feed sluice. When the container is in position, the waste falls into the waste feeding sluice. When the waste container has emptied, the upper waste charging sluice door closes.

The empty waste container rides back down the trolley and is taken to a position in the container magazine assigned for empty containers. The next container filled with waste is automatically aligned with the trolley to await the next charging. Malfunction of the waste charging system provides a warning to the operator and waste feed movement automatically ceases.

The automatic vertical waste feeding sluice is constructed with electrically operated sliding doors at the top and bottom of the sluice. The top door is constructed of heavy steel with a gasket to assure complete tightness when the door is closed, and has a cross sectional area of 59- by 59-inches. This area is slightly smaller than the cross-sectional area of the sluice to prevent waste catching on the interface between the sluice door and the sluice itself. Waste entering the sluice falls by gravity onto a set of liquid cooled sluice flaps positioned above the bottom sluice door. The liquid cooled sluice flaps are placed above the lower sluice door to prevent waste in the sluice from becoming overheated and, for example, allowing materials with a low melting point, such as plastics, to disintegrate and cling to sections of the sluice. The waste flaps are made of heavy steel with high temperature insulation on the side facing the combustion chamber. The sluice chamber is constructed of 8 gauge steel plate and has a volume of 62 cubic feet (in comparison to 50 cubic feet of waste in the containers).

The waste feeding sluice bottom door is constructed of heavy steel and has an integral liquid cooling system. The door moves in and out of a box-shaped feeding door chamber. The feeding door chamber, on which the sluice chamber is resting, has horizontal and vertical removable steel covers for service and inspection. The chamber is fabricated with high temperature insulation and houses the rails, mechanical driving equipment for the door, and the movable feeding door when it is opened. A special ceramic packing provides tight sealing between the incinerator and the sluice door.

Sluice chamber maneuvering is controlled through the logic control system, which receives input signals from electronic temperature controllers, electronic timers, relays, and motor overload switches. The feeding door is normally moved by a pneumatic actuator. If the air supply fails, the door may be operated by an emergency compressed air supply. In case the pneumatic system fails, the door can be closed with a manual hand crank.

When the logic control system determines the primary chamber is ready for a new charge of waste, the lower sluice door opens fully and the sluice flaps rotate downward to allow the waste to fall by gravity into the chamber. The sluice flaps then return to the original horizontal position by rotating upward and locking into position. The lower sluice door closes, and a fan is actuated to exhaust flue gases from the sealed sluice compartment to the secondary combustion chamber. This feature eliminates flue gases from escaping to the environment during the next cyclic operation of the top sluice door. The sluice doors are interlocked through the logic control system to prevent both sluice doors from being open at the same time.

3.7 Combustion System

The combustion system (Figure 13) consists of two chambers; the primary combustion chamber and the secondary chamber. Waste falls into the primary combustion chamber 3 to 5 times per hour, which operates in a temperature range of 1,290 to 1,650 degrees Fahrenheit. The waste is burned in the first half of the primary combustion chamber under oxygen starved conditions to convert the waste into combustible gases and water vapor. The gases from the combustion process are transferred to the secondary combustion chamber for complete burning. The ash is transported from the first section of the primary chamber to the second section of the primary chamber where the oxygen content is increased to burn out the ash to the maximum extent possible. From the time the waste is dumped into the primary chamber until it reaches the ash discharge port is approximately 24 hours. Gases travel to the secondary chamber in approximately one (1) second. The primary chamber is equipped with an auxiliary propane burner. The burner is automatically activated if the chamber temperature falls below the preset nominal limit of 1,290 degrees Fahrenheit. Combustion air entering the primary chamber is controlled by the logic control system, through temperature, oxygen, carbon monoxide, and flue gas opacity monitors. The combustion air supply is approximately 3,600 standard cubic feet per minute (SCFM). A redundant combustion air fan is provided, which will automatically activate if the primary fan fails.

The primary combustion chamber is completely lined with high temperature refractory material such as castables, plastic rammings, and brick. An insulated lining is provided between the refractory lining and the incinerator shell, and is made with insulation blocks, ceramic felt, and mineral wool. The temperature on the outside surface of the incinerator shell remains at approximately 125 degrees Fahrenheit after the incinerator has been operating for long periods.

The chamber floor is of solid construction to prevent unburned material from escaping complete combustion. This feature is opposed to typical incineration systems which use floor grates to provide passage for combustion air.

The proprietary waste stirring and ash transport devices have a cooling fan, which forces air through the devices to maintain controlled environmental service conditions. A redundant cooling air fan automatically activates if the primary fan fails. The chamber is instrumented to continuously record air pressure. Temperature is monitored by redundant thermocouples. A switch on the main control panel allows the operator to compare signals and determine if malfunction has occurred. Thermocouple replacement can be easily accomplished while the incinerator is in service. Flow instrumentation is provided for cooling air to the ash transport system and for combustion air.

Flue gases and water vapor flow from the primary combustion chamber to the secondary combustion chamber. The secondary combustion chamber is operated under excess oxygen conditions in the temperature range of 1,830 to 2,200 degrees Fahrenheit.

The secondary combustion chamber is very large compared to typical incinerators, and is sized to achieve a flue gas retention time of 3 full seconds to assure complete combustion of even hazardous wastes if they accidentally get into the system. The secondary combustion chamber is also equipped with a flammable solution injection system for the incineration of flammable liquid materials. Flammable waste, such as turbine oil, can be charged into the propane burner situated in the floor of the chamber. This system is rated at 30 gallons per hour maximum. The chamber is lined with refractory material similar to the primary combustion chamber.

The upper section of the secondary combustion chamber has instrumentation to monitor temperature, pressure, oxygen content, and carbon dioxide content. Redundant thermocouples provide temperature indications. Readings may be compared at the main control panel to determine failures. Easy access is provided for changing the thermocouples while the incinerator is operating.

The incinerator is equipped with a pressure relief door to relieve sudden over-pressure caused by accidental transients within the incinerator accompanied by a pressure shock-wave. Gases which escape the incinerator during an overpressure transient will be trapped in the incinerator building and then be removed by the building HEPA filter exhaust system. The pressure relief door is positioned on top of the secondary combustion chamber. The door has high temperature ceramic seals to withstand the temperatures in the secondary combustion chamber. The door is held in a closed position by a calibrated, constant-pressure spring. In case of an over-pressure transient, the door will open to reduce the pressure and close immediately after the transient has ceased. (See Section 5.1 for a more detailed discussion of this postulated accident.)

3.8 Ash Handling System

The sealed ash discharge system (Figure 14) consists of an ash transporter and an ash sluice system in the primary combustion chamber of the incinerator. The ash sluice has upper and lower sluice doors which are provided with interlocks to prevent accidental opening of both doors simultaneously. The upper sluice door opens to allow ash from the primary combustion chamber to fall into an air-cooled chamber normally sealed by the two sluice doors. When the ash has cooled sufficiently, as determined by thermocouple instrumentation, the lower sluice door can be opened to allow ash to fall into a container. The ash discharge system is of heavy steel plate construction with steel reinforcements. A sealing system is provided between the ash discharge system and containers. One ash container will accommodate three shifts of operation.

The ash discharge area will consist of a separate enclosure designed to protect against any ash escape. This enclosure will be operated at negative pressure with respect to the incinerator building and vented to the incinerator building ventilation system. Waste enters the incinerator at a rate of 800 to 1,600 pounds per hour. Ash is discharged at a rate of approximately 50 to 90 pounds per hour, or 1 to 2 cubic feet per hour. The bulk of ash produced in the incinerator is discharged from the ash hopper. For every 100 ash containers filled from the ash hopper, 1 to 2 ash containers will be filled from the baghouse filter.

An estimate of the activity balance of the incinerator is shown in the following table. Activity does not exactly balance due to round off. Activity varies according to particle size.

Table for Activity Balance

Incoming waste	913 pounds/hour	12.2 milliCi/hour
Ash discharge	55 pounds/hour	11.6 milliCi/hour
Boiler ash trap	0.04 pounds/hour	5.1 microCi/hour
Baghouse filter	2.6 pounds/hour	0.36 milliCi/hour
HEPA filter and scrubber	0.11 pounds/hour	15.4 microCi/hour

3.9 Heat Recovery System

Flue gases exhaust from the secondary combustion chamber at a rate of about 5,000 SCFM, and enter a vertical three-pass pressure steam boiler. The boiler is capable of providing 8,500 pounds per hour of 100 pounds per square inch - gauge (psig) steam, while reducing the flue gas temperature from a maximum of 2,200 degrees Fahrenheit to approximately 360 degrees Fahrenheit. For initial operation, however, the steam boiler will be operated as a hot water heater only by eliminating the steam chest. The steam chest can be added at some future date to upgrade the system (see Figure 15). The boiler is fabricated from carbon steel. Manholes on top of the boiler facilitate inspection and cleaning. The waste recovery system will be used to heat the incinerator building and the existing process building (see Figure 16).

3.10 Flue Gas Handling System

The cooled flue gases exit the boiler arrangement and enter a baghouse filter. See Figure 17. The bag filter unit consists of a clean flue gas chamber, a filter body chamber, and a dust hopper. The bag filter unit is constructed of heavy gauge mild steel, with all joints welded. The filter system contains distribution piping for compressed air, a compressed air tank, and compressed air valves to provided air pulses to clean the tubular fabric bags. Compressed air is used to blow collected dust from the filter bags. The air pulses occur from as often as 1 per second to intervals of several minutes. The pulse rate is controlled by the logic system, and is a function of the pressure drop between the baghouse inlet and outlet. The bags used are guaranteed to provide flue gas quality downstream of the baghouse of 0.0025 grains or less of particulate matter per standard cubic foot. This air quality compares with an input flue gas quality of 0.009 to 0.026 grains particulate matter per standard cubic foot. A grain is equal to 1/7000 of a pound. This is an efficiency of up to 90 percent for the baghouse alone. If temperatures exceed approximately 440 degrees Fahrenheit, a cooling air intake will automatically open and provide sufficient cooling air to prevent damage to the baghouse filters.

The baghouse filter system contains a clean flue gas chamber constructed of heavy gauge mild steel with all joints welded. The filter bag sleeves are drawn over a basket arrangement, which provides the necessary support to maintain a tubular shape. The filter bags are approximately 6 inches in diameter and 6 feet long. There are 256 vertically mounted bags. The filter body chamber contains the filter bags, which are suspended from the clean flue gas chamber. The chamber is insulated on the outside with 3-inch mineral wool covered by 22 gauge sheet metal. The chamber is provided with inspection and access doors.

Material in the baghouse filter consists of GORE-TEX proprietary membrane[1] laminated to Nomex[2], glass, etc., as specified by the supplier for a specific environmental service.

[1] A product of W. L. Gore & Associates, Ltd., Scotland. Plants and offices are also in Scandanavia, West Germany, France, Australia, Japan, and the U.S.

[2] A DuPont registered trademark.

The lifetime of a set of bags is approximately two years. To avoid non-scheduled downtime, SEG plans that the bags will be changed during the annual planned outage or approximately once a year. Normal downtime for a bag change is approximately 56 hours which includes 48 hours for system cool-down and 8 hours for the actual bag change.

The cone-shaped dust hopper is made of welded heavy gauge mild steel. A damper in the bottom transfers collected dust to an ash container through a sealed system.

Flue gases exhaust from the baghouse filter and enter a HEPA filter bank. The filter banks have prefilters to extend HEPA filter life. Two parallel and independent filter banks have been provided, which allows one bank to be shut down and serviced if excessive pressure drop is registered for the in-service filter bank.

Particulate matter passing the HEPA filter will not exceed 4×10^{-6} grains per standard cubic foot. The Aerodynamic Mean Average Diameter (AMAD) of the particulate exiting the bag filter is in the range of 3 to 4 microns. This is based on measurements taken on 5 different days using an Anderson 2000 Inc., MK 3 High Capacity Stack Sampler. This is an 8 stage cascade impactor dividing particles in 8 sizes between 20 to 0.5 microns.

The HEPA filters have a penetration (P) value as follows:

0.25 to 0.3 microns	$P = 0.03\%$
greater than 0.3 microns	$P < 0.03\%$
less than 0.3 microns	$P < 0.03\%$

HEPA filters used in the nuclear industry are rated to remove 99.97% of the particles having an average diameter of 0.3 microns. SEG currently uses this type of filter as the last stage in filtering 30,000 cubic feet or air from its present plant.

If temperatures exceed approximately 440 degrees Fahrenheit, a cooling air intake will automatically open and provide sufficient cooling air to prevent damage to the HEPA filter. The HEPA filters can be exposed to temperatures up to 440 degrees Fahrenheit without being damaged. However, SEG expects the normal temperature of the air passing through the HEPA filters to be 360 degrees Fahrenheit. Excess temperature in either the baghouse filter or HEPA filters will produce alarm signals in the control room and may initiate automatic incinerator system shut down.

Gases exiting the HEPA filter enter a wet-gas scrubber system which consists of a quencher and a packed tower. The flue gas enters the quencher at a temperature of 360 to 430 degrees Fahrenheit where gases are reduced to about 200 degrees Fahrenheit, and pass through a caustic solution in a packed tower. SEG has estimated the effectiveness to be approximately 90 percent for removing HCl and 60 to 70 percent for removing SO_2.

Following scrubbing, gases as passed to a reheater where the gas is heated to a minimum temperature of approximately 360 degrees Fahrenheit before exiting through the 98-foot high stack. (See Section 5.1 for a discussion of emissions.)

3.11 Monitoring and Control Systems

The incinerator is controlled from a central console system in a closed room, with a window viewing the waste charging system.

The console provides a graphic description of the incinerator system. Lamps indicate the operating status of pumps, fans, waste charging system, primary combustion chamber status, auxiliary burners, equipment, and processes of critical importance to normal operation. Figure 18 outlines the incinerator logic flow.

Visual and audible alarms provide indication of the following conditions:

- o inadequate negative pressure in the primary combustion chamber;
- o high CO content and out-of-limit opacity in the flue gas stream;
- o high temperatures throughout the system;
- o motor and flame controller failure.

Other parameters are continuously recorded. These parameters include:

- o primary and secondary combustion chamber temperatures;
- o temperatures upstream of the baghouse and HEPA filter banks;
- o flue gas opacity;

o primary combustion chamber pressure;

o secondary combustion chamber oxygen and carbon dioxide.

Temperatures in the primary and secondary combustion chmabers are measured with redundant thermocouples that can be switched at the control console if failure of either thermocouple is indicated. Thermocouple replacement can be performed while the incinerator is in service. Combustion air fans, cooling air fans, induced draft fans, pressure indicators, level indicators, and flue gas quality monitoring devices are duplicated, and are automatically switched over by the logic control system. The operator is provided with a warning when switching occurs.

All important process parameters, such as temperatures, pressures, are programmed into the logic control system to prevent unauthorized personnel from adjusting critical process parameters. The operator is allowed to maneuver waste containers and to monitor the system from the control console. SEG states that if abnormal conditions arise, the operator should be able to easily determine the problem and take remedial action.

Certain abnormalities will initiate emergency shut down. These include:

o High temperature in the primary combustion chamber

- o High temperature in the secondary burning chamber
- o Positive pressure in the primary combustion chamber
- o Malfunction of the feeding sluice
- o Abnormal temperature upstream of the baghouse filter
- o Abnormal temperature upstream of the HEPA filter
- o Malfunction of the secondary burner
- o Malfunction of the boiler

Emergency shutdown causes the following actions:

- o Feeding sluice closes
- o Shut down of all burners
- o Shut down of combustion air fans
- o Water spray injected into primary chamber until temperature in the incinerator is less than 400 degrees Fahrenheit
- o HEPA filter bypass opens

o Draft control system maintains negative pressure in incinerator

A draft control system with backup will automatically maintain and control the negative pressure of the incineration process. This automatic system controls the negative pressure by modulating an iris-type damper in the suction inlet of the flue gas fan.

A water tank above the incinerator spray system will provide an emergency supply of gravity fed water in case of water main failure.

Water is sprayed into the incinerator in over-temperature situations at a rate of 0.2 gallons per minute for a total of 50 gallons or until the combustion chamber temperature falls below 400 degrees Fahrenheit. The water spray will create superheated steam that would blind or saturate the HEPA filters if they were not bypassed.

The HEPA filter bypass has been engineered to assure that SEG can maintain negative air pressure inside the incinerator during emergency shutdown procedures. If the filters were not bypassed during the four minute emergency cool-down period, the filters would be blinded by steam vapors which would cause SEG to loose control of the negative air pressure inside the incinerator. The environment is still protected from significant radionuclide release since the non-filtered exhaust gases will still pass through the wet-scrubber before final release. (See Section 5.1, Air Quality, for details of this accident condition including projected release rates.)

An isokinetic air sampler is planned for representative sampling of the radionuclides in the stack. This sampler will be operated continuously except for periods when malfunctions or sample filter changes occur. The isokinetic sampler is intended to be used continuously to monitor flue gases for normal or emergency operation. (See Section 3.16.) The sample filter will be collected and analyzed weekly for gamma emitters in the SEG radiochemistry laboratory. Non-particulate radioactive material such as tritium, carbon-14, and iodine will be accounted for by assuming full release of the inventory charged to the incinerator.

3.12 Auxiliary Generator

An auxiliary diesel generator will permit orderly incinerator shutdown if commercial power is interrupted. The generator will maintain power for essential monitor and control systems, and additionally, for the necessary subsystems and safety features required to accomplish a systematic halt to incinerator operation. The generator will be rated for 120 kilowatts.

The auxiliary generator will be thoroughly tested during the trail burn under simulated power outage situations and will be tested once a month during normal operation.

3.13 Trial Burn

When checkout and testing of the incinerator is complete (projected to be 1989), a trial burn will be conducted by Studsvik and SEG personnel. The 96-hour trial burn will be conducted using nonradioactive waste consisting of plastic, wood, and paper. This operational phase is intended to achieve several goals, among which are:

- the seasoning of combustion chamber refractory material
- final instrumentation testing and calibration prior to startup
- testing of the auxiliary generator under load and no-load conditions and simulated power outage situations
- further supervisory and operational training under the direction of the supplier
- a final test of the waste receipt and sorting procedure
- a complete test of operational emergency situations

3.14 Waste Disposal

As the wastes are burned, about 1 percent of the original volume will remain as ash. That ash will be low-level radioactive waste and must be properly processed for disposal.

Occasionally, filters and other byproducts will need to be disposed. After the waste is removed from the incinerator, it will be analyzed, prepared for shipping, transported to the disposal site, and disposed of.

Ash will be discharged from the incinerator ash hopper into boxes which hold approximately 38 cubic feet of ash. The discharge of the ash will take place in a isolated enclosure below the incinerator. The ash discharge enclosure will be maintained at a negative pressure to assure that no ash will escape from the discharge area. Workers who work in the discharge area will wear protective clothing and respiratory protection to assure their safety. To discharge ash from the incinerator, the box to receive the ash will be sealed to the ash hopper utilizing tight air seals to prevent small amounts of ash from escaping when the ash is discharged. The temperature of the discharge ash is expected to be less than 100 degrees centigrade. After being filled, the box will be carefully removed from the filling position and a gasketed lid sealed to the box to prevent the escape of contamination. Prior to being transferred from the incinerator building to the waste processing building for inclusion into waste going to the burial ground, the outside of the box will be decontaminated as necessary to achieve an acceptable removable contamination level. The decontamination of boxes is currently being done at SEG for any box which have been in the process area and which must be returned to the storage area to await processing. The method of handling the ash assures worker safety and will not cause any environmental contamination.

The ash will then be solidified, compacted, or vitrified and packaged for burial. Upon removal from the ash discharge area, the container will enter the control of SEG's normal waste streams. Ash removed from the baghouse or boiler will be handled in a similar manner.

Prior to being prepared for shipment offsite, a sample of each container (or a representative sample of similar activity containers) of ash will be quantitatively analyzed for gamma-emmitting radionuclides. These radionuclides comprise the majority of the radioactivity in the ash. Liquid scintillation analysis may also be performed for tritium and carbon 14, although these radionuclides will be very minor constituents and will be largely volatilized during incineration. Other radionuclides will be accounted using the generator's analysis of the original waste.

Filters and similar waste cannot easily be sampled for analysis. Therefore, wherever sampling is impractical, the activities of such wastes will be determined by relating the dose rate on the container to the mix of radionuclides incinerated since the waste was last generated. This relationship is easy to determine using commercially available software such as Microshield.

Incinerator wastes will be processed and packaged before being transported for disposal. Containers of ash, filters, and similar wastes will normally be supercompacted onsite in the SEG supercompactor to achieve maximum density and volume reduction. This process has been used since late 1986 at SEG, and meets the disposal requirement that ash be nondispersible. After compaction, the crushed containers are stacked in overpacks, sealed, inspected for defects, surveyed, checked for contamination, and labeled for transport according to standard SEG practices. Effluents from the wet scrubber will be analyzed for radionuclide concentrations. The effluent will be dried or solidified, packaged, and transported to an approved commercial disposal site licensed to receive radioactive waste in accordance with SEG's radioactive material license.

SEG states that in the future, some wastes may be processed by encapsulation in concrete, molten glass, or other similar media; but, for now, compaction and solidification in concrete will be used.

After processing and packaging is complete, the waste is stored onsite, temporarily, until transportation for disposal is arranged. On the day the shipment is scheduled, the containers are staged in the loading area. The waste is inspected again for defects, surveyed, checked for contamination, and any final labeling applied. The vehicle is inspected, and if acceptable, the waste containers are loaded and secured. The vehicle is placarded, according to DOT regulations, and the SEG Transportation Department does a final inspection on the vehicle and load. Just before departure, the Shipping and Receiving Supervisor and the driver review the shipping papers, destination route, handling requirements, and emergency procedures. When the Shipping and Receiving Supervisor is satisfied the shipment is proper and complies with all laws and safety practices, the shipment is released. SEG states that it uses only approved haulers for transporting radioactive wastes.

As of 1988, there were only three approved commercial disposal sites in the United States for low-level radioactive wastes: Barnwell, South Carolina; Beatty, Nevada; and Richland, Washington. Others will be opened, in the early 1990s, to meet the requirements of the Low-Level Waste Policy Act of 1985. There are a few Federally owned disposal sites for Government wastes and special commercial wastes. SEG uses these sites according to the regional compact requirements and in compliance with other requirements that may apply in certain situations. SEG states that it uses only approved disposal sites.

SEG states that it will keep all required waste documentation records. Besides the normal shipping papers, the disposal sites require a list of all generators and their fractional volumes on each shipment. All shipping papers, certifications, surveys, and related records are kept indefinitely. After the waste is shipped off site, the records are filed and the computerized radionuclide inventory data base is updated to indicate that the material is no longer onsite.

3.15 Health and Safety

The incinerator system is designed to operate safely with a number of automatic features. SEG has an established health and safety program to protect employees from both radiological and nonradiological hazards. Because of the complexity of radiological safety, a reference copy of the SEG Radiation Safety Guide is included in Attachment I.

The SEG industrial hygienist establishes and supervises the general safety and industrial hygiene program. The health physics supervisor and technician staff, and the analytical lab staff assist in the daily functioning of the program. The program includes monitoring for, and protection from, hazardous materials in waste and in the plant air. Monitoring and protection are provided for physical hazards such as eye injuries, noise, heat stress, falls, and confined spaces. The SEG safety committee review and investigates unsafe conditions, acts, and accidents, with the goal of reducing or eliminating them. The general safety protection program for the incinerator will be included under the current SEG safety protection program, and does not require any change in the current program.

The radiation safety officer (RSO) at SEG establishes and monitors the radiation protection program. The health physics supervisor administers the program on a daily basis and supervises the technician staff. The analytical lab supports with measurements. The radiation protection program for the incinerator will be included under the current SEG radiation protection program and does not require any change in the current program. This program includes external and internal dose monitoring, contamination and radiation surveys, controlled area designation, protective equipment and clothing use, and other radiation protection practices designed to keep exposures as low as reasonably achievable (ALARA).

Proper training is extremely important to the safe operation of an incinerator. SEG states that the people associated with the operation of the SEG incinerator have the necessary experience and training to perform their assigned jobs correctly. All workers trained in the basics of radiation protection and safety as part of the SEG "new employee indoctrination program" and gain practical radiation protection experience on the job under the supervision of the health physics staff.

The initial incinerator operation crew will be trained in Sweden on an operating radioactive waste incinerator. There, they will learn how the incinerator works, how to operate it safely, the limitations of operation, and emergency procedures. They will spend a large fraction of their time actually running an incinerator similar to the SEG incinerator. Additions to the crew will be trained on the job under the supervision of qualified operators.

Those involved in approving and receiving waste will be trained in the Waste Acceptance Plan requirements, described in Section 3.4 of this environmental assessment, and in the Tennessee Radioactive Material License requirements. Those who sort the waste prior to incineration will also be trained in the requirements of the Waste Acceptance Plan to further assure that only acceptable waste is incinerated.

3.16 Isokinetic Stack Gas Monitor System

An isokinetic stack gas monitor will be used to continuously monitor flue gases for normal or emergency operations. Figure 19 shows an outline diagram of the stack gas monitor detection assemblies. Figure 20 is a conceptual diagram of the detector showing data acquisition arrangements. Figure 21 illustrates the equipment on the cart assembly.

The stack equipment will consist of an isokinetic nozzle together with flow straighteners in the stack. Five inlet nozzles are presented across the stack diameter and the assembly is dimensioned so that it is possible to obtain a representative sample of effluent gas. A flow monitor is located at the nozzle assembly to ensure the matching of gas velocities up the stack and in the sampling nozzles. The gas flow rate will be measured with a pitot tube device.

The air sampling line from the stack will be curved down to the stack monitor system located at the base of the stack. The incoming air sample line will be heated. In addition, long radius bends will be used on all air sample lines to minimize the possibility of water condensation. The air is impacted into a choice of a moving particulate air filter assembly or a fixed filter and detector assembly, which are both capable of collecting a high percentage of particulate above 0.4 microns. The impact area is viewed by an alpha/beta 2.0 inch diameter scintillation detector. For both detector assemblies the geometry is carefully designed so that the moving or fixed paper filter does not attenuate the incident radiation reaching the detector element. the scintillator is energy sensitive so that alpha and beta discrimination may be accomplished by one detector element. The fixed filter paper particulate detector assembly is used as the main particulate detection element since long sample collection times and counting times are required to monitor stack effluent in normal conditions. The moving paper system is used for specific analyses (where a sample can be measured later as a function of time in the laboratory) or in accident conditions. The change over from the fixed filter to the moving filter will be accomplished automatically when the computer senses a step increase in counts from the fixed filter. This change over takes approximately three seconds to initiate and approximately ten seconds to regain stable isokinetic sampling conditions. The exit air stream from the filter is directed into a charcoal filter assembly for iodines and other materials that may collect in the cartridge. The cartridge, a standard SAI filter designed for this type of application, is viewed by a 2.0" by 2.0" NaI (Tl) scintillator shielded in lead so that a maximum sensitivity is obtained. The cartridge is a fixed device that may be manually changed according to conditions indicated by the stack monitor process electronics. The scintillator is capable of spectroscopy and will detect the passing gas volume and any iodine species.

Passing of purge gas will allow measurement of only the iodine components in the cartridge. Such a measurement will be further backed by subsequent analysis of the cartridge in the laboratory.

The remaining air stream is then fed to a lead shielded chamber where a 3.0" diameter beta detector is located. This fixed volume of gas in front of the detector permits the measurement of any noble gases or other "gaseous" materials that passed the particulate and charcoal samplers.

The exhaust stream from the last detection chamber is returned via the vacuum pumps to the stack for release to the environment. A bubbler is attached to this line so that tritium and carbon 14 measurements may be made. This latter measurement system is an off-line monitor where the collected sample is taken to the SEG laboratory for analysis.

The air flow through the monitor is controlled by a flow valve and motor assembly controlled by the main system control computer. All detection assemblies are fitted with solenoid driven check source assemblies for system checking in an on-line operating condition.

Table 5-1-3 shows the projected annual release rates of radionuclides anticipated. The average stack gas flow rate is 5,000 cfm and will run continuously (average 8,760 hours per year). The total exhaust gas volume is therefore 2.63 E 9 cubic feet annually. For every 1.0 curies of activity discharged over this period, the concentration translates to 3.8 pCi per cubic foot of exhausted gas. In standard units, this translates to 1.34 E-10 microcuries per ml. The stack monitor SEG will use will be capable of measuring approximately 10 E-12 microcuries per ml. By converting the data in table 5-1-3 to activity per unit volume, it is clear that only some isotopes will be detectable on line in normal conditions. This is the reason that some filters will be measured in the SEG laboratory. These measurements allow isotopic identification, if required to 10 E-13 microcuries per ml.

The alpha particle measurements will be detectable for normal operation. The stack monitoring system can monitor and provide data for the worst case accident scenario also because the count rates expected will be well below the maximum count rate capabilities of the detectors and electronics.

Many of the isotopes listed in table 5-1-3 will be detectable with the on-line equipment to be installed. The following will require special treatment:

C-14	Relatively low energy beta. Use of CaF(Eu) in gas chamber may provide specific deductability for this isotope. Grab sample taken from the bubbler will also provide measurement back up.

H-3 A sample is obtained with the bubbler and will be analyzed in the SEG laboratory.

The monitor system has its own dedicated measurement and control electronics. Figure 20 shows a functional block diagram of the system. Figure 21 shows an isometric drawing of the stack monitor assembly.

Each detector has its own amplification and discrimination channel and the outputs are accessed into the computer as shown in figure 20. In addition to the detector count outputs being used to assess activity per unit volume of sample gas and total curie content release per unit time, their signals are analyzed to insure that all detection assemblies are functioning properly.

The computer controls the air flow into the monitor system to maintain isokinetic sampling conditions. In addition, pressure drops are monitored across the filter assemblies to sense their proper operation.

All detection channels will be calibrated with NBS traceable sources.

Air samples will be collected on a weekly basis or sooner, depending on when the samples have enough activity to be detected. On-line sample counting will be done on a continuous basis. Air samples will be analyzed in the laboratory on at least a weekly basis.

The air sampler display will be located on the incinerator control panel and over-limits will be enunciated. The incinerator is not designed to shut down automatically if the air sampler is not operating. SEG believes that the proposed control panel alarms will be sufficient.

3.17 Thin Film Evaporator System

The operation of the evaporator is a closed system which will contain water, dilute sodium hydroxide, sodium chloride, sodium nitrate, and sodium sulfate. This solution will be evaporated to a dry solid with the water being condensed and reused as makeup water for the scrubber supply tank. Ventilation off the holding tanks will be passed through our HEPA filter exhaust system.

Operation of the scrubber will generate approximately 3,000 gallons of this scrub solution per 24 hours. The 3,000 gallons of scrub solution will be evaporated to a dry solid using energy from the boiler. The distillate is recycled to the clean water tank and the dry solids, estimated to be 40 cubic feet, that result for the evaporation process are sent to the waste processing department to be disposed of as radioactive waste. This solid will later be mixed with concrete to fill the void spaces in our radioactive waste packages. It should be noted that SEG expects the solid waste to contain very low levels of radionuclides since the air that is being scrubbed has already passed through a baghouse filter and three other stages of air filtration including a HEPA filter.

During operation of this system, water that is evaporated is recondensed on a chilled coil. The recondensed water is returned to the evaporator system for reuse.

4.0 Alternatives Considered

Upon receipt of SEG's request, TVA considered three alternatives: (1) denying SEG's request (i.e., the no action alternative), (2) approving SEG's request, or (3) approving SEG's request with conditions. TVA's preferred alternative is to conditionally approve the request.

The no action alternative or denying SEG's request is rejected because of the apparent need for this kind of service. Reducing the volume of low-level radioactive waste and burning of waste oil contaminated with low-level radiation and thereafter disposing of the residue in landfills licensed for this appears to be more environmentally sound than continued existing licensed methods of disposal which generate a much greater volume of waste. The location of the incinerator on SEG's existing CVRF site is compatible with its current use and minimizes additional transportation of low-level radioactive waste and ash. Also, except for the SEG site there are currently no other available alternative zoned sites or facilities in the Oak Ridge area for the proposed low-level radioactive waste incineration process and TVA is not aware of any other site in the Oak Ridge area which would pose lower risks of environmental impact. Finally, there are few (if any other) qualified or licensed companies in this line of business and because of the limited number of licensed disposal sites, there is a nationwide need to reduce the volume of these wastes.

Because of the regulatory reviews and approvals which the incineration process has already undergone and the conformity of this activity to applicable zoning requirements, consideration was given to unconditionally approving SEG's request. However, as a Federal agency charged with the responsibility of both developing and preserving the natural resources of the TVA region, TVA thinks it is better to be environmentally cautious and has therefore rejected this alternative in favor of conditionally approving the request. Accordingly, TVA proposes to approve SEG's request subject to the conditions listed in Section 8.0, Environmental Commitments.

5.0 Environmental and Socioecomic Impacts of the Proposed Action

5.1 Air Quality

5.1.1 Radioactive Emissions

SEG has performed an analysis to determine the radiological impact on the environment from the SEG incinerator. The analysis was done using the AIRDOS-EPA and RADRISK computer programs as required by EPA regulations and was independently reviewed by TVA.

SEG states that the regional meteorological parameters for this analysis were taken from the Department of Energy (DOE) Toxic Substance Control Act (TSCA) incinerator National Emissions Standards for Hazardous Air Pollutants (NESHAPS) permit application. This TSCA incinerator is located at the Oak Ridge Gaseous Diffusion Plant (ORGDP) only 2,575 meters (1.6 miles) due north of SEG; therefore, all of this DOE meterological data should be applicable to the SEG site.

Based on the calculation in Attachment G, the radionuclide quantities shown in Table 5-1-1 are assumed to be released annually in the airborne effluent of the incinerator. Several of the nuclides listed in AIRDOS-EPA computer program output are not included in this list because they contribute a minuscule fraction of the calculated dose. In most cases, a conservative nuclide release fraction of 0.0001 is assumed relative to the original waste incinerated. The radionuclide release fraction of 0.0001 is based on the Swedish experience of incinerating 3,000 metric tons of low-level radioactive waste plus the HEPA filter manufacturer efficiency guarantee. For iodine, tritium, carbon, and technicium, an exceedingly conservative release fraction of one (1) is assumed; that is, all the activity of these nuclides going into the incinerator is assumed released to the atmosphere. Furthermore, 10 million pounds of waste are assumed to be incinerated each year.

Table 5-1-1 Annual Radionuclide Release Rates

Radionuclide	Quantity (Ci/yr)
Co-60	3.4 E-3
Cs-137	1.4 E-3
Co-58	1.3 E-3
Cs-134	4.8 E-4
I-131	1.7 E-2
Mn-54	5.1 E-4
Cr-51	1.6 E-4
Sb-125	2.9 E-5
Nb-95	1.4 E-4
Zr-95	9.4 E-5
Fe-59	7.5 E-5
Sr-90	1.0 E-5
Ni-63	4.8 E-4
Fe-55	4.7 E-3
H-3	2.6 E 0
C-14	1.4 E-1
Tc-99	5.3 E-1
I-129	2.2 E-2
U-238	2.0 E-4

Each radionuclide in Table 5-1-1 implicitly includes its daughters in equilibrium. For example, the dose analysis includes the daughters of U-238 to radon and the less obvious Ba-137m daughter of Cs-137.

The results appear to indicate that the radiological impact of the airborne effluent from operating the SEG incinerator will be substantially within the EPA limits of 25 millirem per year (whole body) and 75 millirem per year for critical organ (thyroid). The natural background whole-body dose for the area is approximately 120 millirem per year and the critical organ (lung) doses from natural radon is somewhat higher.

The dispersion distances given in Table 5-1-2 were chosen to encompass the general area around SEG including the nearest site boundary 100 meters NNW (sector 2), the nearest <u>potential</u> residential site located approximately 1.3 km south west (sector 7) of SEG, just across the Clinch River, and the nearest real resident located 1.8 km from SEG in the same sector.

Table 5-1-2 Dispersion Distance in Meters

100	(Nearest Site Boundary)
200	
300	
500	
800	(Nearest Commercial Business)
1300	(Nearest Potential Resident)
1800	(Nearest Real Resident)

Since individual centerline doses have been computed, the population in each sector was set to one (1). Every sector has been designated a significant water area to maximize the waterborne dose. The number of cows in each sector is set arbitrarily large and has almost no effect on the results. All other environmental factors have been set to the program default values.

To provide information about the input to the AIRDOS-EPA and RADRISK computer programs, SEG has stated that Attachment G contains a description of the basis for the radionuclide species and quantities assumed to be discharged in the airborne effluent. The actual computer printouts of the AIRDOS-EPA program were sent to EPA by SEG and are not a part of this assessment; however, a copy is available upon request from SEG. These printouts include detailed listings of the data discussed here and consist of AIRDOS models of the SEG incinerator at ranges of 100, 200, 300, 500, 800, 1300, and 1800 meters from the emission point.

The highest dose occurs at 100 meters in the north-northwest. In all cases, about 96 percent of the whole body dose is from Tc-99 and I-129. About 98 percent of the critical organ (thyroid) dose is from these two radionuclides which are assumed to be fully released. Consequently, all other listed radionuclide quantities could be increased significantly without materially affecting the results. The highest dose to a real resident occurs at 1800 meters in the southwest sector. These doses appear to be inconsequential in comparison to the natural background radiation doses of about 120 mrem/yr whole body and substantially higher critical organ (lung) doses from radon. Table 5-1-3 lists the individual centerline doses at various distances for the whole body and the critical organ (thyroid).

Table 5-1-3 Calculated Annual Doses at Various Distances

Distance (meters)	Whole Body Dose (mrem)	Thyroid Dose (mrem)
100	2.3	17
200	1.2	9
300	0.8	6
500	0.5	3.8
800	0.4	2.7
1300	0.3	2.1
1800	0.26	1.7

The total dose to each organ through all pathways at 100 meters from the emission point is shown in Table 5-1-4.

Table 5-1-4 AIRDOS-EPA Organ Total Dose

ORGAN	DOSE (REMS)
WHOLE BODY	0.2330E-02
R MAR	0.1697E-03
ENDOST	0.5513E-03
THYROID	0.1730E-01
BREAST	0.1424E-03
PUL	0.1425E-03
S WALL	0.5545E-02

INT WALL	0.1006E-02
LIVER	0.1675E-03
PANCREAS	0.1305E-03
KIDNEYS	0.1369E-03

Thus, the SEG incinerator is projected to be within the EPA limits of 25 millirem/year (whole body) and 75 millirem/year critical organ (thyroid).

5.1.2 Non-Radiological Emissions

SEG has provided the following comparison of three incinerators planned for this area:

STATUS	SEG PROPOSED	DOE ACTUAL	IT PROPOSED
	Charging Rate (lbs/hr) Average	Charging Rate (lbs/hr) Average	Charging Rate (lbs/hr) Average
	1200	700	60,000
	Emissions (lbs/hr) Average	Emissions (lbs/hr) Average	Emissions (lbs/hr) Average
Particulate	0.00083	2.9	7.8
Sulphur Dioxide	0.18–0.38	0.5	16
Nitrogen Oxides	4	18	48
Organic Compounds	0.55	0.4	2.5
Carbon Monoxide	0.9	2.6	5.9
Fluorides	0.019–0.038	0.01	0.1
HCL	0.09–0.18	—	—

SEG has obtained a temporary operating APC permit for these proposed emissions and they are judged to have an insignificant impact on air quality.

5.1.3 Postulated Accidents

Besides the radiological impact of routine operation, SEG has considered the potential radiological impact of two major, but unlikely, accidents. SEG states that the same dispersion characteristics are applicable for accident conditions and normal operations. The postulated accidents are:

- failure of the heat removal system resulting in thermal destruction of the flue gas filtration system and subsequent release of unfiltered radioactive ash to the environment.

- pressure excursion in the incinerator resulting in rupture of the pressure release diaphragm, release of ash to the incinerator building, and partial ash release to the environment.

Both of these unlikely accidents were evaluated for radiological impact on the environment by determining the approximate radioactivity release to the environment and determining the resulting dose by comparison to previous AIRDOS-EPA runs.

FAILURE OF THE HEAT REMOVAL SYSTEM - If feed water to the heat removal system were to fail catastrophically and the incinerator could not be cooled to less than 400 degrees Fahrenheit before baghouse and HEPA filter destruction occurred, the radioactive ash inventory (up to about 5 kg) trapped on the filters would be released. Within 4 minutes the emergency cool-down system would cool the incinerator to less than 400 degrees Fahrenheit and the redundant filtration system would be switched in. The "redundant filtration system" refers to the second bank of parallel HEPA filters located between the baghouse and the wet scrubber. These two banks of HEPA filters are provided to facilitate filter change and to provide backup HEPA filtration in case of abnormal operating conditions. The HEPA filters are selected by operating dampers in the off-gas ducting system. Even if the redundant filters could not be used, the system ventilation could be stopped at about 400 degrees Fahrenheit and further releases would cease. Besides the radionuclide inventory trapped on the bag filters and HEPA filters, a much smaller quantity of additional unfiltered radioactivity in flue gases would also be released. Five kilograms of ash have about the same radionuclide content as one year of routine releases except that the iodines, technetium, carbon, and tritium would not be present in the ash, having been already released routinely. This accidental release would result in a site boundary (100 meter) whole body dose of less than 0.1 mrem and a thyroid dose of less than 0.3 mrem. Thus it is clear that such an accident would have an insignificant radiological impact on the environment and people.

<u>PRESSURE EXCURSION IN THE INCINERATOR</u> – If a transient overpressure condition occurred such that the pressure release door near the top of the incinerator gave way, a small amount of ash would be blown into the incinerator building. SEG estimates that a pressure excursion would release a few

kilograms from the incinerator into the incinerator building. The released material would include ash and combustion gases. The building ventilation system would release the vented gases in a normal manner and trap any airborne contamination on the system's filters. Most of the solid materials released during a pressure excursion would remain in the incinerator building and would be cleaned up after the incinerator cooled off. SEG states that because plant ventilation is HEPA filtered, minimal release to the environment would occur. It should be noted that significant overpressures can only be caused by explosive materials such as large oxygen bottles. The SEG sorting process described in Section 3.6 should essentially eliminate this possibility.

The pressure relief door operates only in accidental over-pressure transient situations. Movement of the pressure relief door will cause an alarm to sound in the control room and in the incinerator building to alert SEG staff to the possibility of airborne contamination in the incinerator building.

Assuming the worst possible accident where the baghouse and HEPA filter materials are destroyed and approximately 5 Kilograms of material on those filters were released to the atmosphere, an additional 0.006 Ci would be released. This would result in less than a 3 percent increase in the yearly dose at the fence line (100 meters).

Conclusion

Thus, operation of the incinerator with the described mitigative measures will not have a significant impact on air quality.

5.2 Water Quality

All solid waste will be shipped and stored in tightly closed metal containers. Ash generated by the incinerator will fall into metal hoppers which will be covered and taken by fork lift to the process building to be compacted or solidified and shipped in tightly closed metal containers in accordance with SEG's Radiological Material License (RML). All waste oil shipped to and stored outside at SEG will be in at least double containment systems and all shipments will be checked at the gate for surface contamination prior to acceptance by SEG. The waste oil will remain in double containment until it is inside the process building which is on a concrete pad and is diked to prevent runoff of the oil outside the building. After the waste oil is mixed with kerosene to prepare it for burning it will be pumped to a storage tank and then to the incinerator building in double containment type piping. In the incinerator building, the waste oil will remain in double containment piping until burned. In addition, the storage tank will provide double containment protection. These measures should prevent any surface runoff contamination from rainfall or oil spills. There are no floor drains in the process building or the proposed incinerator building and any spills will be contained, cleaned up, and decontaminated in place with absorbents and power vacuum cleaners. In addition, SEG is required by EPA regulations to develop an SPCC plan and maintain the plan onsite so it can be used in an actual spill situation. Oil sludges and filters (from the oil cleaning process), used baghouse filters, HEPA filters and liquid effluent generated by the wet scrubber system (discussed in Section 3.17), absorbent pads, etc., will be treated as radioactive waste in accordance with the RML (liquids will be solidified, solids compacted, and both shipped in approved containers to an approved storage or disposal site). There is no other liquid effluent from the incineration process, and the calculations discussed in Section 5.1 and 5.2 show that there are no significant airborne emissions to drift into water bodies. Therefore, there will be no significant impacts on water quality.

5.3 Aquatic Resources

As indicated in Section 5.2, there will be no uncontrolled liquid waste streams so there is expected to be no impact on aquatic resources.

5.4 Solid and Hazardous Waste

According to the information provided by SEG, there will be no nonradioactive solid wastes or hazardous wastes generated by the incineration process. SEG will not accept waste from clients if it contains any listed or characteristic hazardous waste, as defined by applicable environmental regulations (see Section 3.4). In addition, SEG's sorting operation described in Section 3.6 should insure that correct types of waste are incinerated. As noted in Section 3.14, the radioactive contaminated ash filters, etc., from the incineration process will be disposed of with other compacted radioactive wastes in accordance with the RML. Effluents from the wet scrubber will be analyzed for radionuclide concentrations. The effluent will be dried or solidified, packaged, and transported to an approved commercial disposal site in accordance with SEG's RML.

SEG's criteria for accepting waste oil include certification by the supplier or by SEG's analysis that the waste oil is not a hazardous waste (Attachment H). Primary containment systems used to transport the waste oil will not be recycled. Used, empty containers (usually barrels) will be rinsed out with kerosene (which will be used in the oil burning process) and then compacted and disposed of as radioactive waste in accordance with the RML.

Therefore, there will be no uncontrolled solid or hazardous waste streams and adverse environmental effects from solid and hazardous wastes will not be significant.

5.5 Socioeconomic

5.5.1 Transportation

Any impacts from transportation of waste are expected to be insignificant due to regulatory control, the low level of radioactivity, and the nature of the containers used to move the waste and waste oil. Regulations promulgated by the U.S. Department of Transportation must be complied with in any movements. Shipments should also be manifested and placarded for identification.

Responsibility for transportation of waste to SEG may take several forms: the client may take responsibility for shipping to SEG; SEG may arrange with a common carrier or contract carrier for shipment; or SEG may pick up the material in an SEG vehicle. Although shipping will usually be by truck, SEG may use any legal, proper conveyance such as rail or water transport. Tanker trucks will not be used. (There are no rail or barge facilities at the site, so waste shipments would have to be transferred to trucks at other locations and would still arrive at SEG by truck.) Truck transportation is not expected to increase as a result of incinerator operation at SEG. Radioactive oil may be imported for burning from other countries. Import will be in compliance with 10 C.F.R. 110, International Atomic Energy Agency (IAEA), and applicable Tennessee regulations.

5.5.2 Social

This proposed action is not expected to result in any significant social changes in the area. The area of the proposed incinerator is one of many nuclear or energy related industries. The Clinch River Industrial Park was developed for nuclear related industries. Other nearby emission sources include the DOE K-25 plant with an operational Toxic Substances Control Act incinerator, the DOE Oak Ridge National Laboratory, the DOE Y-12 plant, and TVA's Bull Run and Kingston Steam Plants. IT has proposed a nonradiological incinerator for hazardous wastes on neighboring property, but construction has not begun. Public review of IT's proposal has been favorable. In general, the Oak Ridge community appears receptive to nuclear related industries. The increase in the number of jobs resulting from SEG's proposal or IT's proposal should not cumulatively have significant impacts on the public services or the transportation infrastructure in the area.

5.5.3 Economic

SEG estimated that the incineration process will increase SEG employment by 15 additional people; also, it is expected to further secure the present 140 jobs due to the wider range of services that SEG can offer to its clients. It is expected that this environmentally acceptable method of incinerating low-level radioactive waste would add to SEG's future growth potential.

5.5.4 Land Use

Because the incineration process will be conducted in an industrial park specifically designated for nuclear industries in an area of several other nuclear industries and because no significant environmentally adverse effects are expected, the incineration process should not have a significant effect on land use in the area.

5.5.5 Aesthetics

The incinerator proposed by SEG will result in some site clearing and grading work along with the construction of a 13,000-square foot metal building, a 40-foot and a 98-foot stack.

All construction will occur on Tract No. XWBR-688IE, previously approved by TVA for industrial development. SEG has stated that a band of trees 25 to 100 feet wide will remain to shield the incinerator facility from Bear Creek Road and no construction will occur in the habitat protection area extending 15 meters from the north shoreline of Grassy Creek. Due to the extensive filtration on flue gases, and reheat of the saturated scrubber exhaust the plume should not be visible under most atmospheric conditions. Due to the site's location, the facility should not be visible from Watts Bar Reservoir. Thus, there will be no significant effect on aesthetic values in the area.

5.6 Vegetation

The incinerator construction as proposed herein will involve the destruction of some existing vegetation within the site which has been previously approved by TVA for industrial development. However, no actions are proposed which would endanger the habitat protection area extending 15 meters from the north shoreline of Grassy Creek. In addition, because only minimal or insignificant emissions are expected from the incineration process and because there will be no other uncontrolled waste streams which would otherwise harm vegetation, there should be no adverse effect on vegetation due to incinerator operation. The loss of vegetation due to construction is not considered significant and is acceptable to encourage industrial development of this tract.

5.7 Wildlife and Threatened or Endangered Species

The incinerator construction as proposed herein will not harm wildlife in the area. TVA staff has inspected the site and no significant wildlife or threatened or endangered species were found on the site. Also, no potential habitat for these species was found. In addition, no actions are proposed which would endanger the adjacent habitat protection area extending 15 meters from the north shoreline of Grassy Creek. Furthermore, because only minimal or insignificant emissions are expected from the incineration process and because there will be no other uncontrolled waste streams which would otherwise harm wildlife, there will be no adverse effects on wildlife, threatened or endangered species or critical habitats.

5.8 Floodplains and Wetlands

The incinerator building will be constructed between the existing process building and Bear Creek Road and has a slab elevation of 784.2, which is located well outside the limits of the 500-year floodplain. There are no wetlands on the site. As the incineration process will generate no uncontrolled waste streams and produce minimal or insignificant emissions during operation, no wetlands should be affected. Accordingly, the proposed action is consistent with the policies and concepts of Executive Order Nos. 11988 (Floodplain Management) and 11990 (Protection of Wetlands).

5.9 Cultural Resources

Tract No. XWBR-688IE has been previously cleared for industrial development by the Cultural Resources Program. Therefore, there will be no adverse effect on cultural resources.

5.10 Prime Farmland

The proposed incineration process is on a site already designated by the city of Oak Ridge for industrial development and no additional lands other than these will be disturbed by installation and operation of the incineration process.

Therefore, use of this land for the incinerator is categorically excluded from review of its impact on prime farmland.

6.0 Safety Measures

6.1 Traffic Accident and Spill Prevention

The small amount of additional traffic because of increased capacity to handle waste at SEG due to the incinerator will not pose a significant accident risk. In addition, there are no proposed changes to SEG requirements and procedures for waste handling or method of shipment. All liquids will be shipped in impact resistant containers which provide double containment, and a spill from the containers would be unlikely even if there is an accident to the truck. (The State route 95 and 58 bridges over the Clinch River are in straight sections so overturning of a truck on the bridge with spilling of the drums into the river is very unlikely.) SEG's oil burning procedures will be only minimally revised to apply to incineration and contain numerous provisions for preventing accidental spills from drums, pipes, or tanks.

6.2 Fire and Storm Damage Prevention

As noted in Section 3.1, waste will be stored in sealed containers on the asphalt parking area adjacent to the process building. SEG's proposed incinerator building facility will be tied into the existing fire detection and protection system with automatic notification of the Oak Ridge Fire Department. Also, the proposed incinerator building will be equipped with a dry sprinkler system and portable fire extinguishers. These measures should effectively minimize fire risks. Storms are unlikely to damage the securely packed waste containers stored onsite, and any spills inside the process and storage buildings will be contained by the dikes around them.

7.0 Summary

7.1 Unavoidable Adverse Impacts of the Proposed Action

There will be some minimal environmental effects on air quality due to the incineration process and some small increased risk in the increased transportation and handling potential of the low-level radioactive waste. In addition, some vegetation will be destroyed during construction. However, in each case these impacts and risks are acceptable, minor and have been minimized, and safeguards are employed to minimize them further.

7.2 Probable Environmental Tradeoffs

The small increased risk from the incineration process reduces increased risk of spills and groundwater contamination due to storage at the waste generator sites. Also, the existence of a legally approved disposal method for low-level radioactive waste may encourage compliance, particularly among the small waste generators.

7.3 Irreversible Commitment of Resources

The only irreversible commitment of resources are the burning of the waste itself, burning of propane in the auxiliary burners, the disposal of HEPA filters, and the destruction of some vegetation. However, the waste must be disposed of in any case, so the burning actually recovers some of the resource value of the waste in the form of the heat which will be used to supplement heating of the building. The HEPA filters would have to be discarded anyway once they are used in the building's existing ventilation system. The loss of some vegetation resulting from construction activities and the use of propane as a fuel for the auxiliary burners is an acceptable loss offset by the economic development created by the incinerator. In addition, the incineration process results in a large volume reduction of waste which will significantly reduce loss of land due to disposal of the resulting ash compared to the present waste disposal methods used at SEG.

8.0 Environmental Commitments

To further minimize the potential for adverse environmental impacts, TVA shall condition its approval of SEG's request upon the following commitments:

1. SEG acknowledges and accepts the same terms and conditions with regard to this proposed facility as are contained in the TVA grants of easement dated December 12, 1973, and November 6, 1985, to the city of Oak Ridge, Tennessee, authorizing use of

Tract No. XWBR-688IE, Parcel No. 1 and Parcel No. 2, respectively.

2. It is understood that SEG has obtained all other required authorizations, approvals, licenses, and permits and that the air pollution control equipment described in the information provided by SEG will be properly maintained and operated at all times during operation of the facility.

3. The charge rate for the facility shall not exceed 1,600 pounds per hour capacity. In addition, the facility shall not burn more than 30 gallons per hour of acceptable waste oil and other acceptable flammable liquids.

4. SEG shall refuse receipt of any oils or other liquids contaminated with listed hazardous wastes or which have hazardous waste characteristics such that the oils or liquids would be regulated as hazardous wastes under applicable laws. SEG shall also refuse receipt of any oils or liquids containing polychlorinated biphenyls (PCBs) at levels of 2 ppm or greater. To implement this condition, SEG shall require users of this service to certify that the user's oils or liquids conform to these limitations and SEG shall modify its oil acceptance criteria accordingly.

5. SEG shall notify TVA immediately of any changes in its license or permit status pertaining to operations at the CVRF. In addition, SEG shall immediately notify TVA of any oral or written communication from any Federal, State, or local

authority indicating that SEG is or may be in violation of any pertinent radioactive- or environmental-related statute, regulation, or ordinance in connection with operations at the CVRF.

6. The existing auxiliary waste oil burners previously approved in TVA's September 19 letter to you shall be dismantled and disposed of in accordance with SEG's radioactive material license prior to commercial operation of the incinerator.

7. All oil or other liquids are to be shipped directly to SEG from the generator and there shall be no loading, unloading, or shifting of cargo or container systems en route. In addition, all oil or liquids will be shipped in sealed container systems providing at least double containment and these containers will also be used for storage at SEG's CVRF. The containers shall not be opened until they have been placed within the diked area of the process or storage buildings. The use of tanker trucks is specifically excluded from this approval.

8. All filters shall be changed periodically at intervals required to maintain optimum performance.

9. Use of the ash vitrification system under consideration as a component of the facility is not approved at this time; if use of this system is eventually proposed, SEG shall submit additional information and plans for the system to TVA for approval.

10. SEG shall maintain a 25-foot wide minimum band of trees, shrubs, and lesser vegetation along Bear Creek Road to shield the facility from view.

11. This approval may be revoked by TVA if the facility has not been constructed or operated in accordance with the conditions and understandings herein. Upon receipt of written notice of revocation from TVA, SEG shall cease operating the facility. When the condition(s) causing nonconformance is satisfactorily corrected, SEG may request TVA approval to resume operation.

These conditions will further diminish any possibility of significant adverse environmental impacts and will enhance the effectiveness of the conditions contained in the underlying grants of easement—including those requiring SEG to comply with all applicable pollution control requirements and standards.

9.0 Conclusion

Based on the information provided by SEG and TVA staff's independent reviews and analyses, the incineration process should have no significant impact on the quality of the environment. All unavoidable environmental impacts appear to be minor and have been minimized.

1/31/89

0030H

ENVIRONMENTAL ASSESSMENT

FOR

LOW-LEVEL RADWASTE MANAGEMENT

WATTS BAR NUCLEAR PLANT

JULY 11, 1980

Table of Contents

I. INTRODUCTION

The Tennessee Valley Authority's (TVA) responsibilities under the TVA Act of 1933, 48 Stat. 58, as amended, 16 U.S.C. §§ 831-831dd (1976), include assuring an ample supply of electrical energy at the lowest feasible cost to the area it serves. In meeting this objective, TVA routinely seeks to implement design changes which will improve the safety, availability, and reliability of its operating plants in a manner consistent with this Nation's policy to protect and enhance the natural environment. The proposed action will aid TVA in meeting these objectives.

It is the purpose of this Environmental Assessment (EA) to consider the potential environmental impacts of the low-level radwaste (LLRW) management plans for Watts Bar Nuclear Plant (WBNP). TVA's proposed LLRW management plan is twofold. It consists of (1) installing equipment designed for volume reduction and solidification of LLRW, and (2) constructing facilities designed to safely store the LLRW generated at WBNP for the operational life of the plant. Although each segment of the LLRW management plan could be implemented independently, each is an integral part of the proposal for WBNP and will be considered together as a single action for the purposes of this document.

This EA considers the potential environmental effects of TVA's LLRW management plan for WBNP.

II. NEED

Watts Bar Nuclear Plant is located in Rhea County, Tennessee on the west shore of Chickamauga Lake approximately 8 miles south of Spring City and consists of two 1220-megawatt (electric) pressurized water reactor

(PWR) units. The need for power generation at this facility has previously been addressed in the Final Environmental Impact Statement for WBNP. Routine operation and maintenance of the plant results in the generation of low-level radwaste (LLRW). LLRW consists of a variety of slightly contaminated miscellaneous solids such as paper, rags, protective clothing, plastic bags, gloves, wood, etc., (all such waste will be referred to herein as "trash") as well as radioactive processing wastes such as evaporator concentrates, condensate demineralizer resin rinses (spent regenerants), spent filter cartridges, and spent ion exchange resins. It is estimated that WBNP will generate the following amount of LLRW per year.

Spent Resin	600 cubic feet (dewatered) or 1200 cubic feet (solidified)
Trash	compacted-12,000 cubic feet (210 tons/yr)
	noncompacted-11,650 cubic feet (less than 180 tons/yr)
Evaporator Concentrates	7,000 cubic feet (solidified)
Spent Regenerants	25,000 cubic feet (solidified)
Spent Filter Cartridges	350 cubic feet

Throughout the design phase of WBNP, TVA had planned to package and ship all of the LLRW generated at WBNP to Chem-Nuclear Systems, Inc.'s, commercial radioactive waste burial site in Barnwell, South Carolina. In the past few months, however, significant restrictions have been placed on the amount of packaged LLRW that Barnwell will accept for burial. Chem-Nuclear, Inc., has announced severe volume restrictions, and it now appears that commercial acceptable burial space will become exceedingly scarce and expensive within the next 10 years. In addition, because the announced burial restrictions will be applied on a per utility basis (as opposed to a per plant basis), LLRW generated at WBNP can only be disposed of at Barnwell within TVA system-wide LLRW volume restrictions (i.e., at the expense of LLRW generated at BFNP and SQNP not being disposed of at Barnwell). TVA's LLRW disposal problem will become significantly more critical as TVA's nuclear plants, now under construction, are put into operation. Even without these restrictions, it is likely that additional disposal options would be needed because no other waste disposal facilities are being planned in the southeast or midwest regions of the Nation.

The need to develop alternatives to disposing of LLRW at Chem-Nuclear's Barnwell facility is immediate and represents a potentially serious impact to the operation of WBNP. The intent of the proposed action discussed in this EA is to assure that the unavailability of commercial burial space will not delay startup schedules or restrict future electric power generation at WBNP. The proposed action is consistent with this Nation's policy of attaining energy independence and could potentially reduce future dependence on insecure and increasingly expensive sources of foreign oil. Implementation of the proposed action will make TVA's operations at WBNP essentially immune from outside restrictions on disposal of LLRW for the foreseeable future.

The proposed action consists of design changes/plant additions to handle LLRW on a long-term basis.

III. DESCRIPTION OF THE PROPOSED ACTION

In view of commercial LLRW disposal limitations and other TVA system-wide LLRW management considerations, TVA will package and ship as much LLRW from WBNP to Barnwell as possible. It is likely that only a small amount of LLRW will be shipped from WBNP to Barnwell, and it is quite possible that no LLRW at all will be shipped. Present plans are to store the "as-produced" LLRW ("as-produced" LLRW refers to radioactive waste that is not volume reduced, but is packaged in a form suitable for disposal) in the onsite storage facilities. However, the waste packaging area of WBNP is available if needed for temporary storage of six to nine month's production of LLRW of one unit at full power. The waste packaging area is adjacent to the east end of the auxiliary building and was designed to safely store (i.e., within limits set by 10 CFR 20) packaged radwaste accumulated between shipments to a commercial burial facility.

A. Construction of a Long-Term Onsite LLRW Storage Facility (OSF)

TVA has developed a conceptual design for an onsite LLRW storage facility (OSF) and has selected a suitable location within the Watts Bar (WB) reservation (see Figure 1).

Location Description

The proposed storage facility would be comprised of independent buildings (called modules) for LLRW storage. The proposed facility will be located on an approximate 15-acre site within the Watts Bar Reservation, but outside of the existing WBNP security fence approximately 1200 feet north of the reactor buildings. The area is generally rolling terrain. The grade elevation of the facility would be at approximately 730 feet,

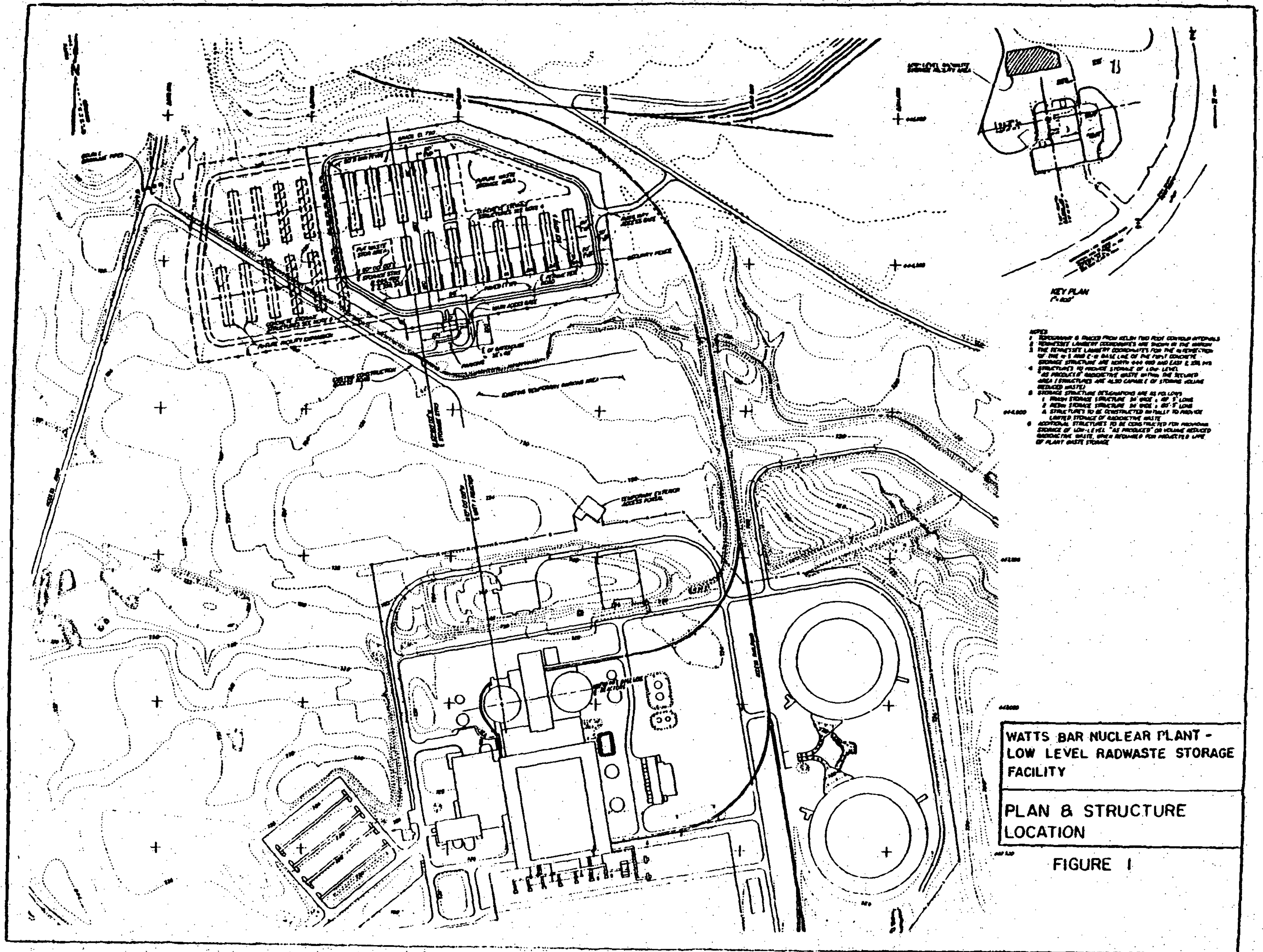
KEY PLAN
WATTS BAR NUCLEAR PLANT - LOW LEVEL RADWASTE STORAGE FACILITY
PLAN & STRUCTURE LOCATION

FIGURE 1

which is well above the regulatory TVA structure profile elevation of 708 and the 500-year flood elevation in the Watts Bar reservation area (elevation 705.5).

The nearest existing structure to the storage facility is the WBNP diesel generator building, which is approximately 800 feet from the nearest point of the OSF security fence.

Conceptual Design Description

Facility Description

Packaged LLRW will be stored in above-ground concrete buildings called modules. The modules will be sized such that three modules will be able to store the estimated annual output of "as-produced" LLRW. The modules will be designed to store "as-produced" LLRW or "volume-reduced" LLRW. The total number of modules planned for storage of packaged LLRW is 13. The modules will be compartmentalized. Access to each module will be provided only from above, and will only be used for placing LLRW in or removing LLRW from the module by crane. No LLRW will be handled during precipitation events.

The interior surfaces of each module will be sealed with decontaminable protective coating. There will be no fire detection equipment in the storage modules; the LLRW will be stored in a form that does not constitute a fire hazard; however, it can be incinerated under controlled conditions. In addition, TVA has performed an analysis that establishes that spontaneous combustion potential of packaged trash is not a fire protection concern.

The storage structures in the OSF will be designed to store the LLRW in such a way that the waste is completely retrievable.

Enough modules will be constructed to store the "as-produced" LLRW until a volume reduction and solidification system can be installed, tested, and operated. Additional modules will be constructed as necessary to store the volume-reduced LLRW for the operational life of the plant.

Structural Requirements

All structures containing LLRW will be constructed of reinforced concrete. In addition to normal operating loads, the OSF structure will be designed to resist loads resulting from extreme environmental events such as high winds, tornadoes, rainfall, and seismic events. The structural characteristics of the OSF will meet or exceed the criteria applicable to the WBNP site.

Shielding Requirements

The OSF will be designed to provide sufficient access controls and shielding to ensure that radiation is at or below acceptable levels during all phases of operation. Occupational exposure to all construction personnel and to all personnel performing the low-level radioactive waste storage operations will be kept as low as reasonably achievable (ALARA). Except during waste handling operations, the dose equivalent at any accessible point outside the storage facility security fence will not exceed an average of 2.0 mrem/hour according to 10 CFR 20. During waste handling operations, dose rates at the security fence may temporarily exceed this value, but will be minimized. In any case, administrative measures will be taken to control occupancy such that no person outside of the security fence can receive a significant fraction of his allowable annual dose.

Fire Protection

No permanently installed fire suppression system will be provided inside the OSF structures. A yard fire main, hydrants, and hydrant houses will be provided to afford manual firefighting capability for the entire OSF. All fires in the LLRW storage facilities will be fought by the WBNP fire brigade. The OSF structures will be designed to contain (within each module) all fire suppression water from a design basis fire in a way that will not preclude processing of the water (if determined to be radioactive) using the existing WBNP liquid radioactive waste treatment system. Nonradioactive water will be treated and discharged to the yard holding pond. Proper respiratory protection will be provided. Fire detection capability requirements will be satisfied by the security measures described below.

Security Requirements

The entire OSF will be enclosed with an 8-foot high chain link fence which includes three feet of barbed wire inclined away from the facility. The security fence for the OSF will be provided with an intrusion detection device with tamper indication which alarms in the continuously manned OSF gatehouse. The OSF will be provided with closed circuit television monitoring capabilities and will be continuously lighted at night. Access to the OSF will be controlled through the OSF gatehouse.

B. Installation of a Volume Reduction and Solidification System (VRS)

TVA proposes to install a VRS for WBNP. The VRS will be housed in a new structure now planned to be located within the existing Watts Bar reservation boundaries. The exact location of the VRS has not yet been finalized, but its preliminary location is adjacent to the condensate demineralizer waste evaporator building between the existing access road and railroad track. The structure will be designed in accordance with NRC Regulatory Guide 1.143. The building size now under consideration is approximately 140 feet long and 80 feet wide. Construction of the VRS building will be accomplished in such a way as to not adversely impact the safety and/or reliability of WBNP.

The VRS will be installed to markedly expand the storage capabilities of the OSF by significantly reducing the volume of the "as-produced" waste to be stored. In addition, the VRS will solidify the LLRW in such a way as to provide a stable dry form for storage or shipment offsite for disposal. The solidification process will not preclude the reprocessing of the solidified, volume-reduced waste for any foreseeable ultimate disposal methods for LLRW.

The VRS will be designed to calcine evaporator concentrates and spent regenerants and incinerate resins and combustible trash. Incineration of combustible trash (approximately 75 percent of the trash expected to be generated at WBNP is combustible) results in volume reduction by a factor of approximately 100. Incineration of spent resins to be produced at WBNP (bead type) results in a volume reduction factor of at least 5, although that factor may be significantly higher depending on the type of system eventually purchased for WBNP. For any VRS under consideration for WBNP, an overall volume reduction factor of 10 will be realized. This takes no credit for volume reduction of noncombustible trash and allows for the additional volume of the solidification agent that would be mixed with the calcined or incinerated LLRW. This will significantly extend the expected useful life of the OSF (the OSF will be designed to store "as-produced" and/or volume-reduced LLRW) such that it could safely store all of the volume-reduced LLRW generated for the expected remaining life of WBNP.

The incineration process generates radioactive ash, nonradioactive combustion gases, and depending on other factors (depleted filters, etc.) some trace radioactive gaseous products. All waste gas from the incineration process will be treated for chemical impurities (with scrub solutions, quench tanks, demisters, etc.) and for radioactivity (with charcoal or silver zeolite absorbers and HEPA filters) before discharge.

Volume reduction and solidification systems are an emerging technology. The design of the VRS will be based on very conservative assumptions concerning amount and radioactivity of the LLRW. The VRS will be capable of processing the expected annual quantities of WBNP LLRW in no more than 365 hours per month but is designed to run continuously. This allows significant operator flexibility and adequate backup capacity.

Fire Protection - Volume Reduction Building (VRB)

Fire suppression equipment will be provided to afford manual fire fighting capability for the entire VRB. All fires in the VRB will be fought by the WBNP fire brigade. Proper respiratory equipment will be provided.

IV. ALTERNATIVE TO THE PROPOSED ACTION

A. No Action

If no action is taken to provide storage of LLRW generated at WBNP, TVA's ability to operate WBNP will be severely hampered. In addition, operating costs will increase substantially.

The availability of commercial burial space in the future is at best uncertain. Accordingly, if no action is taken, the operation of WBNP would be contingent upon the availability of commercial burial space. There is also a potential that WBNP's startup schedule could be adversely impacted by the unavailability of commercial burial space.

At the present time, the current public concerns regarding nuclear waste disposal makes it unlikely that new LLRW disposal facilities will be commissioned by private or governmental groups soon enough to prevent any significant impact on WBNP's generating capacity. Furthermore, if no action is taken at this time, TVA would have to consider limiting or ceasing operation of WBNP very soon after plant startup. Furthermore, halting of power generation at WBNP would still continue to generate small amounts of LLRW due to plant shutdown and decommissioning activities.

Delaying taking any action at this time would offer TVA no advantages in resolving the present and future LLRW storage needs at WBNP; it would only make the situation that much more difficult when action is mandatory. There are no foreseeable occurrences which would help alleviate the situation in the short term that could justify TVA's waiting before taking any action. Therefore, delaying action would have the same effect as no action. TVA's assessment indicates that not taking action or delaying action could severely curtail future electric power generating capability at WBNP during a period in which use of domestic energy sources must be maximized. Jeopardization of the operation at WBNP must be avoided because of the need for power. Therefore, neither the no action nor delayed action alternative is acceptable.

B. Alternative Designs

The VRS to be installed at WBNP will be one that is now commercially available. The volume reduction building will be sized to accommodate any of the commercially available volume reduction/solidification systems. No significantly improved designs could be formulated, developed, and manufactured in a time frame that can support TVA's needs. An alternative VRS design that cannot meet TVA's schedule requirements is therefore an unacceptable alternative. The particular VRS for use at WBNP has not been selected. The VRS parameters used for impact evaluation are conservative and are used to envelope the impacts of this system. The impacts of the system ultimately selected will be no greater than those described.

C. Offsite LLRW Storage

1. Constructing a LLRW Storage Facility at a Location Other Than WBNP

This alternative could use the conceptual design developed by TVA (described above), but the facility would be located at a site other than the Watts Bar reservation. This alternative would require varying amounts of transportation of LLRW from WBNP, and although the radiological impacts of transportation effects is small,[1] the public perception of transporting nuclear waste on public roadways is negative. This alternative would involve significant licensing concerns and could involve significant landuse impacts at other sites. Finally, there is no need to construct a LLRW storage facility at a location other than at WBNP since there are no significant land-use conflicts at the WBNP site, nor would costs be expected to be decreased by this alternative.

2. Constructing a Centralized TVA Volume Reduction and Long-Term Storage Facility

This alternative would receive "as-produced" LLRW from TVA's WBNP and other nuclear plants. Presumably, it would be located at a centralized place within the TVA service region. This alternative has an advantage in that although it would involve a significant siting, design, and construction effort, and incur a large cost, it would ensure that all of TVA's nuclear plants would not be subject to external restrictions on commercial burial space.

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1. NUREG D404 - DGEIS Handling and Storage of Spent Light Water Power Reactor Fuel, March 1978.

This alternative could not be implemented in a time frame which would be compatible with TVA's needs at WBNP or its other operating nuclear plants. Also, this alternative could potentially involve significant licensing concerns and would involve the potential for greater transportation related impacts.

This alternative is unacceptable as an alternative to the proposed action at WBNP. Implementation of the proposed action, however, does not preclude the alternative of constructing a centralized TVA volume reduction and storage facility.

3. Use of Other Existing TVA Structures as Temporary Storage

An alternative to constructing an OSF would be to use an existing structure for temporary storage until the availability of commercial burial space improves. The advantage of this is significant cost savings (approximately $25 million) would result if the OSF did not have to be constructed. Candidates for such storage space could be other TVA nuclear plant sites, especially Phipps Bend Nuclear Plant near Rogersville, Tennessee (approximately 130 miles northeast of WBNP), and Bellefonte Nuclear Plant near Scottsboro, Alabama (approximately 90 miles southwest of WBNP).

Adequate storage space could not be arranged in this manner without seriously impacting the construction/operation of the "host" nuclear facility. It appears that this would be unacceptable from licensing (indications are that the NRC would disallow such a plan), health and safety (increased dose levels on the "host" site to construction and/or operating personnel), and construction (it is unacceptable to delay construction of the "host" nuclear plant for the purposes of temporary storage because of the concomitant delay in additional electric generating capacity that will be needed in this region in the future) standpoints.

This alternative would also involve increased potential for transportation related impacts.

4. <u>Use of an OSF at Another TVA Plant</u>

The LLRW from WBNP could be shipped to another OSF which has been proposed to be built at the Sequoyah Nuclear Plant (SQNP). This would require the maximum amount of LLRW storage at SQNP to be built and LLRW generated at WBNP would be routinely transported to the OSF at SQNP. This would delay the construction of the OSF at WBNP long enough so that it may be unnecessary, assuming that sometime in the future other LLRW disposal sites are built by other sectors. Implementation of the alternative would save approximately $25 million. Delaying construction time of the OSF at WBNP and transporting the LLRW to SQNP would also allow better planning for future LLRW management.

This alternative would involve extensive transportation resulting in the same problems as mentioned in the offsite centralized storage alternative.

It would put an additional burden on the LLRW handling operations at SQNP and might increase the personnel exposure levels at SQNP.

5. <u>Offsite Centralized Disposal</u>

This facility could be patterned after existing low-level radioactive waste disposal facilities such as the Barnwell facility. One facility would be opened to dispose of the low-level radioactive waste from all TVA nuclear plants. The facility would cover about 300 acres of which about 50 acres would be used for the actual disposal operations. The alternative involves extensive transportation resulting in the same problems as mentioned in the offsite centralized storage alternative. Disposal facility operators have attempted to open new disposal facilities in the recent past, but were unsuccessful due to regulatory problems and public opposition. There is currently only minimal guidance from the NRC in the form of draft regulations. The time necessary to evaluate, license, and construct a new disposal facility is optimistically estimated at about six years. Uncertainties associated with this process and the time needed to have the facility available preclude selection of the offsite centralized disposal option. This proposal does not preclude utilization of this option at a later time.

V. ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTION

A. Construction Related Impacts

Construction impacts associated with this project include fugitive dust, gaseous emissions, siltation, noise, socioeconomic, and potential impact on existing structures at WBNP. Construction of the first OSF modules is expected to commence in mid July of 1980. Present planning schedules indicate that the first LLRW storage module will be available by June 1981, with the remaining modules to be completed by December 1982. As presently conceived, construction of the volume reduction building will commence in late 1981 and require approximately 36 months to complete.

Air Quality

The construction activities associated with the new VRS building and radwaste storage facilities will result in some temporary degradation of local air quality. Air pollutants generated from this activity will primarily include (1) fugitive particulate emissions from various activities, including the cleaning of steel and concrete, drilling, painting, and mixing concrete (in a batch plant); (2) fugitive dust from earth excavation and grading; (3) particulate emissions from the open burning of small amounts of wood scraps; and (4) small amounts of particulate, hydrocarbon (HC), nitrogen oxide (NO_x) and carbon monoxide (CO) emissions from fossil-fueled construction and construction employee vehicles.

The construction site mitigation program will consist of fugitive dust suppression, by methods such as water sprinkling, which will substantially reduce fugitive dust. Open burning will be conducted in accordance with all applicable Federal, State, and local regulatory requirements; in addition, no open burning will be conducted during an air stagnation advisory or special dispersion statement issued by the National Weather Service.

Concrete production during construction of the OSF and the VRS will be approximately 50 yds^3 per hour from the existing onsite concrete batch plant. Emissions from the concrete batch plant will be controlled through the use of bag house filters.

Land-Use Impacts

The construction and operation of the OSF as currently conceived will require approximately 15 acres of land, all within the Watts Bar reservation boundary. The proposed action involves no offsite land-use conflicts. The proposed action is compatible with future land-use plans within the Watts Bar reservation for the nuclear plant and its support facilities.

Siltation

During construction of this facility, construction runoff will be drained in a manner that will prevent erosion and minimize the amount of sediment reaching local bodies of water. Control of construction runoff will be in accordance with the practices developed by the Environmental Protection Agency (EPA) pursuant to the Clean Water Act (Guidelines for Erosion and Sediment Control Planning and Implementation, EPA Environmental Protection Technological Series--EPA-R2-72-015, August 1972). Applicable requirements designed to prevent pollution from this construction activity will be met. The NPDES permit for WBNP will be modified, and other actions will be taken as necessary to cover the construction related runoff from the proposed action. With these precautions, construction activities are not expected to have a significant impact on water quality or aquatic communities.

Noise

The usual sources of noise associated with construction activity will be present. However, these impacts are expected to be minor and limited to the site area.

Sanitary Waste

Sanitary wastes generated during construction will be handled in accordance with applicable Federal, State, and local regulations. During the construction period, portable chemical toilets will be provided for use by construction personnel.

Solid Waste

There will be a small amount of solid waste generated due to the construction of the OSF and VRS. Solid wastes generated during construction will be handled in accordance with applicable Federal, state, and local regulations.

Cultural

A cultural resource survey has been conducted and no resources were encountered that are either on or eligible for the National Register. A survey report is currently being written and will be coordinated with the State Historic Preservation Officer.

Endangered or Threatened Species

No known population of endangered, threatened, or otherwise sensitive species will be impacted by the development of the proposed project.

Floodplains/Wetlands

The site for the proposed action is not located in a floodplain nor is it expected to directly or indirectly support or encourage floodplain development. There are no wetlands which will be affected by the project. Therefore, the proposed action is in compliance with TVA policies on floodplain management and wetland protection.

Socioeconomic

The proposed action will require a significant construction effort in view of the urgency of the situation, if the OSF and volume reduction building (VRB) were to be constructed independently (approximately 400-500 construction people would be required). However, two factors will reduce the work force requirements. First, the construction schedules of the two structures will overlap somewhat, and available manpower could be transferred from one construction site to the other as the need arises. Secondly, there is now and will continue to be significant ongoing construction at Watts Bar, and there is manpower available in the area to fill the construction and labor skill requirements for the OSF and VRB. No significant impact to the neighboring communities' school systems, sewer systems, traffic patterns, health services, etc., are expected to result from this construction activity although there will be a small increase in the population of the area.

Effects on Work Force

Measures will be taken in constructing both the OSF and VRB to minimize the construction force's exposure to radiation from the operation of WBNP. The Radiological Emergency Plan for WBNP will be modified as necessary to provide appropriate responses of the construction force to any emergency that may arise at the nuclear plant.

B. Operation of the VRS and OSF

The VRS is sized to process the expected volumes of LLRW in 365 hours per month. It is expected that the VRS will be operated for greater periods of time due to processing accumulated LLRW in the OSF, lost time due to maintenance, operator training, etc. It is expected that the OSF will be operated (i.e., placing LLRW into storage) for 4 hours per day, 5 days a week.

Air Quality

The WBNP is located in Rhea County, Tennessee. A portion of Roane County, Tennessee, within the city of Rockwood (about 32 km north-northeast of the site), is designated nonattainment with respect to the secondary National Ambient Air Quality Standards (NAAQS) for total suspended particulates (TSP). The remaining area within 35 km of the WBNP is designated a Class II, prevention of significant deterioration (PSD) area for SO_2 and TSP. This remaining area is also in attainment with respect to the NAAQS for all EPA-regulated pollutants.

Table 1 gives quantitative information on the nonradiological regulated air pollutants that will be emitted by the VRS incinerator. The annual emission rates given in Table 1 are believed to represent the maximum potential rates for each pollutant, with emission controls on SO_2 and particulates. In addition, the Table 1 values represent the worst-case emissions (incineration with an oil-fired incinerator) for any VRS design ultimately selected for installation at the WBNP.

Based on the expected maximum annual air pollutant emission rate estimates, the VRS should have an insignificant impact on air quality and is not expected to be required to undergo PSD review. Operation of the WBNP VRS incinerator is also not expected to have a significant impact on ambient TSP concentrations in the Rockwood TSP nonattainment area.

Operation of the OSF will not produce any nonradiological air pollutants and, therefore, will not affect ambient air quality. However, there will be insignificant amounts of exhaust from vehicles transporting radwaste from the VRS to the OSF.

Water Quality

The operation of the OSF will not result in a unmonitored liquid release during normal or emergency conditions (i.e., fire). Liquids resulting from operation or fire fighting will be collected, monitored, and disposed of in accordance with established plant disposal procedures.

TABLE 1

MAXIMUM POTENTIAL INCINERATOR EMISSIONS[a]

Air Pollutant	Emission Rate (tpy)[b]
Sulfur dioxide[c]	-
Nitrogen oxides	13[d]
Particulates[e]	-
Carbon monoxide	7[f,g]
Hydrocarbons	6[g,h]

a. Assumes continuous operation at maximum capacity. Maximum charging capacity of incinerator is assumed to be 160 lb of solid waste per hour (this capacity is needed so that 350 tons of WBNP waste can be incinerated each year with the incinerator operating 365 hours per month).

b. Emission factors for particulates, CO, and HC were taken from "Compilation of Air Pollutant Emission Factors," Third Edition, Publication No. AP-42, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, May 1978.

c. Emission rate of 2.2 lbs/yr is calculated. Assumes an uncontrolled emission rate of 10 lb/hr, and a removal efficiency of 99.9975 percent (decontamination factor of 4×10^4).

d. Assumes an uncontrolled emission rate of 3 lb/hr.

e. Emission rate of 0.1 lb/yr is calculated. Assumes a particulate emission factor of 15 lb per ton of waste incinerated and a removal efficiency of 99.9975 percent (decontamination factor of 4×10^4 based on preliminary vendor information).

f. Assumes an uncontrolled CO emission factor of 20 lb. per ton of waste incinerated.

g. An incinerator having a high ambient air feed rate and thorough furnace mixing would emit substantially lower quantities of this pollutant.

h. Assumes an uncontrolled HC emission factor of 15 lb. per ton of waste incinerated.

Sanitary facilities will be provided in the OSF gatehouse, but the liquids will be treated either by piping them directly to the existing sanitary system at WBNP or by installing a small subsurface sanitary waste treatment system dedicated to the OSF. The small flows expected from the OSF sanitary facilities (normal occurancy--two people) would not impact operation of WBNP's sanitary waste treatment system. Subsurface treatment of OSF sanitary waste would not result in the discharge of a liquid effluent.

No NPDES permit or permit modification is required for operation of the OSF.

The operation of the VRS may result in small amounts of drainage, which will be collected in sumps in the VRB. These liquids will be pumped back to the existing liquid radwaste treatment facilities at WBNP. All liquids collected in the VRB sump(s) will be considered as radioactive and transferred to the existing WBNP liquid radwaste system for treatment. Addition of the VRB will not result in an additional NPDES serial discharge point. The EPA will be notified of the additional input to the liquid radwaste system and corresponding increases in the amount of liquids discharged from WBNP liquid radwaste system NPDES serial discharge point.

Noise

Noise impacts onsite or offsite from the operation of the OSF and VRS will be minimal and should not have any significant impact to the site area.

Solid Waste Management

The Resource Conservation and Recovery Act of 1976 (RCRA) specifically excludes nuclear material regulated under the Atomic Energy Act of 1954, as amended (which covers LLRW). Because the operation of the VRS or OSF will result in no significant additional amounts of solid waste to be handled, other than LLRW, the proposed action does not have solid waste management impacts associated with it. Should solid and hazardous wastes other than LLRW be generated, they would be managed in accordance with applicable EPA regulations for solid and hazardous wastes.

Radiological Impacts

An assessment of the potential radiological impacts of operating a VRS and an OSF has been performed. Site-specific data on receptor locations, meteorology, and river flow were used. For the storage of about 1450 Ci/yr of LLRW, annual doses to potential receptors due to postulated leachate spillage from the OSF are estimated to be less than 0.3 mrem/yr (liver) and doses due to direct radiation less than about 3.0 mrem/yr (whole body). The highest estimated annual dose due to the operation of the VRS is 0.7 mrem/yr to the whole body. The resultant doses considering the operation of WBNP, OSF, and VRS are well within the guidelines of 10 CFR Part 50, Appendix I, and the limits of 40 CFR Part 190. Appropriate measures will be taken for the VRS and OSF to maintain exposures to onsite personnel to levels which are as low as reasonably achievable (ALARA). Should there be a fire at the OSF involving one section of a storage module, resultant doses to a member of the public located at the proposed waste heat park facilities would be within the dose criteria given in 10 CFR Part 20.

Transportation of the LLRW from WBNP proper to the OSF does not require that the transfer truck (standard tractor-trailer rig) travel on public roads.

Transportation related radiological impacts associated with the proposed action are extremely minimal since the LLRW is in a solid form when it leaves the waste packaging area to be transported to the OSF. The worst-case accident associated with the proposed action would be a drop or rupture of a full resin liner. The incident could at worst cause a release of approximately 150 ft^3 of a radioactive slurry. Environmental impacts would be limited to a local decontamination problem and a small increase in occupational exposure to workers involved in cleanup operations. No offsite contamination could result nor would there be a release to navigable waters. Environmental impacts would be limited to a local decontamination problem and a very small increase in exposure to any bystanders.

Licensing Impacts

Implementation of the proposed action would have several minor licensing implications.

Installation of the OSF and VRS would require a technical specification change or a slight modification of the operating license for WBNP. Preliminary discussions with the NRC indicate that the requisite licensing changes can be made within TVA's schedule requirements.

Operation of the OSF and VRS should not require an NPDES permit or permit modification. However, a notification of change in the existing permit would be necessary. Construction of the facilities would not require modifications of the NPDES permit unless construction runoff discharge points are different from those identified in the current permit for WBNP. Modification and/or notification of a change in the existing NPDES permit will be made as necessary and are expected to be completed within TVA's present schedule requirements.

The WBNP is not considered a major source (annual emissions of 100 tons or more) for any air pollutant, and it is not expected to become a major source with the addition of the VRS incinerator. However, a new air quality permit will be required before construction and operation of the VRS. The permit application will be submitted directly to the Tennessee Division of Air Pollution Control. Permitting of the VRS is not expected to affect any of the existing air quality permits that have been issued for the WBNP.

Finally, the radiological emergency plans for WBNP would require modification to accomodate the additional numbers of construction personnel onsite as well as to include any responses to emergencies caused by operation of the VRS or OSF.

VI. UNAVOIDABLE ADVERSE ENVIRONMENTAL IMPACTS

There are no significant environmental impacts associated with the construction and operation of the VRS and OSF. A small amount of erosion, noise, siltation, or gaseous and particulate pollutants will result from construction activities, and small amounts of radioactive and nonradioactive gaseous emissions will occur during operation of the VRS and OSF. No significant cumulative impacts have been identified.

VII. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

Irreversible and irretrievable commitments of resources will include fuel oils involved in the construction of the proposed facilities along with materials used for the construction of the OSF and VRB.

VIII. CONCLUSION

The proposed LLRW management plan, including construction of a permanent onsite LLRW storage facility and installation of a volume reduction and solidification system, does not constitute a major Federal action significantly affecting the quality of the human environment. Therefore, preparation of an environmental impact statement is not required. The proposed action has been determined to be in compliance with TVA policies on floodplain management and wetland protection.

PNH

TENNESSEE VALLEY AUTHORITY

TVA
ENGINEERING
LABORATORY

WATER SYSTEMS DEVELOPMENT BRANCH
NORRIS, TENNESSEE

DIVISION OF WATER MANAGEMENT

TECHNICAL REPORT

Tennessee Valley Authority
Division of Water Management
Water Systems Development Branch

RESULTS OF HYDROTHERMAL MODEL TESTS OF THE MULTIPORT DIFFUSER SYSTEM WATTS BAR NUCLEAR PLANT

Report No. 9-2013

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DESCRIPTION OF MULTIPORT DIFFUSER SYSTEM
WATTS BAR NUCLEAR PLANT

INTRODUCTION

The Tennessee Valley Authority is constructing a two-unit nuclear generating plant in Rhea County, Tennessee, on the right bank of Chickamauga Lake adjacent to the Watts Bar Dam Reservation near Tennessee River Mile (TRM) 528 (Figure 1). One closed cycle, natural draft cooling tower per unit is utilized as the primary means of heat dissipation. Blowdown will be discharged at a rate of between 28.3 and 32.5 cubic feet per second (cfs) from each cooling tower basin so as to maintain the concentration of solids in the cooling towers at approximately twice that found in the Tennessee River. Since the blowdown cannot be continuously discharged during periods of no releases from Watts Bar Dam without violating applicable thermal standards, blowdown can be discharged into a holding pond of approximately 190 acre-feet capacity during these periods. When sufficient water is released from Watts Bar Dam, blowdown may be again discharged to the river. This occurs at the minimum release from Watts Bar Hydro Plant of 3500 cfs. In addition, blowdown from the holding pond can be discharged to the river at a rate of approximately 60 cfs.

This report presents the results of hydrothermal physical model tests of the plant's multiport diffuser system. The diffuser system is described and the analytical theory used for the diffuser design is given and compared to the results of the physical model tests. Conclusions concerning the performance of the diffuser and the size of the area of diffuser-induced mixing are given. Previous studies resulted in the choice of a diffuser system oriented perpendicularly to the river flow (Reference 1). Additional hydro-thermal physical model tests were conducted as part of these studies (Reference 2).

DIFFUSER DESIGN

Diffuser Dimensions and Geometry

A physical description of the recommended diffuser system is given in Table 1 and depicted in Figure 2. The diffuser system will consist of two pipes branching from a central conduit at the right bank of Chickamauga Lake and extending in a direction perpendicular to the river flow into the Tennessee River. Each pipe will be controlled by a 54-inch diameter butterfly valve, located a short distance from the wye with the central conduit.

The downstream leg will consist of approximately 297 feet of 4.5-foot diameter paved corrugated steel approach pipe connected to 150 feet of unpaved 1- x 3-inch corrugated steel diffuser pipe of the same diameter. The diffuser pipe section will be half buried in the river bottom and will contain two 1-inch diameter port per corrugation. The centroid of the ports will be oriented at an angle of 45^0 from the horizontal in a downstream direction.

The upstream leg will consist of approximately 447 feet of 3.5-foot diameter paved corrugated steel approach pipe connected to 75 feet of unpaved 1- x 3-inch corrugated steel diffuser pipe of the same diameter. The upstream diffuser pipe section will also be half buried in the river bottom and will extend its entire length of 75 feet beyond the dead end of the downstream diffuser pipe section. The port diameter, spacing and orientation of the upstream leg will be the same as that of the downstream leg.

Diffuser Location

The location of the diffuser system is shown in Figure 3. Both the upstream and downstream legs are located beneath the navigation channel, as indicated by buoy markers on Figure 3. The location of the diffuser was chosen so that the depth of water above the diffuser will be sufficient to allow for the safe passage of barges.

Operational Modes and Characteristics

Modes of Operation

A mode of operation for the diffuser system is defined as any one of the possible combinations of diffuser pipe sections which may discharge blowdown under particular circumstances. Thus, for the Watts Bar Nuclear Plant diffuser system, the first mode consists of only the upstream leg discharging blowdown, the second mode consists of only the downstream leg discharging blowdown, and the third mode consists of both the upstream and downstream legs discharging blowdown. Mode 1 is used when either unit 1 or unit 2 is operated alone. Mode 2 is used when only both units are operated simultaneously or when only stored blowdown is discharged from the holding pond. Mode 3 is used when either or both of the units is operated at the same time as stored blowdown is discharged from the holding pond. Table 2 summarizes the minimum and maximum blowdown flow rates that can be expected for each mode.

Operational Characteristics

The operational characteristics for the minimum and maximum flows of each mode are summarized in Table 3. The average jet exit velocity, approach pipe velocity and the required head at three locations in the pipe are presented.

Table 3 shows that the average jet exit velocity varies from 8.6 to 12.7 feet per second (fps) for all the operational modes, which will provide ample mixing.

Analysis of Diffuser Performance

An analytical expression for the dilution induced by a submerged slot diffuser in shallow water was developed by Adams (Reference 3):

$$S = 1/2(V \sin \gamma + (V^2 \sin^2\gamma + 2\frac{h}{B} \cos \Theta)^{1/2}) \qquad (1)$$

where S = dilution

$$= \frac{\text{entrained river flow + diffuser flow}}{\text{diffuser flow}}$$

$$V = \frac{u_a h}{u_o B} = \frac{Q_R L}{Q_B w} = \text{volume flux ratio}$$

u_a = average river velocity across diffuser

u_o = jet exit velocity

h = average river depth

B = slot width

Q_R = river flow at diffuser site = $u_a wh$

Q_B = diffuser flow = $u_o LB$

L = diffuser length

w = average river width

γ = orientation angle of diffuser in river ($\gamma = 90^o$; perpendicular to river flow)

Θ = discharge angle from river bottom ($\Theta = 0^o$; parallel to river bottom)

This theory is applicable as long as $L/H \geq 5$. Table 4 shows the values of these parameters for the Watts Bar Nuclear Plant diffusers. Equation 1 is applicable because $L/H \approx 10$. The predicted dilution of the Watts Bar diffuser system is 17 at a minimum Tennessee River flow of 3500 cfs.

The two dimensional structure of the discharge plume was predicted using the method of Jirka which is based on the theory of Adams (Reference 4). Full vertical mixing of the discharge plume and the receiving water was predicted for the following criterion:

$$F_T \, V^{3/2} \geq 1.0$$

where

$$F_T = \frac{F_s}{h/B^{3/2}} = \text{diffuser load}$$

F_s = slot densimetric Froude number

$$= \frac{u_o}{\sqrt{g'B}}$$

$$g' = \frac{(\rho_o - \rho_a)g}{\rho_a}$$

ρ_o = density of discharge

ρ_a = density of ambient river water

g = gravitational constant

In general, stratified conditions downstream of the discharge were predicted when this criterion was not met. For the Watts Bar Nuclear Plant diffuser system, the variety of discharge conditions can result in either fully mixed or stratified conditions downstream of the discharge.

MODEL DESCRIPTION

Because the theory used to predict the dilution of the diffuser system was two-dimensional, the final design of the diffuser was evaluated in hydrothermal model studies, where three-dimensional effects were simulated. A detailed description of the physical model is presented in Reference 2 and is summarized herein. The physical model studies were conducted according to geometric, kinematic and Froude scaling criteria in the 8-foot wide, 60-foot long flume at TVA's Engineering Laboratory in Norris, Tennessee. An undistorted model (length/scale ratio 1:60) of approximately 45 percent of the 1100-foot wide river was constructed because of the limited width of the flume. Figure 4 shows that the section of the river modeled was the area of practical interest on the plant side of the river. Because the river exhibited a fairly rectangular cross-section, only a general schematization of the river geometry was necessary (Figure 5). The use of a false wooden floor in the flume eliminated the need for insulation of the bottom of the flume. The equivalent of a river flow (Q_R) of 3500 cfs was used in the model studies, which was the minimum river flow during which blowdown from the plant would be discharged (Reference 1).

Submerged multiport diffusers were modeled using the concept of an equivalent slot width. A series of submerged discharge ports were assumed to be equivalent to a submerged slot of equal length and port area, provided the port spacing was less than the water depth. Diffuser jets discharged at a prototype velocity of 9.5-15.1 fps. The effect of the buoyancy of the discharge was modeled using heat as the source of density differences between the discharge and receiving water body. Density differences between the discharge and the receiving water corresponding to temperature differences of -5^{o}C to 25^{o}C were tested. These density differences were characterized by the parameter g', which was defined earlier. The density of the discharge can be less than the receiving water at the Watts Bar plant site because of the concentration of dissolved solids in the blowdown compared to the river and because of the quicker response of natural draft cooling towers to cooler ambient air temperatures in the autumn months compared to the response of the river at the plant site.

TEST RESULTS

Data Interpretation

Test results for the Watts Bar Nuclear Plant diffuser system are presented in Figures 6-11. Results are presented in the form of discharge concentration isoquants at prototype water depths of 5 and 12 feet.

Comparison of concentration plots for tests of the same river and diffuser flow, discharge buoyancy and geometry indicated that plume structure was generally reproducable. Plume areas, discharge concentrations and other quantifiable data were always of the same order of magnitude for each replicate test but differed substantially enough that the use of such data was justifiable only in a comparative order of magnitude analysis. These variations were probably caused by the stochastic nature of turbulent mixing and the low density and slow scanning rate of the temperature probes compared to the length scales and frequency of turbulent mixing.

Comparison of concentration plots for tests of the same equivalent slot diffuser composed of different port diameter and spacings indicated good agreement. Some tests with large diffuser flow rates showed the effects of boundary layers on the mid-river boundary of the model. Concentration data in these areas were interpreted with caution because viscosity is not scaled correctly in models developed according to Froude scaling criteria; however, these effects were apparent outside areas of jet-induced mixing and did not affect overall results.

Diffuser-Induced Dilution and Plume Structure

Maximum Diffuser Length

Figures 6 through 8 show diffuser discharge concentration plots for the test values of diffuser design parameters given in Table 4. The concentration plots are shown for a diffuser length of 194 feet and three discharge buoyancies: g' = -0.05, 0.05 and 0.20. For g' = -0.05, the negatively buoyant case, the discharge plume was fully mixed over the depth and did not concentrate near the right bank (Figure 6). This showed that a negatively buoyant discharge acting in the opposite direction of vertical jet momentum increased dilution. For g' = 0.05, the discharge buoyancy was slightly positive (Figure 7). High concentration measurements particularly near the bottom boundary of the model indicated that warmer water was retained in the boundary layers because of the greater effect of viscosity in the model as compared to the prototype. At the five-foot depth, Figure 7 shows the entrainment of cooler ambient river water by the diffuser and the contraction of the mixed diffuser flow downstream mentioned by Adams (References 3 and 4). For g' = 0.20, the discharge plume was mixed over the depth, but tended to concentrate near the surface because of the high discharge buoyancy (Figure 8). Boundary effects were evident, particularly at the 12-foot depth, but the discharge plume did not concentrate near the right bank.

A diffuser-induced dilution of 13 was predicted by Equation 1 for the test results in Figures 6-8 (Table 4). This corresponded to a discharge concentration of 0.08. Figures 6-8 show that discharge concentrations one diffuser length downstream along the longitudinal centerline of the diffuser were equal to or less than 0.08. The discharge plume was predicted to be fully mixed over the depth for g' = ±0.05, and to be stratified outside the area of diffuser-induced mixing for g' = 0.20. Figures 6-8 show that the plume structure for these tests was fairly well predicted.

Minimum Diffuser Length

Figures 9 through 11 show discharge concentration plots for a diffuser length of 102 feet and the same discharge buoyancies evaluated previously. For g' = -0.05, the discharge plume was fairly well mixed over the entire depth and did not concentrate near the right bank (Figure 9). For g' = 0.05, the discharge plume was fully mixed over the entire depth (Figure 10). Boundary layer effects were evident, particularly at the 12-foot depth, and were caused by the greater effect of viscosity in the model. For g' = 0.20, the discharge plume became stratified outside of the area of diffuser-induced mixing and did not concentrate near the right bank (Figure 11). In Figures 9-11 boundary layer and viscosity effects were not as important because of the smaller ratio of diffuser length to modeled river width as compared to Figures 6-8.

A diffuser-induced dilution of 13 was predicted by Equation 1 for the test results in Figures 9-11 (Table 4). This corresponded to a discharge concentration of 0.08 (Table 4). Figures 9-11 show that discharge concentrations one diffuser length downstream along the longitudinal centerline of the diffuser were equal to or less than 0.08. The discharge plume was predicted to be fully mixed over the depth for g' = ±0.05 and to be stratified outside the area of diffuser-induced mixing for g' = 0.20. Figures 9-11 show that the plume structure for these tests was well predicted.

APPLICATION OF TEST RESULTS

As noted previously, quantifiable data from replicate tests differed substantially enough that the use of such data was justifiable only in a comparative order of magnitude analysis. Comparison of predicted dilutions for the model diffuser using the two-dimensional theory of Adams and measured dilutions for the model diffuser showed reasonable agreement for both the 194-foot and 102-foot diffuser lengths. This agreement indicated that the mixing from a submerged slot diffuser in shallow water was primarily a two-dimensional phenomenon and the resulting dilution could be reasonably predicted by a two-dimensional theory. Because the predicted dilutions based on the two-dimensional theory of Adams never overestimated the measured dilutions in the model, the two-dimensional theory of Adams can be used to conservatively predict the performance of the multiport diffuser system at the Watts Bar Nuclear Plant.

A comparison of design and test values of diffuser design parameters is given in Table 4. Average river velocity and discharge velocity were larger in the model compared to the prototype diffuser, while river depth and the maximum diffuser length were smaller. Values of other parameters in the model and the prototype were in close agreement. Table 4 shows that the theory of Adams predicts a dilution of 17 for the actual diffuser design and a dilution of 13 for the diffuser model at a minimum Tennessee River flow of 3500 cfs. Figures 6-11 show reasonable agreement between predicted and measured values of dilution for the diffuser model. Therefore, the actual multiport diffuser system at the Watts Bar Nuclear Plant should achieve a dilution of approximately 17 when either the upstream, downstream or both legs of the diffuser system are in operation at a minimum Tennessee River flow of 3500 cfs.

The results of the hydrothermal model tests indicated that concentration of the discharge near the right bank did not occur. In addition, the discharge plume did not form a thermal wedge upstream of the diffuser even at the highest discharge buoyancy. The tendency of the discharge plume in the model to form vertically mixed conditions downstream of the diffuser was well predicted by the theory of Adams. Similar plume structure is predicted for the actual diffuser design.

Mixing Zone

The results of the model tests showed that the expected diffuser-induced dilution was achieved approximately one diffuser length downstream. Thus the area of diffuser-induced mixing extends approximately 150 feet downstream when the downstream leg of the diffuser system is discharging; approximately 75 feet downstream when the upstream leg of the diffuser system is discharging; and 225 feet downstream when both legs of the diffuser system are discharging. The proposed mixing zone should encompass all of these modes of operation and should extend 225 feet downstream over the entire river depth and diffuser system width (225 feet).

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1. Tennessee Valley Authority, Environmental Information, Watts Bar Nuclear Plant, Units 1 and 2, November 18, 1976.

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3. Adams, E. E., "Submerged Multiport Diffusers in Shallow Water With Current," Master's Thesis, Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts, May 1972.

4. Jirka, G., and D.R.F. Harleman, "The Mechanics of Submerged Multiport Diffusers for Buoyant Discharges in Shallow Water," Ralph M. Parsons Laboratory Report No. 169, Massachusetts Institute of Technology, Cambridge, Massachusetts, March 1973.

TABLE 1

DIMENSIONS OF RECOMMENDED DIFFUSERS
WATTS BAR NUCLEAR PLANT

	Upstream Leg	Downstream Leg	Total
Diffuser			
Pipe Length (ft) (unpaved 1- x 3-inch corrugated steel pipe)	75.0	150.0	225.0
Pipe Diameter (ft)	3.5	4.5	
Port Diameter (in)	1.0	1.0	
Number of Ports Per Corrugation	2	2	
Port Spacing Normal to Corrugation (in)	3.0	3.0	
Port Spacing Parallel to Corrugation (in)	3.0	3.0	
Friction Factor	0.0948	0.0841	
Approach Pipe			
Pipe Length (ft) (paved corrugated steel pipe)	447.0	297.0	474.0
Pipe Diameter (ft)	3.5	4.5	
Friction Factor	0.0191	0.0148	

TABLE 2

SUMMARY OF MODES OF OPERATION
BLOWDOWN DIFFUSER SYSTEM
WATTS BAR NUCLEAR PLANT

	Diffuser System Flow Rate		Distribution of Flow			
			Minimum		Maximum	
Mode of Operation	Minimum (cfs)	Maximum (cfs)	Upstream Leg (cfs)	Downstream Leg (cfs)	Upstream Leg (cfs)	Downstream Leg (cfs)
1 One Unit only	28.3	32.5	28.3	----	32.5	----
2 Two Units only or Holding Pond Discharge only	56.6	65.1	----	56.6	----	65.1
3 Either or Both Units + Holding Pond Discharge	88.5	125.3	29.1	59.4	41.2	84.1

Blowdown Rate per unit: 28.3 - 32.5 cfs
Holding Pond Discharge Rate: 60.2 cfs

TABLE 3

OPERATING PROPERTIES OF RECOMMENDED DIFFUSERS
WATTS BAR NUCLEAR PLANT

	Individual Operation of Diffuser Legs				Combined Operation of Diffuser Legs			
	Mode 1		Mode 2		Mode 3			
	Upstream Leg		Downstream Leg		Minimum		Maximum	
	Minimum	Maximum	Minimum	Maximum	Upstream	Downstream	Upstream	Downstream
Blowdown Rate (cfs)	28.3	32.5	56.6	65.1	29.3	59.2	41.5	83.8
Port Velocity (fps)	8.6	9.9	8.6	9.9	9.0	9.0	12.7	12.7
Approach Pipe Velocity (fps)	2.9	3.4	3.6	4.1	3.1	3.7	4.3	5.3
Dead End Head (ft)	2.6	3.4	2.6	3.4	2.8	2.8	5.6	5.7
Diffuser Head Req'd (ft)	2.7	3.5	2.8	3.7	2.9	3.0	5.8	6.1
Total Head Req'd (ft) from Wye	3.0	4.0	3.0	4.0	3.2	3.2	6.5	6.5

TABLE 4

DESIGN AND TEST VALUES
OF DIFFUSER DESIGN PARAMETERS

Symbol Primary	Parameter	Units	Design Value	Test Value
u_o	Discharge Velocity (max)	m/s (fps)	3.9 (12.7)	4.5 (14.8)
u_a	Average River Velocity	cm/s (fps)	4.9 (0.16)	7.0 (0.23)
B	Equivalent Slot Width	cm (ft)	1.33 (0.0436)	1.44 (0.0471)
h	River Depth (min)	m (ft)	6.7 (22)	4.3 (14)
Secondary				
γ	Orientation Angle to River Flow	deg	90	90
Θ	Discharge Angle	deg	45	45
g'	Buoyancy (max)	--	0.20	0.20
	(min)	--	-0.05	-0.05
L	Diffuser Length (max)	m(ft)	69(225)	59(194)
	(min)	m(ft)	23(75)	31(102)
Analytical Theory (References 3 and 4)				
h/B	Submergence	--	505	297
V	Volume Flux Ratio	--	6.4	4.6
S	Dilution	--	17	13

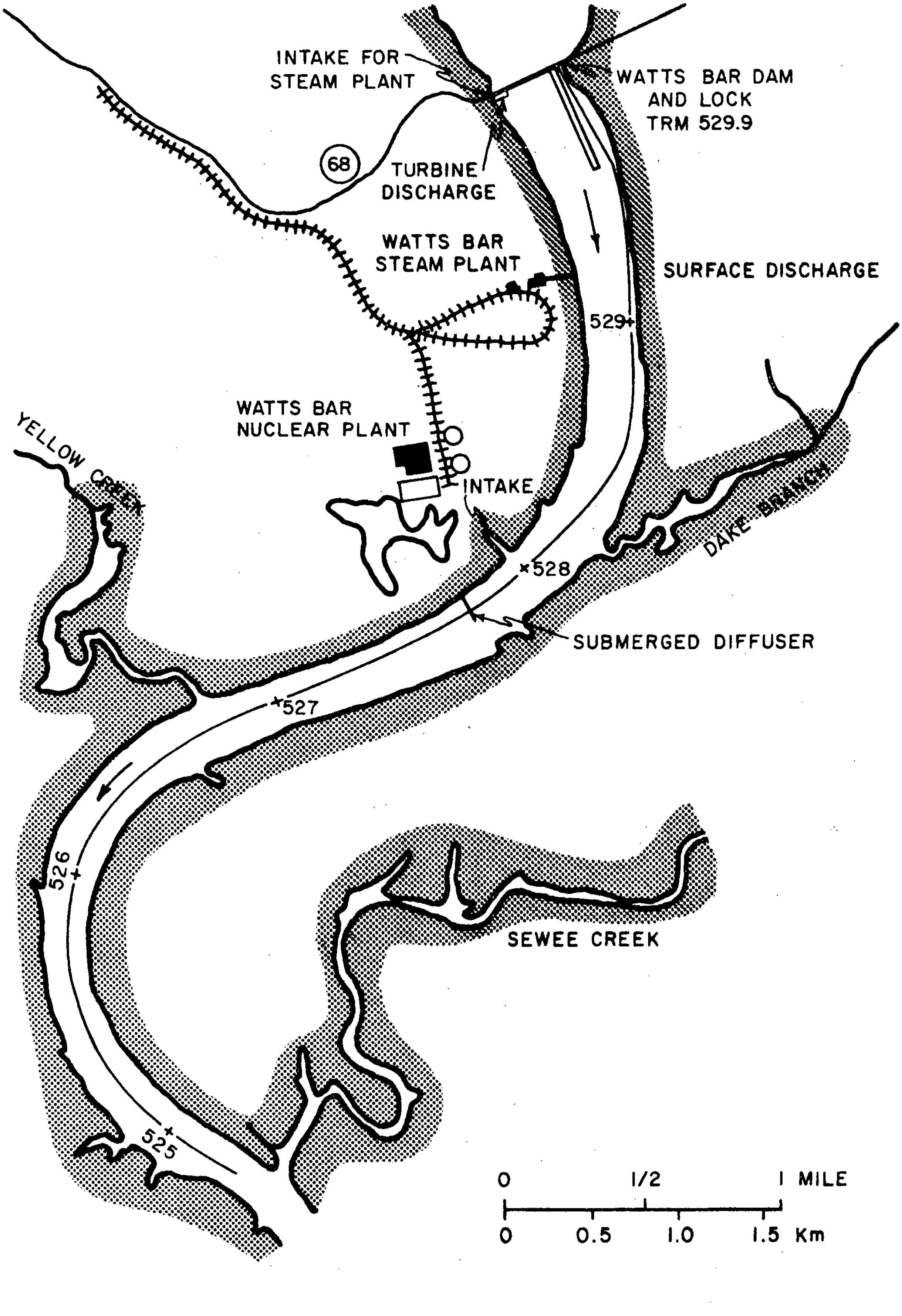


Figure 1: Tennessee River Near Watts Bar Dam

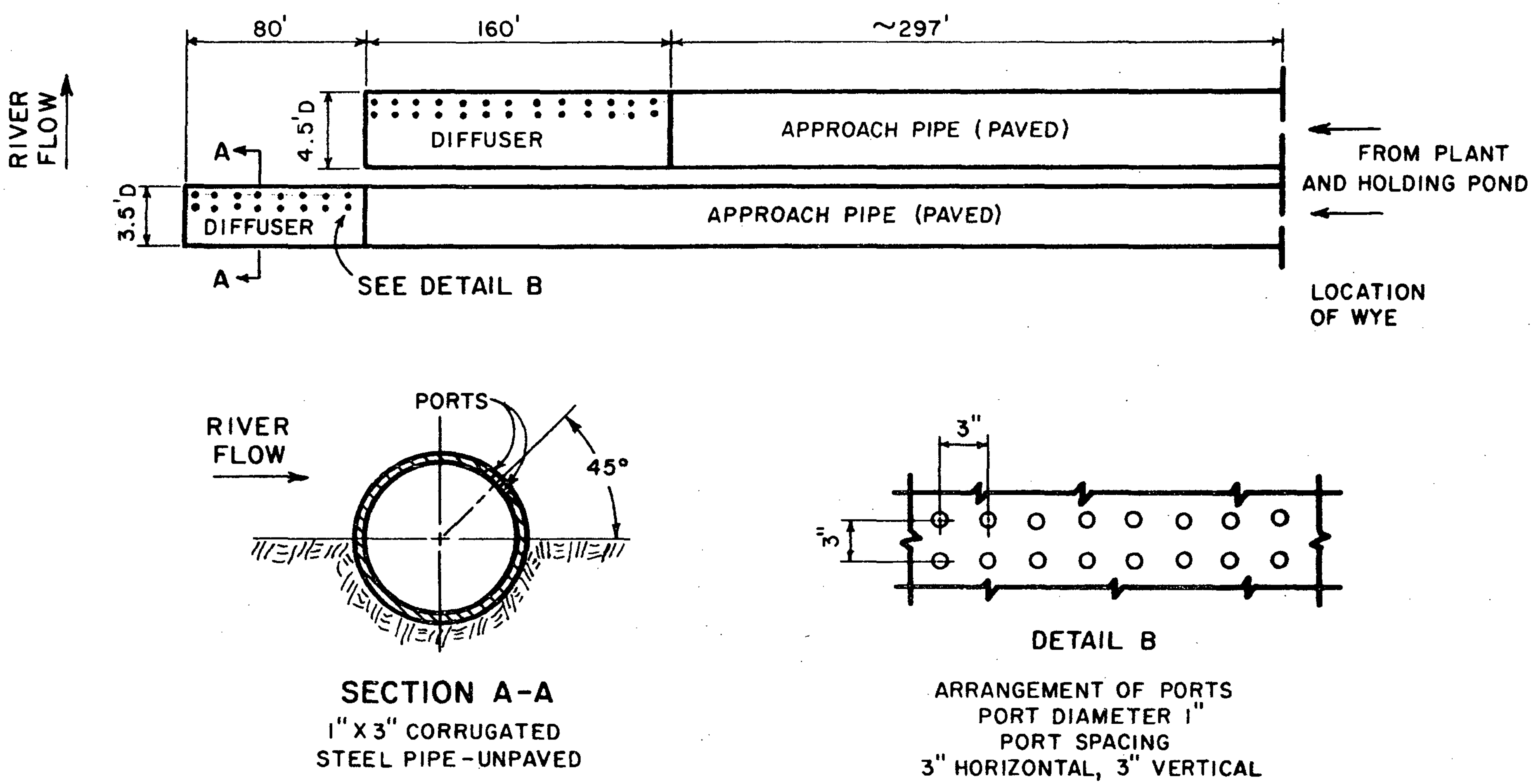


Figure 2: Description of Multiport Diffuser System
Watts Bar Nuclear Plant

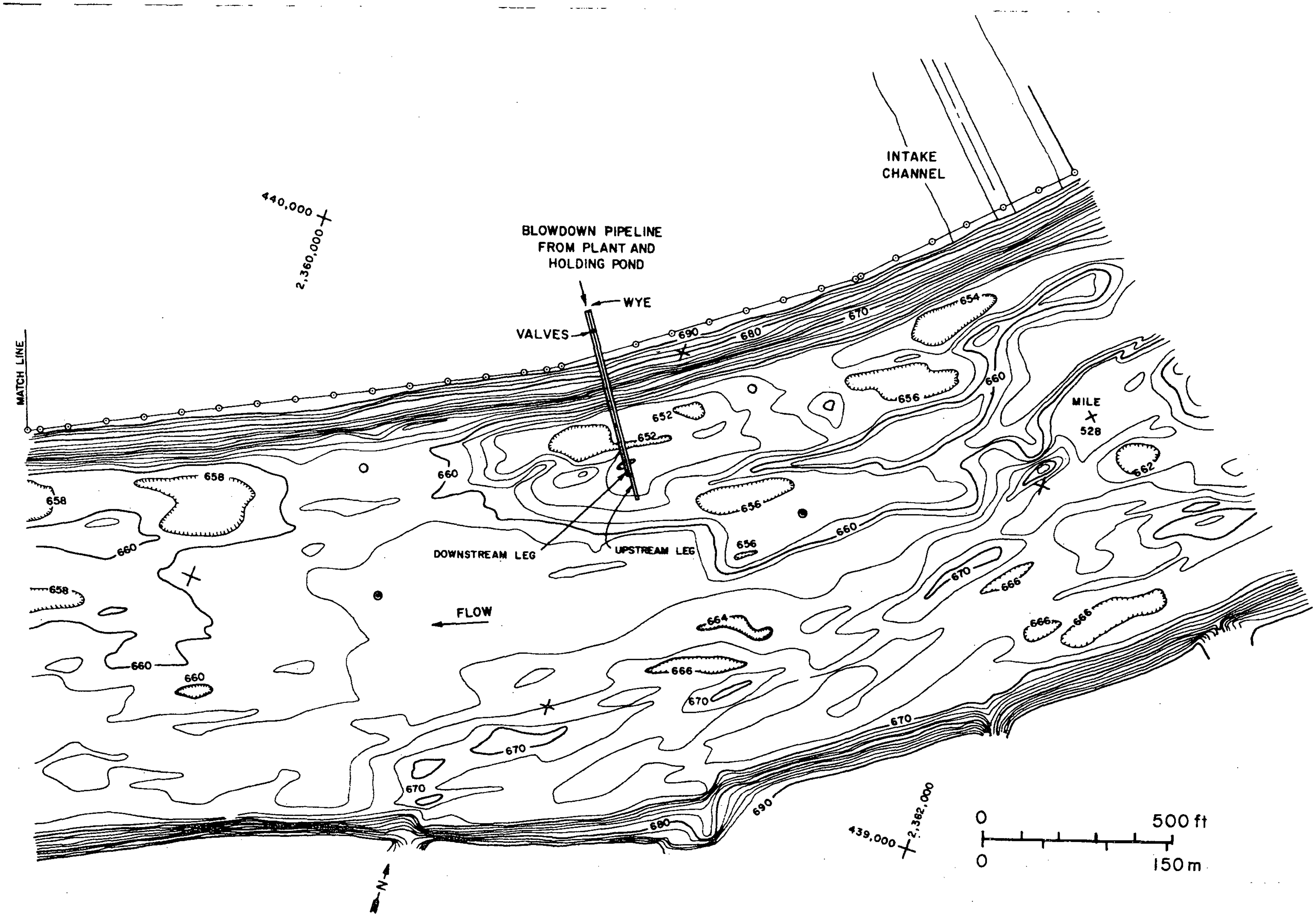


Figure 3 – Location of Multiport Diffuser System

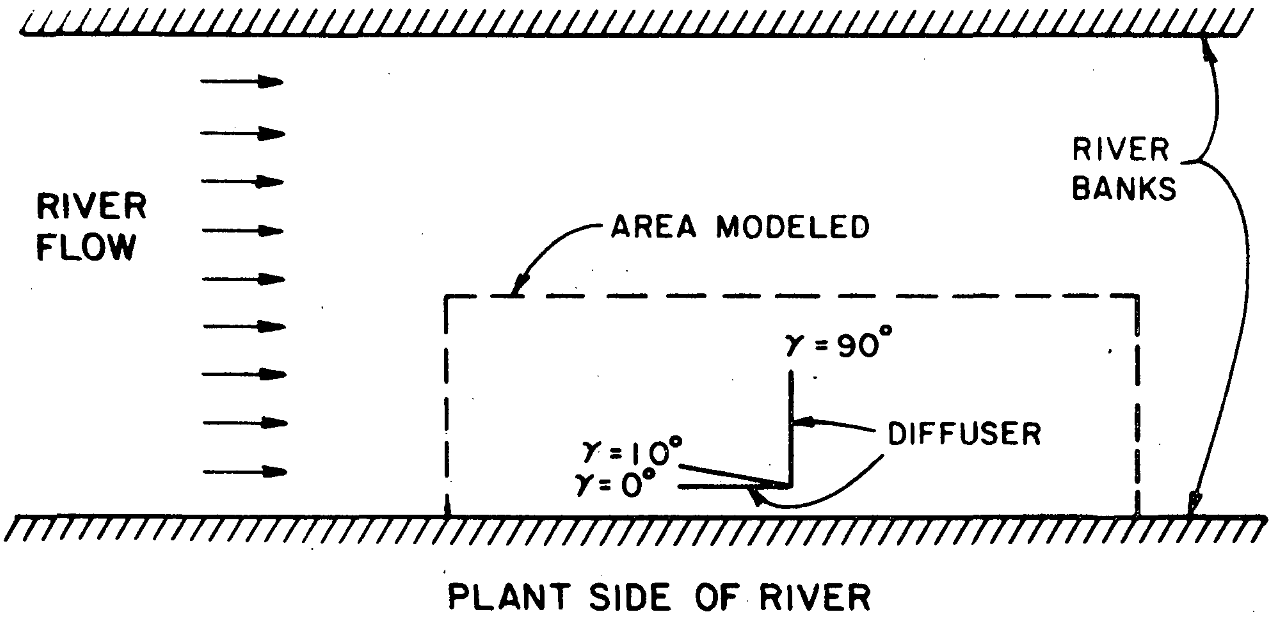


Figure 4 - Plan of Diffuser Model

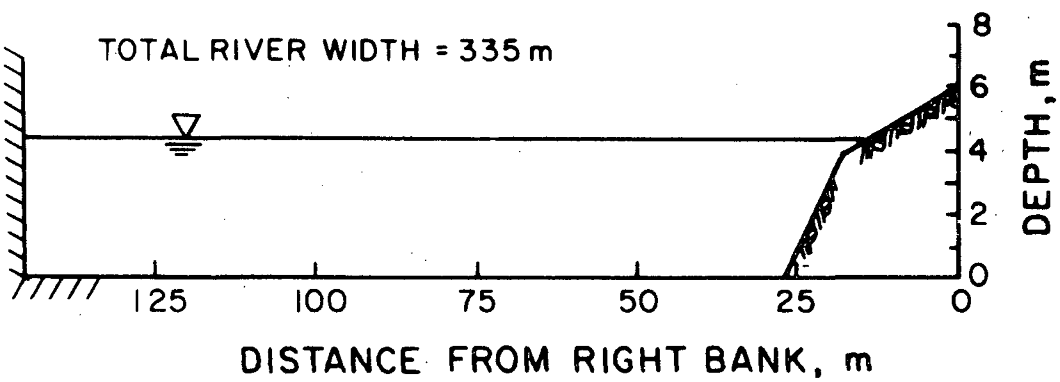


Figure 5 - Model of Prototype River Cross-Section

$\gamma = 90°$

$h = 4.3 m$ (14 ft)

$Q_R = 99 m^3/s$ (3500 cfs)

$B = 1.44 cm$ (0.0471 ft)

$\theta = 45°$

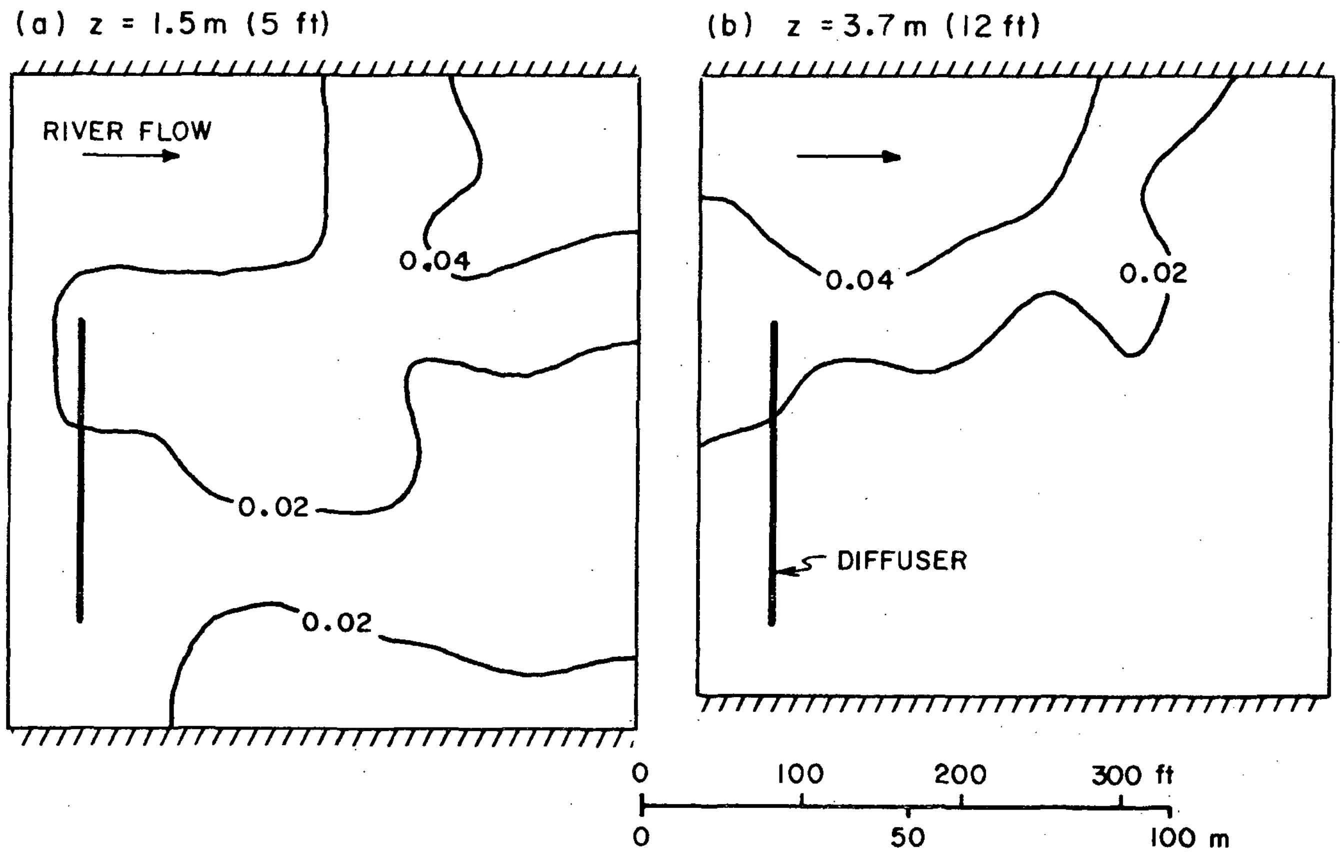


Figure 6 - Diffuser Discharge Concentration Plots, L = 59 m (194 ft), g' = -0.05

$\gamma = 90°$

$h = 4.3\,m$ (14 ft)

$Q_R = 99\,m^3/s$ (3500 cfs)

$B = 1.44\,cm$ (0.0471 ft)

$\theta = 45°$

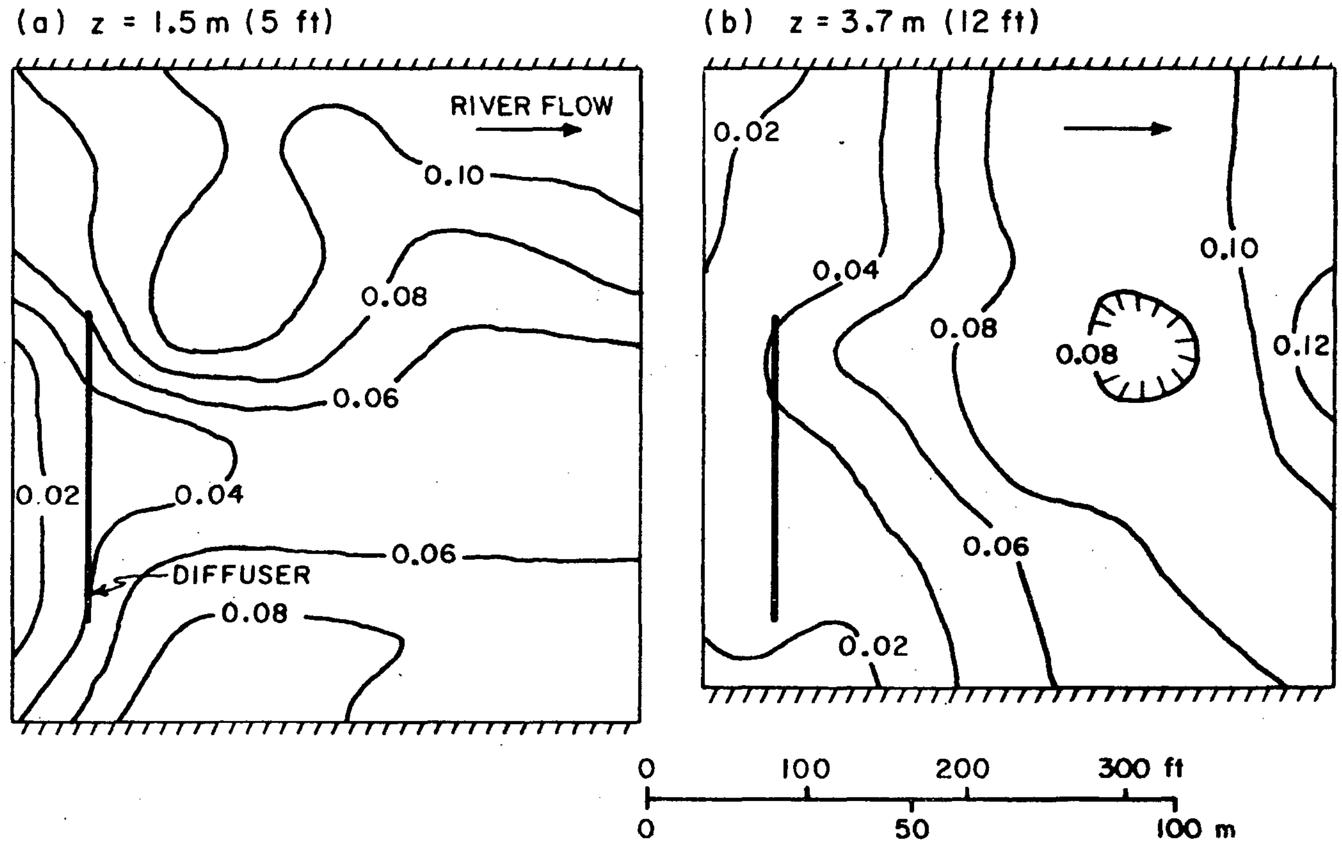


Figure 7 - Diffuser Discharge Concentration Plots, $L = 59\,m$ (194 ft), $g' = 0.05$

$\gamma = 90°$
$h = 4.3$ m (14 ft)
$Q_R = 99\ m^3/s$ (3500 cfs)
$B = 1.44$ cm (0.0471 ft)
$\theta = 45°$

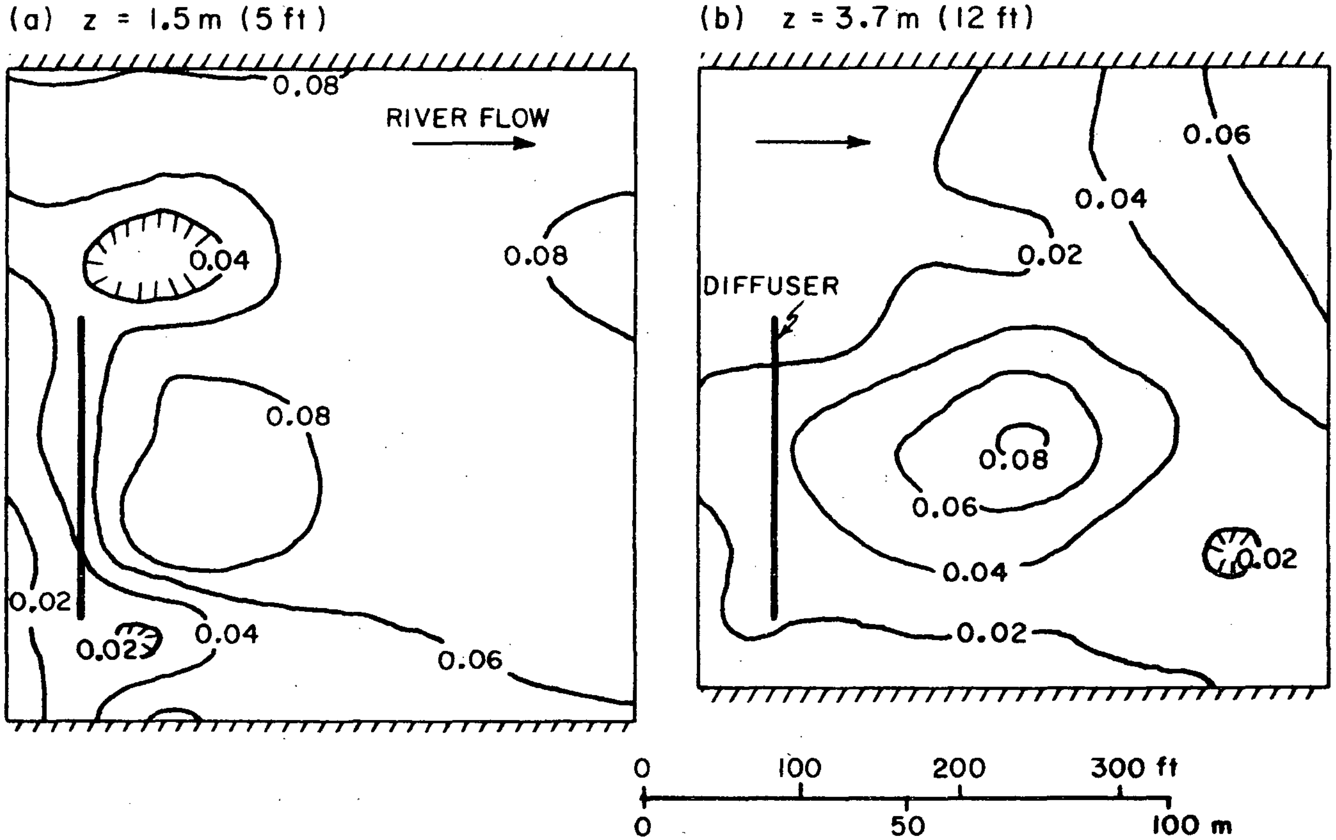
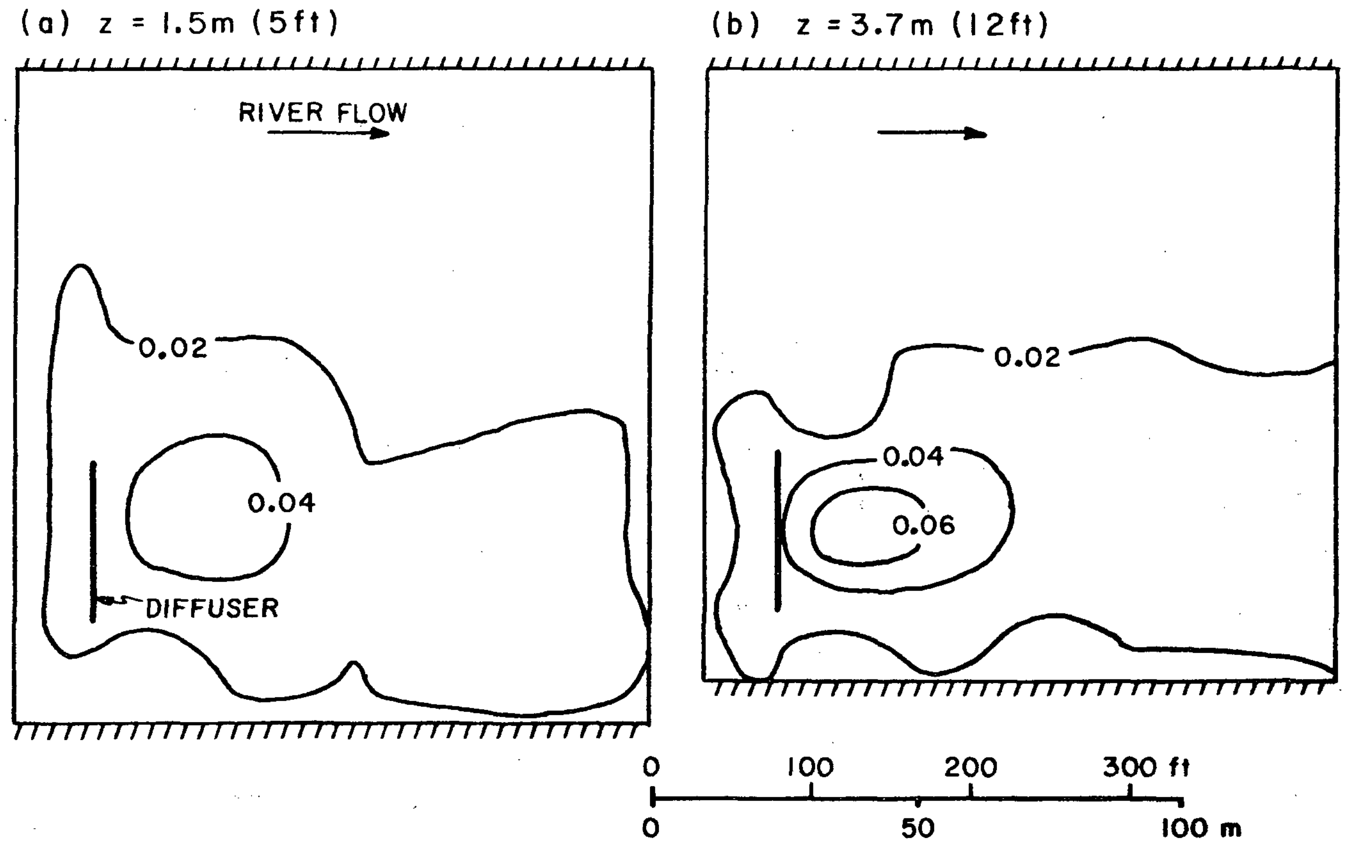


Figure 8 - Diffuser Discharge Concentration Plots, L = 59m (194 ft), g' = 0.20



$\gamma = 90°$
h = 4.3m (14 ft)
Q_R = 99 m^3/s (3500 cfs)
B = 1.44 cm (0.0471 ft)
$\theta = 45°$

Figure 9 – Diffuser Discharge Concentration Plots, L = 31m (102 ft), g' = –0.05

$\gamma = 90°$

$h = 4.3\text{ m } (14\text{ ft})$

$Q_R = 99\text{ m}^3/\text{s } (3500\text{ cfs})$

$B = 1.44\text{ cm } (0.0471\text{ ft})$

$\theta = 45°$

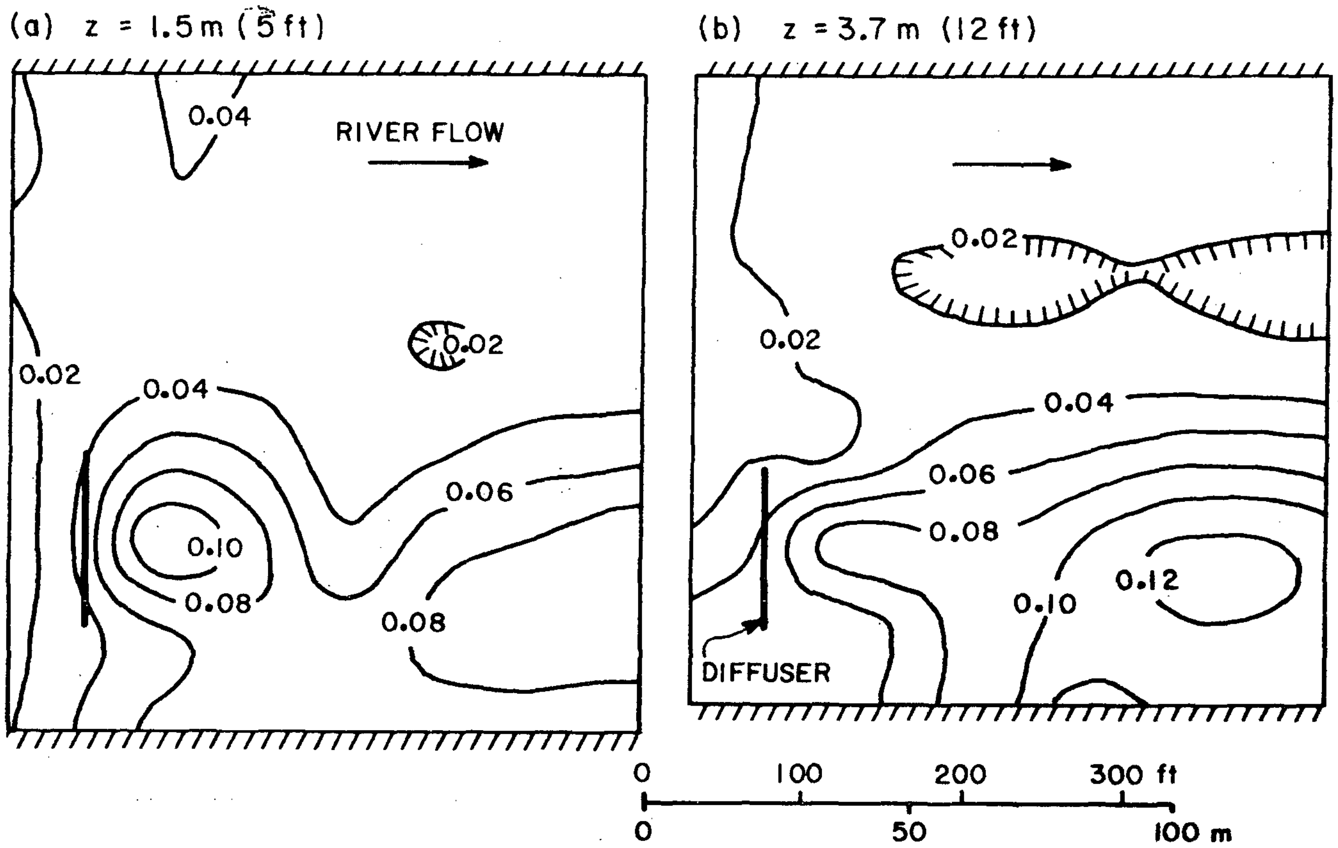


Figure 10 - Diffuser Discharge Concentration Plots, L = 31m (102 ft), g' = 0.05

$\gamma = 90°$
$h = 4.3$ m (14 ft)
$Q_R = 99 \, m^3/s$ (3500 cfs)
$B = 1.44$ cm (0.0471 ft)
$\theta = 45°$

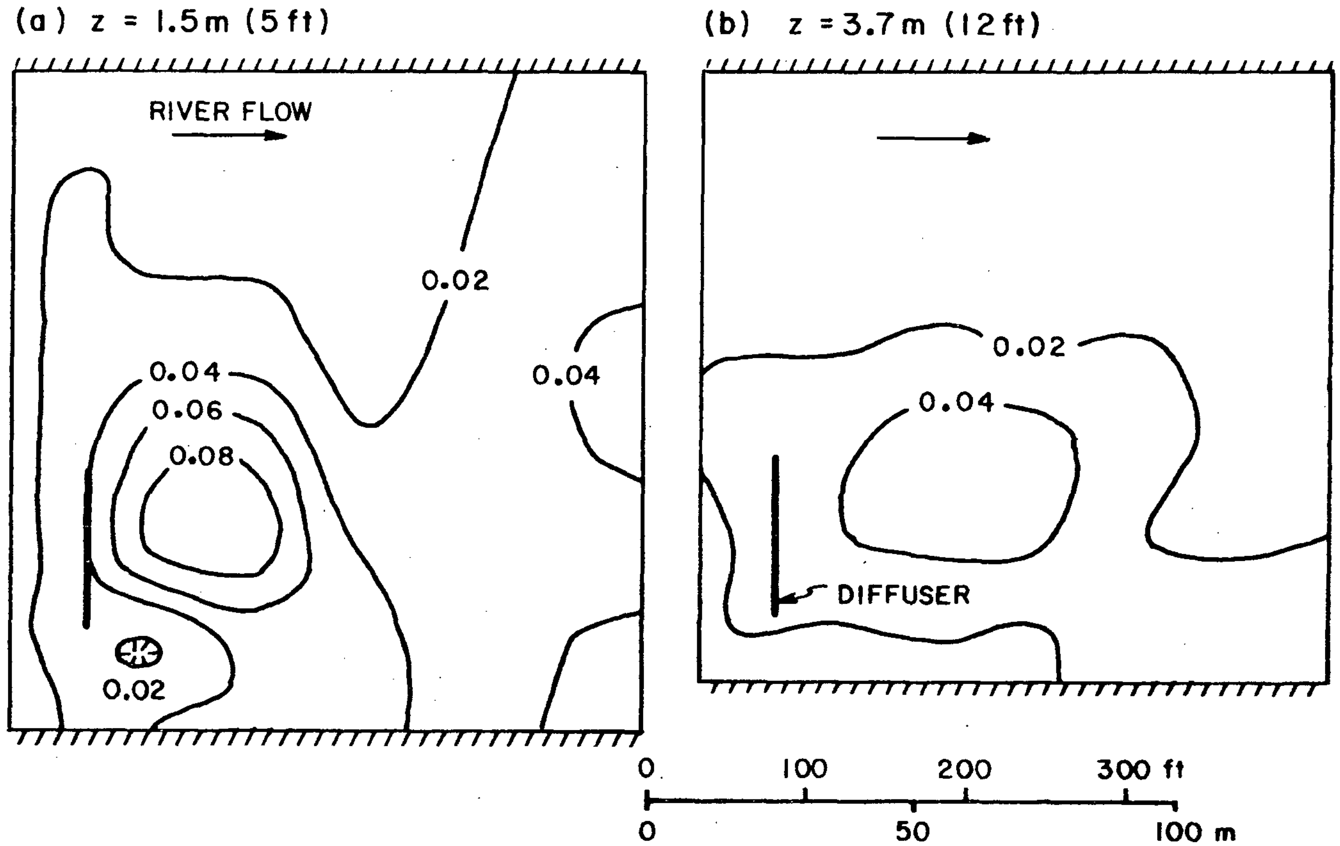


Figure 11 - Diffuser Discharge Concentration Plots, L = 31m (102 ft), g' = 0.20

WR28-1-85-100

EFFECT OF WATTS BAR NUCLEAR PLANT AND WATTS BAR STEAM PLANT DISCHARGES ON CHICKAMAUGA LAKE WATER TEMPERATURES

TENNESSEE VALLEY AUTHORITY
OFFICE OF NATURAL RESOURCES AND ECONOMIC DEVELOPMENT
DIVISION OF AIR AND WATER RESOURCES
ENGINEERING LABORATORY
NORRIS, TENNESSEE

Tennessee Valley Authority
Division of Water Management
Water Systems Development Branch

EFFECT OF WATTS BAR NUCLEAR PLANT AND WATTS BAR STEAM PLANT DISCHARGES ON CHICKAMAUGA LAKE WATER TEMPERATURES

WM28-1-85-100

Prepared by
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February 1977

INTRODUCTION

The Tennessee Valley Authority is constructing a two-unit 2540 megawatts (mw) nuclear generating plant in Rhea County, Tennessee, on the right bank of Chickamauga Lake adjacent to the Watts Bar Dam Reservation near Tennessee River Mile (TRM) 528 (Figure 1). This plant is situated approximately two miles downstream of Watts Bar Dam at TRM 529.9 and approximately one mile downstream of the four-unit 240 mw coal-fired Watts Bar Steam Plant on the right bank of Chickamauga Lake at TRM 529. This report discusses the individual and combined near-field effects of the nuclear and steam plant discharges on Chickamauga Lake water temperatures.

Previous reports have described the design of the multiport diffuser system for the nuclear plant (Reference 1) and the results of hydrothermal model tests of the diffuser (Reference 2). Summaries of river and wet bulb temperatures applicable to the plant site are presented and used to analyze the projected operation of the closed cycle heat dissipation and blowdown discharge systems of the plant. Revised operating properties of the diffuser system are also given using revised estimates of the maximum discharge rate from the plant (Reference 3).

The results of water temperature surveys have been used to study the mixing of the surface discharge from the once-through cooling system of the steam plant (Reference 4). Surface jet models and additional water temperature surveys are used to further characterize the effects of the steam plant discharge.

The combined effect of the steam and nuclear plant discharges is studied for periods of steady river flows and for periods during and

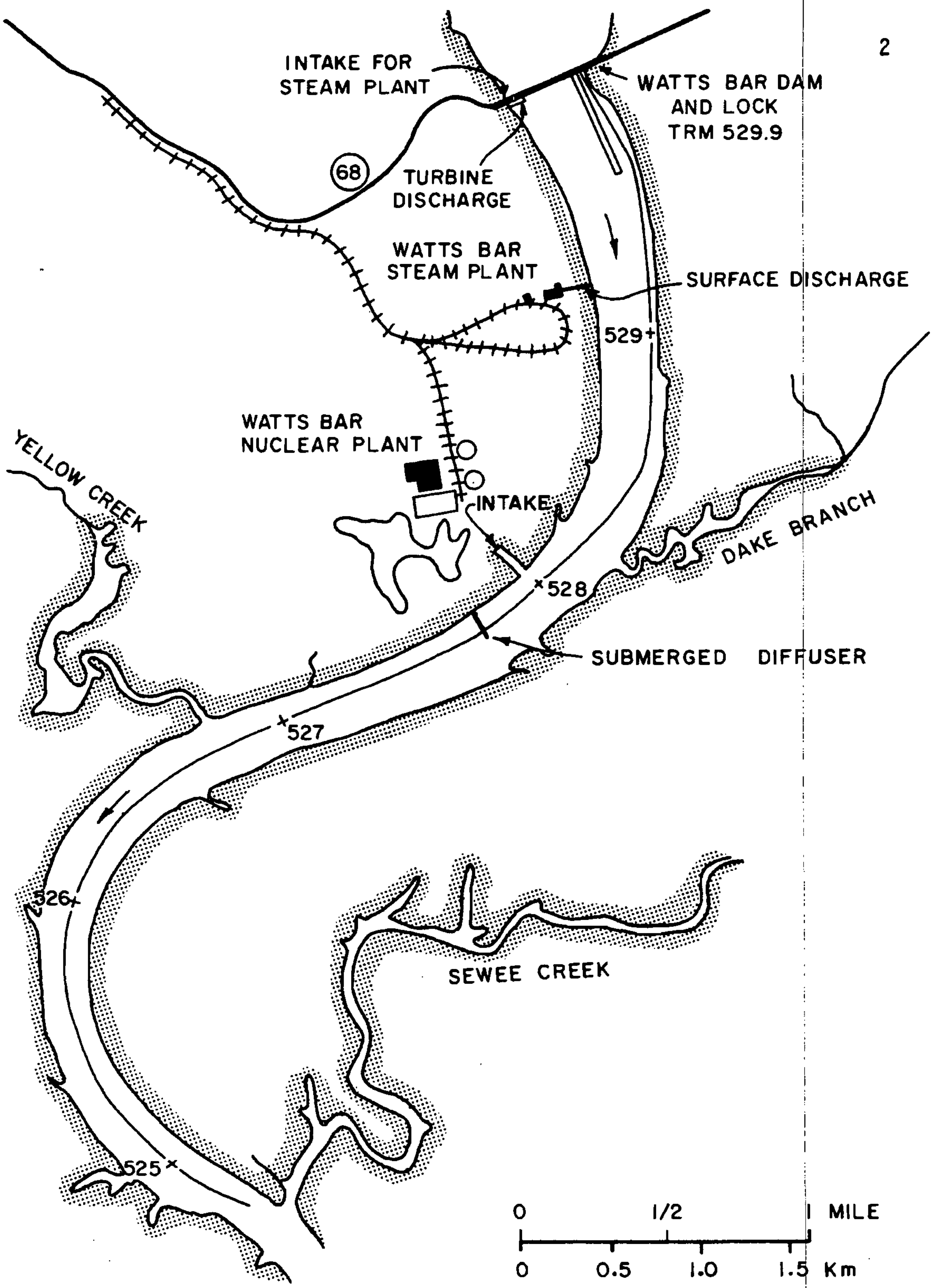

Figure 1: Tennessee River Near Watts Bar Dam

immediately following times of no release from Watts Bar Dam. Advection and diffusion models are utilized to determine the near field effects of the plant discharges. Compliance with the water temperature standards of the State of Tennessee is analyzed.

WATTS BAR DAM DISCHARGES

Watts Bar Dam discharge records, maintained since its closure on January 1, 1942, indicate that the average discharge at the dam has been 26,480 cubic feet per second (cfs). Flow data for water years 1951-1965 indicate an average flow of about 21,500 cfs during the summer months and about 35,500 cfs during the winter months. Watts Bar Dam is operated to provide peaking power as indicated in Figure 2, which shows no discharge from the dam 10.5 percent of the hours during the year. The maximum duration of no discharge periods is 12 hours, except for planned special operations. The normal discharge through each of the five turbines at the dam ranges from 7,500 to 10,000 cfs. The minimum flow at which the turbines can operate is 3,500 cfs, although discharges seldom fall below about 5,000 cfs per unit.

Water surface elevations downstream of Watts Bar Dam in the vicinity of the plant sites are determined by the headwater elevation at Chickamauga Dam and the discharge from Watts Bar Dam. Chickamauga Lake elevations vary from a normal maximum elevation of 683.0 feet in the summer months to a normal minimum elevation of 675.0 feet in the winter months. However, Watts Bar Dam discharges may raise the water surface elevation if the lake elevation is less than 683.0 feet. Table 1 shows the approximate stage-discharge relationship below Watts Bar Dam at minimum pool conditions in the winter.

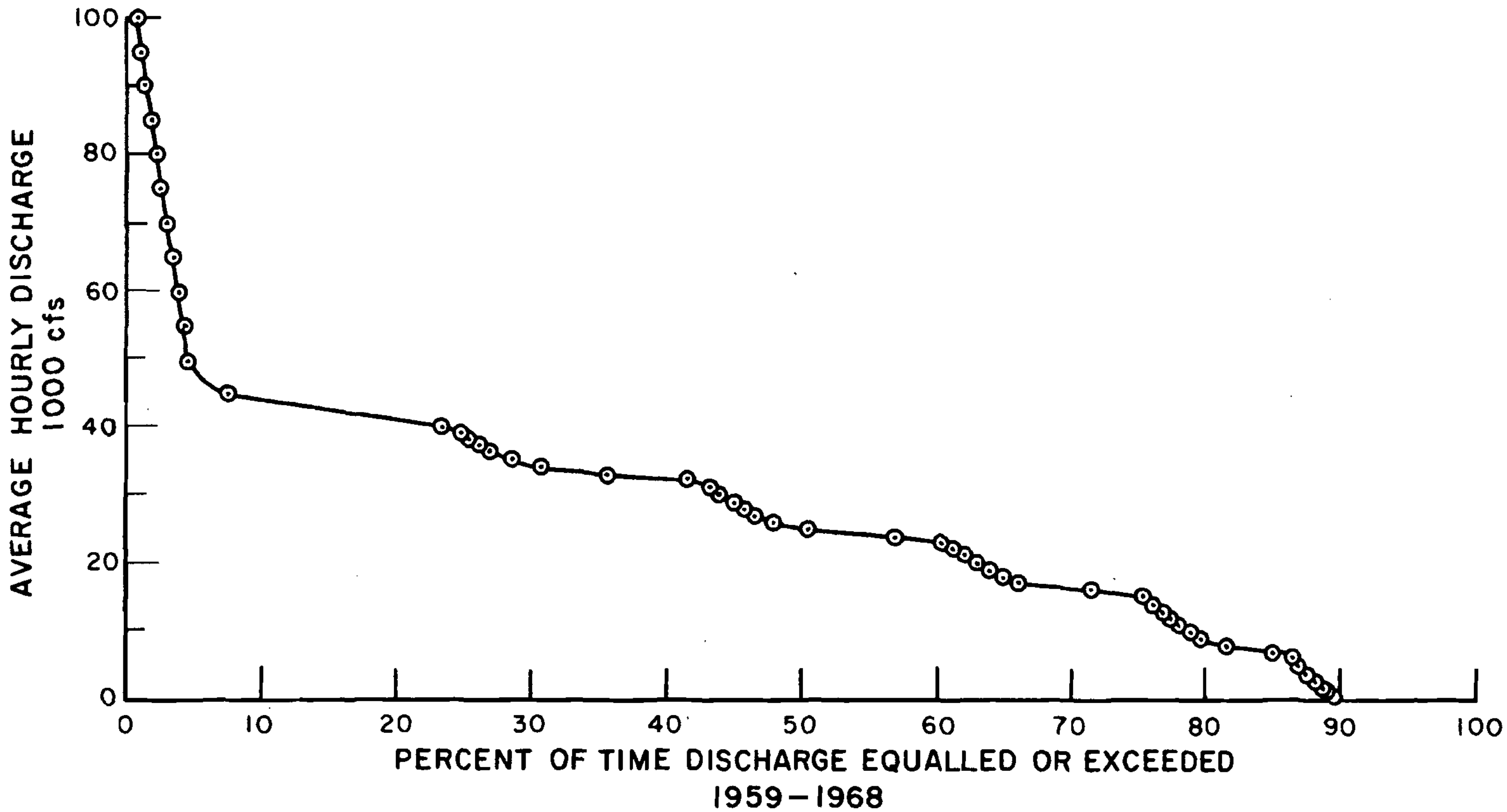

Figure 2 : Flow Frequency at Watts Bar Dam

Table 1

Approximate Stage Discharge Relationship

Immediately Below Watts Bar Dam

Chickamauga Lake Elevation 675.0 feet

Water Surface Elevation (feet)	Watts Bar Dam Discharge (cfs)
675	0
677	12,500
679	25,000
681	37,500
683	50,000
696	190,000

WATTS BAR NUCLEAR PLANT DISCHARGE CHARACTERISTICS

Intake and Discharge Design

A closed-cycle heat dissipation system consisting of two natural draft cooling towers is utilized for the Watts Bar Nuclear Plant. Makeup water for the plant is supplied via an intake channel and pumping station at TRM 528.0. The average and maximum intake flow rates are 133 cfs and 143 cfs, respectively, at a concentration factor of two.

A physical description of the diffuser discharge system is given in Table 2 and depicted in Figure 3. The diffuser system consists of two pipes branching from a central conduit at the right bank of Chickamauga Lake and extending in a direction perpendicular to the river flow into the Tennessee River. Each pipe is controlled by a 54-inch diameter butterfly valve located a short distance from the wye with the central conduit.

The downstream leg consists of approximately 297 feet of 4.5-foot diameter paved corrugated steel approach pipe connected to 160 feet of unpaved 1- x 3-inch corrugated steel diffuser pipe of the same diameter. The diffuser pipe section is half buried in the river bottom and contains two 1-inch diameter ports per corrugation. The centroid of the ports is oriented at an angle of 45° from the horizontal in a downstream direction.

The upstream leg consists of approximately 447 feet of 3.5-foot diameter paved corrugated steel approach pipe connected to 80 feet of unpaved 1- x 3-inch corrugated steel diffuser pipe of the same diameter. The upstream diffuser pipe section is also half buried in the

Table 2

Dimensions of Recommended Diffusers

Watts Bar Nuclear Plant

	Upstream Leg	Downstream Leg	Total
Diffuser			
Pipe Length (ft) (unpaved 1- x 3-inch corrugated steel pipe)	80.0	160.0	240.0
Pipe Diameter (ft)	3.5	4.5	
Port Diameter (in)	1.0	1.0	
Number of Ports Per Corrugation	2	2	
Port Spacing Normal to Corrugation (in)	3.0	3.0	
Port Spacing Parallel to Corrugation (in)	3.0	3.0	
Friction Factor	0.0948	0.0841	
Approach Pipe			
Pipe Length (ft) (paved corrugated) steel pipe)	447.0	297.0	474.0
Pipe Diameter (ft)	3.5	4.5	
Friction Factor	0.0191	0.0148	

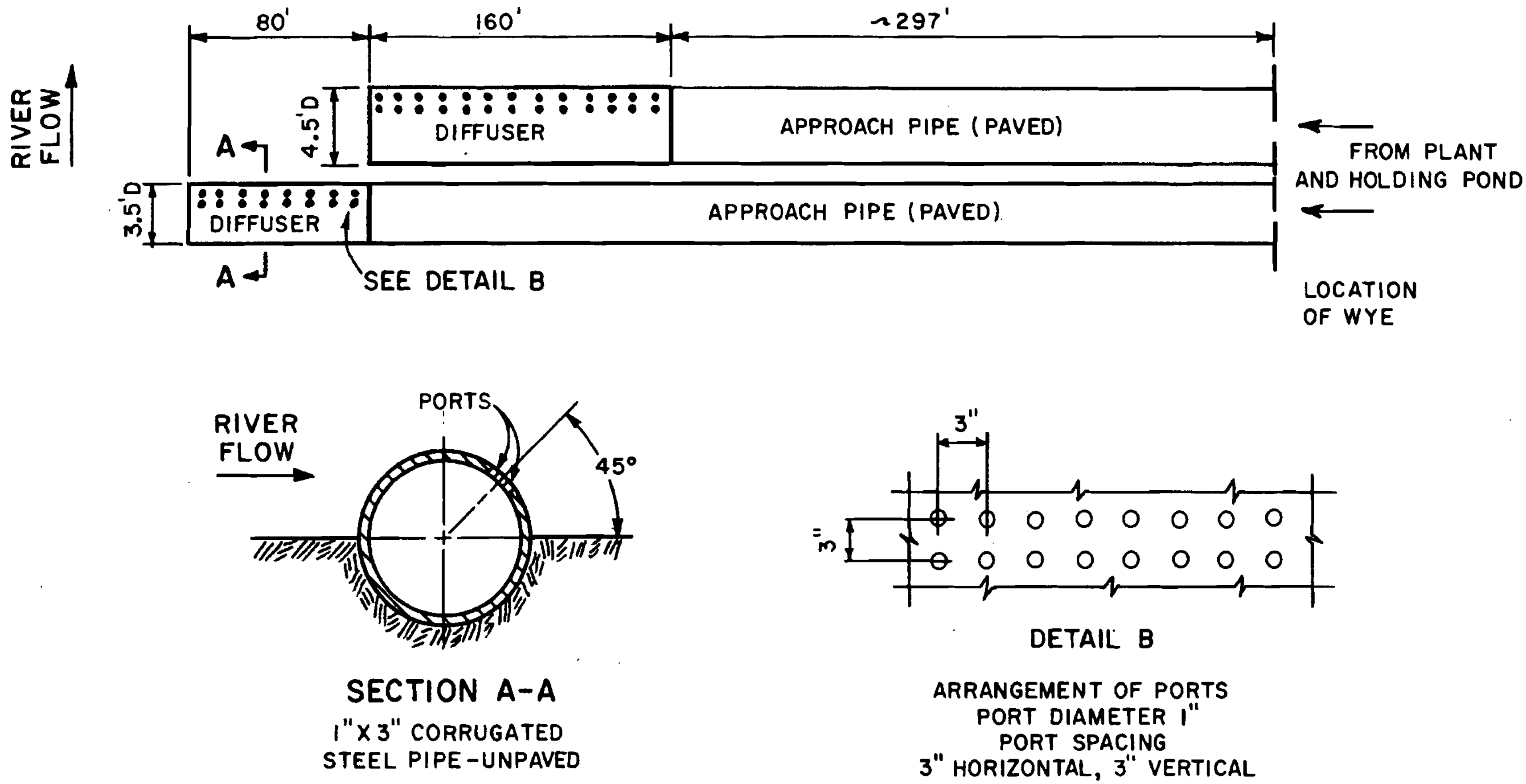

Figure 3: Description of Multiport Diffuser System
Watts Bar Nuclear Plant

river bottom and extends its entire length of 80 feet beyond the dead end of the downstream diffuser pipe section. The port diameter, spacing and orientation of the upstream leg is the same as that of the downstream leg.

The location of the diffuser system at TRM 527.8 is shown in Figure 4. Both the upstream and downstream legs are located beneath the navigation channel, as indicated by buoy markers on Figure 4. The location of the diffuser was chosen so that the depth of water above the diffuser will be sufficient to allow for the safe passage of barges.

Discharge Rates

Blowdown will be discharged at a rate of between 44.6 and 85.0 cfs from the cooling tower basins so as to maintain the concentration of dissolved solids in the cooling towers at approximately twice that found in the Tennessee River (Reference 3). Blowdown will be discharged into a holding pond of approximately 190 acre-feet capacity during periods of no releases from Watts Bar Dam to avoid exceeding applicable thermal standards. When sufficient water is released from Watts Bar Dam (at least 3500 cfs), blowdown may again be discharged to the river. Blowdown from the holding pond can be discharged to the river at a rate of 60.2 to 85.0 cfs.

Modes of Operation

A mode of operation for the diffuser system is defined as any one of the possible combinations of diffuser pipe sections which may discharge blowdown under particular circumstances. Thus, for the

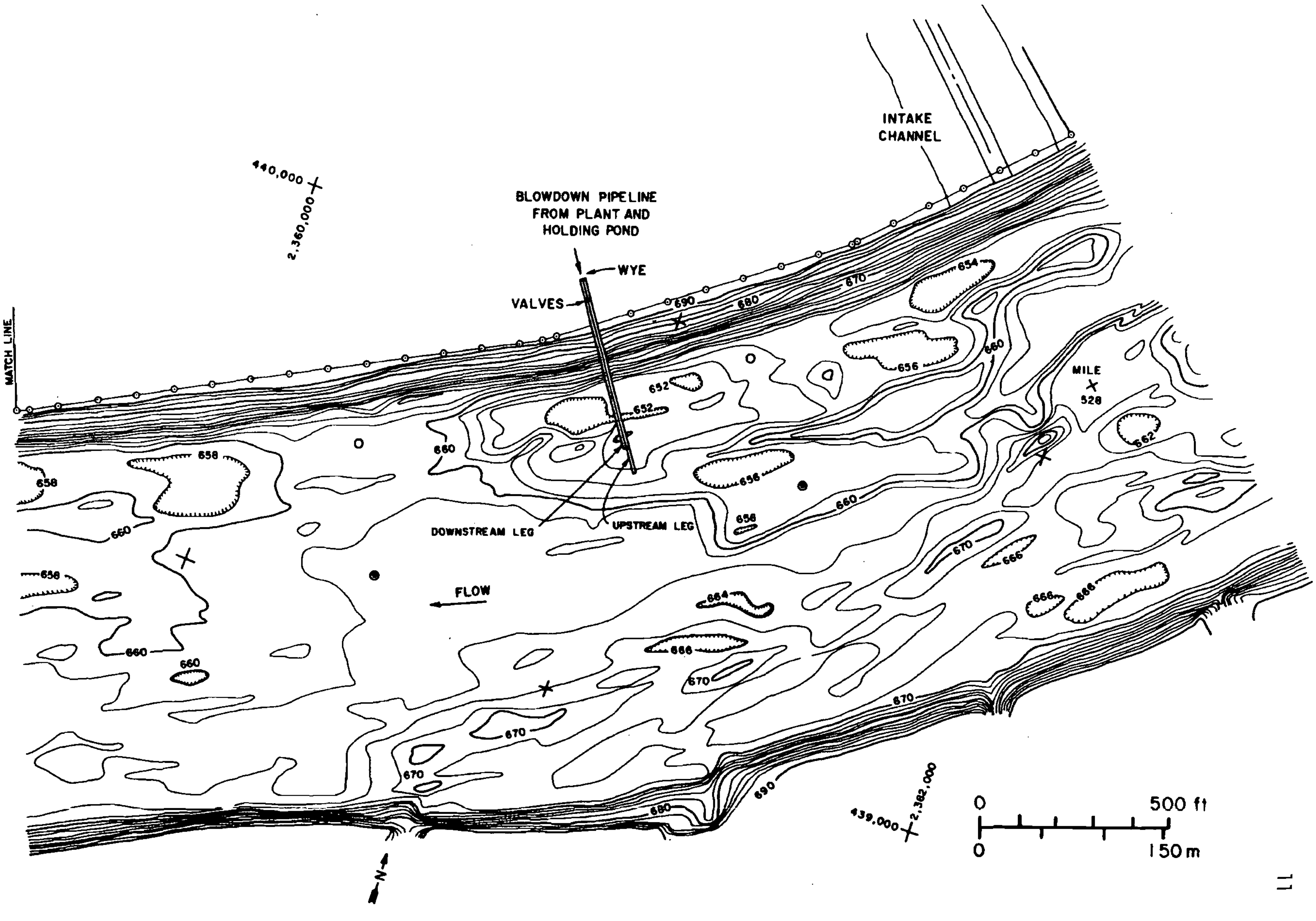

Figure 4 – Location of Multiport Diffuser System
Watts Bar Nuclear Plant

Watts Bar Nuclear Plant diffuser system, the first mode consists of only the upstream leg discharging blowdown; the second mode consists of only the downstream leg discharging blowdown; and the third mode consists of both the upstream and downstream legs discharging blowdown. Mode 1 is used when either unit 1 or unit 2 is operated alone and there is no holding pond discharge. Mode 2 is used when both units are operated simultaneously and there is no holding pond discharge or when stored blowdown is discharged from the holding pond and there is no discharge from the cooling tower basins. Mode 3 is used when either or both of the units are operated at the same time as stored blowdown is discharged from the holding pond. Table 3 summarizes the minimum and maximum blowdown flow rates that can be expected for each mode.

Operational Characteristics

The operational characteristics for the minimum and maximum flows of each mode are summarized in Table 4. The average jet exit velocity, approach pipe velocity and the required head at three locations in the pipe are presented. Table 4 shows that the average jet exit velocity varies from 6.8 to 17.3 feet per second (fps) for all the operational modes, which provides ample mixing.

Discharge Temperature

The discharge temperature will depend primarily on the blowdown temperature from the natural draft cooling towers. Heat losses will occur when blowdown is stored in the holding pond, but these losses are conservatively assumed to be zero for this analysis.

Table 3

Summary of Modes of Operation
Blowdown Diffuser System
Watts Bar Nuclear Plant

	Mode of Operation	Diffuser System Flow Rate		Distribution of Flow			
				Minimum		Maximum	
		Minimum (cfs)	Maximum (cfs)	Upstream Leg (cfs)	Downstream Leg (cfs)	Upstream Leg (cfs)	Downstream Leg (cfs)
1	One unit only	22.3	50.0	22.3	----	50.0	----
2	Two units only or Holding pond discharge only	44.6	85.0	----	44.6	----	85.0
3	Either or both units + Holding pond discharge	82.5	170.0	27.5	55.0	56.7	113.3

Blowdown rate for one unit: 22.3 - 50.0 cfs
Blowdown rate for two units: 44.6 - 85.0 cfs
Holding pond discharge rate: 60.2 - 85.0 cfs

Table 4

Operating Properties of Blowdown Diffusers

Watts Bar Nuclear Plant

	Individual Operation of Diffuser Legs				Combined Operation of Diffuser Legs			
	Mode 1		Mode 2		Mode 3			
	Upstream Leg		Downstream Leg		Minimum		Maximum	
	Minimum	Maximum	Minimum	Maximum	Upstream	Downstream	Upstream	Downstream
Blowdown Rate (cfs)	22.3	50.0	44.6	85.0	27.5	55.0	56.7	113.3
Port Velocity (fps)	6.8	15.3	6.8	13.0	8.4	8.4	17.3	17.3
Approach Pipe Velocity (fps)	2.3	5.2	2.8	5.3	2.9	3.5	5.9	7.1
Dead End Head (ft)	1.6	8.1	1.6	5.8	2.4	2.4	10.4	10.4
Diffuser Head Req'd (ft)	1.7	8.4	1.7	6.3	2.5	2.6	10.8	11.1
Total Head Req'd (ft) from Wye	1.9	9.4	1.8	6.7	2.8	2.8	12.1	11.9

Blowdown Temperature

The performance characteristics of the natural draft cooling towers at the site depend primarily on the wet bulb temperature. A summary of wet bulb temperatures applicable to Watts Bar based on 11 years of record at Chattanooga, Tennessee, is given in Table 5 (Reference 5). The estimated blowdown temperature from the natural draft cooling towers is shown as a function of the wet bulb temperature on Figure 5. The relationship between blowdown and wet bulb temperatures is given as a polynomial curve fit of monthly average blowdown temperature computed as a function of monthly average meteorological data. The performance curve for natural draft cooling towers has been provided by Research Cottrell, Inc. (Reference 6). The predicted yearly cycle of blowdown temperatures for natural draft cooling towers, based on these wet bulb temperatures and estimated performance characteristics, is given in Table 6. Average blowdown temperatures range from 63°F in January to 85°F in July. The maximum blowdown temperature is 95°F.

River Temperature

A summary of tailrace temperatures at Watts Bar Dam is given in Table 7. These temperatures are representative of water temperatures at the plant site and will be used to compute expected initial temperature differences between the blowdown and the river before mixing. Table 7 shows that monthly average river temperatures vary from 43.5°F in January to 76.5°F in August. The maximum weekly observed tailrace temperature was 86.0°F in July and August, and the minimum weekly tailrace temperature was 32.0°F in January.

Table 5

Summary of Wet Bulb Temperatures

National Weather Service

Chattanooga, Tennessee

1963 - 1973

Month	Trihourly Maximum (°F)	Monthly Average +σ (°F)	Monthly Average (°F)	Monthly Average -σ (°F)	Trihourly Minimum (°F)
January	65	45.6	33.6	21.6	- 9
February	64	43.7	33.9	24.1	2
March	70	54.5	44.1	33.7	15
April	74	62.5	53.5	44.5	27
May	77	67.8	60.5	53.2	33
June	80	73.2	67.9	62.6	42
July	82	74.8	70.5	66.2	52
August	83	75.3	70.5	65.7	53
September	79	71.9	65.4	58.9	34
October	75	63.2	54.1	45.0	27
November	71	55.6	44.8	34.0	11
December	68	48.9	37.6	26.3	9

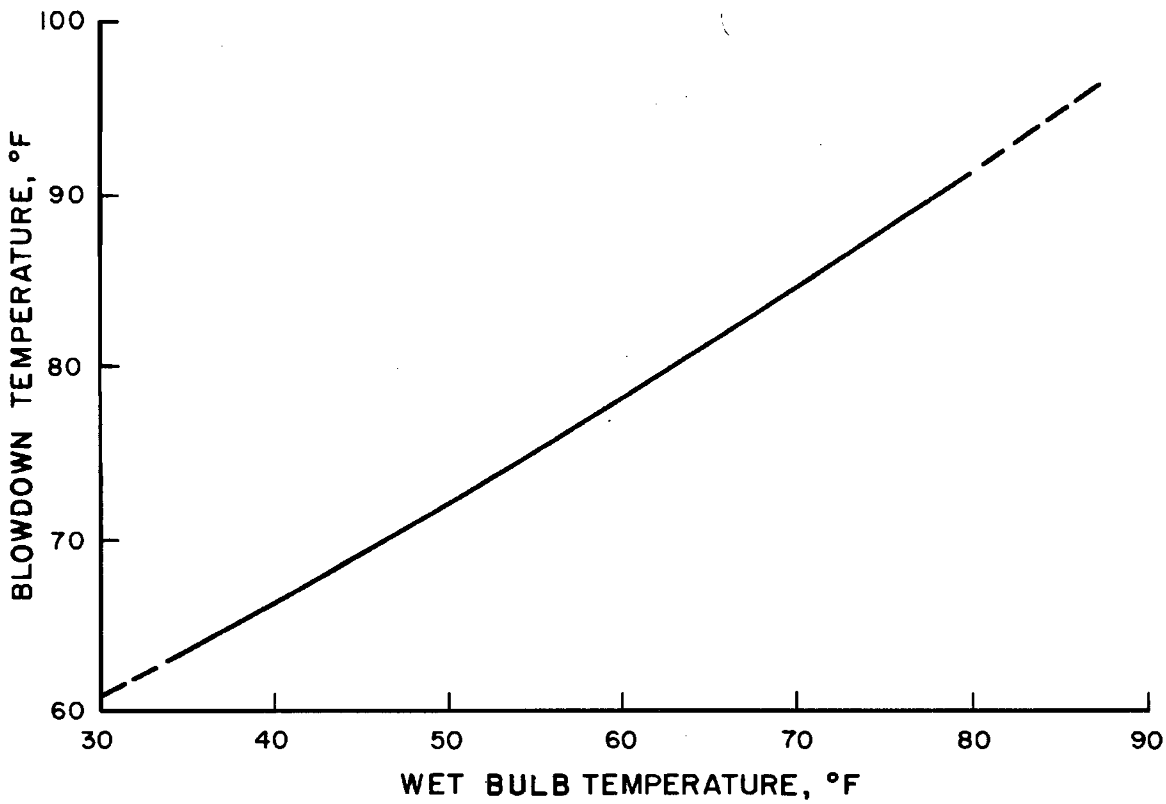

Figure 5 : Cooling Tower Performance Curve
Watts Bar Nuclear Plant

Table 6

Summary of Blowdown Temperatures

Watts Bar Nuclear Plant

Month	Monthly Average +σ (°F)	Monthly Average (°F)	Monthly Average -σ (°F)
January	69	63	(57)[1]
February	68	64	(59)
March	74	68	63
April	79	74	69
May	83	78	74
June	86	82	79
July	87	85	82
August	88	84	81
September	85	81	77
October	80	74	69
November	75	68	63
December	71	66	(60)

1. Parentheses indicate blowdown temperatures based upon extrapolated cooling tower performance curves.

Table 7

Summary of Tailrace Temperatures

Watts Bar Dam

February 1950 - September 1977

Month	Minimum (°F)	Average (°F)	Maximum (°F)
January	32.0	43.5	51.8
February	36.5	43.9	62.6
March	37.4	48.9	62.6
April	47.8	56.8	65.3
May	48.2	66.0	76.1
June	64.4	72.7	84.2
July	67.1	76.1	86.0
August	69.8	76.5	86.0
September	64.4	75.6	81.5
October	48.2	68.5	77.0
November	41.9	57.9	71.6
December	37.4	48.7	59.0
AVERAGE		60.5	

n.b. Based upon 1320 weekly observations, varying in number from 40 to 67 in any full year of record. Data missing for 1956, January-June 1957 and February 1969.

A summary of the probability of high tailrace temperatures is given in Table 8, showing river temperatures approaching the State of Tennessee maximum water temperature standard of 86.9°F (30.5°C).

Temperature Difference Between Blowdown and River Before Mixing

Table 9 shows the temperature difference between the blowdown and the river before mixing. Although the difference between the maximum possible blowdown temperature and the minimum observed river temperature is the greatest positive temperature difference, the conditions necessary to produce the maximum blowdown temperature and the minimum weekly river temperature are highly unlikely to occur simultaneously. The maximum blowdown temperature will most likely occur when the wet bulb temperature is the highest and the minimum river temperature will occur when the wet bulb temperature is the lowest. For the purpose of evaluating discharge system effects, it is more realistic to use the temperature difference between the average tri-hourly blowdown temperature plus one standard deviation for each month and the minimum weekly river temperature for each month for design conditions. Table 9 shows that the expected differences between blowdown and river temperatures before mixing vary from -9°F in November to 37°F in January and March.

Table 8

Probability of High Tailrace Temperatures

Watts Bar Dam

February 1950 - September 1977

T_i (°C)	T_i (°F)	Percentage of Weekly Observations Exceeding T_i (percent/year)	Average No. of Weekly Observations Exceeding T_i (No./year)
23.5	74.3	23.1	12.0
24.5	76.1	15.8	8.2
25.5	77.9	7.3	3.8
26.5	79.7	3.1	1.6
27.5	81.5	0.7	0.4
28.5	83.3	0.5	0.2
29.5	85.1	0.3	0.2
30.5	86.9	0.0	0.00

n.b. Based upon 1320 weekly observations, varying in number from 40 to 67 in any full year of record. Data missing for 1956, January-June 1957 and February 1969.

Table 9

Before Mixing

Watts Bar Nuclear Plant

Month	$T_{B_{-\sigma}} - T_{R_{max}}$ (°F)	$T_{B_{avg}} - T_{R_{avg}}$ (°F)	$T_{B_{+\sigma}} - T_{R_{min}}$ (°F)
January	(5)[1]	19	37
February	(4)	20	32
March	0	19	37
April	4	17	31
May	-2	12	35
June	-5	9	22
July	-4	9	11
August	-5	7	18
September	-5	5	21
October	-8	6	32
November	-9	10	33
December	(1)	17	34
AVERAGE		13	

1. Parentheses indicate temperature differences computed using blowdown temperatures based upon extrapolated cooling tower performance curves.

WATTS BAR STEAM PLANT DISCHARGE CHARACTERISTICS

Intake and Discharge Design

Once-through cooling water for the plant is supplied by gravity from Watts Bar Dam through a conduit system approximately 3,600 feet long. The centerline of the intake opening is located at elevation 716 feet and is contiguous with the upstream face of Watts Bar Dam at the right abutment of the dam. After passing through the condensers, the heated water is discharged via an open canal to a concrete drop structure (also known as a "morning glory") from which it is discharged into the river through a seven-foot wide by ten-foot high culvert. The culvert outlet has a top elevation of 675.0 feet which coincides with the minimum pool of Chickamauga Lake. Topography in the vicinity of the discharge area is given in Figure 6.

Discharge Rate and Temperature

When the plant is operated at rated capacity, the plant requires 626 cfs of cooling water and raises the temperature of water withdrawn through Watts Bar Dam by 10°F. Higher discharge rates of 775 cfs with correspondingly lower condenser temperature rises have been noted during water temperature surveys.

Because the elevation of the centerline of the turbines (elevation 676 feet, approximately 60 feet deep) is 40 feet below the steam plant intake, water temperatures entering the turbines in the dam could theoretically be lower than water temperatures entering the steam plant when Watts Bar Lake is stratified. A study of withdrawal layers into

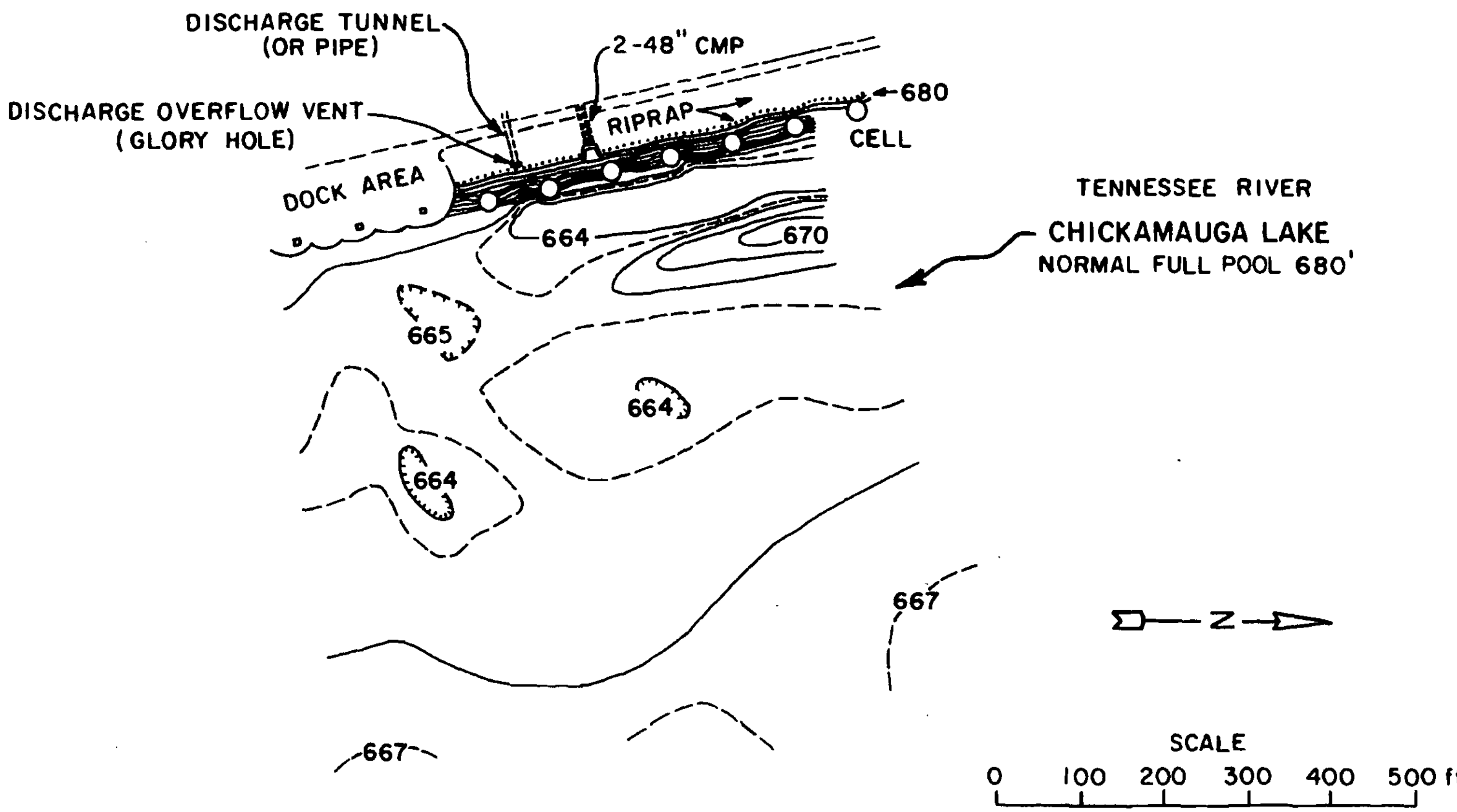

Figure 6: Condenser Water Discharge Area
Watts Bar Steam Plant

the turbines at Watts Bar Dam indicates that water from all depths enter the turbines, even when a warm surface layer is present in the summer months (Reference 7). Therefore the temperature of water entering the steam plant should be approximately equal to the temperature of water entering the turbines at Watts Bar Dam. The maximum 10°F condenser temperature rise at the Watts Bar Steam Plant is thus representative of the maximum difference between the steam plant discharge temperature and the river temperature before mixing.

NEAR-FIELD MIXING OF PLANT DISCHARGES

Watts Bar Nuclear Plant Diffuser

An analytical expression for the dilution induced by a submerged slot diffuser in shallow water was developed by Adams (Reference 8):

$$S = \tfrac{1}{2}(V \sin \gamma + (V^2 \sin^2\gamma + 2 \cos \theta)^{\frac{1}{2}}) \qquad (1)$$

where S = dilution

$= \dfrac{\text{entrained river flow + diffuser flow}}{\text{diffuser flow}}$

$$V = \frac{u_a h}{u_o B} = \frac{Q_R L}{Q_B w} = \text{volume flux ratio}$$

u_a = average river velocity across the diffuser

u_o = jet exit velocity

h = average river depth

B = slot width

Q_R = river flow at diffuser site = $u_a wh$

Q_B = diffuser flow = $u_o LB$

L = diffuser length

w = average river width

γ = orientation angle of diffuser in river (γ = 90°; perpendicular to river flow)

θ = discharge angle from river bottom (θ = 0°; parallel to river bottom)

Hydrothermal model tests discussed in Reference 2 showed that this equation could be used to conservatively predict the performance of the multiport diffuser system at the Watts Bar Nuclear Plant.

The two-dimensional structure of the discharge plume was predicted using the method of Jirka which is based on the theory of Adams (Reference 9). Full vertical mixing of the discharge plume and the receiving water was predicted for the following criterion:

$$F_T \; S^{3/2} \geq 1.0 \tag{2}$$

where

$$F_T = \frac{F_s}{h/_B{}^{3/2}} = \text{diffuser load}$$

F_s = slot densimetric Froude number

$$= \frac{u_o}{g'B}$$

$$g' = \frac{(\rho_o - \rho_a)g}{\rho_a}$$

ρ_o = density of discharge

ρ_a = density of ambient river water

g = gravitational constant

In general, stratified conditions downstream of the discharge were predicted when this criterion was not met. For the Watts Bar Nuclear Plant diffuser system, the variety of discharge conditions can result in either fully mixed or stratified conditions downstream of the discharge. For the maximum diffuser system flow, fully mixed conditions result.

Table 10 shows the design values of the diffuser parameters given in Equation 1. These design values correspond to the minimum Tennessee River flow of 3,500 cfs past the site and the maximum diffuser discharge of 170 cfs. Equation 1 predicts a diffuser-induced dilution of 16 for these conditions. Table 11 shows the expected mixed

Table 10

Design Values
Of Diffuser Parameters

Symbol Primary	Parameter	Units	Design Value
u_o	Discharge Velocity (max)	m/s (fps)	5.3 (17.3)
u_a	Average River Velocity	cm/s (fps)	4.9 (0.16)
B	Equivalent Slot Width	cm (ft)	1.33 (0.0436)
h	River Depth (min)	m (ft)	6.7 (22)
Secondary			
γ	Orientation Angle to River Flow	deg	90
θ	Discharge Angle	deg	45
g'	Buoyancy (max)	$cm/sec^2 (ft/sec^2)$	6.1(0.20)
	(min)	$cm/sec^2 (ft/sec^2)$	-1.5(-0.05)
L	Diffuser Length (max)	m(ft)	69(225)
	(min)	m(ft)	23(75)
Analytical Theory (Reference 6)			
h/B	Submergence	--	505
V	Volume Flux Ratio	--	4.7
S	Dilution	--	16

Table 11

Expected Mixed Temperature Rise at
Edge of Diffuser Mixing Zone
Watts Bar Nuclear Plant

Month	Minimum	Average	Maximum
January	(0.3)[1]	1.2	2.3
February	(0.3)	1.3	2.0
March	0.0	1.2	2.3
April	0.3	1.1	1.9
May	-0.1	0.8	2.2
June	-0.3	0.6	1.4
July	-0.3	0.6	0.7
August	-0.3	0.4	1.1
September	-0.3	0.3	1.3
October	-0.5	0.4	2.0
November	-0.6	0.6	2.1
December	(0.1)	1.1	2.1
AVERAGE		0.8	

1. Parentheses indicate mixed temperature rises computed using blowdown temperatures based upon extrapolated cooling tower performance curves.

temperature rises at the edge of the area of diffuser-induced mixing using the initial temperature differences between the blowdown and the river before mixing shown in Table 9. Mixed temperature rises vary from -0.6°F in November to 2.3°F in January and March, averaging 0.8°F. Figure 7 shows the maximum expected mixed temperature rise as a function of river flow assuming an initial temperature difference between the blowdown and the river before mixing of 37°F in January and March.

The results of the hydrothermal model tests indicated there was no concentration of the discharge near the right bank. In addition, the discharge plume did not form a thermal wedge upstream of the diffuser even at the highest discharge buoyancy. In the model, the tendency of the discharge plume to form vertically mixed conditions downstream of the diffuser was well predicted by the theory of Adams. Similar plume structure is predicted for the actual diffuser design.

The results of the model tests showed that the expected diffuser-induced dilution was achieved approximately one diffuser length downstream. Thus, the area of diffuser-induced mixing extends approximately 160 feet downstream when the downstream leg of the diffuser system is discharging; approximately 80 feet downstream when the upstream leg of the diffuser system is discharging; and 240 feet downstream when both legs of the diffuser system are discharging. The proposed mixing zone should encompass all of these modes of operation and should extend 240 feet downstream over the entire river depth and diffuser system width (240 feet).

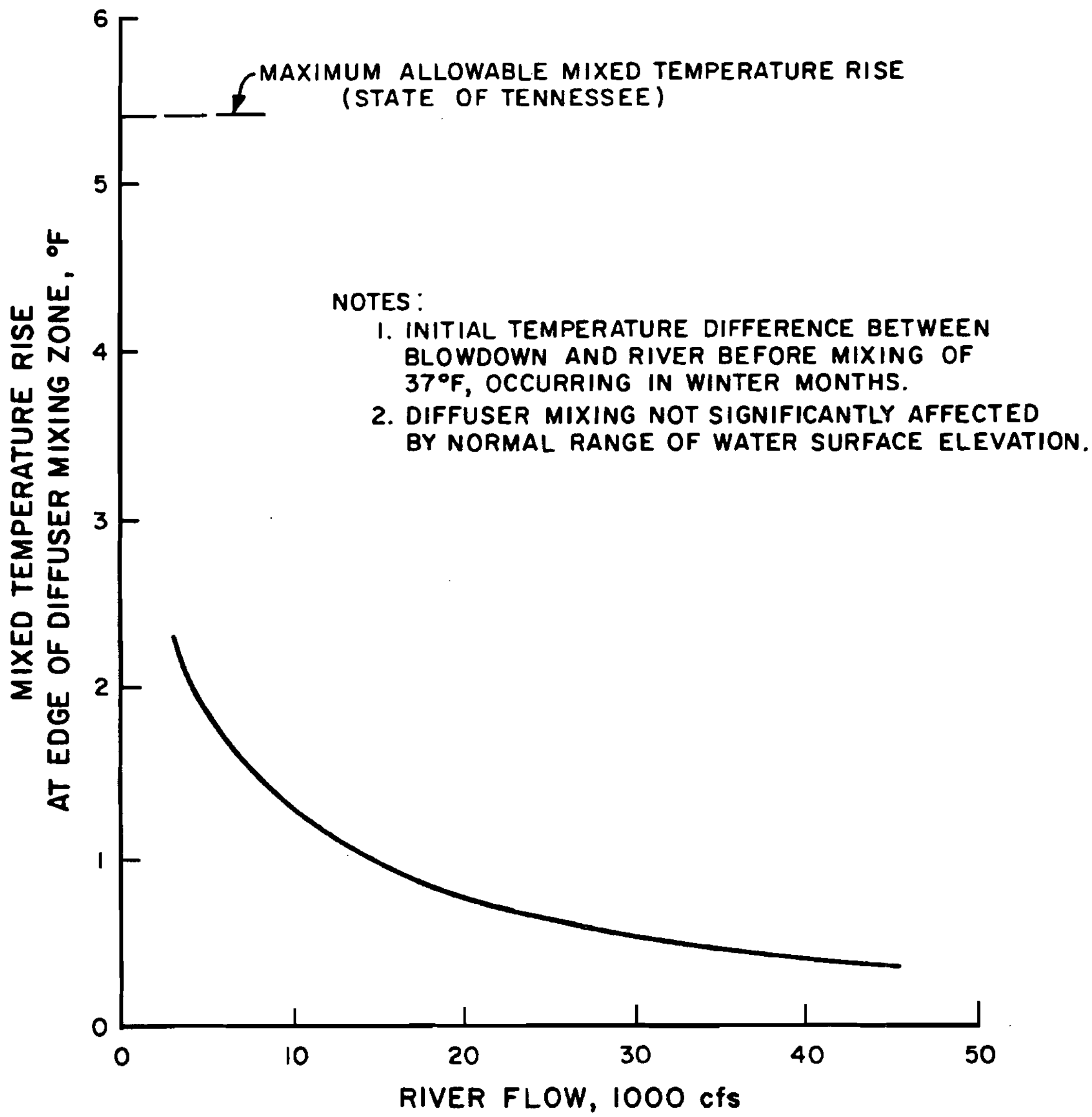

Figure 7: Maximum Mixed Temperature Rise at Edge of Diffuser Mixing Zone Watts Bar Nuclear Plant

Watts Bar Steam Plant Surface Discharge

Mixing With River Flow

The maximum initial temperature rise of 10°F above ambient of the surface discharge is reduced by turbulent mixing of the discharge with the receiving water. This mixing is a result of the relative velocity of the river, which is a function of the dam discharge and water surface elevation, and of the surface discharge, which has a maximum velocity of 9-11 fps perpendicular to the shoreline.

The dilution achieved by the steam plant discharge was modeled using the surface jet model of Shirazi and Davis (Reference 10). The maximum mixed temperature rise after initial mixing at the five-foot depth is shown on Figure 8 as a function of river flow and water surface elevation. The maximum temperature rise of 5°F occurs on the plume centerline at a river flow of 5000 cfs and a water surface elevation of 675.0 feet. The average temperature rise of the plume for these conditions is 3°F. This average is computed assuming a Gaussian lateral temperature distribution and a plume width of four standard deviations (Reference 10). The maximum mixed temperature rises shown in Figure 8 occur in the winter months when ambient river temperatures are below 50°F. When ambient river temperatures are higher than 50°F, the mixed temperature rises can be as much as 0.5°F lower than those in Figure 8. Mixed temperature rises are larger in the winter because of the non-linear, density-temperature relationship for water.

The size of the initial mixing region for the steam plant discharge depends on the magnitude of the river flow, but the region does not extend more than 300-800 feet from the discharge point.

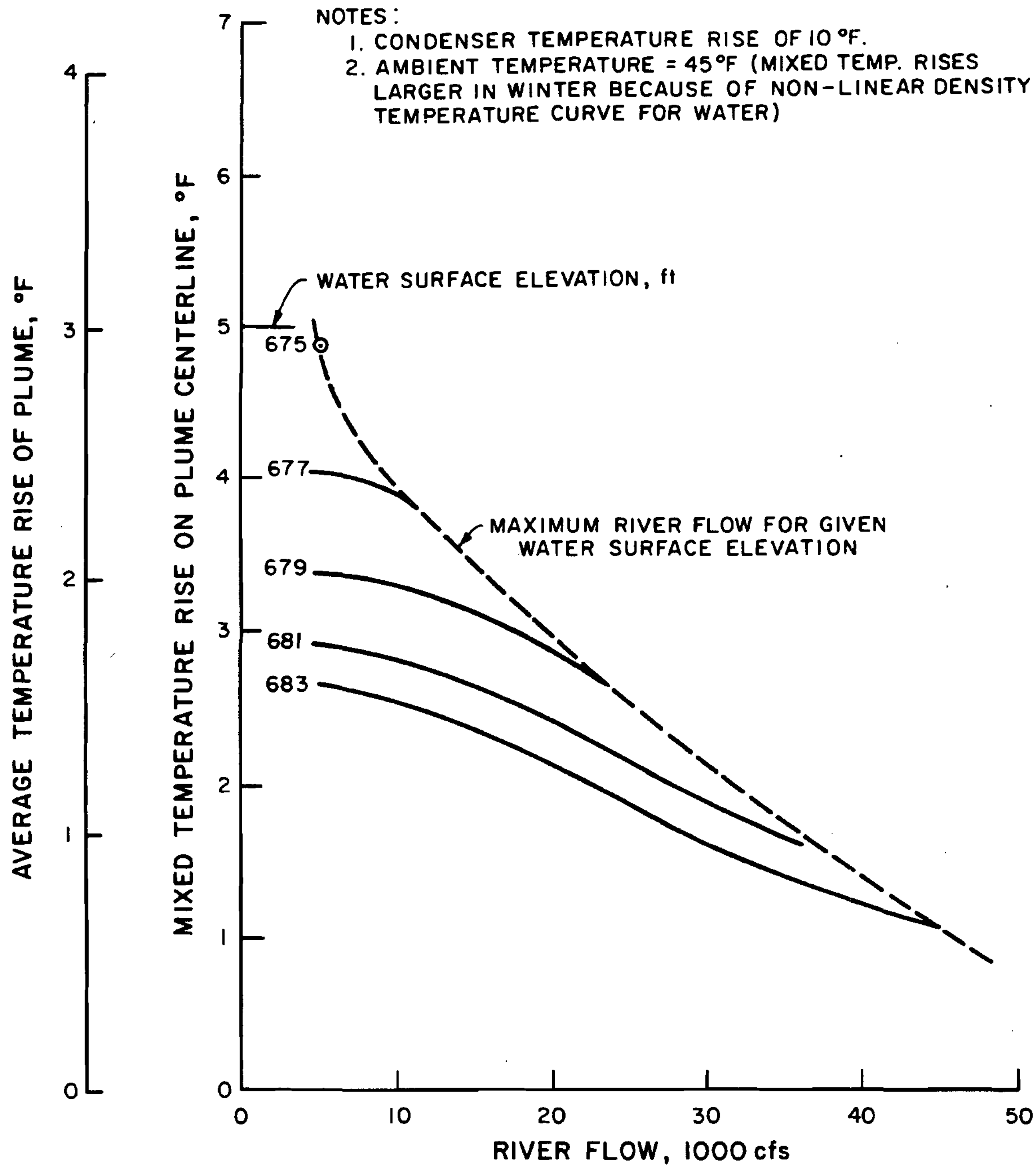

Figure 8: Maximum Mixed Temperature Rise After Initial Mixing at the Five Foot Depth Watts Bar Steam Plant

The effect of river flow is to deflect the heated plume, confining its influence to a zone extending along the right bank of the river. The lateral extent of the induced temperature distribution increases with decreasing river flow. The induced temperature distribution in the river is very weakly stratified except in the region near the discharge. The combination of the relatively shallow river depth (10-20 feet) and the intense mixing induced by the discharge results in nearly complete vertical mixing.

Reference 4 discusses field observations of water temperatures downstream of the steam plant discharge during steady river flow. Dilution of the discharge was well predicted by the surface jet model of Shirazi and Davis (Reference 10).

<u>Mixing Without River Flow</u>

As previously mentioned, periods of no river flow can last as long as 12 hours because of the operation of Watts Bar Dam for peaking power purposes. During a shutdown of river flow, heated water is not convected away from the vicinity of the steam plant discharge and is reentrained in the mixing process, causing a gradual increase in temperatures in the vicinity of the plant.

Previous studies have shown the rate of temperature increases in the vicinity of the steam plant for no river flow periods of up to six hours (Reference 4). Immediately after shutdown, initial surface jet mixing reduced the maximum condenser temperature rise of 10°F to about 2-3°F. After six hours of shutdown, the temperature rise after surface jet mixing was about 3-4°F. The downstream and upstream extent of the temperature buildup was also time dependent with the

2°F isotherm shifting approximately 1000-1500 feet upstream during the six-hour shutdown. No extensive measurements of the warm water slug downstream of the steam plant were made. Temperature rises of less than 1°F were found downstream of the proposed nuclear plant discharge at TRM 527; however, these are primarily attributable to previous periods of steam plant discharge in the presence of river flow.

A study of the extent of temperature buildup caused by the steam plant discharge during a river flow shutdown of 12 hours duration were conducted on October 30, 1977, with all four steam plant units in operation. Figure 9 shows the longitudinal excess temperature distribution of the warm water slug compared to that of the previous study with a six hour shutdown. The effect of extended durations of river shutdown is to increase the longitudinal extent of the warm water slug downstream rather than the maximum temperature increase of the warm water slug. The downstream edge of the warm water slug proceeded downstream as a stratified surface layer, causing less than a 1°F temperature rise in the vicinity of the proposed nuclear plant discharge at TRM 527.8. Figure 9 shows that temperature measurements in the immediate vicinity of the steam plant discharge fluctuated between 2.5°F and 4.0°F, probably due to the high turbulence in the vicinity of the discharge. No significant difference occurred in the upstream longitudinal temperature distribution between the 6- and 12-hour shutdown. Apparently, the temperature distribution upstream of the steam plant discharge reaches a steady state condition after approximately six hours of no river flow.

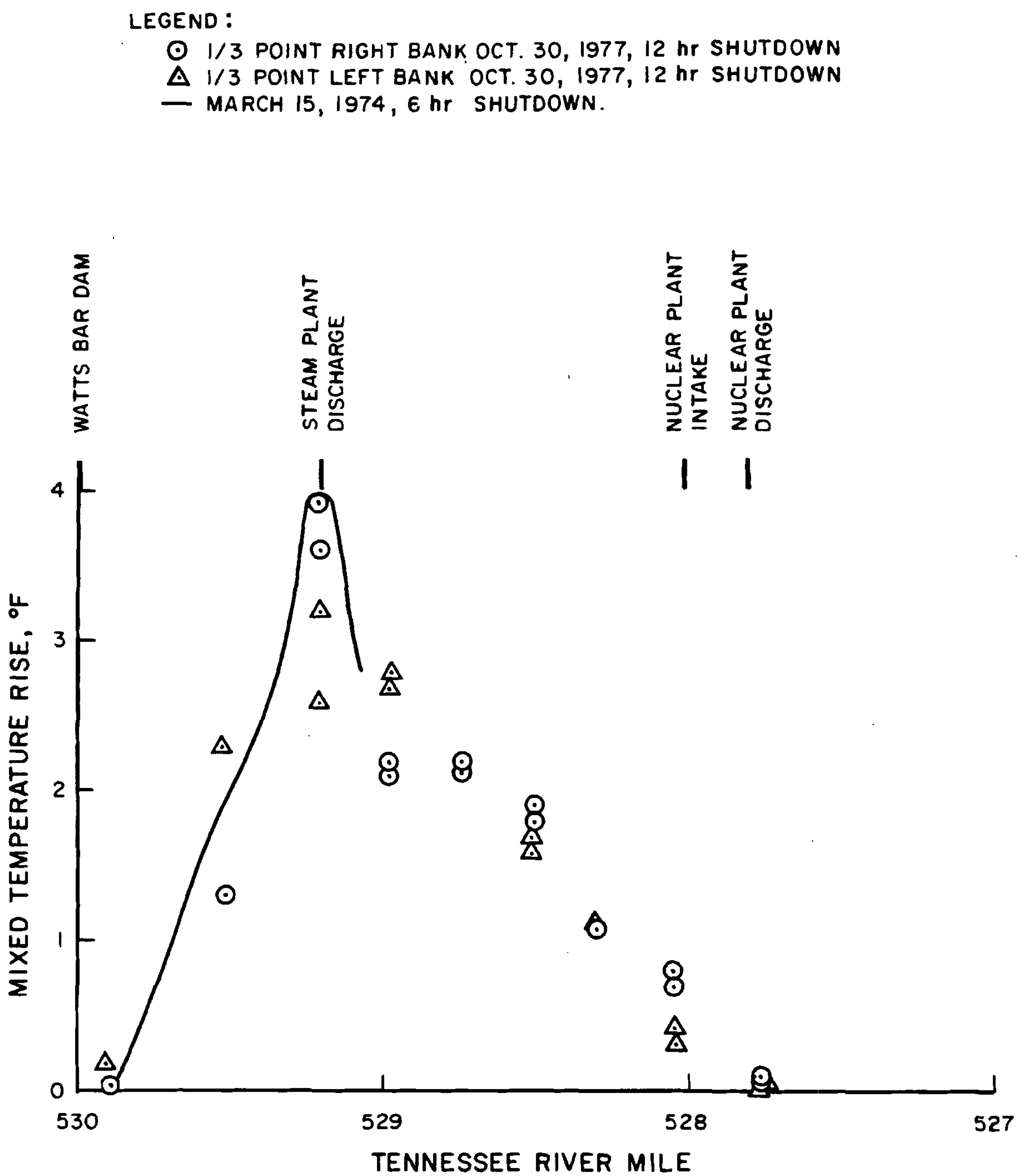

Figure 9: Longitudinal Excess Temperature Distribution
Below Watts Bar Dam
After Periods of Steam Plant Discharge and No River Flow

Combined Near Field Effect of Plant Discharges

Mixing With Steady River Flow

The combined mixed temperature rise of the Watts Bar Nuclear and Steam Plants at the downstream edge of the diffuser mixing zone can be calculated for steady river flow by adding the individual mixed temperature rises after near-field mixing for each case. The average mixed temperature rise of the steam plant plume is used because it is representative of the ambient temperature of water entrained by the nuclear plant diffuser. Water temperature surveys of the steam plant plume show that it hugs the right bank with the warmest temperatures occurring near the bank (Reference 4). Hydrothermal model tests of the nuclear plant diffuser showed no concentration of the diffuser discharge near the right bank (Reference 2). Lateral mixing in the river between the plants and turbulent diffuser mixing will result in a fairly uniform lateral temperature distribution at the downstream edge of the diffuser mixing zone.

Figure 10 shows the maximum mixed temperature rise at the five-foot depth of the combined plant discharges using the mixed temperature rises for the nuclear and steam plants in Figures 7 and 8, respectively. The maximum temperature rise for any flow or elevation is shown to be less than the maximum allowable temperature rise of the State of Tennessee of 5.4°F.

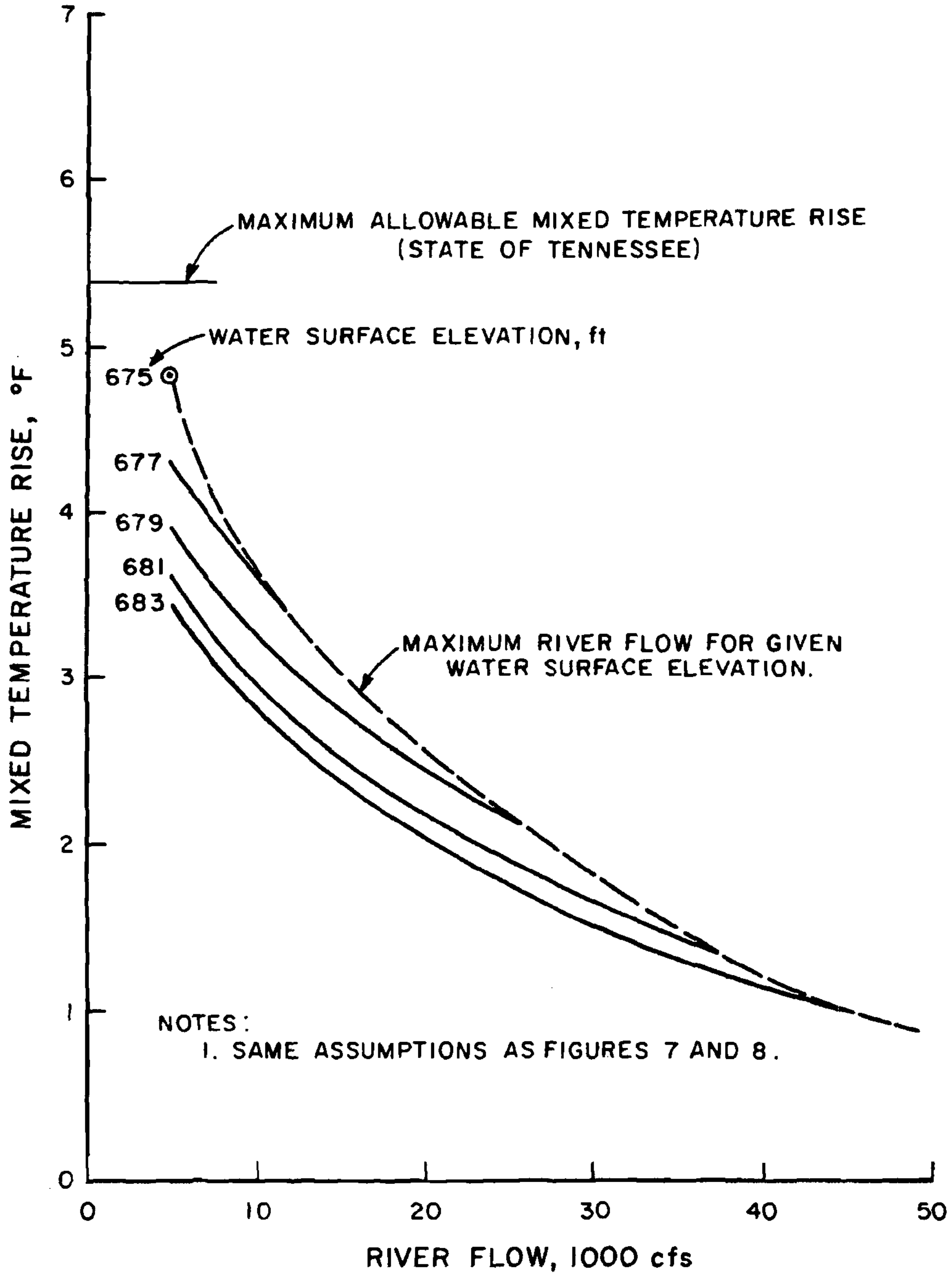

Figure 10: Maximum Mixed Temperature Rise at the Five Foot Depth After Initial Mixing Watts Bar Steam and Nuclear Plant

Mixing After Periods of No River Flow

The resumption of dam discharges following shutdown periods will advect the warm water slug discharge from the Watts Bar Steam Plant during the shutdown period past the Watts Bar Nuclear Plant diffuser. Blowdown will be discharged through the nuclear plant diffuser when the dam resumes operation and will entrain this warm water in the mixing process. Higher mixed temperature changes and rates of temperature change can occur.

Temperature changes and rates of temperature change immediately following no release periods at Watts Bar Dam were analyzed using an advection model for the movement of the warm water slug downstream. The mixing of the nuclear plant diffuser and the steam plant surface discharge after the resumption of river flow were analyzed as discussed previously.

Model Assumptions--The assumptions for the model were the following:

1. River flow and elevation at the downstream edge of the diffuser mixing zone were the same as the flow and elevation at the tailwater of Watts Bar Dam, with an appropriate time delay to account for the travel time of discharge waves from the dam.
2. River velocity was computed using cross-sectional areas derived from field measured flow and velocity data according to the relation:

   $A = (z-z_0)\ b$

where A = cross-sectional area

z = water surface elevation

z_o = bottom elevation downstream of diffuser

= 661.0 feet

b = effective flow-carrying river width

≅ 800 feet

3. Maximum discharge rates and temperature rises from the steam and nuclear plants (Figures 7 and 8).
4. The initial temperature distribution of the warm water slug after 12 hours of no discharge from the dam was used neglecting the scattered temperature measurements in the immediate vicinity of the steam plant discharge (Figure 9). An average of the temperatures measured at the discharge point was used in developing a curve fit for the initial temperature distribution.
5. No surface heat loss from the river.
6. No dispersion of the warm water slug in the river.
7. Water temperature changes and rates of change attributable to the steam and nuclear plants are calculated as the difference in the measured water temperatures of water discharged through Watts Bar Dam and water at the downstream edge of the nuclear plant diffuser mixing zone.

For an input set of flow and elevation data, the model computes the temperature change and rate of temperature change every minute at a selected point of interest in the vicinity of the nuclear plant diffuser. The resulting temperature history can be analyzed for the maximum temperature rises and rates of rise.

Model Verification--Figure 11 shows a comparison of model results with measured data taken at TRM 527.8 after the resumption of river flow following a 12-hour river flow shutdown on October 30, 1977. Shown for reference on Figure 11 are the measured velocities near the surface and bottom during the survey. Low surface velocities existed before the resumption of dam discharges and signaled the arrival of a warm surface layer caused by the steam plant discharge. At higher river flows after 1300 hours, the velocity distribution was uniform with near-surface and near-bottom velocities of similar magnitude.

Figure 11 shows that the computed temperature history at the five-foot depth compares reasonably well with the measured temperature history at the same depth. The maximum temperature change and rate of change predicted by the model in Figure 11 were 2.7°F and 1.5°F/hr, respectively, compared to the measured values of 2.7°F and 1.8°F/hr, respectively. This comparison suggests that the model be used with an error margin for the rate of temperature change of about 0.3°F/hr. This margin would be expected to be smaller at higher flow rates when the rate of temperature change is limited by the maximum possible temperature change. The rate of temperature change was over predicted by the model after the passage of the center of the warm water slug. This is caused by the conservative assumption neglecting dispersion of the warm water slug in the river. The arrival time of the center of the warm water slug and the steady-state temperature rise of the steam plant discharge (using the plume average temperature rise in Figure 8) were well predicted by the model.

Model Results--Calculations of the maximum rate of temperature change at various water surface elevations and river flows were made

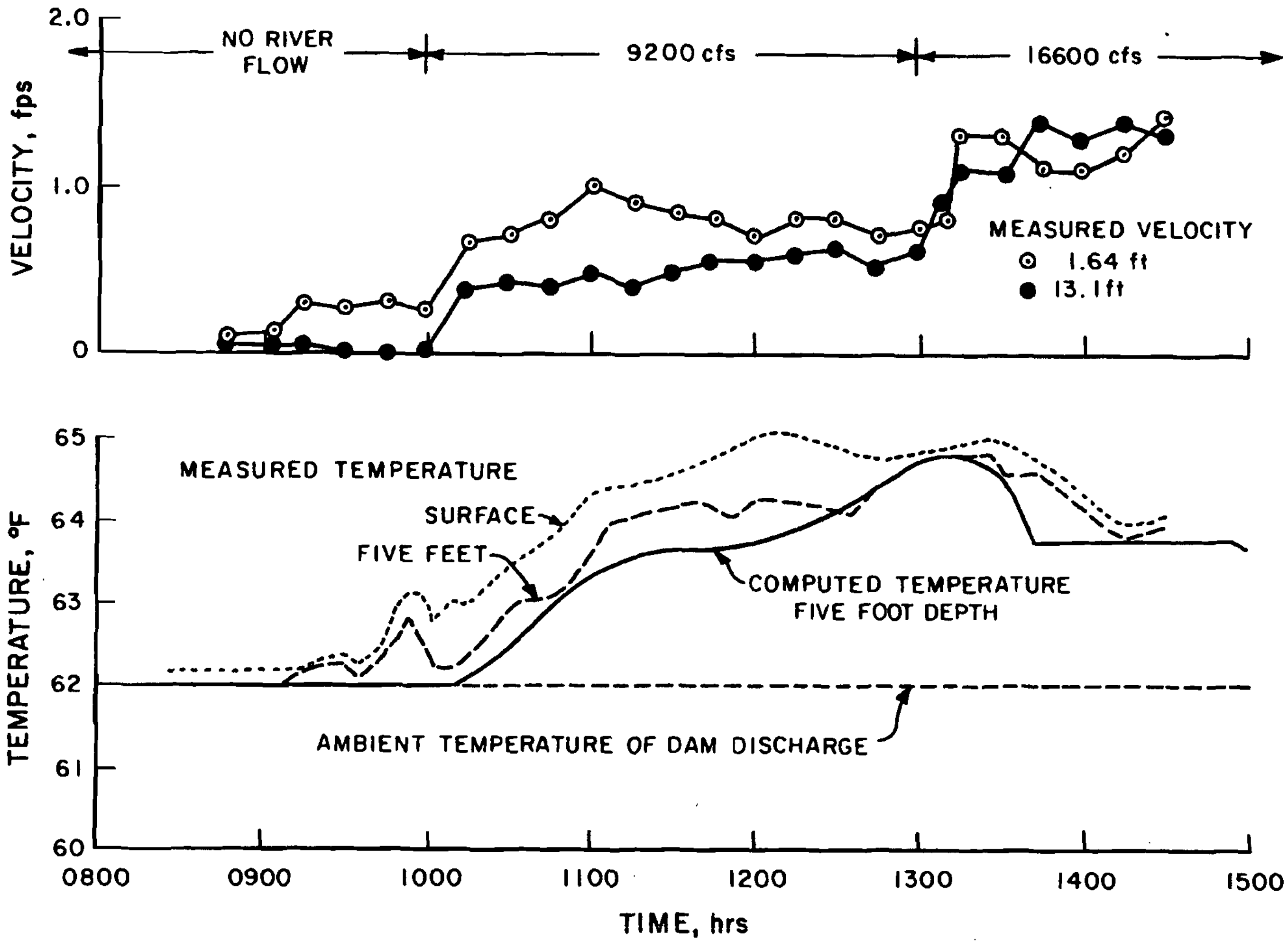

Figure 11: Velocity and Temperature at TRM 527.8, October 30, 1977 After 12 hrs of No Flow at Watts Bar Dam

using the model. Figure 12 shows that the maximum rate of temperature change was 2.7°F/hr when the nuclear plant was not in operation immediately following a 12-hour river flow shutdown. The maximum rate of change was reached at river flows greater than approximately 25,000 cfs and was limited by the maximum possible temperature rise in the warm water slug after 12 hours of no river flow.

Figure 13 shows that the maximum rate of temperature change was 3.3°F/hr when the nuclear plant was in operation immediately following 12 hour river flow shutdowns. The maximum rate of change was reached at river flows greater than approximately 25,000 cfs and was limited by the maximum possible temperature rise in the warm water slug and the maximum possible mixed temperature rise due to the nuclear plant discharge at river flows greater than 25,000 cfs.

The maximum rates of temperature change for steady river flows in Figure 13 are also the limiting rates of temperature change for normal startup conditions at Watts Bar Dam. These normal conditions are an increasing or steady number of turbines in operation, such as two units the first hour, three units the second hour and five units in succeeding hours. The only startup condition which was found to cause higher rates of temperature change were four units in the first hour and one unit in the second hour. This higher rate of temperature change could occur with an unlikely startup condition at Watts Bar Dam after a maximum shutdown period of 12 hours, maximum operation of Watts Bar Steam Plant and maximum operation of Watts Bar Nuclear Plant during the winter months with below normal river temperatures and above normal wet bulb temperatures. Thus, Figure 13 represents the maximum rate of temperature change to be expected downstream of the Watts Bar Nuclear Plant.

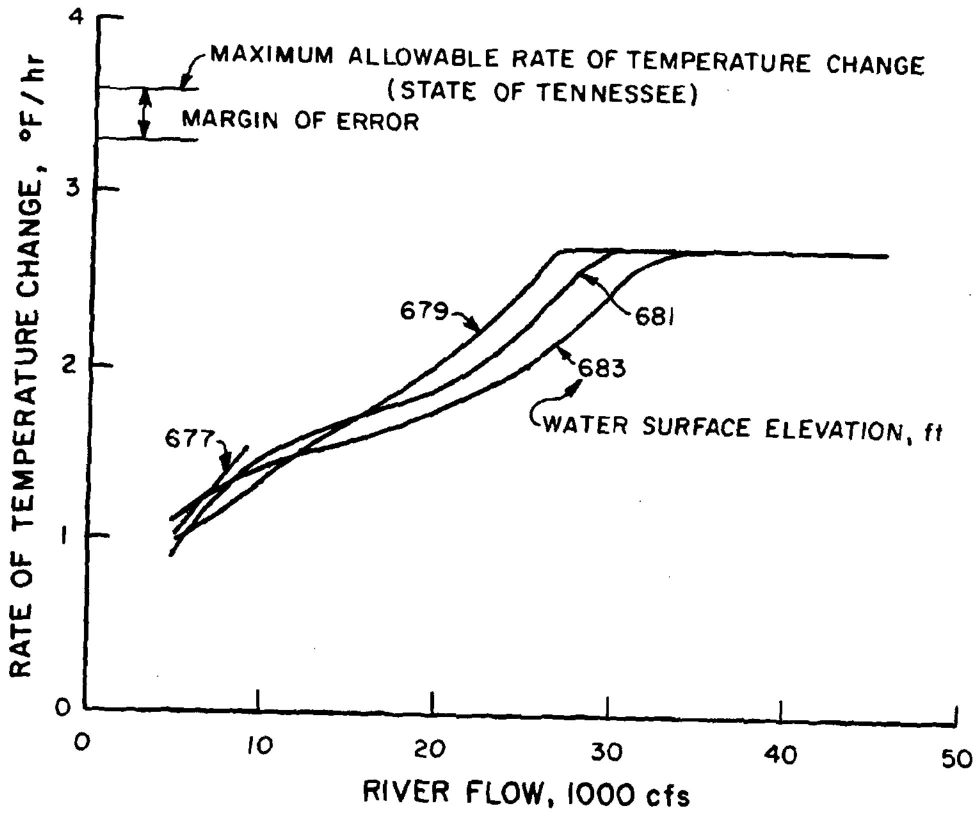

Figure 12 : Maximum Rate of Temperature Change Following 12 hr River Flow Shutdown Watts Bar Steam Plant

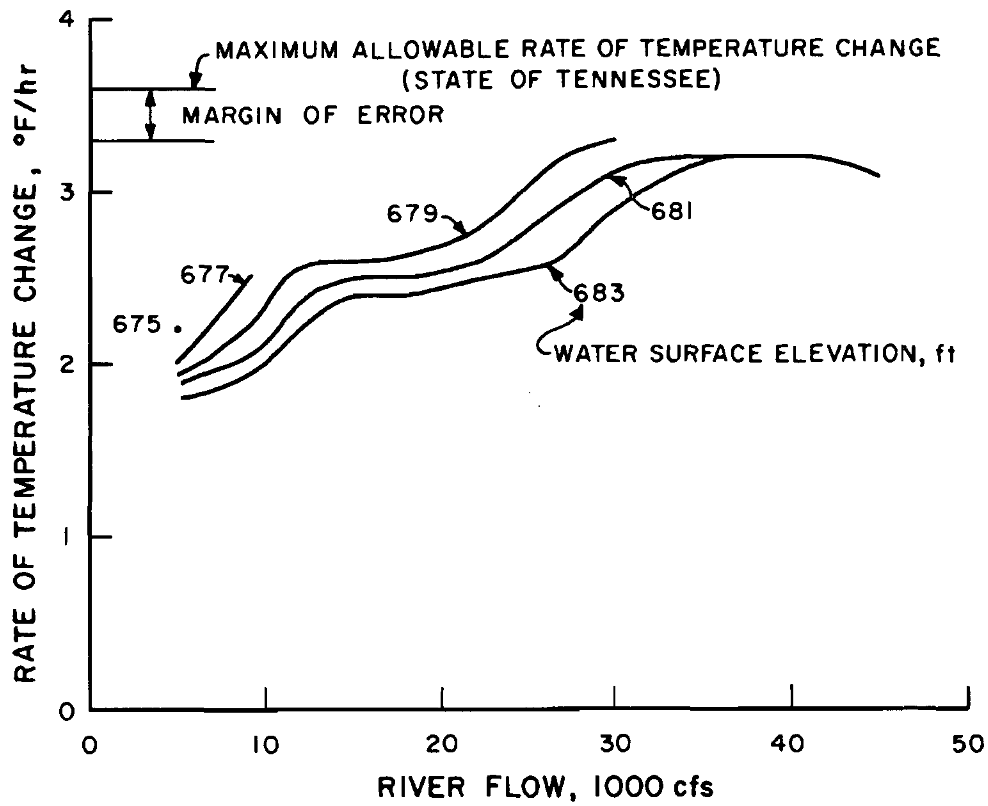

Figure 13 : Maximum Rate of Temperature Change
Following 12 hr River Flow Shutdown
Watts Bar Nuclear and Steam Plants

EVALUATION OF COMPLIANCE WITH THERMAL STANDARDS

Maximum Water Temperature

Discharges from the nuclear and steam plants will not cause a mixed temperature in the river greater than 86.9°F (30.5°C), except when tailrace temperatures at Watts Bar Dam approach or exceed 86.9°F (30.5°C). The discharge temperature from nuclear and steam plants may exceed 86.9°F in the months of April or May through October, and the tailrace temperature at Watts Bar Dam may approach 86.9°F in the months of June through September. Thus, if the tailrace temperature approaches or exceeds 86.9°F, the mixed temperature in the river may exceed 86.9°F due in part to the thermal discharges from the plants.

Maximum Water Temperature Change

The maximum mixed temperature rise caused by the nuclear plant diffuser discharge is 2.3°F in January and March (Figure 7). Thus, the diffuser discharge at the five-foot depth on the downstream edge of the diffuser mixing zone from the Watts Bar Nuclear Plant alone will not cause a water temperature change greater than 5.4°F (3°C) under any flow or meteorological condition.

The maximum mixed temperature rise caused by the steam plant surface discharge at the five-foot depth on the downstream edge of the diffuser mixing zone is 2.9°F during the winter months (Figure 8). The corresponding maximum temperature rise at the five-foot depth on the steam plant plume centerline is 4.9°F in the vicinity of the steam plant discharge. Thus, the surface discharge from the Watts Bar Steam

Plant alone will not cause a water temperature change greater than 5.4°F (3°C) under any flow or meteorological condition.

The maximum mixed temperature rise caused by the combined steam and nuclear plant discharge during steady river flows at the five-foot depth at the downstream edge of the diffuser mixing zone is 4.9°F during the winter months (Figure 10). The maximum mixed temperature rise caused by a warm water slug discharged by the steam plant during a 12-hour river flow shutdown is 2.7°F during the periods immediately following the resumption of river flow (Figure 11). The resumption of discharge from the nuclear plant immediately following this shutdown period would cause a total maximum water temperature change of 5.0°F (Figures 7 and 11). Thus, the combined operation of the Watts Bar Nuclear and Steam Plants will not cause a water temperature change greater than 5.4°F (3°C) under any flow or meteorological condition.

Maximum Rate of Temperature Change

Because the maximum mixed temperature rise caused by the nuclear plant discharge at the downstream edge of the diffuser mixing zone is 2.3°F, the maximum rate of change of temperature caused by the Watts Bar Nuclear Plant discharge alone will not exceed 3.6°F (2°C) per hour. Because the maximum mixed temperature caused by the steam plant discharge at the downstream edge of the diffuser mixing zone is 2.9°F, the maximum rate of change of temperature caused by the Watts Bar Steam Plant alone will not exceed 3.6°F (2°C) per hour.

If the steam plant and nuclear plant begin discharging at a time such that their respective discharges arrive at the downstream edge of the diffuser mixing zone within an hour of each other, the rate of rate of temperature change could exceed 3.6°F (2°C) per hour. Because the steam plant, due to its age, must increase from zero to full power very gradually, and because the temperature difference between the nuclear plant discharge and river is unlikely to be at its maximum expected value, it is not expected that a maximum rate of temperature change in excess of 3.6°F (2°C) per hour will occur for this condition. the resumption of river flow with the nuclear plant in operation (Figure 13). This value is 2.7°F/hr without the nuclear plant in operation (Figure 12). Thus, the combined operation of the steam and nuclear plants during this condition will not cause a rate of temperature change greater than 3.6°F (2°C) per hour.

Mixing Zone and Temperature Monitors

The proposed mixing zone for the nuclear plant should extend 240 feet downstream over the entire river depth and diffuser system width (240 feet) and should encompass all modes of operation of the discharge system.

Water temperatures measured near the downstream edge of the nuclear plant mixing zone and in the turbine discharge of Watts Bar Dam should be used to show the combined effect of the Watts Bar Nuclear and Steam Plants.

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ESTIMATES OF ENTRAINMENT OF FISH EGGS AND LARVAE BY WATTS BAR STEAM PLANT, 1975, AND ASSESSMENT OF THE IMPACT ON THE FISHERIES RESOURCE OF WATTS BAR RESERVOIR

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Fisheries and Waterfowl Resources Branch
Division of Forestry, Fisheries, and Wildlife Development
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CHAPTER 1

INTRODUCTION

The mortality of aquatic organisms resulting from entrainment in condenser cooling water constitutes a potential adverse ecological impact of steam-electric power plants. The general recognition of entrainment as a potential source of impact on fish populations has been a recent event; with a few notable exceptions (e.g., Kerr, 1953; Markowski, 1962), investigations of the phenomenon began in the late 1960's and first reached the open fisheries literature in the early 1970's. Carlson and McCann (1969) were apparently the first to estimate numbers and percentages of fish eggs and larvae entrained (at a pumped-storage power plant); Marcy (1971, 1973) combined entrainment and mortality studies of fish larvae at a steam-electric plant and established a standard method of estimating entrainment in flowing waters; and Coutant (1970, 1971, and 1974) has provided a conceptual framework for evaluating impact.

1.1 Objectives

This report presents results of investigations of entrainment of fish eggs and larvae at Watts Bar Steam Plant during 1975. The objectives of the investigation were:

1. To determine the numbers and taxonomic identity of fish eggs and larvae in the vicinity of the plant.
2. To determine the numbers and taxonomic identity of fish eggs and larvae entrained by the plant.
3. To assess the impact of this entrainment on the fish populations of Watts Bar Reservoir.

1.2 Location and General Site Characteristics

Watts Bar Steam Plant is located on the west shore of Chickamauga Reservoir in Rhea County, Tennessee, at Tennessee River Mile (TRM) 529.2 (Figure 1). It is approximately 1.3 km (0.8 mile) below Watts Bar Dam. Cooling water is supplied from Watts Bar Reservoir. There is considerable cove and embayment habitat on Watts Bar Reservoir. At full pool the reservoir has an area of 15,789 ha.

1.3 Physical and Operational Characteristics

Watts Bar Steam Plant is fossil-fueled with four units having a total generating capacity of 240 megawatts. Initial operation of the first unit began in February 1942, and the last unit was placed in operation in April 1945. The plant currently operates as a peaking plant, supplying power during periods of high demand.

Circulating water for the plant is supplied by gravity feed through an intake structure contiguous with the upstream face of Watts Bar Dam (Figure 2). Six intake water passages lead to two underground conduits which lead to the powerhouse. The intake apertures extend from 240.6 msl to 234.0 msl. Minimum surface elevation of Watts Bar Reservoir is 240.6. Maximum flow through the plant is 17.7 m^3/s.

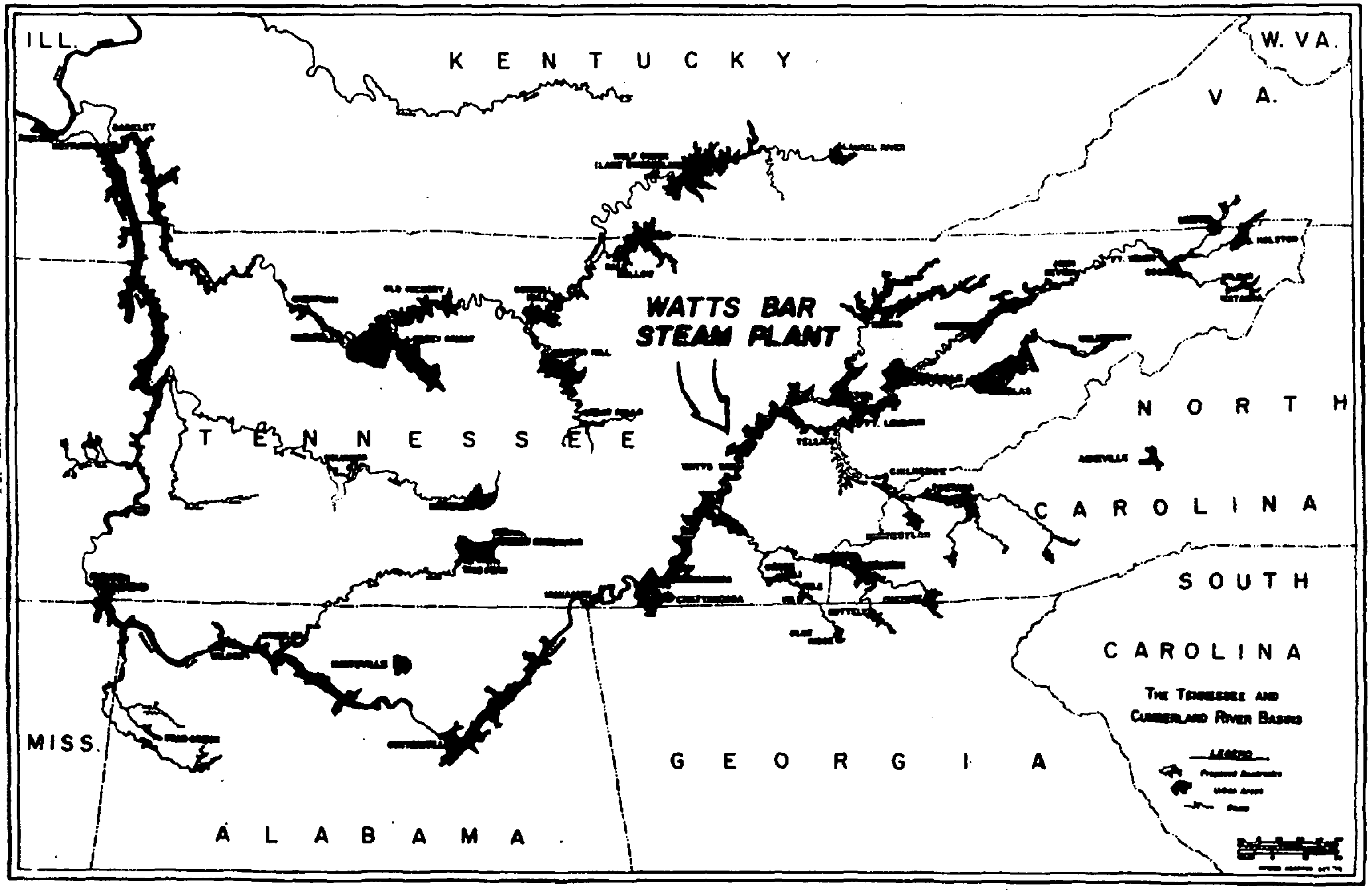

Figure 1. Location of Watts Bar Steam Plant

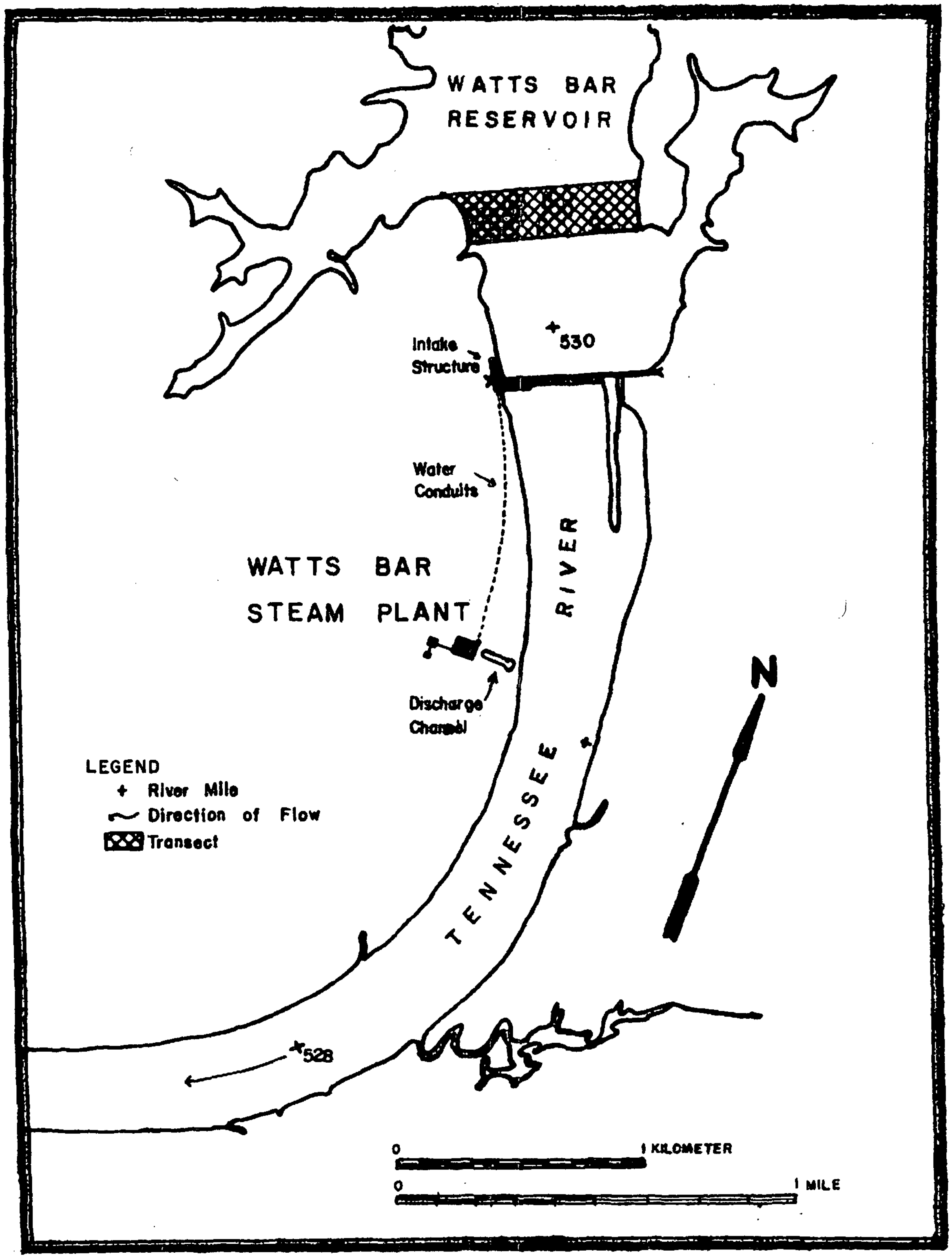

Figure 2. Location of Reservoir Transect and Intake Sampling Station, Watts Bar Steam Plant, Watts Bar Reservoir.

CHAPTER 2

METHODS AND MATERIALS

To determine the number of fish eggs and larvae available for entrainment, samples were taken at night within a reservoir transect located at TRM 530.3 (Figure 2). Collections from additional areas were used to supplement occurrence and relative abundance data. Samples were also taken within the intake structure to determine the numbers of fish eggs and larvae entrained. Biweekly sampling commenced March 24, 1975, and continued through July 28, 1975. All samples were filtered through 0.79 mm mesh nets.

2.1 Reservoir Sampling

Five stations were sampled within the reservoir transect: a station at either shoreline, a mid-channel station, and a station approximately halfway from each shore to mid-channel. The following methods were used:

1. Pumping - Moving pump samples of 10-minute duration were taken at shoreline stations where the use of other methods was impractical. A model 120TP3-1 Homelite trash pump (1.36 m^3/min capacity) was utilized. A 3 meter long section of 7.6 cm (I.D.) intake hose was manipulated to sample the 0-1.0 m contour as close to the shore as possible. Pump samples were strained through a net suspended over the side of the boat. Samples were taken at a boat speed of roughly 0.3 m/s. Volumes filtered ranged from 4-10 m^3 per sample.

2. Push-Netting - Horizontal push-net samples were taken at the station near each shoreline and at mid-channel using a 0.78 m^2 (1 m in diameter) conical net attached to the bow of the boat. Paired, 2.5-minute

samples (one upstream and one downstream) were taken at these stations. Flow was recorded with a TSK flowmeter mounted in the center of the net. Approximately 150 m^3 of water was filtered with each push; sampling speed was approximately 1.3 m/s.

3. Vertical Netting - Three to five vertical lifts per sample were taken with a 1.88 m^2 beam net at three equidistant stations across the transect. The boat was anchored at each station. The net was lowered, then lifted with a winch at approximately 0.5-1.0 m/s, and the net was tripped at 1 m to avoid sampling the upper meter of the water column. Depending on water depth and number of lifts, the volume of water filtered at each station ranged between 75-150 m^3.

2.2 Intake Sampling

Due to the position of the intake structure and the turbulent flow in front of the trashracks, pumping was selected as the method for sampling larval fish and eggs in the entrained water. Pumped samples of one hour duration were taken simultaneously in three of the six screen wells with a Model 120TP3-1 Homelite trash pump. Wells were alternated between sampling periods. Day and night samples were taken. Pump discharges were filtered through nets fixed inside overflow tubs. Volume filtered per sample ranged between 40-60 m^3. The traveling screens were washed prior to sampling to enhance flow through the screen wells, and maximum flow through the intake structure was maintained during sampling.

2.3 Laboratory Analysis

Samples were preserved in the field in 10 percent Formalin and returned to the laboratory. Eggs and all fish less than 31 mm total length were identified to the lowest possible taxon using polarized stereomicroscopy and available taxonomic keys (e.g., Hogue, MS; May and Gassaway, 1967; Norden, MS; Taber, 1967). Level of identification depended upon the taxon in question, developmental stage and condition of the specimen. Multilated specimens were termed "unidentified," while those identifiable only to family level were termed "unspecified."

2.4 Data Analyses

Ten sampling periods at biweekly intervals were identified as follows:

Sample Period	Sample Date
1	3-24-75
2	4-07-75
3	4-21-75
4	5-05-75
5	5-19-75
6	6-02-75
7	6-16-75
8	6-30-75
9	7-14-75
10	7-28-75

Results of laboratory analyses of each sample were converted into densities (numbers/1000 m^3). The cross-sectional profile of the reservoir transect was subdivided into areas sampled ~~by each gear type at each station~~. Station weight was then calculated as the ratio of each sample area to the total cross-sectional area. Weighted mean reservoir density was then calculated $\Sigma(D_s W_s)$; where D_s = unweighted sample density and W_s = station weight. Because shallow~~, shoreline areas~~ constituted an insignificant portion of the ~~reservoir cross section,~~ pump samples were included in species-occurrence analysis but not in the estimates of mean densities or entrainment. Densities for all intake samples were averaged to provide an intake concentration for each sample period.

Percent entrainment for each sample period was estimated by the following equation:

$$\left(\frac{D_i}{D_r} \times \frac{Q_i}{Q_r}\right) \times 100$$

Q_i = Plant intake flow (m^3/day).

Q_r = Reservoir flow (m^3/day).

D_r = Weighted mean density (N/1,000 m^3) of eggs or larvae in the reservoir transect.

D_i = Mean density (N/1,000 m^3) of eggs or larvae ~~in the~~ adjacent to the intake ~~basin~~ location.

Reservoir flows were obtained from the River Control Branch, Division of Water Management, TVA, (Table 1); intake water demand for the plant was established from plant operational data records.

In addition, an estimate of total entrainment of larvae over the entire sampling period (127 days) was made. For this estimate, average reservoir and intake densities were calculated as above and multiplied by the respective 24-hour reservoir flow and intake demand to yield 24-hour estimates of numbers of fish. The areas under the curves of numbers vs. time for intake and reservoir samples were integrated to yield estimates of total numbers of larvae entrained and total numbers of larvae passing the plant. The ratio of these numbers was then converted to a percentage; this value is an estimate of total percent annual entrainment.

Table 1. Reservoir Flow and Intake Flow*, Watts Bar Steam Plant, Watts Bar Reservoir, 1975.

Sample Period		Qr M^3x10^6	Qi M^3x10^6	Qi/Qr
3-24	1	200.64	0	
4-7	2	192.08	0	
4-21	3	73.41	0.5604	0.0076
5-5	4	70.96	0.4526	0.0064
5-19	5	62.15	0.7653	0.0123
6-2	6	64.11	0.9779	0.0153
6-16	7	68.27	0.8530	0.0125
6-30	8	87.35	1.0329	0.0118
7-14	9	74.87	1.1076	0.0148
7-28	10	73.40	1.0483	0.0143

Qr = Total reservoir flow

Qi = Total intake flow

* - Flows are 24-hour totals

CHAPTER 3

RESULTS AND DISCUSSION

3.1 Occurrence and Relative Abundance of Taxa

Fish larvae of 19 taxa (10 families) were collected (Table 2). Sciaenid eggs were collected only in the reservoir while unspecified eggs were collected only in intake sample. Of all the larvae taken during the study, unspecified clupeids (probably *Dorosoma*) dominated the collections (Table 3). Among nonclupeid taxa, only *Lepomis* spp. (1.16 percent) exceeded 1.0 percent of the total catch. Game and commercial species, while appearing frequently, were not numerically important components of the catch.

Hiodontidae, Catostomidae, Ictaluridae, Atherinidae, and Percidae were not collected in intake samples (Table 3). Relative abundances between the reservoir and intake were similar (Table 4).

3.2 Entrainment

The estimation of entrainment and the evaluation of entrainment impacts on the fisheries resource of the reservoir is a two-phase process. The first phase is the estimation and evaluation of total entrainment, i.e., all eggs and all larvae; the second phase is concerned with evaluation of impacts on particular taxa. If the first phase yields results indicative of a nonsignificant fisheries impact, the second phase can be limited to determining the occurrence of selective entrainment of important taxa.

3.2.1 Eggs

Total entrainment of eggs was not calculated because of their erratic occurrence in samples. Eggs were not collected in both reservoir and intake samples during any sample period. *Aplodinotus grunniens* eggs occurred

Table 2. Fish eggs and larvae collected at two locations, Watts Bar Steam Plant, Watts Bar Reservoir, 1975.

TAXA	Intake Samples	Plant Transect
Seasonal		
Unspecified fish eggs	6775	
Aplodinotus grunniens eggs		16
Unspecified clupeids	244	20,400
Alosa chrysochloris		2
Dorosoma spp.		6
D. cepedianum		8
D. petenense	5	324
Hiodon tergisus		4
Unspecified cyprinids		128
Cyprinus carpio	1	31
Unspecified catostomids		9
Ictalurus punctatus		21
Labidesthes sicculus		12
Morone spp.	3	49
Lepomis spp.	7	244
Micropterus spp.		4
M. dolomieui	1	4
Pomoxis spp.		15
Unspecified percids		1
Aplodinotus grunniens	1	24
Unidentified larvae	1	1
Sample Period 1-3.		
No fish eggs or larvae collected		
Sample Period 4.		
Unspecified clupeids		586
Dorosoma spp.		6
Cyprinus carpio		6
Unspecified catostomids		4
Morone spp.		14
Pomoxis spp.		5
Unspecified percid		1
Sample Period 5.		
Unidentified larva		1
Unspecified clupeids	95	5,025
Hiodon tergisus		1
Unspecified cyprinid		1
Cyprinus carpio	1	23
Unspecified catostomids		5
Morone spp.	3	33
Lepomis spp.	1	111

Table 2. (Continued)

TAXA	Intake Samples	Plant Transect
Micropterus spp.		4
M. dolomieui		4
Pomoxis spp.		10
Sample Period 6.		
Aplodinotus grunniens eggs		10
Unidentified larva	1	
Unspecified clupeids	89	5,142
Alosa chrysochloris		1
Dorosoma cepedianum		1
D. petenense	1	28
Hiodon tergisus		2
Unspecified cyprinids		7
Cyprinus carpio		1
Ictalurus punctatus		1
Labidesthes sicculus		2
Morone spp.		2
Lepomis spp.	5	73
Micropterus dolomieui	1	
Aplodinotus grunniens		1
Sample Period 7.		
Unspecified fish eggs	6,775	
Unspecified clupeids	43	4,341
Dorosoma cepedianum		2
D. petense		25
Hiodon tergisus		1
Unspecified cyprinids		8
Cyprinus carpio		1
Ictalurus punctatus		14
Labidesthes sicculus		6
Lepomis spp.		6
Aplodinotus grunniens		2
Sample Period 8.		
Aplodinotus grunniens eggs		5
Unspecified clupeids	10	4,089
Alosa chrysochloris		1
Dorosoma cepedianum		3
D. petenense	2	162
Unspecified cyprinids		23
Ictalurus punctatus		2
Labidesthes sicculus		2

Table 2. (Continued)

TAXA	Intake Samples	Plant Transect
Lepomis spp.		32
Aplodinotus grunniens		2
Sample Period 9.		
Aplodinotus grunniens egg		1
Unspecified clupeids	4	1,064
Dorosoma cepedianum		1
D. petenense	1	28
Unspecified cyprinids		83
Ictalurus punctatus		2
Labidesthes sicculus		2
Lepomis		3
Aplodinotus grunniens		15
Sample Period 10.		
Unspecified clupeids	3	153
Dorosoma cepedianum		1
D. petenense	1	81
Unspecified cyprinids		6
Ictalurus punctatus		2
Lepomis spp.	1	19
Aplodinotus grunniens	1	4

Table 3. Relative abundance of taxa of fish larvae collected in the vicinity of Watts Bar Steam Plant, 1975.

TAXA	Number Collected	Percent Relative Abundance
Clupeidae		
Unspecified clupeids	20,646	95.79
Alosa chrysochloris	2	0.01
Dorosoma spp.	6	0.03
Dorosoma cepedianum	8	0.04
D. petenense	329	1.50
Hiodontidae		
Hiodon tergisus	4	0.02
Cyprinidae		
Unspecified cyprinids	129	0.60
Cyprinus carpio	32	0.15
Catostomidae		
Unspecified catostomids	10	0.05
Ictaluridae		
Ictalurus punctatus	21	0.10
Atherinidae		
Labidesthes sicculus	12	0.06
Percichthyidae		
Morone spp.	52	0.24
Centrarchidae		
Lepomis spp.	251	1.16
Micropterus spp.	4	0.02
M. dolomieui	5	0.02
Pomoxis spp.	15	0.07
Percidae		
Unspecified percid	3	0.01
Stizostedion spp.	2	0.01
Sciaenidae		
Aplodinotus grunniens	25	0.12
Unidentified larvae	2	0.01

Table 4. RELATIVE ABUNDANCE (PERCENT) OF TEN FAMILIES OF FISH LARVAE, WATTS BAR STEAM PLANT, WATTS BAR RESERVOIR, 1975.

Family	Reservoir Samples	Intake Samples
Clupeidae	97.43	95.04
Hiodontidae	0.02	-
Cyprinidae	0.75	0.38
Catostomidae	0.04	-
Ictaluridae	0.10	-
Atherinidae	0.06	-
Percichthyidae	0.23	1.15
Centrarchidae	1.25	3.05
Percidae	*	-
Sciaenidae	0.11	0.38

* Less than 0.01 percent.

during sample periods 6, 8, and 9 while unidentified fish eggs occurred only during sample period 7.

3.2.2 Fish Larvae

Reservoir densities of fish larvae are of a regular pattern; peak density (total larvae) occurred during sample period 6 (Table 5). Clupeids were the most abundant taxon throughout the season (Figure 3). Abundance of other families contributed nominally to total densities.

Clupeids, percichthyids, and centrachids were the most frequently occurring and most abundant larvae in intake samples. Centrarchidae was the only other family occurring in intake samples during more than one sample period. Reservoir densities were characteristically much larger than intake densities. Only in 2 out of 50 possible instances were intake densities greater (Table 5, Figure 3).

Biweekly estimates of percent entrainment of total larvae ranged from 0.11-0.86 percent. Peak percent entrainment occurred during sample period 5 when four families occurred in intake samples. During no other sample period did more than two families occur in the intake. Total entrainment of larvae over the 127-day sampling season was estimated to be 0.24 percent; based on an estimate of the total transported population of 4.47×10^9 and an estimate of 1.08×10^7 total larvae entrained.

Table 6 presents biweekly entrainment estimates for five families. Entrainment of families exceeded 1 percent in only three instances; the largest single value (2.54 percent) was noted for centrarchids in sample period 6 (Table 5).

Table 5. AVERAGE DENSITIES ($n/1000\ m^3$) AND PERCENT ENTRAINMENT BY SAMPLE PERIOD AND FAMILY FOR WATTS BAR STEAM PLANT, WATTS BAR RESERVOIR, 1975.

Family	1	2	3	4	5	6	7	8	9	10	Season Total*
Clupeidae											
Dr	-	-	-	174.07	389.77	2954.20	378.03	506.08	100.17	195.75	
Di	-	-	-	-	272.99	292.97	157.16	47.62	46.95	12.82	
Percent Entrainment	-	-	-	-	0.86	0.15	0.52	0.11	0.70	0.10	0.28
Cyprinidae											
Dr	-	-	-	0.81	3.37	0.08	0.28	0.37	1.18	0.10	
Di	-	-	-	-	2.87	-	-	-	-	-	
Percent Entrainment	-	-	-	-	1.04	-	-	-	-	-	0.53
Percichthyidae											
Dr	-	-	-	0.19	4.32	0.18	-	-	-	-	
Di	-	-	-	-	8.62	-	-	-	-	-	
Percent Entrainment	-	-	-	-	2.46	-	-	-	-	-	2.25
Centrarchidae											
Dr	-	-	-	0.08	10.13	11.74	0.22	4.73	0.04	4.08	
Di	-	-	-	-	2.87	19.53	-	-	-	-	
Percent Entrainment	-	-	-	-	0.34	2.54	-	-	-	-	1.17
Sciaenidae											
Dr	-	-	-	-	-	3.68	1.70	6.32	15.35	6.66	
Di	-	-	-	-	-	-	-	-	-	3.21	
Percent Entrainment	-	-	-	-	-	-	-	-	-	0.69	0.07
Total Larvae											
Dr	-	-	-	175.18	409.60	2980.95	402.35	522.47	122.99	211.82	
Di	-	-	-	-	287.36	315.76	157.16	47.62	46.95	19.25	
Percent Entrainment	-	-	-	-	0.86	0.17	0.49	0.11	0.57	0.13	0.24

*Calculated from integration routine.

Dr = Weighted density within reservoir transect.

Di = Density in intake.

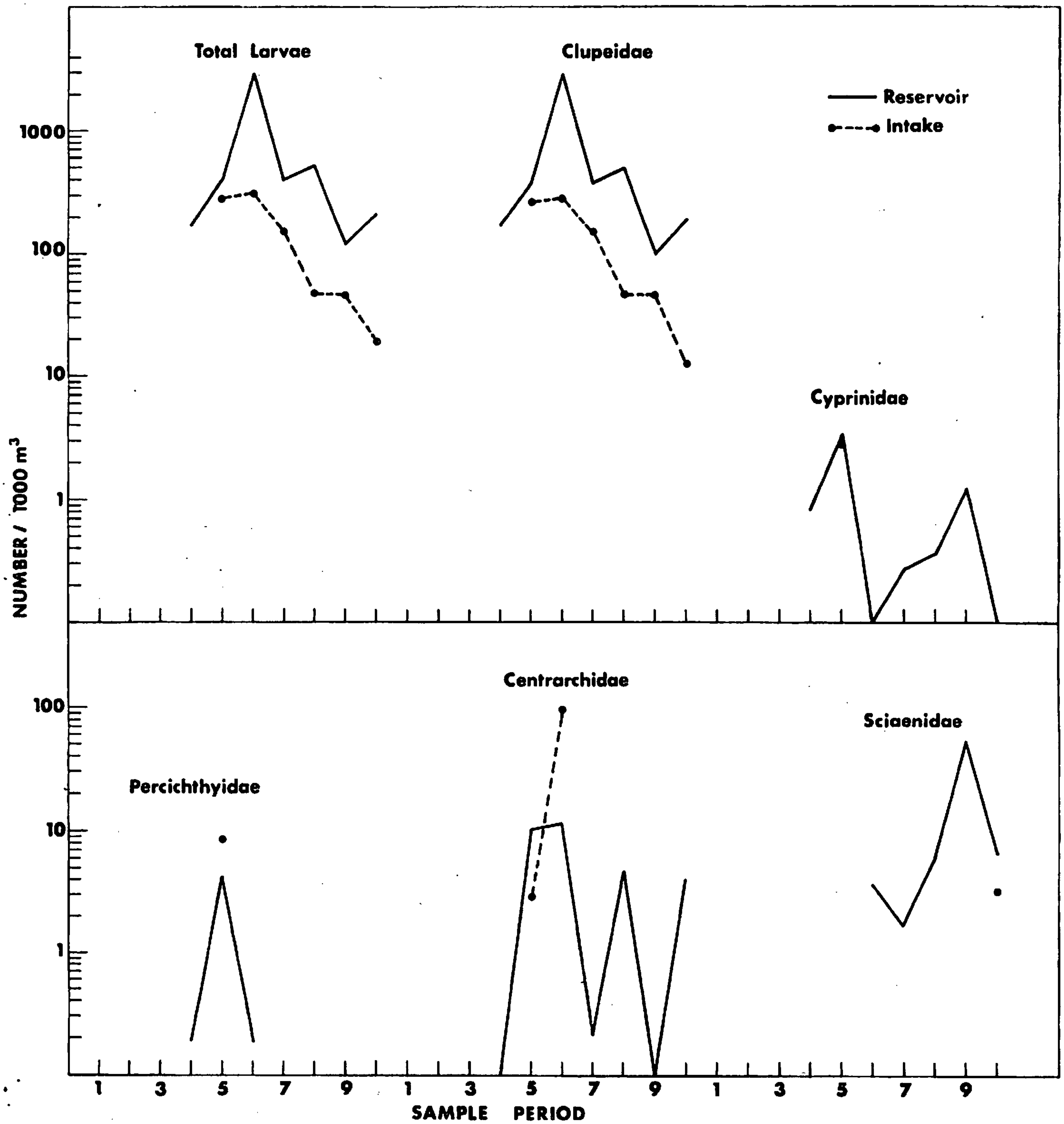

Figure 3. Mean Densities of Fish Larvae in Watts Bar Reservoir and in Intake Samples of Watts Bar Steam Plant, 1975.

3.3 Assessment of Entrainment Impact

Watts Bar Steam Plant is estimated to entrain 0.24 percent of the transported larval fish population. Because of the nature and design of the discharge channel, mortality of entrained larvae is assumed to be 100 percent. However, the relatively low demand for cooling water (17.7 m^3/sec maximum) by Watts Bar Steam Plant and its role as a peaking plant minimize its impact on the larval fish of Watts Bar Reservoir.

There are no quantitative guidelines to follow in assessing the magnitude of entrainment impact. Obviously, entrainment impact must be judged in terms of its eventual effects on adult populations. Presently, only one study has attempted to translate entrainment losses into effects on adult populations. Hess, et al., (1975) modeled the effects of various levels of entrainment losses on the total population size of winter flounder. Their results show that a 5 percent entrainment mortality expressed annually over 35 years translates to a 6 to 9 percent reduction in the total adult population. While their studies are not directly applicable to freshwater reservoir situations, their results are viewed as conservative (i.e., worst case) estimates. Hence, an entrainment estimate of 0.24 percent is judged to be an insignificant impact on the fishery resource of Watts Bar Reservoir.

CHAPTER 4

SUMMARY

1. Sampling for fish eggs and larvae was performed at Watts Bar Steam Plant. The objectives were:
   a. To determine the numbers and taxonomic identity of eggs and larvae in the vicinity of the plant.
   b. To determine the numbers and taxonomic identity of fish eggs and larvae entrained by the plant.
   c. To assess the environmental impact of this entrainment on the fish populations of Watts Bar Reservoir.

2. Hydraulic entrainment by the plant as estimated during 10 biweekly sampling periods ranged from 0 to 1.53 percent of reservoir flow.

3. Fish belonging to 19 taxa (10 families) were collected; unidentified fish eggs and *Aplodinotus grunniens* eggs were collected.

4. Egg collections were mostly of unidentified fish eggs. Collections of larvae were dominated by clupeids (probably *Dorosoma*). Other than clupeids, only *Lepomis* spp., exceeded 1 percent of total catch.

5. Samples from the intake channel corresponded with reservoir samples in terms of relative abundance of families.

6. Only unidentified eggs were entrained. They were not collected in the reservoir. *A. grunniens* eggs were collected only in the reservoir.

7. Entrainment of total larvae ranged from 0.11 to 0.86 percent of the transported population for the 10 sampling periods; total entrainment

over the entire sampling season was estimated to be 0.24 percent. Clupeids contributed most heavily to numbers entrained as seen by their concentrations in intake samples.

8. The low estimate of percent entrainment of larval fish (0.24) points to a conclusion of no significant adverse impact on the fisheries resource of Watts Bar Reservoir owing to entrainment of fish eggs and larvae by Watts Bar Steam Plant.

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TVA

Watts Bar Nuclear Plant

Unit 0

Periodic Instruction

0-PI-ENV-14.1

Environmental Reports And Regulatory Submittals

Revision 0003

Quality Related

Level of Use: Reference Use

Effective Date: 05-11-2009

Responsible Organization: CEM, Chemistry

Prepared By: Dawn Booker

Approved By: Darrin J. Hutchison

Revision Log

Revision or Change Number	Effective Date	Affected Page Numbers	Description of Revision/Change
Rev 0	01/13/06	All	Initial issue. Procedure developed to comply with SPP-5.5, Rev 4, *Environmental Control*.
Rev 1	04/25/06	Appendix A, Page 2 of 4	Deleted reporting requirement "TVA Water Use Report". Changed due date for "Non Radiological Environmental Operating Report" to April 25.
Rev 2	4/30/07	All	This procedure has been converted from Word 95 to Word XP using rev 1, by The Conversion Team. Added reporting requirement "Solid Waste Facility Annual Report", with a due date of October 1st.
Rev 3	5/11/09	1, 2, 4, 5, 7-10	Clarified scope language. Added procedure references, and the following reports: Environmental Conditions Review, Water Withdrawal Registration, Passive Mix Zone Test, and Flow Calibration to Appendix A. Deleted reference to sewage treatment plant and operator. Changed "PROCEDURE" to "REFERENCE" in Appendix A.

Table of Contents

1.0 INTRODUCTION

1.1 Purpose

This Periodic Instruction (PI) ensures that environmental reports and submittals, as required by regulations and permits, are submitted in a timely manner to ensure that no regulatory violations are incurred.

1.2 Scope

Includes documentation of preparation and independent verification of all reports required to be submitted in support of the Clean Air Act, Clean Water Act, Resource Conservation and Recovery Act, Toxic Substances Control Act, Comprehensive Environmental Response, Compensation and Liability Act, and Emergency Planning and Community Right-to-Know Act activities, permits, and other environmental requirements at WBN.

1.3 Frequency

A. This PI shall be issued the first day of each quarter.

B. This Instruction is applicable in all modes and can be performed in all modes.

2.0 REFERENCES

2.1 Developmental References

A. 40 Code of Federal Regulations (CFR) Part 60

B. 40 CFR Part 61

C. 40 CFR Part 122

D. 40 CFR Part 136

E. 40 CFR Parts 260-268

F. 40 CFR Part 279

G. 40 CFR Part 423

H. 40 CFR Part 761

I. Air Pollution Control Permits

J. General Tennessee Multi-Sector Permit for Storm Water Associated with Industrial Activities, Permit No. TNR051343.

2.1 Developmental References (continued)

K. NPDES Permit TN0020168

L. ECM-1, Air Pollution Control Program

M. ECM-3, National Pollutant Discharge Elimination System (NPDES) Program

N. ECM-4, Erosion/Storm Water Pollution Prevention Controls

O. ECM-5, Handling, Storage, and Disposal of Used Oil and Hazardous Waste

P. ECM-8, Spill Prevention, Control, and Countermeasure (SPCC) Plan

Q. ECM-12, Superfund Amendment and Reauthorization Act of 1986 (SARA) Reporting

R. 0-PI-ENV-14.2, Identification and Interpretation of Intake Warning Indicators

S. TN Code Annotated Section 69-8-301 et seq.

2.2 Performance References

None

3.0 PRECAUTIONS

None

4.0 PREREQUISITE ACTIONS

Collect reporting data utilizing appropriate PI's.

5.0 ACCEPTANCE CRITERIA

Reports are completed and submitted on time.

6.0 PERFORMANCE

NOTE
This Section will be repeated for each report/submittal listed in Appendix A.

[1] **DEVELOP** the required report or submittal in accordance with the governing procedure listed in Appendix A **AND**

INITIAL Appendix A as the preparer.

[2] **OBTAIN** independent verification of all data input into the regulatory report prior to submittal to management for review **AND**

OBTAIN the initials of the verifier on Appendix A.

[3] **SUBMIT** the report for management review a minimum of two (2) working days prior to the due date to the appropriate regulatory agency/office.

[4] **SUBMIT** the report to the appropriate regulatory agency/office by the due date noted in Appendix A.

DOCUMENT the submittal date on Appendix A.

[5] **REPEAT** steps 6.0[2] through 6.0[4] for each report/submittal listed in Appendix A.

7.0 RECORDS

7.1 QA Records

Appendix A

7.2 Non QA Records

None

Appendix A
(Page 1 of 4)

WBN Environmental Reporting

1st Quarter Reporting

REPORT	DUE DATE	SUBMITTED TO	REFERENCE	PREPARER	INDEPENDENT VERIFIER	SUBMITTAL DATE
DMR	January 15th	TDEC	ECM-3			
DMR	February 15th	TDEC	ECM-3			
Biocide Plan	February 15th	TDEC	NPDES Permit			
Water Withdrawal Registration	February 15th	TDEC	TN Code Annotated Section 69-8-301 et seq.			
SARA Tier II Report	March 1st	SERC LEPC Local Fire Dept.	ECM-12			
Annual Hazardous Waste Report	March 1st	TDEC	None			
DMR	March 15th	TDEC	ECM-3			
NPDES Storm Water Annual Sampling Report	March 31st	TDEC	ECM-4			
Annual Air Report	March 31st	TDAPC	ECM-1			
Comprehensive Site Compliance Evaluation (Storm Water)	March 31st	On-site Record	ECM-4			

Appendix A
(Page 2 of 4)

WBN Environmental Reporting

2nd QUARTER REPORTING

REPORT	DUE DATE	SUBMITTED TO	REFERENCE	PREPARER	INDEPENDENT VERIFIER	SUBMITTAL DATE
Annual NPDES Flow Calibration Report	April 15th	Kept Onsite	NPDES Instruction Manual			
DMR	April 15th	TDEC	ECM-3			
Non Radiological Environmental Operating Report	May 11th	NRC via Licensing	ECM-3			
DMR	May 15th	TDEC	ECM-3			
DMR	June 15th	TDEC	ECM-3			
PCB Annual Document Log	June 30th	Kept Onsite	ECM-5			
Environmental Conditions Review	June 30th	On-site Record	0-PI-ENV-14.2			
SARA TRI Report	July 1st	EPA	ECM-12			
Winter Passive Mix Zone Report	June 15th	TDEC	NPDES Permit			

Appendix A
(Page 3 of 4)

WBN Environmental Reporting

3rd QUARTER REPORTING

REPORT	DUE DATE	SUBMITTED TO	REFERENCE	PREPARER	INDEPENDENT VERIFIER	SUBMITTAL DATE
DMR	July 15th	TDEC	ECM-3			
DMR	August 15th	TDEC	ECM-3			
DMR	September 15th	TDEC	ECM-3			
Annual Fish Monitoring Report	When Completed	TDEC	None			
Solid Waste Facility Annual Report	October 1	TDEC	None			

Appendix A
(Page 4 of 4)

WBN Environmental Reporting

4th QUARTER REPORTING

REPORT	DUE DATE	SUBMITTED TO	PROCEDURE	PREPARER	INDEPENDENT VERIFIER	SUBMITTAL DATE
DMR	October 15th	TDEC	ECM-3			
DMR-QA Study	October 28th	EPA, TDEC	ECM-3			
DMR	November 15th	TDEC	ECM-3			
Asbestos Notification Report	November 15th	TDAPC	ECM-1			
DMR	December 15th	TDEC	ECM-3			
Summer Passive Mix Zone Report	December 15th	TDEC	NPDES Permit			

LEGEND:

C/D - Construction / Demolition
DMR - Discharge Monitoring Report
LEPC - Local Emergency Planning Committee
NPDES - National Pollutant Discharge Elimination System
NRC - Nuclear Regulatory Commission
PCB - Polychlorinated Biphenyl
SARA - Superfund Amendments and Reauthorization Act
SERC - State Emergency Response Commission
TDAPC - Tennessee Division of Air Pollution Control
TDEC - Tennessee Department of Environment & Conservation

LaRoche

TENNESSEE VALLEY AUTHORITY

ENVIRONMENTAL INFORMATION

SUPPLEMENT NO. 1
RESPONSES TO NRC QUESTIONS FOR OPERATING LICENSE STAGE ENVIRONMENTAL REVIEW

WATTS BAR NUCLEAR PLANT UNITS 1 AND 2

MAY 9 1977 EH fx 3

Mr. Edson G. Case, Acting Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Case:

In the Matter of the Application of) Docket Nos. 50-390
Tennessee Valley Authority) 50-391

Submitted under separate cover are 41 copies of a document entitled "Environmental Information Supplement No. 1 Responses to NRC Questions for Operating License Environmental Review." This material responds to NRC's questions for additional information on the Watts Bar Nuclear Plant forwarded by letters from William H. Regan, Jr., to Godwin Williams, Jr., dated April 5 and April 12, 1977. Additional copies of Supplement 1 will be distributed in accordance with Enclosure 2 of the letter from William H. Regan, Jr., to Godwin Williams, Jr., dated April 12, 1977.

An additional submittal is being forwarded directly to the NRC staff Watts Bar Nuclear Plant Environmental Project Manager. This additional material consists of six copies each of technical reports requested by the NRC staff. These reports are referenced in Supplement No. 1, as appropriate. A listing of titles of these reports is enclosed.

The Supplement 1 responses and discussions related to need for power as provided in my letters to you dated April 15 and April 26, 1977, complete our reply to your staff's request for additional environmental information on the Watts Bar Nuclear Plant.

Very truly yours,

J E Gilleland

J. E. Gilleland
Assistant Manager of Power

MAY 16 77	
HSS	
LEW	

Subscribed and sworn to before me this 9th day May 1977

Notary Public

My Commission Expires 10/10/78

Enclosure
LMP:OEG:JMW:SD

CC: See page 2

Supplement 1 to

Watts Bar Nuclear Plant Environmental Information

TENNESSEE VALLEY AUTHORITY RESPONSES
TO
NUCLEAR REGULATORY COMMISSION QUESTIONS
ON
WATTS BAR NUCLEAR PLANT
ENVIRONMENTAL INFORMATION
UNITS 1 AND 2

Questions forwarded by

USNRC letters from Wm. H. Regan, Jr.

to Godwin Williams, Jr., dated April 5 and April 12, 1977

Submitted May 9 1977

1. DEMOGRAPHY

Question Number 1.1:

Provide an update of Section 1.1 (8)(d), Population Distribution, as well as Figures 1.1-7, 1.1-8 and 1.1-9, indicating current estimates.

Response:

Provided in response to this question is an updated discussion of the population distribution about the Watts Bar Nuclear Plant.

POPULATION DISTRIBUTION

Present population data were based on the 1970 Census of Population. Projected population data were based on county projections prepared by the Bureau of Economic Analysis (BEA), in cooperation with the Southern Economic Review Groups - Georgia, North Carolina, and Tennessee (Reference 1). These projections incorporated the Census Bureau's 1972 "Series E" national population projections. The Southern Economic Review Groups are cooperative Federal-state groups formed to assist BEA in preparing county projections for planning and development purposes. Subdivisions of the county estimates and projections were made by TVA. These subdivisions were based on census and other maps, on judgements from field experience, and on such factor as topography, transportation networks, and historical growth patterns.

Population Within 10 Miles

Almost 11,000 people lived within 10 miles of the Watts Bar site in 1970 with more than 80 percent of these between 5 and 10 miles from the site. Two small towns, Spring City and Decatur, which in 1970 had populations of 1,756 and 698 respectively, are located between 5 and 10 miles from the site. Decatur is south and south-southwest from the site, while Spring City is northwest and north-northwest. The remainder of the area within 10 miles of the site is sparsely populated. Most of the population growth in the area is expected to be in or adjacent to Spring City and Decatur.

Tables 1.1-1 through 1.1-7 contain the estimates from 1970 and the 1978 thru 2020 projections of population at various distances and directions from the site out to 10 miles.

Population Between 10 and 50 Miles

The area between 10 and 50 miles from the site lies mostly in the lower and middle portions of east Tennessee, with small areas in southwestern North Carolina and in northern Georgia. The population of this area is projected to increase by over 38 percent (or 247,000 persons) between 1970 and 2020. Over 50 percent of this total increase is expected to be in the area between 40 and 50 miles from the site.

The largest urban concentration between 10 and 50 miles is the city of Chattanooga, located to the southwest and south-southwest. This city had a population in 1970 of 119,923; about 80 percent of this population was located between 40 and 50 miles from the site, while the rest was located beyond 50 miles. The Chattanooga urbanized area had a population of about 224,000 in 1970; of these, about 78 percent were located between 40 and 50 miles with the remainder beyond 50 miles. East Ridge, which had a population in 1970 of 21,799, the majority of which was located within the 40- to 50-mile zone, had about 4,000 persons beyond the 50-mile radius. This city is part of the Chattanooga urbanized area. The city of Knoxville is located to the east-northeast of the site. Of its 1970 population of 174,587, about 5 percent was located between 40 and 50 miles of the site, with the remainder beyond 50. The Knoxville urbanized area had a 1970 population of 190,502. Not more than 10 percent of this population was located within 50 miles of the site.

There are three smaller urban concentrations in this area with population greater than 20,000. The city of Oak Ridge, which had a 1970 population of 28,319, is located about 40 miles to the northeast. The twin cities of Alcoa and Maryville, which had a combined population in 1970 of 21,547, are located between 45 and 50 miles to the east-northeast. Cleveland, with a 1970 population of 20,651, is located about 30 miles to the south. Most of the population growth of the area is expected to occur around these and the larger population centers.

There are, in addition, a number of smaller communities dispersed throughout the area, surrounded by low-density rural areas.

Tables 1.1-8 through 1.1-14 contain the estimates for 1970 and the 1978 thru 2020 projections of population at various distances and directions from the site out to 50 miles.

References

1. Projections, Economics Activity in Tennessee, Series E Population; January 1976, Tennessee Valley Authority Requisition Number 520002, Bureau of Economic Analysis, U.S. Department of Commerce. Available from National Technical Information Service. This document is also available for the states of Georgia and North Carolina under Georgia intra-governmental order number SAD PD-75-1.

WATTS BAR
1970 Population Distribution
Within 10 Miles of the Site

		Miles from Site					
	Total	0-1	1-2	2-3	3-4	4-5	5-10
N	415	-	-	5	-	-	410
NNE	175	-	-	30	10	20	115
NE	730	-	5	85	80	30	530
ENE	490	-	10	25	55	65	335
E	415	-	-	10	35	30	340
ESE	480	5	5	10	40	60	360
SE	420	-	-	15	30	30	345
SSE	500	-	5	10	30	15	440
S	1,260	-	40	25	15	80	1,100
SSW	440	5	15	5	40	20	355
SW	395	5	5	5	15	-	365
WSW	985	10	15	55	35	25	845
W	530	5	10	10	30	35	440
WNW	315	5	30	20	60	60	140
NW	1,750	-	15	40	75	110	1,510
NNW	1,435	-	-	-	60	20	1,355
Total	10,735	35	155	350	610	600	8,985

TABLE 1.1-2

WATTS BAR

1978 Population Distribution

Within 10 Miles of the Site

		Miles from Site					
	Total	0-1	1-2	2-3	3-4	4-5	5-10
N	465	-	-	10	-	-	455
NEE	190	-	-	30	10	20	130
NE	740	-	5	90	80	30	535
ENE	500	-	10	25	60	65	340
E	420	-	-	10	35	30	345
ESE	545	5	5	10	45	75	405
SE	530	-	-	20	35	35	440
SSE	630	-	5	10	35	20	560
S	1,595	-	40	30	20	105	1,400
SSW	540	10	15	10	45	20	440
SW	395	5	5	10	20	-	355
WSW	970	10	20	60	40	30	810
W	550	10	10	10	35	40	445
WNW	345	5	35	20	65	65	155
NW	1,960	-	15	40	80	125	1,700
NNW	1,605	-	-	-	65	25	1,515
Total	11,980	45	165	385	670	685	10,030

WATTS BAR
1980 Population Distribution
Within 10 Miles of the Site

	Total	Miles from Site					
		0-1	1-2	2-3	3-4	4-5	5-10
N	480	-	-	10	-	-	470
NNE	195	-	-	30	10	20	135
NE	745	-	5	90	80	30	540
ENE	500	-	10	25	60	65	340
E	420	-	-	10	35	30	345
ESE	560	5	5	10	45	80	415
SE	565	-	-	20	40	40	465
SSE	675	-	5	10	40	25	595
S	1,690	-	40	35	20	110	1,485
SSW	565	10	15	10	45	20	465
SW	395	5	5	10	20	-	355
WSW	960	10	20	60	40	30	800
W	555	10	10	10	35	40	450
WNW	360	5	35	20	70	70	160
NW	2,020	-	15	40	85	130	1,750
NNW	1,650	-	-	-	70	25	1,555
Total	12,335	45	165	390	695	715	10,325

TABLE 1.1-4
Watts Bar
1990 Population Distribution
Within 10 Miles of the Site

	Total	Miles from Site					
		0-1	1-2	2-3	3-4	4-5	5-10
N	510	-	-	10	-	-	500
NNE	200	-	-	30	10	20	140
NE	770	-	5	90	80	30	565
ENE	480	-	10	25	60	65	320
E	430	-	-	10	35	35	350
ESE	605	5	5	10	45	90	450
SE	635	-	-	20	45	40	530
SSE	770	-	5	15	40	25	685
S	1,855	-	40	35	20	125	1,635
SSW	615	10	15	10	50	20	510
SW	410	10	10	10	20	-	360
WSW	975	10	20	65	45	30	805
W	570	10	10	10	35	45	460
WNW	380	5	35	20	75	75	170
NW	2,145	-	15	45	95	135	1,855
NNW	1,750	-	-	-	70	25	1,655
Total	13,100	50	170	405	725	760	10,990

WATTS BAR
2000 Population Distribution
Within 10 Miles of the Site

	Total	Miles from Site 0-1	1-2	2-3	3-4	4-5	5-10
N	520	-	-	10	-	-	510
NNE	205	-	-	30	10	25	140
NE	750	-	5	90	80	30	545
ENE	500	-	10	25	60	65	340
E	435	-	-	10	40	35	350
ESE	630	5	5	10	45	100	465
SE	680	-	-	25	50	45	560
SSE	820	-	5	20	40	30	725
S	2,070	-	40	40	25	135	1,830
SSW	675	10	15	10	45	25	570
SW	415	10	10	10	20	-	365
WSW	975	10	20	65	40	35	805
W	575	10	10	10	40	45	460
WNW	390	5	35	20	80	75	175
NW	2,175	-	15	45	95	135	1,885
NNW	1,780	-	-	-	75	25	1,680
Total	13,595	50	170	420	745	805	11,405

TABLE 1.1-10
WATTS BAR
1980 Population Distribution
Within 50 Miles of the Site

	Total	Miles from Site				
		0-10	10-20	20-30	30-40	40-50
N	7,135	480	1,725	305	1,320	3,305
NNE	33,340	195	7,040	17,385	7,785	935
NE	70,710	745	1,640	10,620	15,865	41,840
ENE	120,895	500	1,460	8,740	19,145	91,050
E	27,530	420	7,695	5,330	5,185	8,900
ESE	14,690	560	2,600	8,415	3,000	115
SE	37,545	565	21,220	10,225	1,800	3,735
SSE	17,105	675	2,585	3,875	3,310	6,660
S	67,675	1,690	1,085	18,035	41,380	5,485
SSW	117,065	565	1,240	6,770	9,075	99,415
SW	148,265	395	2,650	4,835	20,355	120,030
WSW	23,035	960	10,060	955	5,765	5,295
W	7,325	555	565	3,920	1,185	1,100
WNW	20,375	360	635	2,585	2,715	14,080
NW	13,400	2,020	560	1,745	3,780	5,295
NNW	23,365	1,650	685	13,920	3,310	3,800
Total	749,455	12,335	63,445	117,660	144,975	411,040

WATTS BAR
1990 Population Distribution
Within 50 Miles of the Site

		Miles from Site				
	Total	0-10	10-20	20-30	30-40	40-50
N	7,065	510	1,675	285	1,315	3,280
NNE	35,250	200	7,130	19,150	7,940	830
NE	75,540	770	1,690	11,110	16,935	45,035
ENE	134,840	480	1,540	9,145	20,970	102,705
E	28,520	430	8,530	5,385	5,240	8,935
ESE	15,990	605	2,665	9,760	2,860	100
SE	41,275	635	24,460	10,695	1,750	3,735
SSE	17,620	770	2,750	3,945	3,420	6,735
S	79,495	1,855	1,110	21,250	49,470	5,810
SSW	125,400	615	1,270	7,005	9,385	107,125
SW	155,935	410	2,775	5,110	21,760	125,880
WSW	25,960	975	11,230	975	7,065	5,715
W	7,570	570	570	4,090	1,235	1,105
WNW	21,295	380	655	2,715	2,800	14,745
NW	13,760	2,145	590	1,850	3,980	5,195
NNW	25,545	1,750	710	15,955	3,400	3,730
Total	811,060	13,100	69,350	128,425	159,525	440,660

TABLE 1.1-14

WATTS BAR
2020 Population Distribution
Within 50 Miles of the Site

	Total	0-10	10-20	20-30	30-40	40-50
		Miles from Site				
N	6,825	535	1,555	255	1,315	3,165
NNE	36,755	205	7,160	20,470	8,210	710
NE	82,165	705	1,685	11,030	18,435	50,310
ENE	161,655	470	1,565	9,170	22,540	127,910
E	29,295	430	9,160	5,270	5,385	9,050
ESE	17,075	665	2,730	11,230	2,360	90
SE	44,775	725	27,185	11,770	1,520	3,575
SSE	18,120	860	3,430	3,955	3,590	6,285
S	99,105	2,390	1,480	26,825	62,715	5,695
SSW	135,675	770	1,225	6,905	9,245	117,530
SW	167,775	430	2,830	5,605	24,005	134,905
WSW	32,665	985	11,945	940	11,575	7,220
W	8,075	585	520	4,700	1,380	890
WNW	22,830	400	705	3,035	2,920	15,770
NW	14,845	2,240	635	1,995	4,620	5,355
NNW	27,735	1,830	720	18,290	3,575	3,320
Total	905,370	14,225	74,530	141,445	183,390	491,780

Question Number 1.2

Provide an update of Table D-3 of Appendix D, indicating current estimates.

Response:

See Table 1.1-12 of TVA Response to NRC Question 1.1 above.

2. TERRESTRIAL ECOLOGY

Question Number 2.1

Provide an update of the Table in Section 2.2 of the Final Environmental Statement (FES--November 9, 1972, p. 2.2-1).

Response:

Step I

Line Name	Voltage (kV)	Approximate Length of New Construction (Miles)	Approximate Date Required
Bull Run-Sequoyah, Loop into Watts Bar Nuclear Plant	500	10.0	September 1977
Watts Bar Hydro-Watts Bar Nuclear No. 1	161	1.0	In Service
Watts Bar Hydro-Watts Bar Nuclear No. 2	161	1.0	In Service
Step II			
Watts Bar-Volunteer	500	88.0	January 1979
Watts Bar-Roane	500	40.0	January 1978
Watts Bar-Sequoyah No.2	500	40.0	September 1977

Question Number 2.2

Provide an update on the number of acres and corresponding land use types required for transmission line rights of way.

Response:

Approximately 2,008 acres of new right of way easements will be required to construct the 180 miles of transmission line connections into the Watts Bar Nuclear Plant. Although the number of miles of transmission lines and the number of acres required are now different from those originally given in TVA's Watts Bar Nuclear Plant Environmental Statement, the land use types given on page 2.2-2 remains essentially the same, i.e., 25 percent woodland, 25 percent farming and pasture, and the remainder uncultivated openland.

Question Number 2.3:

Where proposed transmission lines cross important waterfowl areas, provide a description of these areas and estimates of local flight patterns and duration of seasonal migrations.

Response:

Three noteable water areas are crossed by the proposed transmission line routes. One of these, immediately upstream from the Sequoyah Nuclear Plant site on Chickamauga Reservoir has extremely low use by waterfowl.

A second crossing occurs in a waterfowl area immediately downstream from Watts Bar Nuclear Plant site. The area is a tailwater region with a relatively narrow flood plain bordered by wooded ridges. It is occasionally used in fall by small flocks of resting waterfowl due to its proximity to Yellow Creek and Washington Ferry Wildlife Management Areas. Predominant flight patterns consist of routes between the river and Yellow Creek Wildlife Management Area, between Yellow Creek Wildlife Management Area and Washington Ferry Wildlife Management Area, and along the river between the plant site and Washington Ferry Wildlife Management Area. Yellow and Sewee Creeks provide good wood duck breeding habitat resulting in some spring and summer use in the general area. Migrant and wintering waterfowl, however, greatly outnumber resident breeding populations in fall, winter and early spring.

The Hiwassee River crossing occurs in a narrow portion of the river with limited waterfowl habitat. Broad, shallow embayments upstream and downstream (Rogers, Candies, North and South Mouse Creeks) do, however, provide suitable habitat for resident, migratory and wintering waterfowl, and shore birds. Topographically, the area can be characterized as Ridge and Valley with the valley floorsin agricultural uses (row crop or pasture) and ridges forested. Rogers and Candies Creek Wildlife Management Areas are located in the upper regions of the respective valleys occupying a partially wooded flood plain with floodable croplands managed specifically to attract migratory and wintering waterfowl. Waterfowl use occurs on a year-round basis with highest concentrations during fall, winter and early spring months. In general, summer flight patterns are unknown, although Candies Creek may be used by roosting-staging wood ducks in late summer. Migratory and wintering waterfowl tend to follow waterways comming upstream from the Blythe Ferry-Hiwassee Island complex at the mouth of the Hiwassee River, entering Candies and Rogers Creek embayments from the riverside and similarly for North and South Mouse Creek embayments farther upstream. Return flights are essentially the reverse with significant interchange between various embayments adjoining but on opposite sides of the main river and especially between Rogers and Candies Creek Wildlife Management Areas.

Question Number 2.4:

Provide an analysis of potential impacts to birds including migratory waterfowl from onsite vertical barries such as cooling towers.

Response:

Elevated structures (cooling towers, transmission lines, meteorological and communication towers, and guy wires) cause some hazard to avian populations. Reports of bird kills resulting from collisions with TV towers, lighted buildings, and airport ceilometers exist in literature.

Substantial, multidirectional variation in avian mortality caused by elevated structures is apparently related to a variety of factors including location along migratory pathways, location in relationship to a height of surrounding terrain, height and physical configuration of the structure, prevailing weather conditions, illumination, etc. In general, major mortalities have occured during coincident periods of peak migration and inclement weather conditions at very tall TV towers (approximately 1,000 feet above ground level) and at brightly lit buildings. However, significant mortalities have occurred on clear nights with good visibility at certain locations. At present, we can only concur with the conclusions of other workers (Crawford, 1974) that cause and effect relationships are not well understood.

We are not aware that bird mortality has been found to be significant at power generation facilities with large structures (such as tall stacks and natural draft cooling towers). Although we are unable to provide the requested analysis of potential impacts to birds from onsite vertical barriers, we do not expect significant avian mortality to occur at Watts Bar Nuclear Plant.

Crawford, R. L. 1974. Bird casualties at a Leon County, Florida, TV tower: October 1966 - September 1973. No. 18 Bul. Tall Timbers Res. Sta.

Question Number 2.5:

Provide a description of transmission line corridor maintenance practices that are anticipated to affect terrestrial biota, such as use of chemical herbicides, access road maintenance and mechanical clearing.

Response:

The large majority of rights of way that are not kept clear by farming or other uses are recleared on approximately 4- or 5-year cycles by the use of farm tractors and rotary cutters supplemented with the necessary power sawing of large trees that would endanger the transmission line. For right of way that is inaccessible to mowing equipment and is remote to inhabited areas, the brush is controlled by the aerial application of herbicidal chemcials registered with the Environmental Protection Agency and used within labeled restrictions. When herbicides are used, there application is carefully controlled to avoid damage to wildlife, damage to plants off the right of way and contamination of watercourses. Watercourses are located by ground and air reconnaissance, and no chenical is applied within 100 feet of any watercourse; those areas are cleared by hand or mechanical methods.

Occasionally, routine inspection and maintenance activities may require the grading of a rough access road or the reclearing of an infrequently-used woods road. When access is needed across a field or through brush where no previous access existed, TVA repairs the area traversed to its original condition. TVA does not maintain an elaborate system of access roads.

In connection with the Bellefonte Nuclear Plant, TVA has supplied NRC with a document entitled REPORT OF TRANSMISSION LINE RIGHT OF WAY CLEARING AND MAINTENANCE METHODS (BELLEFONTE NUCLEAR PLANT) dated January 1977, which the NRC found fully acceptable for that project. We feel that reference to this report will provide adequate response to NRC staff questions regarding TVA's methods of clearing and maintaining transmission line rights-of way. TVA has also provided NRC with similar information in response to staff review questions concerning the Hartsville Nuclear Plants, and Phipps Bend Nuclear Plant and the Yellow Creek Nuclear Plant.

Question Number 2.6:

Summarize specific transmission line maintenance practices used in critical areas (e.g., marshes, bogs, natural areas).

Response:

In performing transmission line maintenance, methods and equipment are used which do little damage to the terrain. Normally, TVA uses rubber-tired vehicles; but in some cases it is necessary to use a crawler type of tractor. For marshes, bogs, etc., TVA has available a wide-tracked crawler type, material and personnel carrier. These vehicles permit TVA personnel to get to locations where line maintenance is required with little disruption to the terrain. When transmission line problems arise, it is necessary to repair the transmission line as quickly as possible; however, TVA attempts to accomplish this with a minimum of adverse effects to the environment.

In connection with the Bellefonte Nuclear Plant, TVA has suppled NRC with a document entitled REPORT OF TRANSMISSION LINE RIGHT OF WAY CLEARING AND MAINTENANCE METHODS (BELLEFONTE NUCLEAR PLANT) dated January 1977, which the NRC found fully acceptable for that project. We feel that reference to this report will provide adequate response to NRC staff questions regarding TVA's methods of clearing and maintaining transmission line rights-of-way. TVA has also provided NRC with simililar information in response to staff review questions concerning the Hartsville Nuclear Plants, the Phipps Bend Nuclear Plant and the Yellow Creek Nuclear Plant.

Question Number 2.7:

Provide the maximum predicted and average electric field strength at one meter above ground level for lines energized at 500-kV.

Response:

The calculated maximum electric field strength at one meter above ground level for the 500-kV transmission line connections to the Watts Bar Nuclear Plant is 9.1 kV(RMS)/meter. This maximum value will occur at the low point of conductor sag approximately three feet outside the outermost conductor. Along the edge of the right-of-way at this same point, the calculated value of electric field strength one meter above ground is 1.75 kV(RMS)/meter (See Figure 2.7-1).

500KV TRANSMISSION LINE GRADIENT CALCULATION

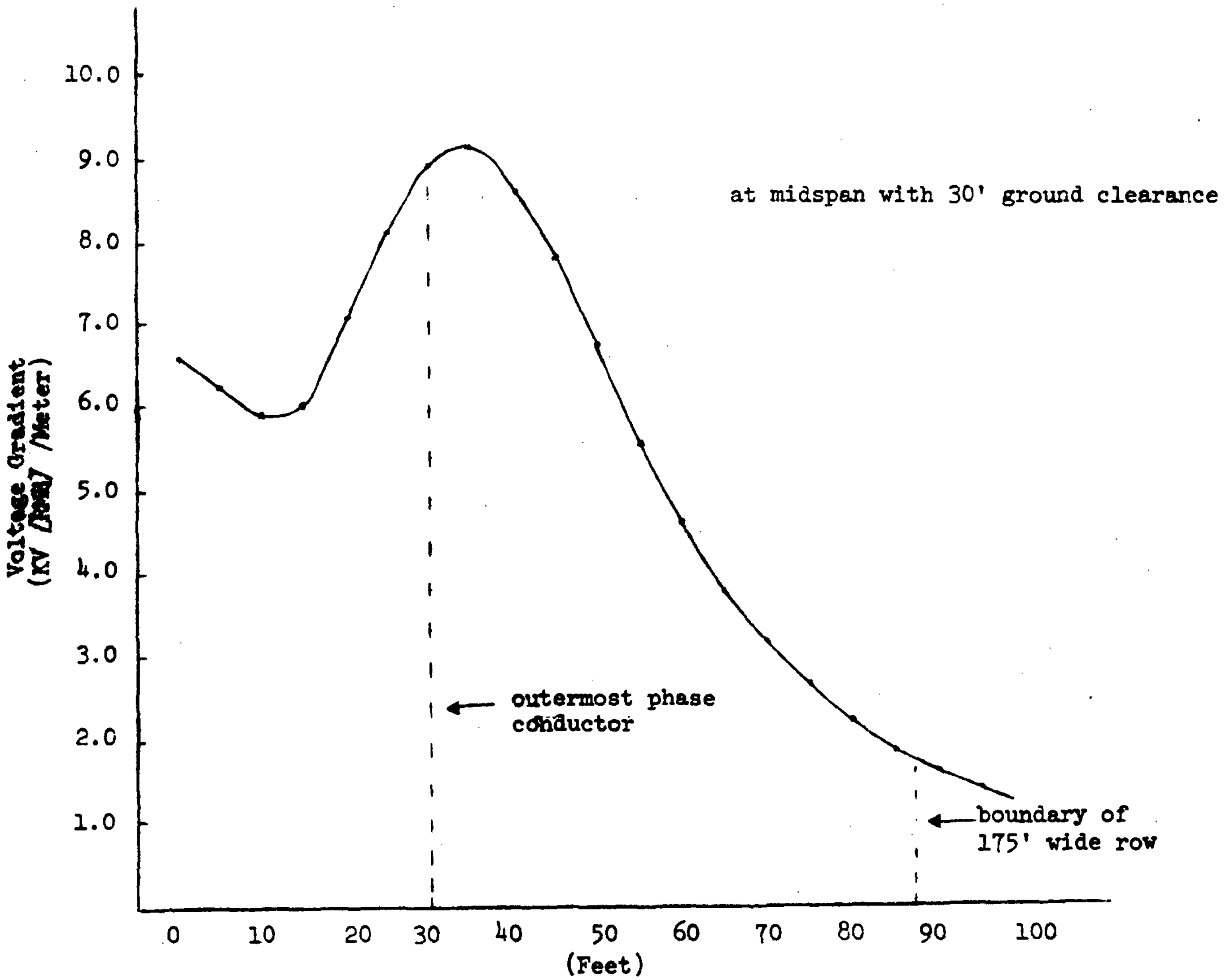


Figure 2.7-1
DISTANCE FROM CENTER PHASE CONDUCTOR

Question Number 2.8:

Describe design features such as minimum ground clearances and protective actions such as grounding and bonding, which will mitigate both transient current spark discharges and induced steady state-short circuit shock potential on stationary objects (fences, etc.) and non-stationary objects (tractor trailers, buses, farm equipment, etc.), which may be found beneath the lines on roadways, in fields, etc.)

Response:

TVA designs all of its transmission lines to meet or exceed the minimum ground clearances as specified by the National Electric Safety Code. Transmission lines can, under certain conditions, cause mild static charges to develop on some types of fencing and other ungrounded objects under the lines. These charges are similar to the common static charges people experience when walking on certain types of indoor carpeting in dry weather. To help alleviate this annoyance, TVA incorporates in its construction procedure the grounding of all fences which are located on a 500-kV transmission line corridor. If, in the construction of a transmission line, it is necessary for TVA to cross through a fence, the gate that is installed will be grounded along with the fence. During the operational life of the transmission lines, TVA will investigate reports of induced voltages and use corrective equipment and materials necessary to eliminate the induced voltages on the right of way and off the right of way with the permission of the landowner.

Question Number 2.9:

Provide an outline of any plans to be taken to monitor release of acid mist and acid fly ash from plume mergence and possible resulting environmental impact (FES-CP, p.2.6-19). Provide an analysis of deposition of salt drift (NaCl) if predicted rates are greater than 20 kg/ha/yr and if no (sic) more than 10 kg/ha are deposited in any single month during the most sensitive part of the growing season.

Response:

A routine surveillance program for terrestrial effects of the Watts Bar Steam Plant operation will be slightly expanded to cover inspection for these effects when the Watts Bar Nuclear Plant cooling towers begin to function (about 1979, if the projected schedule is maintained). During the growing season, at least three site visits will be made by qualified TVA personnel in inspect vegetation for any evidence of damage from acid mist and/or acid fly ash. Spring will be the optimum time for inspection because the initial growth of the season is generally more vulnerable. However, it is not expected that there will be any significant effects, especially offsite.

A study of drift from natural draft cooling towers was conducted for the Hartsville Nuclear Plants. A summarization of the method and results of the study is given in the response to Question 5-14 on the Hartsville Nuclear Plants Environmental Report. A conservative estimate of drift deposition at the Watts Bar Nuclear Plant can be obtained by use of the results of the Hartsville drift study. Cooling tower design and operation information relevant to drift deposition at the two sites follows:

1. The Hartsville drift deposition study utilized meteorological conditions conducive to maximum cooling tower drift rates. The assumed meteorological conditions can be expected to occur at either site, although rather infrequently. Also, deposition was assumed to be distributed evenly over a 45° sector, so that site specific wind data were not necessary.

2. The Hartsville cooling towers will be slightly larger than the Watts Bar cooling towers. Respective Hartsville and Watts Bar cooling tower dimensions are 425 and 354 feet for tower diameter (top) and 530 and 478 feet for tower height.

3. Cooling tower makeup water will be supplied at maximum rates of 250 ft^3/s and 172 ft^3/s at Hartsville and Watts Bar, respectively. At both plants, the cooling tower makeup water is expected to have a maximum total dissolved solids contents of 153 mg/l.

4. Estimated drift rate per tower is similar at the Hartsville and Watts Bar Nuclear Plants. The drift rates are 45 gal/min and 50 gal/min, respectively.

5. The Hartsville study used a concentration factor 6.6, which corresponds to a drift mass flux of 529 lbs/day/tower. The Watts Bar cooling towers will normally operate with a concentration factor of 2, which corresponds to a drift mass flux of 150 lbs/day/tower.

6. The Hartsville study reported a maximum of about 2.8 mg/m^2/day (0.84 kg/ha/month) at the distance of slightly greater than 1 kilometer for a two-tower group. Applying the maximum rate over the entire year gives a value of 10.08 mg/ha/yr for total solids deposition. NaCl salt will comprise only a small fraction of the total solids deposition.

Based on the above information, TVA concludes that an analysis of salt (NaCl) drift deposition at the Watts Bar Nuclear Plant site is not required.

Question Number 2.10:

Provide an updated list of threatened or endangered fauna and flora species (Federal Register Vol. 40:127, Part V, July 1, 1975, and Vol. 41:208, Part IV, October 27, 1976) known to occur along the proposed transmission corridors and adjacent areas, their seasons of occurrence and critical habitats. This may be done by consulting with the Regional Office of the Fish and Wildlife Service (Threatened and Endangered Species Specialist), together with state liaison representatives or specialists.

Response:

Sensabaugh Cave, located 2.2 air miles northwest of Ten Mile, Tennessee, is known to support a summer colony of the gray bat (Myotis grisescens). This cave is located approximately 0.3 miles southeast of the proposed Watts Bar-

Volunteer 500-kV transmission line.

The line crosses the Watts Bar Dam tailwater. Lampsilis orbiculata, listed by the Federal Government as an endangered species, is found in the tailwater in the vicinity of the plant but will not be affected by construction of the line. The line will also cross the Little Tennessee River at river mile 7 and the snail darter (Percina tanasi), an endangered species, is found in this portion of the river. At the time the environmental assessment for this project was completed, three threatened plant species, listed by the U.S. Department of the Interior, were potential inhabitants of the area traversed by the right of way. Bugbane (Cimicifuga rubifolia, Kearney) and yellow foxglove (Aureolaria patula (Chapm.) Pennell) found along wooded river bluffs, were not, however, included in the latest list issued by the Department of the Interior (Federal Register, June 16, 1976, Vol. 41, No. 117). Both species bloom in late summer, August and September. Price's potato bean (Apios priceana, Robinson) occurs as a threatened species on the latest Department of the Interior list. This species blooms in spring and current information reveals it is not found in the region traversed by the proposed right of way.

Question Number 2.11:

Provide the staff with a copy of the Volunteer, Tennessee, 500-kV Substation and Transmission Connections, Final Environmental Statement (July 6, 1976). Provide documentation of consultations with the Tennessee Historical Commission and other appropriate historical and archaeological agencies for coordination and identification of historical and archaeological sites ("Environmental Information", TVA, November 18, 1976, p. A-2).

Response:

Preliminary historical coordination with the Tennessee Historical Commission did not reveal any conflicts with the proposed Watts Bar-Volunteer 500-kV Transmission Line (letter dated January 9, 1976, included with this response). Final historical and archaeological coordination is currently in progress and should be completed during May 1977. Documentation of final coordination and consultations will be available to NRC when completed.

Six copies of the Volunteer, Tennessee 500-kV Substation and Transmission Line Connections Final Environmental Statement (July 6, 1976) have been included in a separate package that is being transmitted directly to the NRC staff Environmental Project Manager (on Watts Bar Nuclear Plant) for distribution to the appropriate NRC-staff technical reviewer(s).

STATE OF TENNESSEE (2-10)
TENNESSEE HISTORICAL COMMISSION
170 SECOND AVENUE, NORTH
NASHVILLE, TENNESSEE 37201
TELEPHONE (615) 741-2371

HERBERT L. HARPER, Executive Director
State Historic Preservation Officer

January 9, 1976

Mr. Robert E. Roark
Recreation Planner
Recreation Resources Branch
Division of Reservoir Properties
TVA
Knoxville, Tennessee 37902

Dear Bob:

This will acknowledge receipt of your letter of December 19 together with the maps showing the proposed route of a transmission line from the Watts Bar Nuclear Plant in Rhea County to the Volunteer Substation in Knox County.

Based upon the information submitted, I am not aware of any historical or cultural resources that would be affected by this project. However, it is possible that an on-site inspection might reveal properties of historical or architectural significance.

Sincerely,

Herbert L. Harper

Herbert L. Harper

HLH:11

Question Number 2.12:

Indicate TVA's policy on substitution of more desirable wildlife plantings in place of Kentucky 31 fescue. Provide estimations of comparative cost and specific problems associated with substitutions.

Response:

There are some instances where a grass seed mixture is substituted for Kentucky 31 fescue. Usually, this is the practice on managed wildlife preserves and refuges where men and equipment are available to seed and restore the land to their own satisfaction. In such cases their expenses are reimbursed by TVA with no measurable increase in cost over the normal contracting method. For further information see responses to Phipps Bend Environmental Report Questions (e.g., question 4.9 of Phipps Bend ER, Supplement 1).

3. AQUATIC ECOLOGY

Question Number 3.1:

Provide (in tabular format) data for the 1971-1973 catch of commercial and recreational fish and shellfish from Chickamauga Reservoir. Report the catch by principal species, indicating the quantities used as human food. In qualitative terms, describe any anticipated change from the 1971-1973 catch levels.

Response:

Fish

Table 3.1-1 shows the 1971-1973 commercial fish harvest estimate for individual Tennessee Valley Authority reservoirs. The Chickamauga catch ranked seventh (373,000 pounds) and was 5.0 percent of the Valley-wide estimate. We expect this percentage, on the average, is applicable over a five-year period, and do not anticipate future catches to deviate over 12 percent from the average. The Chickamauga commerical harvest was 100,000 pounds in 1963 and 144,000 in 1965. These estimates were 2.8 and 1.1 percent, respectively, of the Valley's total harvest estimates. Table 3.1-2 shows species catch for Chickamauga Reservoir for 1972. These data are the most recent commercial harvest data available, and they probably will not be updated until the latter part of 1977 or 1978. A subarea survey is conducted yearly, but it is not possible to specifically identify the Chickamauga portion of these data.

Included with this response is a summary report of the sport fish harvest for Chickamauga Reservoir covering 1972-1975. This information shows trends of reservoir-wide harvest and pressure.

Shellfish

a. The annual shell harvest for the Tennessee River from 1945-1967 is shown in Table 31 of the Environmental Information document dated November 1976. Information for recent years is as follows:

Annual Shell Harvest - Chickamauga Reservoir

Year	Total Shells (tons)	Species
1970	7	pigtoe (*P. cordatum*)
1971	None	-
1972	None	-
1973	Reports indicate a few mussels were harvested. Kinds or tons not identified.	
1974	Reports indicate a few mussels were harvested. Kinds or tons not identified.	
1975	Reports indicate a few mussels were harvested. Kinds or tons not identified.	
1976	No data collected.	

Principal commercial species in the area are _Quadrula pustulosa_, _Pleurobema cordatum_, _Quadrula metanevra_, and _Plagiola Lineolate_.

b. There are no "shellfish" (mussels) harvested for human comsumption.

c. There are no shellfish harvested currently or projected for recreational purposes in the TVA area.

Table 3.1-1 Estimated annual harvest from TVA reservoirs - 1971-1973.

Reservoir	Annual Pounds Harvested
Guntersville	1,938,000
Wheeler	1,938,000
Wilson	806,000
Fort Loudon	593,000
Nickajack	491,000
Douglas	422,000
Chickamauga	373,000
Watts Bar	107,000
Cherokee	40,000

Table 3.1-2 1972 Chickamauga Reservoir commercial fisherman survey (actual catch of 24.32 percent of fisherman).

Species	Pounds Caught	Pounds sold to dealers	Pounds sold to individuals
Catfish	45,409	23,858	21,141
Buffalo	34,870	31,400	3,320
Carp	10,180	7,000	3,080
Drum	160	160	-
Spoonbill	160	160	-
Others	-	-	-
Total	90,779	62,578	27,541

SURVEY OF SPORT FISHING

CHICKAMAUGA RESERVOIR

January 1, 1972 through December 31, 1975

By

Vester P. Mitchell, Jr.

and

Billy B. Carroll

Tennessee Valley Authority
Division of Forestry, Fisheries, and Wildlife Development
Muscle Shoals, Alabama

July 1976

SURVEY OF SPORT FISHING

CHICKAMAUGA RESERVOIR

January 1, 1972 through December 31, 1975

Introduction

This report covers data collected during a year-round survey of sport fishing effort and success in Chickamauga Reservoir prior to operation of Sequoyah Nuclear Plant. It is one phase of an overall study to determine possible effects of Sequoyah Nuclear Plant on reservoir fisheries conditions. Data presented were collected from January 1972 through December 1975.

Survey procedure was formulated by personnel of the Tennessee Wildlife Resources Agency (formerly Tennessee Game and Fish Commission) and TVA following closely a design prepared for Tennessee by Dr. D. W. Hayne of the Institute of Statistics at Raleigh, North Carolina. Collection of field data was performed by TVA personnel; data processing by TVA and Tennessee Wildlife Resources Agency.

Chickamauga Reservoir at full pool (elevation 682.5) is 15,740 ha. Its shoreline stretches for 1,300 Kl through five Tennessee counties. Chickamauga Dam is located 760 Kl upstream from the mouth of the Tennessee River and impounds water 95 Kl upstream to the base of Watts Bar Dam.

Methods

This survey was of the roving clerk type with day, work area, and time of day randomly selected. Workdays were drawn, with replacement, until enough days had been selected to fill out the prescribed five-day, weekly work load for the clerk; a record was kept of the number of times it was necessary to draw each day in order to complete the weekly schedule. After the workdays for a week had been selected, the work area and time for each day were chosen. Work areas were laid out to be just large enough to be covered in a boat in one work period. Chickamauga Reservoir was divided into seven work areas--four above the plant site, one including the plant site, and two below the plant (see map).

Each day was divided into two work periods, from sunrise until noon and from noon until sunset (except during Daylight Savings Time when the division was at 1:00 p.m. instead of noon). After the time of day had been selected, the given time for making the instantaneous counts was chosen at random from four possible times during the work period. At this preselected time, the clerk counted the number of persons fishing in the work area. During the rest of the work day, the clerk collected information on the number of each species of fish caught, the weights of individual fish, hours fished, and related data from each fisherman interviewed. A more comprehensive questionnaire, including economic information, was completed for every tenth fisherman interviewed. Estimates of fishing success were made from the interviews and estimates of fishing pressure from the counts of fishermen; total catch was estimated as the product of success and pressure.

A separate estimate of the weekly fishing pressure in fisherman hours (P) was made for each work period by use of the following formula:

$$P = \frac{a \times c}{b \times d \times e}$$

where

a = work area count

b = probability of drawing this work area

c = number of hours in work period

d = probability of drawing this work day

e = probability of drawing this work time (a.m. or p.m.)

The probabilities for work days, areas, and times had been assigned using information on fishing pressure provided by TVA personnel from previous information of fishermen use on Chickamauga Reservoir. Each day's estimate of weekly pressure was weighted by the number of times that particular day was drawn in setting up the original sampling schedule and combined as a mean ($\overline{P}$) for the week.

Estimated weekly harvest (number) of each species is the average catch per hour of that species from the clerk's total interviews for the week multiplied by the pressure ($\overline{P}$). The weekly harvest of a particular species multiplied by its average weight in the creel provides the weekly weight of each species caught. Estimated total number and weight of all fish caught each week are summations of the catch of individual species.

Total number of fishing trips is derived from the average length of completed fishing trips in hours divided into the total fisherman hours. Total and itemized expenditures per fishing trip were obtained by adding all economic interview data and dividing by the number of such interviews.

All tabulations and calculations used in this survey were made by IBM 360-20 computer using programs developed and written by Dr. Don Hayne of the Institute of Statistics, North Carolina State University at Raleigh. The computer program prints the creel clerk's work schedule, expands the counts into estimated pressure and, employing catch data, makes harvest estimates by week, month, and year.

Results

Fishing Pressure

Total fishing effort for Chickamauga Reservoir during the 48-month period, January 1, 1972, through December 31, 1975, was estimated to be 1,045,500 hours, or 276,000 trips. From January 1 through December 31, 1972, the total effort was 338,900 hours, or 82,800 fishing trips. During the 12 months of 1973, 252,100 hours and 64,100 trips were estimated. During the 12 months of 1974, 216,900 hours and 60,400 trips were estimated. From January 1 through December 31, 1975, the total effort was 237,600 hours, or 68,900 fishing trips (Table 1).

Fishing pressure varied seasonally with major effort expended during May in 1972 (81,238 hr) and July in 1975 (39,500 hr). Minimum effort occurred during December in 1972 (1,647 hr) and January in 1975 (5,225 hr). The average length fishing trip was 4.1 hr in 1972, 3.9 hr in 1973, 3.6 hr in 1974, and 3.5 hr in 1975. Mean annual effort per hectare was 21.5 hr (5.3 trips) in 1972, 16 hr (4.1 trips) in 1973, 13.8 hr (3.8 trips) in 1974, and 15.1 hr (4.4 trips) in 1975.

Catch

The total estimated catch for the 48-month period was 917,800 fish and 264,200 Kg. The estimated catch for 1972 was 288,600 fish weighing 79,100 Kg. During 1973 an estimated harvest of 244,700 fish at 91,515 kg was made. The estimated catch for 1974 was 204,500 fish weighing 47,300 Kg. During 1975 an estimated harvest of 180,000 fish at 46,300 Kg was made (Table 2).

The mean catch per hour was 0.85 fish in 1972, 0.98 in 1973, 0.94 in 1974, and 0.76 in 1975. In terms of biomass the catch rates were 0.23, 0.36, 0.21, and 0.19 Kg/hr respectively. The annual catch per hectare was 18.3 fish in 1972, 15.5 fish in 1973, 13.0 fish in 1974, and 11.4 fish in 1975; 5.0, 5.8, 3.0, and 2.9 Kg/hr respectively.

Twenty-seven taxa were identified in the sport fish catch. White crappie were the dominant species in all four years. White crappie accounted for 35, 59, 27, and 37 percent of the total harvest by number in 1972, 1973, 1974, and 1975 respectively. In terms of biomass white crappie

Made up 30, 36, 24, and 29 percent respectively. Other dominant species in the catch were bluegill, white bass, channel catfish, drum, and largemouth bass. These six species mentioned comprised 88 percent of the total sport fish catch by number and 78 percent by weight.

... 31, 1975, Chickamauga Reservoir,
Tennessee.

Month	Hours of Pressure 1972	Hours of Pressure 1973	Hours of Pressure 1974	Hours of Pressure 1975	Number of Trips 1972	Number of Trips 1973	Number of Trips 1974	Number of Trips 1975
January	2,854	10,609	6,840	5,225	738	2,121	1,504	1,778
February	4,197	5,444	8,093	14,994	1,109	1,089	2,416	7,497
March	40,377	17,041	12,915	19,074	10,424	4,868	2,974	5,020
April	33,246	35,848	27,250	29,925	8,258	8,234	7,494	7,742
May	81,238	37,835	28,527	30,660	17,607	10,510	7,486	7,665
June	75,374	29,961	18,663	18,231	18,170	6,478	5,096	6,077
July	45,543	19,096	32,350	39,500	11,347	5,338	11,100	9,943
August	20,577	38,678	28,880	22,578	5,558	9,618	6,650	5,571
September	14,193	19,477	15,594	19,647	4,152	5,361	5,124	6,552
October	11,119	25,528	21,080	19,838	2,623	7,326	5,302	5,209
November	8,570	6,494	9,546	12,300	2,443	1,341	2,803	3,917
December	1,647	6,045	7,130	5,500	330	1,780	2,413	1,834
Total	338,935	252,056	216,868	237,572	82,759	64,064	60,362	68,805

Table 2. Estimated catch by species, January 1, 1972, through December 31, 1975, Chickamauga Reservoir, Tennessee.

	Number				Biomass (Kg)			
Species	1972	1973	1974	1975	1972	1973	1974	1975
White crappie	99,838	143,392	55,873	66,444	23,764	33,145	11,441	13,265
Bluegill	73,845	38,102	75,749	46,348	8,913	5,980	9,994	6,942
White bass	29,108	12,005	13,779	10,850	10,470	3,857	4,340	2,571
Channel catfish	20,901	13,517	14,213	15,370	9,501	10,541	6,805	7,546
Drum	17,414	4,557	4,229	544	6,311	1,479	1,292	127
Largemouth bass	15,972	10,066	12,295	16,916	8,425	5,286	5,684	9,076
Skipjack herring	3,304	1,378			1,336	210		
Blue catfish	5,746	5,106	3,108	2,360	2,432	24,947	1,147	753
Redear sunfish	6,494	3,449	10,446	6,916	1,007	610	1,630	1,348
Spotted bass	5,508	3,434	4,025	4,537	1,845	1,427	1,554	1,526
Smallmouth bass	4,283	97	163	362	1,827	42	91	101
Black crappie	1,874	2,068	4,215	4,234	440	474	948	1,072
Sauger	1,410	3,679	4,737	3,502	981	1,374	1,651	887
Other sunfish*	398	841	259	273	53	123	21	33
Yellow perch	564	909	566		73	179	111	
Yellow bass	390	225	475	747	70	79	98	84
Flathead catfish	633	286	30	497	364	216	14	955
Rockbass	323	564			138	103		
Bullhead	142		110		86		107	
Carp	270	96	28		704	185	57	
Walleye	68		137		124		188	
Smallmouth buffalo	42	7			103	8		
Longnose gar	90				90			
Rockfish	12	842	33		16	1,243	62	
Mooneye	18				7			
Minnows		76				7		
Paddlefish			48				44	
Total	288,647	244,696	204,518	179,900	79,080	91,515	47,279	46,286

*Includes longear sunfish, green sunfish, warmouth, etc.

Table 3. Harvest rate of sport fish, January 1, 1972, through December 31, 1975, Chickamauga Reservoir, Tennessee.

	Harvest per hour of fishing		Harvest per hectare	
	Number	Biomass (Kg)	Number	Biomass (Kg)
1972	0.85	0.23	18.3	5.0
1973	0.97	0.36	15.5	5.8
1974	0.94	0.21	13.0	3.0
1975	0.76	0.19	11.4	2.9

Question Number 3.2:

Provide a qualitative estimate of the fishing success that could occur at the closest, publicly accessible, location to the diffuser discharge.

Response:

During the previously mentioned sport fish creel survey, the analysis system employed was not conducive to data summaries by subareas of the reservoir. In 1976 changes were made in the data analysis system to accommodate subarea estimates. The 1976 data have not been completely analyzed but should be completed by June 1977. The area nearest the diffuser and most heavily utilized by sport fishermen is the Watts Bar tailwater, immediately below the dam.

Question Number 3.3:

Provide a list of aquatic species (or lowest practical taxa) which are "important" as defined by NRC Reg. Guide 4.2.

Response:

Table 3.3-1 includes 60 fish species that were collected over the past 15 years with cove rotenone samples in Chickamauga Reservoir. Using a liberal interpretation of NRC Reg. Guide 4.2, all of these species can be considered important.

Table 3.3-2 includes mussels considered "important" and their criteria for being considered "important" as described in NRC Regulatory Guide 4.2. No other group of aquatic organisms other than fish fall into this "important" category.

TABLE 3.3-1
Fish Species List Obtained from Cove
Rotenone Samples in Chickamauga Reservoir

Number	Common Name	Scientific Name
1	Chestnut lamprey	*Icythyomyzon castaneus* Girard
2	Spotted gar	*Lepisosteus oculatus* (Winchell)
3	Longnose gar	*L. osseus* (Linnaeus)
4	Shortnose gar	*L. platostomus* Rafinesque
5	Skipjack herring	*Alosa chrysochloris* (Rafinesque)
6	Gizzard shad	*Dorosoma cepedianum* (Lesueur)
7	Threadfin shad	*D. petenense* (Günther)
8	Mooneye	*Hiodon tergisus* Lesueur
9	Stoneroller	*Campostoma anomalum* (Rafinesque)
10	Rosyside dace	*Clinostomus funduloides* Girard
11	Carp	*Cyprinus carpio* Linnaeus
12	Silver chub	*Hybopsis storeriana* (Kirtland)
13	Golden shiner	*Notemigonus crysoleucas* (Mitchill)
14	Emerald shiner	*Notropis atherinoides* (Rafinesque)
15	Ghost shiner	*N. buchanani* (Meek)
16	Spotfin shiner	*N. spilopterus* (Cope)
17	Striped shiner	*N. chrysocephalus* (Rafinesque)
18	Bluntnose minnow	*Pimephales notatus* (Rafinesque)
19	Bullhead minnow	*P. vigilax* (Baird and Girard)
20	River carpsucker	*Carpiodes carpio* (Rafinesque)
21	Quillback carpsucker	*C. cyprinus* (Lesueur)
22	Highfin carpsucker	*C. velifer* (Rafinesque)
23	Northern hog sucker	*Hypentelium nigricans* (Lesueur)
24	Smallmouth buffalo	*Ictiobus bubalus* (Rafinesque)
25	Bigmouth buffalo	*I. cyprinellus* (Valenciennes)

TABLE 3.3-1 (continued)

Number	Common Name	Scientific Name
26	Black buffalo	*Ictiobus niger* (Rafinesque)
27	Spotted sucker	*Minytrema melanops* (Rafinesque)
28	Silver redhorse	*Moxostoma anisurum* (Rafinesque)
29	Shorthead redhorse	*M. macrolepidotum* (Lesueur)
30	River redhorse	*M. carinatum* (Cope)
31	Black redhorse	*M. duquesnei* (Lesueur)
32	Golden redhorse	*M. erythrurum* (Rafinesque)
33	Blue catfish	*Ictalurus furcatus* (Lesueur)
34	Black bullhead	*I. melas* (Rafinesque)
35	Channel catfish	*I. punctatus* (Rafinesque)
36	Flathead catfish	*Pylodictis olivaris* (Rafinesque)
37	Blackstripe topminnow	*Fundulus notatus* (Rafinesque)
38	Blackspotted topminnow	*F. olivaceus* (Storer)
39	Mosquitofish	*Gambusia affinis* (Baird & Girard)
40	White bass	*Morone chrysops* (Rafinesque)
41	Yellow bass	*M. mississippiensis* Jorden and Eigenmann
42	Rock bass	*Ambloplites rupestris* (Rafinesque)
43	Warmouth	*Lepomis gulosus* (Cuvier)
44	Redbreast sunfish	*L. auritus* (Linnaeus)
45	Green sunfish	*L. cyanellus* Rafinesque
46	Orangespotted sunfish	*L. humilis* (Girard)
47	Bluegill	*L. macrochirus* (Rafinesque)
48	Longear sunfish	*L. megalotis* (Rafinesque)
49	Redear sunfish	*L. microlophus* (Günther)
50	Smallmouth bass	*Micropterus dolomieui* Lacépède
51	Spotted bass	*M. punctulatus* (Rafinesque)

TABLE 3.3-1 (continued)

Number	Common Name	Scientific Name
52	Largemouth bass	*Micropterus salmoides* (Lacépède)
53	White crappie	*Pomoxis annularis* Rafinesque
54	Black crappie	*P. nigromaculatus* (Lesueur)
55	Rainbow darter	*Etheostoma caeruleum* Storer
56	Yellow perch	*Perca flavescens* (Mitchill)
57	Logperch	*Percina caprodes* (Rafinesque)
58	Sauger	*Stizostedion canadense* (Smith)
59	Freshwater drum	*Aplodinotus grunniens* Rafinesque
60	Brook silverside	*Labidesthes sicculus* (Cope)

TABLE 3.3-2

Number	Common Name	Scientitic Name
I. Species that are commercially valuable:		
1.	White wartyback	Quadrula pustulosa
2.	Ohio River pigtoe	Pleurobema cordatum
3.	Three-ridge	Amblema plicata
4.	Monkeyface	Quadrula metanevra
5.	Butterfly	Plagiola lineolata
II. Species that is rare, threatened, or endangered:		
1.	Pink Mucket	Lampsilis orbiculata
III. Species that is biological indicator of radionuclides in the environment:		
1.	Asiatic clam	Corbicula manilensis

Question Number 3.4:

Provide detailed information on concentrations and distribution (spatially) of fish early life stages in the site vicinity. Describe any ongoing or planned studies to determine the relative significance of the tailrace spawning habitat to the Chickamauga Reservoir (e.g., compare with spawning of the same species in tributaries to the Reservoir).

Response:

Following is a discussion of the larval fish entrainment data collected in 1976.

CONCENTRATIONS AND SPATIAL DISTRIBUTION OF ICHTHYOPLANKTON IN THE VICINITY OF WATTS BAR NUCLEAR PLANT

To determine the spatial and temporal concentrations and distributions of ichthyoplankton in the vicinity of Watts Bar Nuclear Plant Site samples were taken along a transect adjacent to the intake construction site at Tennessee River Mile 528.0. Five stations equidistantly spaced, were sampled biweekly from March 29, 1976 through September 9, 1976. At each station, full-stratum samples were taken four times a day (dawn, day, dusk, night) during each sampling period. All samples were taken with a 0.5 m beam net (0.5 mm mesh)towed at 1.0 m/sec. Flow was recorded with a General Oceanics large-vane flowmeter mounted in the net mouth. All tows were of 10 min duration, and approximately 150 m^3 of water was filtered with each tow. All tows were in an upstream direction.

Samples were preserved in the field in 10 percent Formalin and returned to the laboratory. Fish early life stages were identified to the lowest possible taxon using polarized stereomicroscopy and available taxonomic keys (e.g., Hogue, Wallus and Kay, 1976; May and Gasaway, 1967; Norden, MS: Taber, 1967). Level of identification depended upon taxon in question, developmental stage and condition of specimens. Mutilated specimens were termed "unidentified" and those identifiable only to the family level were termed "unspecified".

Fish larvae of 16 taxa belonging to 8 families were collected (Table 1). Unspecified clupeids were the most abundant taxon overall (91.17 percent relative abundance). The only other taxa which exceeded 1.0 percent relative abundance were Aplodinotus grunniens (freshwater drum) and Lepomis spp.

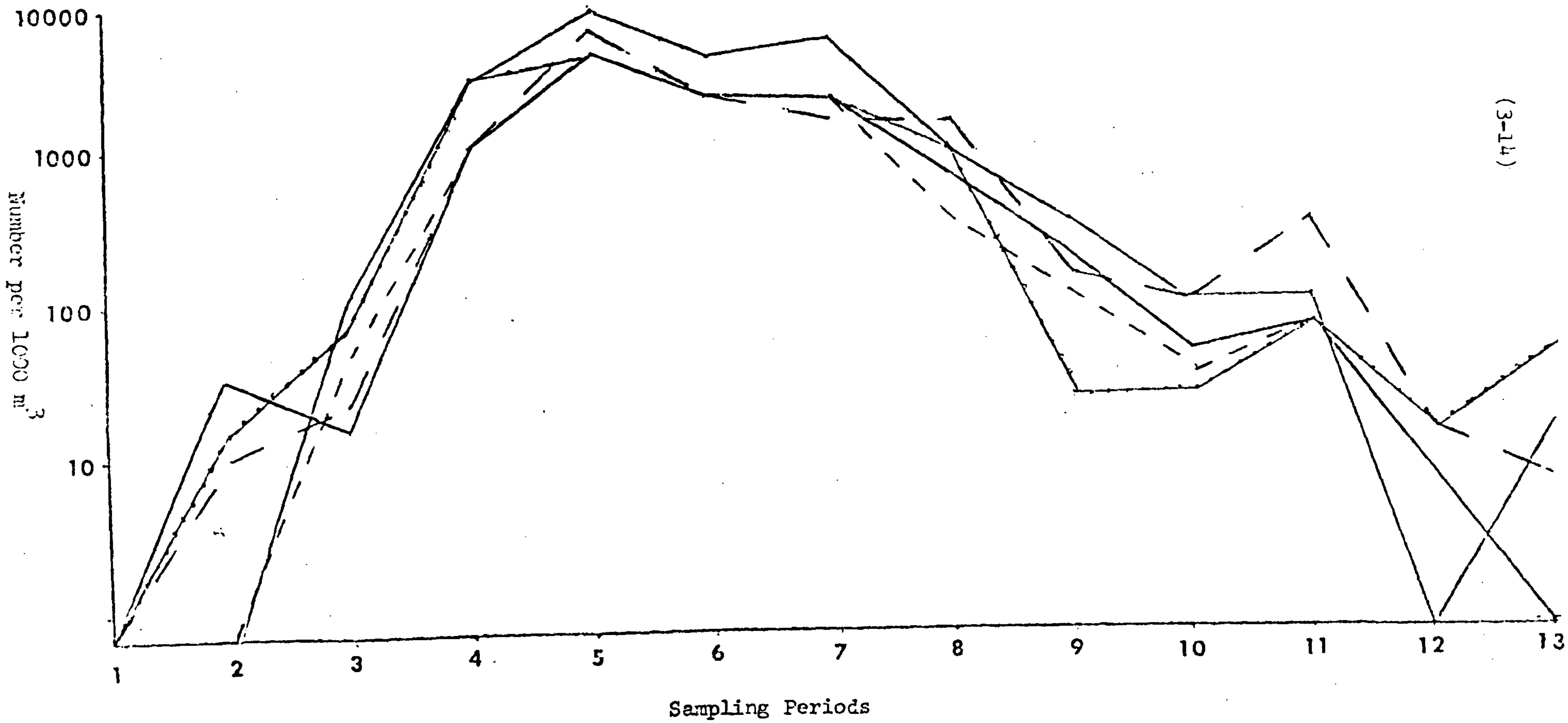
Table 1. Total Number Captured and Relative Abundance (%) of Fish Larvae.

Taxon	No. Collected	Percent Relative Abundance
Clupeidae		
Unspecified clupeids	9913	91.17
Dorosoma cepedianum	2	0.02
Dorosoma petenense	32	0.29
Sciaenidae		
Aplodinotus grunniens	601	5.53
Centrarchidae		
Lepomis spp.	209	1.92
Pomoxis spp.	24	0.01
Ictaluridae		
Ictalurus furcatus	1	0.01
Icatlurus punctatus	45	0.41
Pylodictis olivaris	1	0.01
Cyprinidae		
Unspecified cyprinids	7	0.06
Pimephales group	1	0.01
Cyprinus carpio	27	0.25
Percicthyidae		
Morone sp.	1	0.01
Morone (not *saxatilis*)	5	0.05
Catostomidae		
Minytrema melanops	2	0.02
Percidae		
Stizostedion sp.	1	0.01
Unidentified	1	0.01

Few larvae were collected which were produced by migratory (tailrace) spawners. These were six *Morone* spp., two *Minytrema melanops*, and a single *Stizostedion* spp. The combined relative abundance of these taxa was less than one tenth of one percent of the total catch. If the Watts Bar tailrace had been an important spawning area in 1976, we would have expected their young to have occurred in considerably higher numbers.

Of the taxa collected, only clupeids were abundant enough to merit close scrutiny of their spatial distribution. During sampling periods 3-11 clupeids were collected at all stations and in no instance was there more than an order-of-magnitude difference between concentrations at the five stations (Figure 1). Also, there was no consistent pattern of high or low concentrations at any one station; therefore, the horizontal distribution of clupeids was essentially uniform throughout the season. Uniformity of horizontal distributions of most taxa is also apparent upon examination of percent relative abundance of all taxa collected by station (Table 2). Ictalurids were most abundant at the middle channel station (the deepest water station). All ictalurids captured were alevins ranging in size from 17-40 mm total length. Ictalurids of these sizes should be capable swimmers, and apparently, they actively selected the deepest water area for habitation.

Figure 1. Concentrations of Clupeidae by Station for each Sampling Periods.



(3-14)

Table 2. Percent Relative Abundance of Fish Larvae Captured at 5 Stations-Watts Bar Nuclear Site - 1976.

Taxon	Left Shoreline	Left Channel	Middle Channel	Right Channel	Right Shoreline
Unidentified Fish	0.06				
Unspecified clupeids	90.23	91.83	89.10	93.54	92.93
Dorosoma cepedianum	0.06				0.05
D. petenense	0.17	0.37	0.25	0.28	0.42
Unspecidied cyprinids	0.06	0.18	0.03	0.06	0.05
Pimephales group			0.03		
Cyprinus carpio	0.52	0.25	0.19	0.17	0.19
Minytrema melanops	0.12				
Ictalurus furcatus			0.03		
I. punctatus	0.12	0.12	0.94	0.28	0.09
Pylodictis olivaris			0.03		
Morone sp.	0.06				
Morone (not saxatilis)		0.12			0.14
Lepomis sp.	2.27	1.35	2.00	1.61	2.21
Pomoxis sp.	0.17	0.25	0.25	0.22	0.19
Stizostedion sp.			0.03		
Aplodinotus grunniens	6.16	5.53	7.13	3.84	3.72

Estimates of the total seasonal entrainment of each family was made. For these estimates the number of larvae and eggs assumed to be entrained on each sample date was calculated as:

$N_i = D_i \times Q_i$, where:

N_i = Number entrained for each family on each date;

D_i = Density of each family on each date in right shoreline station;

Q_i = 24 hour maximum plant water demand (77,500 g.p.m. - makeup).

Similarly, an estimate of the number of larvae transported past the plant site on each sample date was calculated as:

$N_r = D_r \times Q_r$, where:

N_r = Number transported for each family on each date;

D_r = Mean density for each family at plant transect.

Q_r = 24 hour river flow past plant site on each date.

The above daily estimates were then integrated to yield estimates of total numbers of larvae and eggs transported and total number entrained. The ratio of these numbers was then converted to a percentage; this value is an estimate of total percent annual entrainment (Table 3).

Estimated seasonal entrainment was low for all families captured. Maximum estimated entrainment was 1.55 percent for Percichthyidae (*Morone* spp.). Estimates for the other familes and for all fish and eggs combined were all less than 1.5 percent. An estimated 2.47×10^9 larvae were transported past the plant site during the 1976 season, and an estimated 6.80×10^7 larvae were entrained. These estimates agree closely with observed hydraulic entrainment for the same time period (Table 4). Maximum observed hydraulic entrainment was estimated to be 1.46 percent on April 21, 1976.

Table 3. Estimated Seasonal Entrainment (%) of Fish Families, Watts Bar Nuclear Site, 1976.

Family	Seasonal #'s Transported	Seasonal #'s Entrained	Entrainment (%)
Sciaenid Eggs	6.5575×10^7	2.1457×10^5	0.33
Clupeidae	2.2188×10^9	2.5047×10^7	1.13
Cyprinidae	1.1640×10^7	7.7600×10^4	0.67
Catostomidae	3.7328×10^5		
Ictaluridae	1.3669×10^7	2.5178×10^4	0.18
Percichthyidae	2.4804×10^6	3.8480×10^4	1.55
Centrarchidae	6.2125×10^7	6.3013×10^5	1.01
Percidae	1.6405×10^5		
Sciaenidae	1.6127×10^8	9.8184×10^5	0.61
Total Eggs	6.8089×10^7	2.1457×10^5	0.32
Total Fish	2.4707×10^9	2.6800×10^7	1.08

Table 4. Reservoir Flow (Q_r) and Intake Flow (Q_i), Watts Bar Nuclear Site, Watts Bar Reservoir, 1976.

Date	Sample Period	Qr $M^3 x 10^7$	Qi* $M^3 x 10^5$	Qi/Qr
3/24	1	6.0430	4.2245	0.0070
4/07	2	4.1592	4.2245	0.0102
4/21	3	2.8870	4.2245	0.0146
5/05	4	3.4252	4.2245	0.0123
5/18	5	4.4772	4.2245	0.0094
6/03	6	5.2846	4.2245	0.0080
6/17	7	7.8290	4.2245	0.0054
6/29	8	6.3856	4.2245	0.0066
7/14	9	5.8962	4.2245	0.0072
7/28	10	7.1685	4.2245	0.0059
8/09	11	8.0003	4.2245	0.0053
8/25	12	7.0706	4.2245	0.0060
9/09	13	7.7067	4.2245	0.0055

* - Flows are 24-hour Totals.

It is, therefore, our conclusion that:

1. The majority of fish early life stages were uniformly distributed in the vicinity of the Watts Bar Nuclear Site, and biological entrainment may be considered to approximate hydraulic entrainment;

2. In 1976, the tailrace was not an important spawning site for migratory spawners, but that the extensive rip-rap areas associated with the Watts Bar Lock and Dam appear to be attractive to sedentary spawning centrarchids and ictalurids. Futher study will be required to determine whether 1976 was an unusally poor year for migratory spawners, or whether the tailrace is not a preferred spawning area for these groups.

LITERATURE CITED

Hogue, J. J., R. Wallus, and L. K. Kay. 1976. Preliminary guide ot the identification of larval fishes in the Tennessee River. Tennessee Valley Authority, Division of Forestry, Fisheries, and Wildlife, Technical Note B19. 67 pp.

May, E. G. and C. R. Gasaway. 1967. A preliminary key to the identification of larval fishes of Oklahoma, with particular reference to Canton Reservoir, including a selected bibliography. Okla. Dept. Wildl. Conser. Research Lab. Report No. 5.

Norden, C. R. MS. A key to larval fishes from Lake Erie. University of Southwestern Louisiana, Lafayette.

Taber, C. 1967. The distribution and identification of larval fish in the Buncome Creek Arm with some observations on spawning habits and relative abundance. Ph.D. dissertation, University of Oklahoma, Norman.

Question Number 3.5:

Provide data and/or reports on the cove rotenone sampling in Chickamauga Reservoir.

Response:

The following reports are provided as information for this response:

Fish Inventory Data Chickamauga Reservoir - 1971
Fish Inventory Data Chickamauga Reservoir - 1972
Fish Inventory Data Cichkamauga Reservoir - 1973
Computer Output of Cove Rotenove Samples (Tables 3.5-1 thru 3.5-25)

The enclosed reports and computer output of cove rotenone samples in Chickamauga Reservoir may contain some estimates that appear to be inconsistent. The reports, written shortly after the samples were taken relied on hand-calculated subsample information based on a limited number of fish, whereas the computer-calculated subsample information is based on all fish of the same size and species taken in the reservoir. Since 1974 the computer-based system has had more detailed analysis programs, hence, the estimates are more reliable.

FISH INVENTORY DATA

CHICKAMAUGA RESERVOIR

FISH INVENTORY DATA

CHICKAMAUGA RESERVOIR

1970

Tennessee Valley Authority
Fisheries and Waterfowl Resources Branch

February 1971

INTRODUCTION

This report contains recently gathered information on fishes living along the shoreline and in the coves of Chickamauga Reservoir. It is the result of sampling studies done during July and August 1970 by the Tennessee Valley Authority.

Technical data presented will be used by the various agencies involved with fish management and fishery resource development. It should be helpful to biologists called on to investigate fish kills or other effects of changes in water quality, to evaluate the introduction of exotic fish into the reservoir, and as background for determining effects on fish of the Sequoyah Nuclear Plant now under construction at about TRM 485.

The specific data gathered reflect the number, size, mass, and variety of species found and indicate reproductive success of the various fishes which inhabit the cove and shoreline areas of Chickamauga.

FISH INVENTORY DATA
CHICKAMAUGA RESERVOIR
1970

Total surface area of Chickamauga Reservoir at full pool (elevation 682.5) is 35,400 acres. During the sampling period, July 6 to August 5, 1970, the lake elevation dropped from 682.2 to 680.7 and the reservoir area varied between 34,200 and 32,800 acres. Surface temperatures varied from 77.5 to 87.4 degrees F.

The lake was subdivided into four major areas and three coves in each area were sampled with rotenone (see map). Sample areas ranged from 0.43 to 2.39 surface acres, average depths from 3.3 to 5.8 feet.

Field procedures for treatment of each cove and collection of data followed standard sampling methods now used in cove rotenone samples throughout the Southeast. Marked fish of various species were added to eight coves prior to treatment to check on fish recovery. Scale or spine samples were collected from species likely to be caught by sport fishermen for analyses of their age and growth.

SUMMARY OF FINDINGS

Average cove population—3,345 fish and 181.6 pounds per acre—8,266 fish and 203.6 kilograms* per hectare (Table 3).

Major fish classes by number—game 24 percent, rough 7 percent, and forage 69 percent (Tables 4 and 7).

Major fish classes by weight—game 12 percent, rough 55 percent, and forage 33 percent (Tables 4 and 7).

Dominant species by number—threadfin shad 30 percent, gizzard shad 28 percent, bluegill 15 percent, assorted minnows 12 percent, and drum 5 percent (Table 5).

Dominant species by weight—gizzard shad 29 percent, smallmouth buffalo 24 percent, drum 14 percent, bigmouth buffalo 9 percent, and bluegill 6 percent (Table 5).

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*Conversions to metric measurements are shown because both national and international scientific usage of the metric system is becoming more widespread.

Size distribution of game fish—young-of-year 75 percent, intermediates 16 percent, harvestable (adults) 9 percent (Tables 6 and 7).

Size distribution of all fish—young-of-year 84.4 percent, intermediates 6.5 percent, harvestable (adults) 9.1 percent (Tables 6 and 7).

Spawning success—large numbers of forage fish indicate excellent spawning success. Largemouth, spotted bass, and bluegill reproduction has been good.

Marked fish recovered—210 of 381 for 55.1 percent (Table 8).

Growth rates—growth rates of bluegill in Chickamauga were above those of largemouth bass; white crappie and channel catfish below the average in east Tennessee reservoirs (Table 9).

GENERAL CONCLUSIONS

The average standing cove fish crop in Chickamauga Reservoir in 1970 of 181.6 pounds per acre is below that found in most TVA mainstream impoundments. Forage fish populations, both by number and weight, were less than expected in this kind of reservoir; weight of rough fish (55%) was greater. Sampling error (one standard deviation) for standing crop estimates in the 12 samples was calculated to be ± 10.9 percent. The percentage of marked fish recovered averaged only 55 percent; consequently the total recovery is probably conservative. Represented in the total catch were 37 species of fish among 24 genera belonging to 9 families.

Yellow perch appeared for the first time in a TVA fish inventory on this lake and they were well dispersed over the lake. Their numbers decreased going upstream from the dam. Area IV (see map) had 65; Area III had 45; Area II had 4 and Area I had one. This fish has apparently invaded the lake from the Upper Hiwassee River where it had been introduced by State Fish and Wildlife agencies in Chatuge, Nottley, and Blue Ridge reservoirs.

The last inventory conducted on Chickamauga was in August, 1959. At that time block nets were not used to confine fish to the kill area, but a heavy curtain of rotenone was dispersed at the outer edge of the cove where a net would have been placed. This must be considered when comparisons are made.

Number and weight of harvestable-size fish was greater in 1970 than in either of the two previous sample years (Table 10). Numbers of game fish per acre were up from 428 in 1959 to 791 in 1970 and 75 percent of the latter were young-of-year. Forage fish numbers per acre in 1970 were almost five times that in earlier samples (Table 11).

STANDING FISH CROP—VOLUME ESTIMATES

Standing crop data for fish are usually presented in terms of surface area of samples, i.e., pounds per acre or kilograms per hectare. To determine if cove depth has any influence on the estimate of biomass, weight of fish was also calculated for water volume (per acre-foot and hectare-meter) for the 12 samples from Chickamauga Reservoir (Table 12).

In these 12 coves there was not sufficient difference in mean depth to alter the standing crop results obtained on an area basis. Depth of coves ranged from 3.3 to 5.8 feet (1.0 to 1.8 meters). There was good correlation ($r = 0.914$) between weight per unit volume of water (kilograms per hectare-meter) and weight per unit area (kilograms per hectare). Thus, for this set of samples it would seem to make little difference whether the standing crop was calculated on an area or volume basis, since these relationships here were nearly the same.

The same may not necessarily apply to samples in other reservoirs, particularly storage impoundments where mean cove depth may vary considerably. Standing crop on a water-volume basis may eventually prove to be another useful tool for analysis of reservoir samples of fish, and it should be examined on other lakes where considerable cove sample data are available.

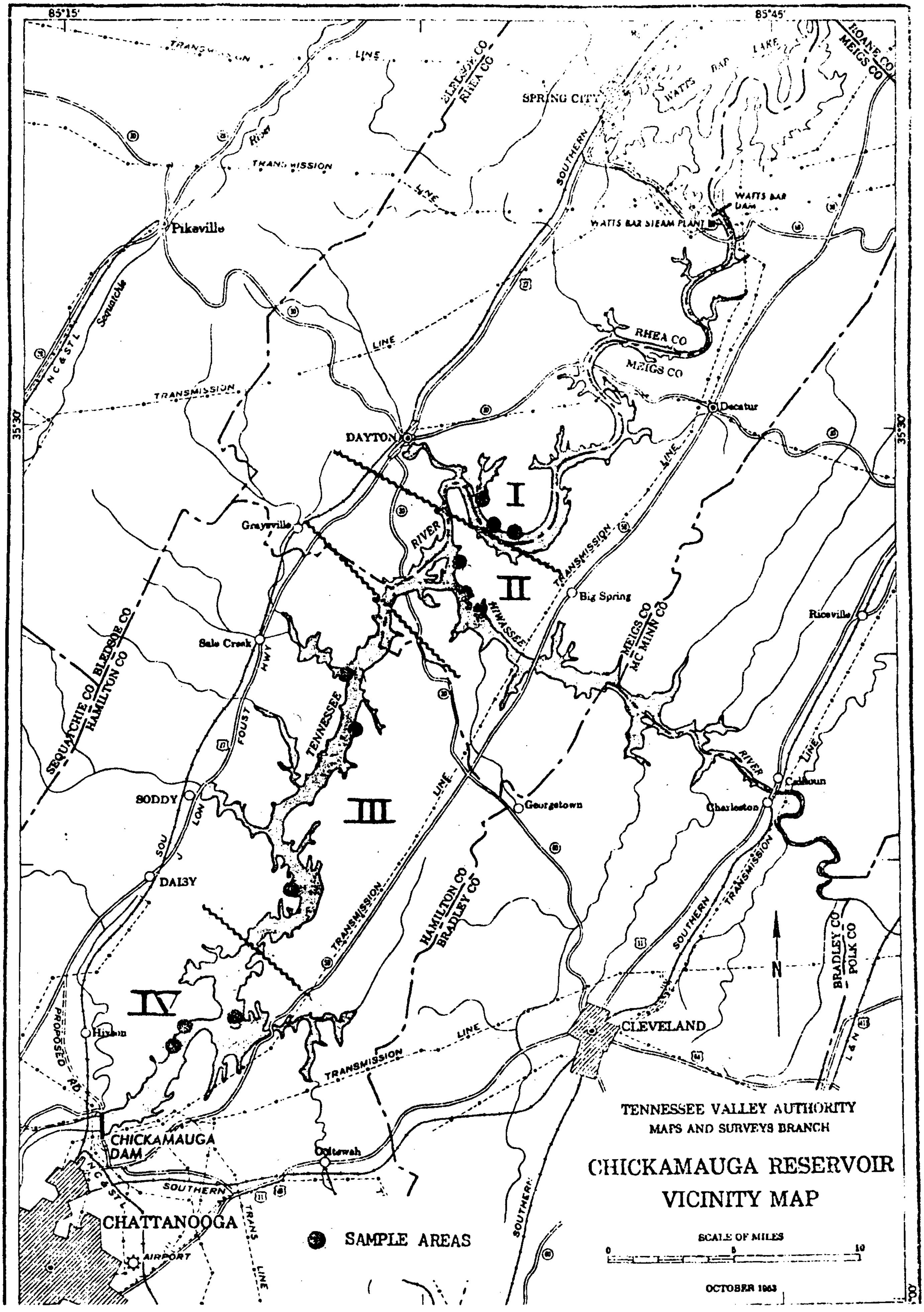

TENNESSEE VALLEY AUTHORITY
MAPS AND SURVEYS BRANCH
CHICKAMAUGA RESERVOIR
VICINITY MAP
SAMPLE AREAS
SCALE OF MILES
0
5
10
OCTOBER 1963
I
II
III
IV
DAYTON
SPRING CITY
WATTS BAR LAKE
WATTS BAR DAM
WATTS BAR STEAM PLANT
Pikeville
Decatur
Graysville
Big Spring
Sale Creek
Riceville
SODDY
DAISY
Georgetown
Calhoun
Charleston
CLEVELAND
Hixson
CHICKAMAUGA DAM
Ooltewah
CHATTANOOGA
AIRPORT
RHEA CO
MEIGS CO
MEIGS CO
MC MINN CO
HAMILTON CO
BRADLEY CO
BRADLEY CO
POLK CO
SEQUATCHIE CO
BLEDSOE CO
HAMILTON CO
ROANE CO
MEIGS CO
TENNESSEE
RIVER
HIWASSEE
TRANSMISSION
LINE
SOUTHERN
PROPOSED RD
N
85°15'
85°45'
35°30'

Table 1. COMMON AND SCIENTIFIC NAMES* OF FISHES IN ROTENONE SAMPLES
CHICKAMAUGA RESERVOIR, 1970

Game

White bass - Morone chrysops
Largemouth bass - Micropterus salmoides
Spotted bass - Micropterus punctulatus
White crappie - Pomoxis annularis
Black crappie - Pomoxis nigromaculatus
Bluegill - Lepomis macrochirus
Warmouth - Lepomis gulosus
Longear sunfish - Lepomis megalotis
Green sunfish - Lepomis cynellus
Redear sunfish - Lepomis microlophus
Rock bass - Ambloplites rupestris
Yellow perch - Perca flavescens
Sauger - Stizostedion canadense

Rough

potted gar - Lepisosteus oculatus
ongnose gar - Lepisosteus osseus
kipjack herring - Alosa chrysochloris
Iooneye - Hiodon tergisus
arp - Cyprinus carpio
uillback - Carpiodes cyprinus
mallmouth buffalo - Ictiobus bubalus
igmouth buffalo - Ictiobus cyprinellus
lack buffalo - Ictiobus niger
potted sucker - Minytrema melanops
lack redhorse - Moxostoma duquesnei
olden redhorse - Moxostoma erythrurum
lue catfish - Ictalurus furcatus
hannel catfish - Ictalurus punctatus
lathead catfish - Pylodictis olivaris
rum - Aplodinotus grunniens

orage

izzard shad - Dorosoma cepedianum
ıreadfin shad - Dorosoma petenense
olden shiner - Notemigonus crysoleucas
nerald shiner - Notropis atherinoides
otfin shiner - Notropis spilopterus
untnose minnow - Pimephales notatus
ook silversides - Labidesthes sicculus
gperch - Percina caprodes

rom American Fisheries Society Publication Number 6, Third Edition, 1970

Table 2. SIZE CLASSES* AND SUBSAMPLES USED IN 1970 FISH INVENTORIES

Species	Young-of-year	Intermediate	Harvestable
	length in inches		
Game			
Walleye	1-8	9-11	12 and over
Sauger	1-8	9-11	12 "
Largemouth bass	1-4	5-9	10 "
Smallmouth bass	1-4	5-8	9 "
White bass	1-6	7-8	9 "
Rock bass	1-3	4-5	6 "
White crappie	1-3	4-7	8 "
Black crappie	1-3	4-7	8 "
Bluegill	1-2	3-5	6 "
Other sunfishes	1-2	3-5	6 "
Rainbow trout	1-6	--	7 "
Rough			
Gar	1-12	13-19	20 "
Mooneye	1-6	7-11	12 "
Skipjack herring	1-6	7-11	12 "
Blue catfish	1-5	6-9	10 "
Channel catfish	1-5	6-9	10 "
Flathead catfish	1-5	6-11	12 "
Bullhead	1-4	5-7	8 "
Carp	1-8	9-12	13 "
Carpsuckers	1-8	9	10 "
Redhorses	1-7	8-10	11 "
Other suckers	1-7	8-10	11 "
Drum	1-5	6-8	9 "
Forage**			
Threadfin shad	1-5	--	6 "
Gizzard shad	1-5	--	6 "
Miscellaneous forage fishes	--	--	--

Subsamples: Mixed threadfin and gizzard shad (5 inches and less) - 3 pounds
Mixed species other than shad (3 inches and less) - 3 pounds
Sorted individual species (3 inches and less) - 1 pound

*The size class divisions for each species are arbitrary but based on knowlege of growth rates and information from creel census and commercial harvest records.

** Shad were recorded either as young-of-year or adult; sizes of other forage fish were not differentiated.

Table 3. SAMPLE AREAS AND POPULATIONS PER ACRE AND HECTARE, 1970 CHICKAMAUGA RESERVOIR

Sample area		Size		Mean depth		Number of fish		Pounds of fish per acre	Kilograms of fish per hectare
		Acre	Hectare	Feet	Meters	per acre	per hectare		
Area I	Cove I	0.43	0.18	4.3	1.3	13,074	32,306	343.8	385.5
	Cove II	.70	.28	3.7	1.1	3,524	8,708	154.9	173.7
	Cove III	.67	.27	3.3	1.0	3,584	8,856	271.0	303.9
Area II	Cove I	1.36	.55	4.1	1.2	1,982	4,898	142.3	159.6
	Cove II	2.39	.96	4.2	1.3	2,409	5,953	166.0	186.2
	Cove III	1.70	.69	3.8	1.2	7,084	17,505	205.3	230.2
Area III	Cove I	1.50	.61	4.3	1.3	3,094	7,645	200.7	225.1
	Cove II	.70	.28	4.7	1.4	2,487	6,146	163.4	183.2
	Cove III	1.20	.49	5.4	1.6	1,176	2,906	117.6	131.9
Area IV	Cove I	2.24	.90	4.9	1.5	3,709	9,165	200.6	225.0
	Cove II	2.20	.89	5.8	1.8	2,910	7,191	216.6	242.9
	Cove III	1.10	.45	5.5	1.7	599	1,480	72.8	81.6
All samples (av.)		16.19	6.55	4.5	1.4	3,345	8,266	181.6	203.6

Table 4. COVE POPULATIONS BY AREA AND MAJOR FISH GROUPS, 1970, CHICKAMAUGA RESERVOIR

Sampling area description	Fish group	Number of species	Number per acre	Pounds per acre
Area I	Game	8	850	37.0
3 samples	Rough	9	241	93.0
1.80 acres	Forage	8	4,737	113.3
July 13-14		25	5,828	243.3
Area II	Game	8	1,112	26.8
3 samples	Rough	11	292	106.3
5.45 acres	Forage	8	2,357	39.2
July 27-29		27	3,761	172.3
Area III	Game	10	776	15.8
3 samples	Rough	12	248	91.3
3.40 acres	Forage	8	1,268	56.6
July 6-9		30	2,292	163.7
Area IV	Game	7	464	15.0
3 samples	Rough	11	137	102.7
5.54 acres	Forage	8	2,173	63.9
August 3-5		26	2,774	181.6
All areas	Game	13	791	21.5
12 samples	Rough	16	224	100.5
16.19 acres	Forage	8	2,330	59.6
		37	3,345	181.6

Table 5, SPECIES COMPOSITION OF COVE POPULATION, CHICKAMAUGA RESERVOIR, 1970

Species	Percent of total number	Percent of total weight
Threadfin shad	29.9	3.2
Gizzard shad	27.6	29.0
Bluegill	15.3	5.7
Assorted minnows	12.2	.6
Drum	5.2	13.7
Largemouth bass	3.3	2.4
Other sunfish	1.8	1.8
Spotted bass	1.7	.3
White crappie	.9	1.4
White bass	.5	.1
Smallmouth buffalo	.4	23.7
Channel catfish	.2	1.7
Yellow perch	.2	.1
Spotted sucker	.2	.2
Bigmouth buffalo	.1	8.8
Golden redhorse	.1	1.6
Blue catfish	.1	.9
Skipjack herring	.1	.2
Carp	.1	3.2
Flathead catfish	.1	.3
Black redhorse	T	.5
Spotted gar	T	T
Longnose gar	T	T
Quillback	T	.4
Sauger	T	.1
Black crappie	T	T
Mooneye	T	T
Black buffalo	T	.1
Rock bass	T	T

T = less than 0.05 percent

Table 6. SIZE DISTRIBUTION PER ACRE BY SPECIES
CHICKAMAUGA RESERVOIR, 1970

	Young-of-year		Intermediate		Harvestable	
	No.	Wt. pounds	No.	Wt. pounds	No.	Wt. pounds
Threadfin shad	984	2.6	-	-	17	3.2
Gizzard shad	744	3.3	-	-	178	49.4
Bluegill	412	1.7	75	4.4	26	4.3
Assorted minnows	406	1.0	-	-	1	0.1
Drum	48	0.8	89	10.4	38	13.6
Largemouth bass	99	0.6	8	1.5	3	2.2
Other sunfish	29	0.4	21	1.1	9	1.8
Spotted bass	56	0.3	1	0.1	T	0.1
White crappie	15	0.1	10	1.2	4	1.3
White bass	15	0.1	T	T	-	-
Smallmouth buffalo	1	T	2	1.0	13	42.0
Channel catfish	2	T	4	0.6	3	2.5
Yellow perch	1	T	6	0.1	T	T
Spotted sucker	4	T	1	0.1	T	0.3
Bigmouth buffalo	-	-	-	-	5	16.2
Golden redhorse	1	0.1	T	0.1	2	2.8
Blue catfish	T	T	2	0.2	1	1.4
Skipjack herring	3	T	T	0.1	T	0.1
Carp	-	-	-	-	2	5.8
Flathead catfish	1	T	T	T	1	0.5
Black redhorse	T	T	T	0.1	T	0.8
Spotted gar	-	-	-	-	1	T
Longnose gar	T	T	-	-	T	T
Quillback	-	-	-	-	T	0.8
Sauger	-	-	-	-	1	0.2
Black crappie	-	-	-	-	T	T
Mooneye	T	T	-	-	-	-
Black buffalo	-	-	-	-	T	0.2
Rock bass	-	-	-	-	T	T
Total	2821	11.0	219	21.0	305	149.6

Table 7. SIZE DISTRIBUTION OF MAJOR FISH GROUPS, CHICKAMAUGA RESERVOIR, 1970

Fish groups	Percent by number				Percent by weight			
	Young-of-year	Inter-mediate	Harvest-able	Total	Young-of-year	Inter-mediate	Harvest-able	Total
Game	18.8	3.6	1.3	23.7	1.8	4.6	5.5	11.9
Rough	1.8	2.9	2.0	6.7	.5	6.9	47.9	55.3
Forage*	63.8	-	5.8	69.6	3.8	-	29.0	32.8
All fishes	84.4	6.5	9.1	100.0	6.1	11.5	82.4	100.0

*Shad considered as young and adult; other small forage species listed with young-of-year.

Table 8. PERCENT OF MARKED FISH RECOVERED CHICKAMAUGA RESERVOIR, 1970

	Number marked	Number recovered	Percent recovered
Bluegill	133	79	59.4
Crappie	57	24	42.1
Largemouth bass	52	32	61.5
Buffalo	39	26	66.7
Redhorse	26	19	73.0
Carp	23	7	30.4
Drum	18	15	83.3
Smallmouth bass	12	2	16.7
Longear sunfish	7	2	28.6
Redear sunfish	6	1	16.7
Channel catfish	2	1	50.0
Smallmouth bass	1	0	0.0
Sauger	1	1	100.0
Shellcracker	1	0	0.0
Warmouth	1	0	0.0
Spotted sucker	1	1	100.0
Yellow perch	1	0	0.0
All	381	210	55.1
Sample Area			
I-1	36	25	69.4
I-2	32	13	40.6
I-3	42	26	61.9
II-1			50 est.
II-3	61	36	59.0
III-1	52	30	57.7
III-2	54	22	40.7
IV-2	42	17	40.5
Average	62	41	66.1

Table 9. AVERAGE GROWTH RATES FOR CHICKAMAUGA RESERVOIR,1970

Species	Year Class	No. Fish	Total length in inches at end of year 1	2	3	4	5	6
Bluegill	67 - 69	138	2.1	4.3	5.9			
Largemouth bass	65 - 69	65	3.6	8.0	11.0	14.3	19.6	
White crappie	67 - 69	26	2.0	6.1	9.2			
Channel catfish	64 - 69	36	3.2	6.4	8.8	11.6	14.4	18.5

Table 10. COMPARISON OF PER ACRE NUMBERS AND WEIGHTS IN POUNDS OF HARVESTABLE FISH IN DIFFERENT YEARS, CHICKAMAUGA RESERVOIR

	Harvestable fish		Percent of harvestable fish in total sample	
	No.	Wt.	No.	Wt.
1970	305	149.6	9.1	82.4
1959	134	102.7	11.2	54.9
1958	87	64.8	7.4	55.6

Table 11. COMPARISON OF PER ACRE NUMBERS AND WEIGHTS OF VARIOUS FISH CLASSES IN DIFFERENT YEARS, CHICKAMAUGA RESERVOIR, 1970

	Game		Rough		Forage		Total Fish per acre	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
1970	791	21.5	224	100.5	2,330	59.6	3,345	182
1959	428	18.1	275	104.8	493	63.9	1,197	187
1958	510	10.9	170	57.3	484	48.4	1,164	117

Table 12. COMPARISON OF STANDING FISH CROP DATA FOR CHICKAMAUGA RESERVOIR, JULY 1970, AS DETERMINED BY SURFACE AREA AND VOLUME OF COVES

Area of lake	Cove	Surface area (acres)	Depth (feet)	Total pounds of fish	Pounds per acre	Pounds per acre-foot	Surface area (hectares)	Depth (meters)	Total kilograms of fish	Kilograms per hectare	Kilograms per hectare-meter
I	1	0.43	4.3	147.8	343.8	79.9	0.18	1.3	67.1	385.5	286.5
	2	0.70	3.7	109.1	154.9	42.1	0.28	1.1	49.2	173.7	159.7
	3	0.67	3.3	181.6	271.0	82.1	0.27	1.0	82.4	305.3	305.3
II	1	1.36	4.1	193.5	142.3	34.7	0.55	1.2	87.7	159.6	133.0
	2	2.39	4.2	396.8	166.0	39.5	0.97	1.3	180.0	186.2	142.7
	3	1.70	3.8	349.0	205.3	54.0	0.69	1.2	158.3	230.2	191.2
III	1	1.50	4.3	301.1	200.7	46.7	0.61	1.3	136.6	225.1	172.2
	2	0.70	4.7	114.4	163.4	34.8	0.28	1.4	51.9	183.2	132.4
	3	1.20	5.4	124.8	117.6	19.3	0.49	1.6	56.6	131.9	72.2
IV	1	2.24	4.9	449.3	200.6	40.9	0.91	1.5	203.8	225.0	149.3
	2	2.20	5.8	476.5	216.6	37.3	0.89	1.8	216.1	242.9	134.9
	3	1.10	5.5	80.1	72.8	13.2	0.45	1.7	363.0	81.6	47.5
Mean			4.5		181.6	40.2		1.37		203.6	148.6

FISH INVENTORY DATA

CHICKAMAUGA RESERVOIR

1972

Tennessee Valley Authority
Fisheries and Waterfowl Resources Branch

November 1972

INTRODUCTION

This report contains recent information on the population of fishes along the shoreline and in coves of Chickamauga Reservoir. It contains the results of samples taken with rotenone during September 1972 by the Tennessee Valley Authority, with some assistance from the Tennessee Game and Fish Commission.

These samples constitute one phase of a broad study to monitor fish populations before and after operation of the Sequoyah Nuclear Power Plant. These data are part of the preoperational studies. Technical data presented will be used in an overall evaluation of the effects of thermal discharges from this plant; they should also be helpful to biologists called on to investigate fish kills, evaluate introductions of exotic species, or to study other fisheries conditions in Chickamauga Reservoir.

Specific data reported here reflect the number, size, mass, and variety of species found, and indicate reproductive success of the various fishes which inhabited the coves and shoreline area of Chickamauga Reservoir during 1972.

FISH INVENTORY DATA

CHICKAMAUGA RESERVOIR

1972

SAMPLE AREAS AND PROCEDURES

Total surface area of Chickamauga Reservoir at full pool (elevation 682.5) is 35,400 acres. During the sampling period, September 19 to September 29, 1972, the lake was two feet below full pool, making reservoir area 32,800 surface acres. Surface water temperatures varied from 76.1 to 77.9 degrees F, dissolved oxygen from 4.5 to 5.0 ppm, and pH was 7.0 to 7.5 at all stations.

Rotenone samples were taken in the same four coves as in previous years, dating back to 1970 (see map); this year sample areas ranged from 1.05 to 3.10 surface acres, average depths from 1.6 to 6.4 feet.

Field procedures for treatment of the area and collection of data followed standard sampling methods now used in cove rotenone samples throughout the southeast. Marked fish were added to all coves prior to treatment to check on fish recovery. Scale and spine samples were collected from selected species as needed to help complete age and growth analysis for certain Chickamauga fishes. A complete list of the fishes found in this inventory is given in Table 1; size classes and subsamples used in data analysis are shown in Table 2.

SUMMARY OF FINDINGS

Average cove populations--5,804 fish and 282.1 pounds per acre--14,332 fish and 316.2 kilograms per hectare (Table 3).

Major fish classes by number--game 26 percent, rough 4 percent, and forage 70 percent (Tables 4 and 7).

Major fish classes by weight--game 14 percent, rough 40 percent, and forage 46 percent (Tables 4 and 7).

Dominant species by number--threadfin shad 49.7 percent, bluegill 20.2 percent, miscellaneous forage 14.9 percent, gizzard shad 5.1 percent, drum 3.4 percent, and longear sunfish 2.0 percent (Table 5).

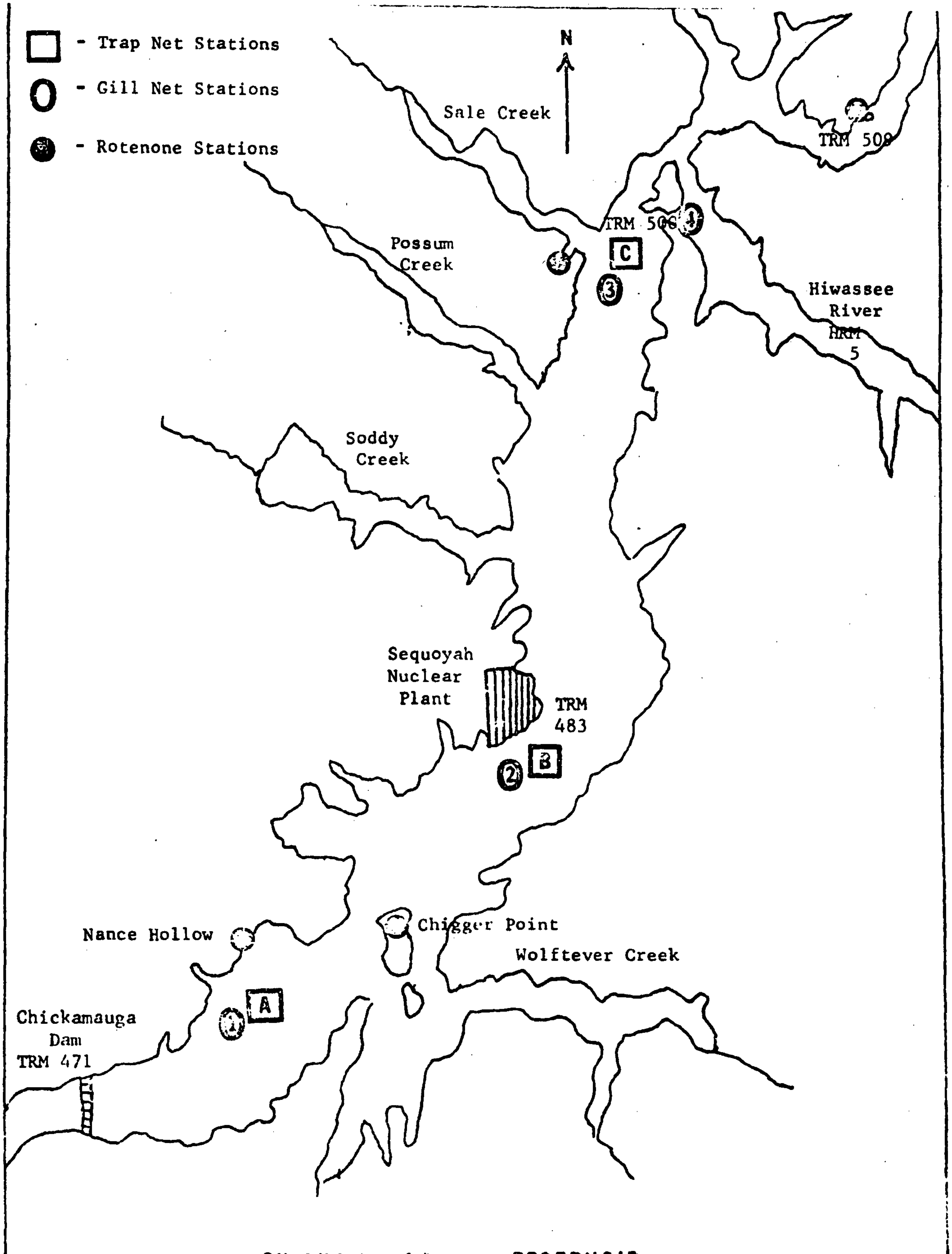
Dominant species by weight--gizzard shad 35.3 percent, smallmouth buffalo 13.9 percent, threadfin shad 10.3 percent, drum 9.1 percent, carp 8.8 percent, and bluegill 6.5 percent, (Table 5).

Size distribution of all fish--young-of-year 88 percent, intermediate 4 percent, and harvestable (adult) 8 percent (Tables 6 and 7).

Size distribution of game fish--young-of-year 81 percent, intermediate 11 percent, and harvestable (adult) 8 percent.

Spawning success--good reproduction and survival of game and forage species, especially threadfin shad, bluegill, miscellaneous forage, and drum. Young-of-year, largemouth and spotted bass amounted to 8 and 42 per acre respectively.

Marked fish--returns from the four areas where marked fish were released prior to sampling ranged from 54 to 81 percent and averaged 74 percent (Table 8).



CHICKAMAUGA RESERVOIR

Table 1. Common and Scientific Names* of Fishes in Rotenone Samples Chickamauga Reservoir, 1972.

<u>Game</u>

White bass - *Morone chrysops*
Yellow bass - *Morone mississippiensis*
Bluegill - *Lepomis macrochirus*
Warmouth - *Lepomis gulosus*
Longear sunfish - *Lepomis megalotis*
Green sunfish - *Lepomis cyanellus*
Redear sunfish - *Lepomis microlophus*
Largemouth bass - *Micropterus salmoides*
Spotted bass - *Micropterus punctulatus*
White crappie - *Pomoxis annularis*
Black crappie - *Pomoxis nigromaculatus*
Sauger - *Stizostedion canadense*
Yellow perch - *Perca flavescens*

<u>Rough</u>

Longnose gar - *Lepisosteus osseus*
Skipjack herring - *Alosa chrysochloris*
Mooneye - *Hiodon tergisus*
Carp - *Cyprinus carpio*
River carpsucker - *Carpiodes carpio*
Smallmouth buffalo - *Ictiobus bubalus*
Spotted sucker - *Minytrema melanops*
Hogsucker - *Hypentelium nigricans*
Golden redhorse - *Moxostoma erythrurum*
Black redhorse - *Moxostoma duquesnei*
River redhorse - *Moxostoma carinatum*
Channel catfish - *Ictalurus punctatus*
Blue catfish - *Ictalurus furcatus*
Black bullhead - *Ictalurus melas*
Flathead catfish - *Pylodictis olivaris*
Drum - *Aplodinotus grunniens*

<u>Forage</u>

Threadfin shad - *Dorosoma petenense*
Gizzard shad - *Dorosoma cepedianum*
Golden shiner - *Notemigonus crysoleucas*
Emerald shiner - *Notropis atherinoides*
Bluntnose minnow - *Pimephales notatus*
Blackstripe topminnow - *Fundulus notatus*
Mosquitofish - *Gambusia affinis*
Brook silversides - *Labidesthes sicculus*
Fantail darter - *Etheostoma flabellare*
Logperch - *Percina caprodes*
Orangespotted sunfish - *Lepomis humilis*

*According to <u>American Fisheries Society Special Publication No. 6,</u> 1970.

Table 2. Size Classes* and Subsamples Used in 1972 Fish Inventories

Species	Young-of-year	Intermediate	Harvestable
	- - - - - - - - - length in inches	- - - - - - - -	
Game			
White bass	1-6	7-8	9 and over
Yellow bass	1-3	4	5 "
Bluegill	1-3	4-5	6 "
Other sunfishes	1-3	4-5	6 "
Largemouth bass	1-4	5-9	10 "
Spotted bass	1-4	5-8	9 "
Rock bass	1-3	4-5	6 "
White crappie	1-3	4-7	8 "
Black crappie	1-3	4-7	8 "
Sauger	1-8	9-11	12 "
Walleye	1-8	9-11	12 "
Yellow perch	1-6		7 "
Rough			
Gar	1-12	13-19	20 "
Skipjack herring	1-6	7-11	12 "
Mooneye	1-6	7-11	12 "
Carp	1-8	9-12	13 "
Carpsuckers	1-7	8-10	11 "
Other suckers	1-7	8-10	11 "
Redhorse	1-7	8-10	11 "
Blue catfish	1-5	6-9	10 "
Bullhead	1-4	5-7	8 "
Channel catfish	1-5	6-9	10 "
Flathead catfish	1-5	6-11	12 "
Drum	1-5	6-8	9 "
Forage**			
Threadfin shad	1-5	--	6 "
Gizzard shad	1-5	--	6 "
Miscellaneous forage fishes	--	--	--
Orangespotted sunfish	1-2	3	4 "

*The size class division for each species is arbitrary but based on knowledge of growth rates and information from creel census and commercial harvest records.

**Shad were recorded either as young-of-year or adult; sizes of other forage fish were not differentiated.

Table 3. Sample Areas and Fish Populations per Acre and Hectare, Chickamauga Reservoir, 1972

Sample Area	Size		Mean Depth		Number		Weight	
	Acres	Hectares	Feet	Meters	Per Acre	Per Hectare	Pounds Per Acre	Kilograms Per Hectare
Nance Hollow	3.10	1.26	6.4	1.95	4,701	11,608	319.2	357.8
Chigger Point	2.40	.97	1.6	.49	6,396	15,794	205.5	230.3
Sale Creek	2.30	.93	4.7	1.43	4,427	10,932	206.9	231.9
TRM 508.0	1.05	.43	2.9	.88	10,728	26,491	511.3	573.1
All Samples	8.85	3.59	3.9	1.19	5,804	14,332	282.1	316.2

Table 4. Populations by Area and Major Fish Groups, Chickamauga Reservoir, 1972.

Sample Area	Fish Group	Number of Species	Number per Acre	Pounds per Acre
Nance Hollow	Game	12	1,128	35.9
	Rough	12	251	141.3
	Forage	6	3,322	142.0
		30	4,701	319.2
Chigger Point	Game	10	2,631	47.1
	Rough	10	198	78.1
	Forage	7	3,567	80.3
		27	6,396	205.5
Sale Creek	Game	11	910	23.4
	Rough	11	130	71.3
	Forage	9	3,387	112.2
		31	4,427	206.9
TRM 508	Game	12	1,616	65.1
	Rough	11	673	187.6
	Forage	11	8,439	258.6
		34	10,728	511.3
All Areas (8.85 acres)	Game	12	1,537	39.2
	Rough	12	255	111.5
	Forage	11	4,012	131.4
		35	5,804	282.1

Table 5. Species Composition of Cove Populations, Chickamauga Reservoir, 1972.

Species	Percent of Total Number	Percent of Total Weight
Threadfin shad	49.7	10.3
Bluegill	20.2	6.5
Miscellaneous minnows	14.9	1.0
Gizzard shad	5.1	35.3
Drum	3.4	9.1
Longear sunfish	2.0	.7
Redear sunfish	.9	2.4
Spotted bass	.8	.3
Largemouth bass	.6	2.6
White crappie	.4	.8
Channel catfish	.3	2.8
Smallmouth buffalo	.2	13.9
Spotted sucker	.2	2.0
Yellow perch	.2	.2
Warmouth	.2	.1
Yellow bass	.2	.1
Carp	.1	8.8
Skipjack	.1	.3
Orangespotted sunfish	.1	t
Flathead catfish	t	.2
Golden redhorse	t	1.2
Green sunfish	t	t
Black crappie	t	t
Hogsucker	t	.1
River redhorse	t	.1
Longnose gar	t	.3
White bass	t	t
Sauger	t	.1
Black redhorse	t	.2
Black bullhead	t	t
River carpsucker	t	.1
Blue catfish	t	.3
Total	99.6	99.8

t = Less than .05

Table 6. Size Distribution per Acre by Species, Chickamauga Reservoir, 1972.

Species	Young-of-year		Intermediate		Harvestable	
	Number	Weight (lb)	Number	Weight (lb)	Number	Weight (lb)
Threadfin shad	2858	29.15	-	-	-	-
Bluegill	999	4.71	103	5.56	61	8.15
Miscellaneous minnows	856	2.70	-	-	-	-
Drum	101	1.99	55	6.40	41	17.29
Longear sunfish	78	.49	36	1.34	2	.21
Spotted bass	42	.36	6	.21	t	.15
Redear sunfish	21	.17	10	.60	19	6.02
White crappie	14	.09	4	.27	4	1.81
Yellow perch	13	.30	-	-	1	.16
Largemouth bass	8	.11	21	2.73	6	4.56
Warmouth	8	.05	4	.24	1	.09
Spotted sucker	7	.23	t	.16	6	5.37
Yellow bass	3	.05	6	.07	1	.08
Channel catfish	1	.01	5	.61	11	7.40
Green sunfish	1	.05	1	.07	t	.04
White bass	1	.04	t	.02	-	-
Black crappie	1	t	-	-	t	.12
Smallmouth buffalo	1	.15	1	.14	11	38.97
Gizzard shad	t	.01	-	-	292	99.47
Golden redhorse	t	.01	t	.04	2	3.47
Flathead catfish	t	t	t	.07	t	.52
Sauger	t	.05	1	.13	t	.11
Skipjack	t	.01	4	.58	t	.18
Blue catfish	t	t	-	-	1	.95
Hogsucker	-	-	t	.02	t	.17
Longnose gar	-	-	t	.02	t	.86
Carp	-	-	-	-	5	24.95
River redhorse	-	-	-	-	t	.16
Black redhorse	-	-	-	-	1	.46
Black bullhead	-	-	t	.02	-	-
River carpsucker	-	-	-	-	t	.29
Total	5015	40.73	260	19.34	465	222.01

t = Less than .05 for number and 0.01 for weight

Table 7. Size Distribution of Major Fish Groups, Chickamauga Reservoir, 1972.

Fish Group	Percent by Number				Percent by Weight			
	Young-of-year	Intermediate	Harvestable	Total	Young-of-year	Intermediate	Harvestable	Total
Game	21	3	2	26	2	4	8	14
Rough	2	1	1	4	1	3	36	40
Forage	65	t	5	70	11	t	35	46
All Fish	88	4	8	100	14	7	79	100

Table 8. Percent of Marked Fish Recovered, by Area, Chickamauga Reservoir, 1972.

Species	Number Marked	Number Recovered	Percent Recovered
Redear	59	50	84.7
Carp	52	41	78.8
Bluegill	42	26	61.9
Largemouth bass	38	28	73.7
Shad	36	25	69.4
Smallmouth buffalo	17	15	88.2
Spotted bass	17	7	41.2
White crappie	11	7	63.6
Drum	9	8	88.9
Redhorse	4	2	50.0
Longear	3	3	100.0
Black crappie	1	1	100.0
Spotted sucker	1	1	100.0
Golden shiner	1	1	100.0
Yellow perch	1	1	100.0
Flathead catfish	1	1	100.0
Channel catfish	1	0	0.0
Yellow bass	1	0	0.0
All	295	217	73.6
Sample Area			
Sale Creek	106	86	81.1
Chigger Point	56	30	53.6*
Nance Hollow	51	39	76.5
TRM 508	82	62	75.6
All	295	217	73.6
Average	74	54	

*Large hole found in block net

Table 9. Comparison of Rotenone Survey Results in Coves of Chickamauga Reservoir - 1970-1972.

Cove Area	Year	Sample Area Size (ac)	No. Fish per Acre	Lb Fish per Acre
Nance Hollow	1970	2.20	2,910	216.6
	1971	3.10	2,574	251.4
	1972	3.10	4,701	319.2
Chigger Point	1970	2.24	3,709	200.6
	1971	2.40	1,159	167.8
	1972	2.40	6,396	205.5
Sale Creek	1970	1.50	3,094	200.7
	1971	2.30	3,734	88.7
	1972	2.30	4,427	206.9
TRM 508.0	1971	1.05	5,549	321.9
	1972	1.05	16,728	511.3

FISH INVENTORY DATA

CHICKAMAUGA RESERVOIR

1973

Tennessee Valley Authority
Fisheries and Waterfowl Resources Branch

February 1974

INTRODUCTION

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These samples constitute one phase of a broad study to monitor fish populations before and after operation of the Sequoyah Nuclear Power Plant. These data are part of the preoperational studies. Technical data presented will be used in an overall evaluation of the effects of thermal discharges from this plant; they should also be helpful to biologists called on to investigate fish kills, evaluate introductions of exotic species, or to study other fisheries conditions in Chickamauga Reservoir.

Specific data reported here reflect the number, size, mass, and variety of species found, and indicate reproductive success of the various fishes which inhabited the coves and shoreline area of Chickamauga Reservoir during 1973.

This report was prepared by Berry Stalcup, Muscle Shoals, Alabama.

FISH INVENTORY DATA

CHICKAMAUGA RESERVOIR

1973

SAMPLE AREAS AND PROCEDURES

Total surface area of Chickamauga Reservoir at full pool (elevation 682.5) is 35,400 acres. During the sampling period, September 17 to September 28, 1973, the lake was two feet below full pool, making reservoir area 32,800 surface acres. Surface water temperatures varied from 74.7 to 76.6 degrees F, dissolved oxygen from 3.0 to 5.0 ppm, and pH was 7.0 to 7.5 at all stations.

Rotenone samples were taken in the same four coves as in previous years, dating back to 1970 (see map); this year sample areas ranged from 1.05 to 3.10 surface acres, average depths from 1.6 to 6.4 feet.

Field procedures for treatment of the area and collection of data followed standard sampling methods now used in cove rotenone samples throughout the southeast. Marked fish were added to all coves prior to treatment to check on fish recovery. A complete list of the fishes found in this inventory is given in Table 1; size classes used in data analysis are shown in Table 2.

SUMMARY OF FINDINGS

Average cove populations--4,938 fish and 258 pounds per acre--12,112 fish and 289 kilograms per hectare (Table 3).

Major fish classes by number--game 37 percent, rough 7 percent, and forage 56 percent (Tables 4 and 7).

Major fish classes by weight--game 14 percent, rough 47 percent, and forage 39 percent (Tables 4 and 7).

Dominant species by number--threadfin shad 41 percent, bluegill 25 percent, gizzard shad 6 percent, drum 5 percent, and redear sunfish 5 percent (Table 5).

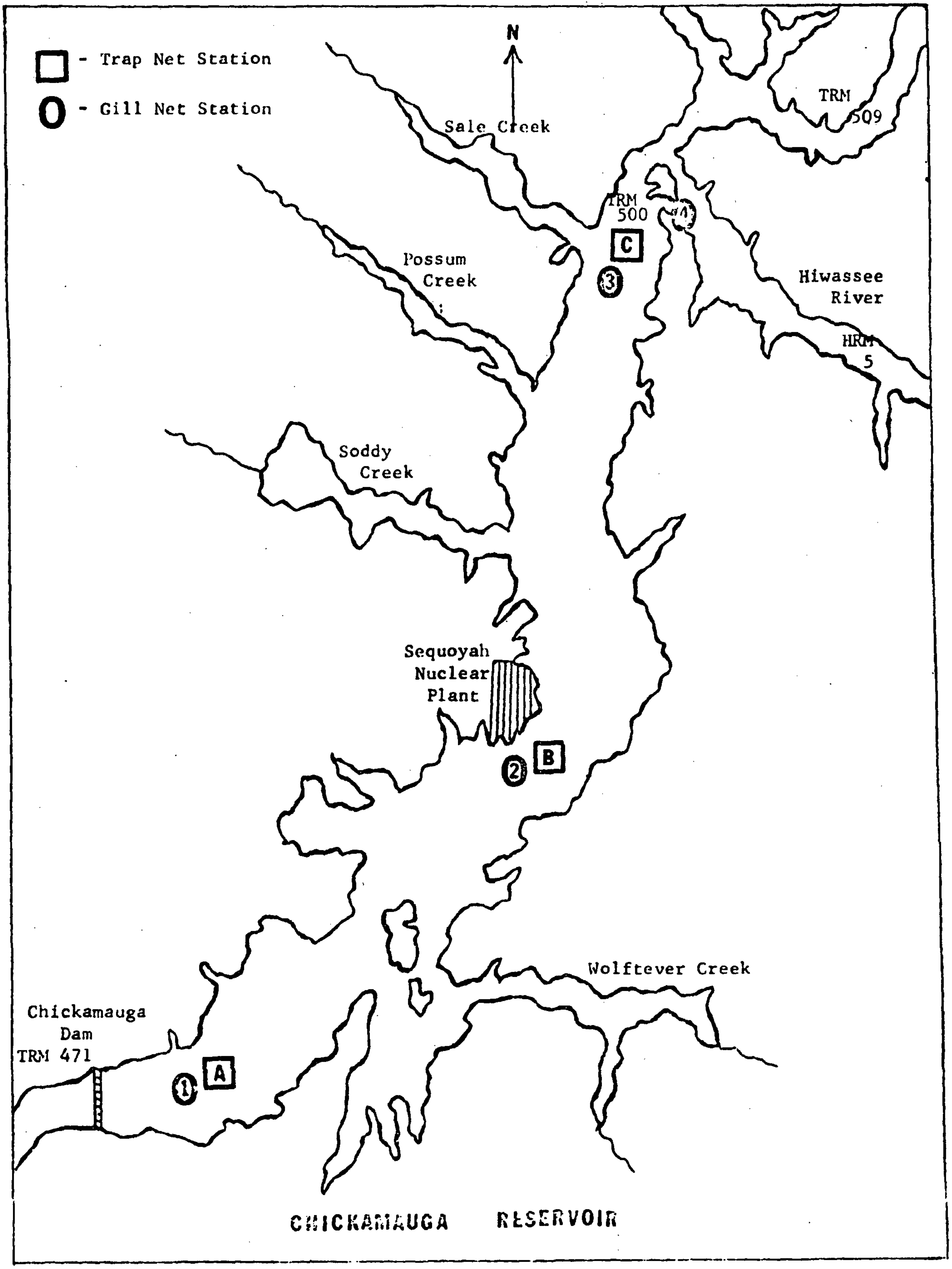
Dominant species by weight--gizzard shad 31 percent, smallmouth buffalo 15 percent, carp 14 percent, drum 11 percent, threadfin shad 8 percent, and bluegill 6 percent (Table 5).

Size distribution of all fish--young-of-year 84 percent, intermediate 7 percent, and harvestable (adult) 9 percent (Tables 6 and 7).

Size distribution of game fish--young-of-year 84 percent, intermediate 11 percent, and harvestable (adult) 5 percent (Tables 6 and 7).

Spawning success--good reproduction and survival of game and forage species, especially threadfin shad, bluegill, and redear sunfish. Young-of-year, largemouth and spotted bass amounted to 24 and 27 per acre respectively (Table 6).

Marked fish--returns from the four areas where marked fish were released prior to sampling ranged from 75 to 81 percent and averaged 78 percent (Table 8).



- Trap Net Station
- Gill Net Station
N
Sale Creek
TRM
509
TRM
500
C
3
4
Possum
Creek
Hiwassee
River
HRM
5
Soddy
Creek
Sequoyah
Nuclear
Plant
2
B
Wolftever Creek
Chickamauga
Dam
TRM 471
1
A
CHICKAMAUGA RESERVOIR

Table 1. Common and Scientific Names* of Fishes in Rotenone Samples Chickamauga Reservoir, 1973.

Game

White bass - *Morone chrysops*
Yellow bass - *Morone mississippiensis*
Bluegill - *Lepomis macrochirus*
Warmouth - *Lepomis gulosus*
Longear sunfish - *Lepomis megalotis*
Green sunfish - *Lepomis cyanellus*
Redear sunfish - *Lepomis microlophus*
Largemouth bass - *Micropterus salmoides*
Spotted bass - *Micropterus punctulatus*
White crappie - *Pomoxis annularis*
Sauger - *Stizostedion canadense*
Yellow perch - *Perca flavescens*

Rough

Spotted gar - *Lepisosteus oculatus*
Longnose gar - *Lepisosteus osseus*
Skipjack herring - *Alosa chrysochloris*
Mooneye - *Hiodon tergisus*
Carp - *Cyprinus carpio*
River carpsucker - *Carpiodes carpio*
Smallmouth buffalo - *Ictiobus bubalus*
Spotted sucker - *Minytrema melanops*
Hogsucker - *Hypentelium nigricans*
Golden redhorse - *Moxostoma erythrurum*
Shorthead redhorse - *Moxostoma macrolepidotum*
Channel catfish - *Ictalurus punctatus*
Blue catfish - *Ictalurus furcatus*
Flathead catfish - *Pylodictis olivaris*
Drum - *Aplodinotus grunniens*

Forage

Threadfin shad - *Dorosoma petenense*
Gizzard shad - *Dorosoma cepedianum*
Golden shiner - *Notemigonus crysoleucas*
Emerald shiner - *Notropis atherinoides*
Spotfin shiner - *Notropis spilopterus*
Bluntnose minnow - *Pimephales notatus*
Bullhead minnow - *Pimephales vigilax*
Blackstripe topminnow - *Fundulus notatus*
Mosquitofish - *Gambusia affinis*
Brook silversides - *Labidesthes sicculus*
Logperch - *Percina caprodes*
Orangespotted sunfish - *Lepomis humilis*

*According to American Fisheries Society Special Publication No. 6, 1970.

Table 2. Size Classes* Used in 1973 Fish Inventories.

Species	Young-of-year	Intermediate	Harvestable
	---------- length in mm	----------	----------
<u>Game</u>			
White bass	1-150	151-200	201 and over
Yellow bass	1-75	76-100	101 "
Bluegill	1-75	76-125	126 "
Other sunfishes	1-75	76-125	126 "
Largemouth bass	1-100	101-125	226 "
Spotted bass	1-100	101-200	201 "
Rock bass	1-75	76-125	126 "
White crappie	1-75	76-175	176 "
Black crappie	1-75	76-175	176 "
Sauger	1-200	201-275	276 "
Walleye	1-200	201-275	276 "
Yellow perch	1-150	201-275	151 "
<u>Rough</u>			
Gar	1-300	301-475	476 "
Skipjack herring	1-150	151-275	276 "
Mooneye	1-150	151-275	276 "
Carp	1-200	201-300	301 "
Carpsuckers	1-175	176-250	251 "
Other suckers	1-175	176-250	251 "
Redhorse	1-175	176-250	251 "
Blue catfish	1-125	126-225	226 "
Bullhead	1-100	101-175	176 "
Channel catfish	1-125	126-225	226 "
Flathead catfish	1-125	126-275	276 "
Drum	1-125	216-200	201 "
<u>Forage</u>**			
Threadfin shad	1-125	--	126 "
Gizzard shad	1-125	--	126 "
Minnows	--	--	--
Orangespotted sunfish	1-50	51-75	76 "

*The size class division for each species is arbitrary but based on knowledge of growth rates and information from creel census and commercial harvest records.

**Size of minnows was not differentiated.

Table 3. Sample Areas and Fish Populations per Acre and Hectare, Chickamauga Reservoir, 1973

Sample Area	Size		Mean Depth		Number		Weight	
	Acres	Hectares	Feet	Meters	Per Acre	Per Hectare	Pounds Per Acre	Kilograms Per Hectare
Nance Hollow	3.10	1.26	6.4	1.95	3,519	8,687	252.0	282.4
Chigger Point	2.40	.97	1.6	.49	3,581	8,861	176.3	197.6
Sale Creek	2.30	.93	4.7	1.43	4,621	11,429	179.9	201.6
TRM 508.0	1.05	.43	2.9	.88	12,919	33,519	633.5	710.1
All Samples	8.85	3.59	3.9	1.19	4,938	12,112	257.9	289.1

Table 4. Populations by Area and Major Fish Groups, Chickamauga Reservoir, 1973.

Sample Area	Fish Group	Number of Species	Number per Acre	Pounds per Acre
Nance Hollow	Game	10	1,278	27.2
	Rough	12	329	118.4
	Forage	9	1,912	106.4
		31	3,519	252.0
Chigger Point	Game	12	1,825	32.6
	Rough	9	204	101.2
	Forage	8	1,552	42.5
		29	3,581	176.3
Sale Creek	Game	12	2,453	24.8
	Rough	10	269	98.3
	Forage	6	1,899	56.8
		28	4,621	179.9
TRM 508	Game	11	2,007	79.8
	Rough	9	791	223.2
	Forage	8	10,121	330.5
		28	12,919	633.5
All Areas (8.85 acres)	Game	12	1,818	34.3
	Rough	15	335	120.9
	Forage	12	2,785	102.7
		39	4,938	257.9

Table 5. Species composition of Cove Population, Chickamauga Reservoir, 1973.

Species	Percent of Total Number	Percent of Total Weight
Threadfin shad	40.8	7.7
Bluegill	24.7	5.9
Gizzard shad	6.4	31.1
Drum	4.8	10.7
Redear sunfish	4.8	2.4
Bullhead minnow	3.9	.2
Longear sunfish	3.6	.7
Brook silversides	1.6	.1
Emerald shiner	1.4	.1
Blackstriped topminnow	1.3	.1
Largemouth bass	1.1	2.4
Spotted sucker	1.1	2.4
Warmouth	1.0	.3
Spotted bass	.6	.2
Logperch	.6	.3
White crappie	.4	.8
Channel catfish	.4	3.3
Yellow perch	.3	.3
Smallmouth buffalo	.2	14.5
Carp	.2	14.1
Yellow bass	.2	.1
Green sunfish	.2	.1
White bass	.1	.1
Skipjack herring	.1	.3
Golden shiner	.1	.1
Spotfin shiner	.1	-
Flathead catfish	-	.6
Golden redhorse	-	.6
River carpsucker	-	.2
Shorthead redhorse	-	.1
Sauger	-	-
Blue catfish	-	-
Spotted gar	-	-
Longnose gar	-	-
Orangespotted sunfish	-	-
Mooneye	-	-
Mosquitofish	-	-
Hogsucker	-	-
Bluntnose minnow	-	-
Total	100.0	99.8

- = Less than .05

Table 6. Size distribution per acre by species, Chickamagua Reservoir, 1973.

Species	Young-of-year		Intermediate		Harvestable	
	Number	Weight (lb)	Number	Weight (lb)	Number	Weight (lb)
Threadfin shad	2,013	19.82				
Bluegill	1,020	3.22	135	4.32	65	7.69
Redear sunfish	211	1.34	9	.40	17	4.49
Bullhead minnow	196	.57				
Longear sunfish	149	.53	27	.99	2	.17
Drum	82	1.17	109	10.02	44	16.45
Brook silversides	78	.23				
Emerald shiner	70	.16				
Blackstriped topminnow	65	.19				
Spotted sucker	48	1.94	2	.47	4	3.73
Warmouth	42	.30	2	.11	2	.31
Logperch	28	.64				
Spotted bass	27	.23	2	.19	-	.11
Largemouth bass	24	.34	21	2.51	6	3.42
White crappie	10	.60	4	.32	5	1.59
Green sunfish	9	.11	1	.02	-	.02
Yellow bass	8	.05	1	.02	2	.04
White bass	6	.13	1	.06	-	.09
Yellow perch	6	.39			4	.44
Orangespotted sunfish	4	.02	2	.05		
Golden shiner	4	.34				
Spotfin shiner	3	.07				
Skipjack herring	2	.04	4	.64		
Channel catfish	1	.01	7	1.09	10	7.35
Sauger	1	.08	-	.03	1	.27
Mosquitofish	1	-				
Smallmouth buffalo	-	.01	-	.09	9	37.23
Gizzard shad	-	-			315	80.24
Golden redhorse	-	.02			1	1.64
Flathead catfish	-	.01	-	.13	1	1.31
[illegible]e catfish			-	.03		
Hogsucker			-	.08	-	.20
Longnose gar			-	.03		
Carp					7	36.29
Mooneye	-	-			-	.06
Shorthead redhorse			1	.25		.13
Spotted gar			-	.01		
River carpsucker					-	.49
Total	4,108	32.56	328	21.86	495	203.76

- = Less than .5 for number and 0.01 for weight.

Table 7. Size Distribution of Major Fish Groups, Chickamauga Reservoir, 1973.

Fish Group	Percent by Number				Percent by Weight			
	Young-of-year	Intermediate	Harvestable	Total	Young-of-year	Intermediate	Harvestable	Total
Game	31	4	2	37	3	4	7	14
Rough	3	3	1	7	1	5	41	47
Forage	50	-	6	56	8	-	31	39
All Fish	84	7	9	100	12	9	79	100

Table 8. Percent of Marked Fish Recovered, by Area, Chickamauga Reservoir, 1972.

Species	Number Marked	Number Recovered	Percent Recovered
White crappie	151	103	68.2
Redear sunfish	63	55	87.3
Bluegill	50	43	86.0
Gizzard shad	33	25	75.7
Drum	17	15	88.2
Carp	14	13	92.8
Smallmouth buffalo	11	9	81.8
Channel catfish	7	4	57.1
Spotted bass	6	5	83.3
Longear sunfish	4	4	100.0
Flathead catfish	3	3	100.0
White bass	3	2	66.6
Yellow bass	2	2	100.0
Largemouth bass	2	1	50.0
Redhorse sucker	2	2	100.0
Total	368	286	77.7
Sample Area			
Nance Hollow	106	86	81.1
Chigger Point	100	75	75.0
Sale Creek	100	77	77.0
TRM 508	62	48	77.4
Total	368	286	77.7
Average	92	72	

Table 9. Comparison of Rotenone Survey Results in Coves of Chickamauga Reservoir - 1970-1973.

Cove Area	Year	Sample Area Size (ac)	No. Fish per Acre	Lb Fish per Acre
Nance Hollow	1970	2.20	2,910	216.6
	1971	3.10	2,574	251.4
	1972	3.10	4,701	319.2
	1973	3.10	3,519	252.0
Chigger Point	1970	2.24	3,709	200.6
	1971	2.40	1,159	167.8
	1972	2.40	6,396	205.5
	1973	2.40	3,581	176.3
Sale Creek	1970	1.50	3,094	200.7
	1971	2.30	3,734	88.7
	1972	2.30	4,427	206.9
	1973	2.30	4,621	179.9
TRM 508.0	1971	1.05	5,549	321.9
	1972	1.05	10,728	511.3
	1973	1.05	12,919	633.5

NUMBER OF SAMPLES AND TOTAL NUMBERS (PER HECTAR) AND

TOTAL WEIGHT (KG/HA) BY SIZE CLASS

RESRV=7

YEAR	# Samples Per Year SCOUNT	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
47	1	33.3	0.748	332.099	64.2901	239.51	52.648	604.9	117.686
49	1	645.9	2.252	265.574	40.0246	140.98	25.090	1052.5	67.367
50	7	2064.2	7.532	340.250	56.2336	724.73	92.470	3129.2	156.236
51	1	1331.1	5.736	167.213	8.7016	134.43	24.477	1632.8	38.915
52	3	1407.4	4.086	54.535	1.6953	140.09	24.409	1602.0	30.190
54	2	5184.0	24.434	488.889	25.8654	761.73	172.443	6434.6	222.762
55	1	6118.9	20.409	615.315	30.8829	1163.06	254.839	7897.3	306.131
56	2	4265.2	14.065	506.111	24.5885	802.25	134.230	5573.5	172.883
57	2	6850.5	27.274	871.337	32.7688	2636.69	444.393	10358.5	504.436
58	2	2405.5	22.040	247.143	10.2175	365.83	80.859	3018.5	113.117
59	1	1579.0	5.981	500.000	22.5495	883.81	195.380	2962.9	223.910
70	12	6639.2	13.634	529.506	23.8930	931.24	176.927	8099.9	214.454
71	4	6643.4	28.826	581.899	93.0585	770.70	131.861	7996.0	253.746
72	4	3793.4	110.913	905.275	29.3162	798.15	217.003	5496.8	357.232
73	4	12009.7	67.324	947.200	35.1398	1556.38	284.447	14513.2	386.911
74	4	3776.9	34.516	670.834	21.4338	1081.25	192.062	5529.0	248.011
75	4	10847.5	37.599	439.655	14.5601	1363.04	184.949	12650.2	237.108
.	55	5340.8	28.293	530.655	32.9600	920.75	165.477	6792.2	226.729

TABLE 3.5-1
COMPUTER OUTPUT OF COVE RETENONE SAMPLES

TABLE 3.5-2
COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

TOTAL NUMBERS AND WEIGHT BY SIZE CLASS -- RESRVOIR WIDE AVERAGE

RESRV=7

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
10401001	LEPISOSTEUS OCULATUS	0.17	0.025	0.73	0.209	.	.	0.90	0.233
10401002	LEPISOSTEUS OSSEUS	0.50	0.001	0.27	0.031	0.02	0.086	0.79	0.118
10601003	ALOSA CHRYSOCHLORIS	3.97	0.034	4.48	0.362	1.10	0.375	9.54	0.770
10604007	DOROSOMA CEPEDIANUM	315.81	5.878	.	.	681.87	83.192	997.68	89.070
10604008	DOROSOMA PETENENSE	2839.87	19.102	.	.	19.41	0.632	2859.28	19.733
10604801	MIXED DOROSOMA	287.52	2.677	.	.	.	.	287.52	2.677
10801002	HIODON TERGISUS	0.37	0.004	0.03	0.007	0.03	0.008	0.44	0.020
11100000	CYPRINIDAE	31.70	0.036	.	.	.	.	31.70	0.036
11102003	CAMPOSTOMA ANOMALUM	0.09	0.001	.	.	.	.	0.09	0.001
11103005	CARASSIUS AURATUS	0.03	0.001	.	.	.	.	0.03	0.001
11104011	CLINOSTOMUS FUNDULOIDES	0.52	1.245	.	.	.	.	0.52	1.245
11105012	CYPRINUS CARPIO	0.32	0.001	0.12	0.033	11.05	22.483	11.49	22.517
11114052	HYBOPSIS STORERIANA	0.83	0.004	.	.	.	.	0.83	0.004
11124061	NOTEMIGONUS CRYSOLEUCAS	6.42	0.218	.	.	.	.	6.42	0.218
11125000	NOTROPIS SP.	6.10	0.008	.	.	.	.	6.10	0.008
11125073	NOTROPIS ATHERINOIDES	25.23	0.057	.	.	.	.	25.23	0.057
11125084	NOTROPIS BUCHANANI	0.30	0.000	.	.	.	.	0.30	0.000
11125143	NOTROPIS SPILOPTERUS	2.68	0.006	.	.	.	.	2.68	0.006
11125159	NOTROPIS EMILIAE	0.11	0.000	.	.	.	.	0.11	0.000
11125160	NOTROPIS CHRYSOCEPHALUS	0.94	0.002	.	.	.	.	0.94	0.002
11129000	PIMEPHALES SP.	44.87	0.122	.	.	.	.	44.87	0.122
11129166	PIMEPHALES NOTATUS	113.28	0.113	.	.	.	.	113.28	0.113
11129169	PIMEPHALES VIGILAX	525.61	0.544	.	.	.	.	525.61	0.544
11201001	CARPIODES CARPIO	.	.	.	.	0.05	0.078	0.05	0.078
11201002	CARPIODES CYPRINUS	.	.	.	.	0.27	0.290	0.27	0.290
11206028	HYPENTELIUM NIGRICANS	0.03	0.001	0.15	0.017	0.14	0.046	0.32	0.064
11207000	ICTIOBUS SP.	.	.	0.22	0.044	2.48	3.323	2.70	3.367
11207030	ICTIOBUS BUBALUS	3.06	0.368	5.51	9.130	16.29	26.983	24.86	36.481
11207031	ICTIOBUS CYPRINELLUS	.	.	.	.	3.03	5.350	3.03	5.350
11207032	ICTIOBUS NIGER	.	.	0.10	0.314	0.06	0.098	0.16	0.413
11209034	MINYTREMA MELANOPS	38.77	0.652	6.04	0.815	13.10	4.639	57.91	6.107
11210000	MOXOSTOMA SP.	5.45	0.100	0.47	0.057	0.97	0.593	6.89	0.750
11210038	MOXOSTOMA MACROLEPIDOTUM	.	.	0.18	0.019	0.02	0.029	0.20	0.049
11210039	MOXOSTOMA CARINATUM	0.03	0.001	0.02	0.004	0.07	0.020	0.12	0.026
11210044	MOXOSTOMA DUQUESNEI	0.10	0.011	0.20	0.032	1.58	0.696	1.89	0.739
11210045	MOXOSTOMA ERYTHRURUM	3.66	0.045	0.46	0.068	5.11	3.125	9.23	3.238
11301002	ICTALURUS FURCATUS	0.18	0.001	1.14	0.088	1.38	0.624	2.70	0.713
11301004	ICTALURUS MELAS	.	.	0.07	0.004	.	.	0.07	0.004
11301005	ICTALURUS NATALIS	.	.	.	.	0.03	0.013	0.03	0.013
11301009	ICTALURUS PUNCTATUS	1.83	0.013	8.80	0.552	13.35	4.912	23.98	5.478
11303032	PYLODICTIS OLIVARIS	1.94	0.008	0.89	0.132	1.70	0.800	4.52	0.939
11500000	CYPRINODONTIDAE	19.32	0.025	.	.	.	.	19.32	0.025
11506024	FUNDULUS NOTATUS	4.07	0.000	.	.	.	.	4.07	0.000
11506026	FUNDULUS OLIVACEUS	0.68	0.001	.	.	.	.	0.68	0.001
11602001	GAMBUSIA AFFINIS	0.51	0.001	.	.	.	.	0.51	0.001
12201002	MORONE CHRYSOPS	20.73	0.123	0.25	0.016	0.28	0.058	21.26	0.197
12201003	MORONE MISSISSIPPIENSIS	8.67	0.106	2.39	0.173	0.32	0.040	11.37	0.320
12300801	MIXED SUNFISHES	0.00	0.301	.	.	.	.	0.00	0.301
12302003	AMBLOPLITES RUPESTRIS	0.16	0.001	0.42	0.003	0.10	0.007	0.68	0.010
12307000	LEPOMIS SP.	0.84	0.142	.	.	.	.	0.84	0.142
12307012	LEPOMIS GULOSUS	41.57	0.169	6.76	0.152	2.59	0.237	[illegible].92	0.5[illegible]

TOTAL NUMBERS AND WEIGHT BY SIZE CLASS -- RESRVOIR WIDE AVERAGE

RESRV=7

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
12307014	LEPOMIS CYANELLUS	6.41	0.045	2.86	0.060	0.30	0.018	9.57	0.123
12307016	LEPOMIS HUMILIS	4.22	0.011	3.17	0.025	0.38	0.014	7.78	0.049
12307017	LEPOMIS MACROCHIRUS	1642.15	3.238	282.79	5.655	107.24	7.117	2032.18	16.010
12307019	LEPOMIS MEGALOTIS	151.84	0.440	47.40	0.903	3.01	0.218	202.25	1.560
12307020	LEPOMIS MICROLOPHUS	117.73	0.659	28.08	0.712	37.99	4.179	183.80	5.550
12307801	HYBRID LEPOMIS SPP.	0.05	0.000	0.09	0.001	.	.	0.14	0.002
12308026	MICROPTERUS PUNCTULATUS	102.92	0.357	5.08	0.163	1.44	0.235	109.44	0.755
12308027	MICROPTERUS SALMOIDES	128.56	0.495	33.65	2.371	15.65	4.637	177.87	7.503
12309029	POMOXIS ANNULARIS	38.56	0.074	15.86	0.665	14.73	2.329	69.15	3.068
12309030	POMOXIS NIGROMACULATUS	0.22	0.001	.	.	0.48	0.060	0.70	0.061
12400802	UNIDENTIFIED DARTER (NOT STIZOSTEDION)	0.00	0.000	.	.	.	.	0.00	0.000
12402000	ETHEOSTOMA SP.	0.10	0.000	.	.	.	.	0.10	0.000
12402012	ETHEOSTOMA CAERULEUM	0.10	0.000	.	.	.	.	0.10	0.000
12402060	ETHEOSTOMA SPECTABILE	0.09	0.000	.	.	.	.	0.09	0.000
12403075	PERCA FLAVESCENS	17.93	0.315	.	.	.	.	17.93	0.315
12404077	PERCINA CAPRODES	17.27	0.209	.	.	.	.	17.27	0.209
12405097	STIZOSTEDION CANADENSE	0.55	0.032	0.39	0.049	0.77	0.192	1.71	0.273
12501001	APLODINOTUS GRUNNIENS	124.33	1.216	182.60	10.282	86.99	14.904	393.91	26.403
12905002	LABIDESTHES SICCULUS	34.62	0.047	.	.	.	.	34.62	0.047
19000801		377.06	0.720	.	.	.	.	377.06	0.720

TABLE 3.5-3
COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

TOTAL NUMBERS AND WEIGHT BY SIZE CLASS -- YEARLY AVERAGE

------------------------------ RESRV=7 YEAR=47 ------------------------------

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
10100000	PETROMYZONTIDAE	1.2346	0.000000	.	.	.	.	1.235	0.0000
10401003	LEPISOSTEUS PLATOSTOMUS	.	.	2.469	0.8259	2.469	1.5580	4.938	2.3840
10601003	ALOSA CHRYSOCHLORIS	2.4691	0.050617	2.469	0.0840	.	.	4.938	0.1346
10604007	DOROSOMA CEPEDIANUM	.	.	.	.	148.148	14.7049	148.148	14.7049
11105012	CYPRINUS CARPIO	.	.	75.309	25.5148	32.099	24.1654	107.407	49.6802
11201000	CARPIODES SP.	.	.	1.235	0.2037	.	.	1.235	0.2037
11201002	CARPIODES CYPRINUS	.	.	.	.	4.938	1.4926	4.938	1.4926
11207030	ICTIOBUS BUBALUS	3.7037	0.418519	171.605	35.4173	.	.	175.309	35.8358
11207031	ICTIOBUS CYPRINELLUS	.	.	.	.	1.235	0.8432	1.235	0.8432
11301002	ICTALURUS FURCATUS	.	.	.	.	3.704	1.7630	3.704	1.7630
11301009	ICTALURUS PUNCTATUS	.	.	.	.	2.469	0.8099	2.469	0.8099
12307017	LEPOMIS MACROCHIRUS	16.0494	0.083951	56.790	1.1185	12.346	0.7111	85.185	1.9136
12308026	MICROPTERUS PUNCTULATUS	2.4691	0.022222	.	.	.	.	2.469	0.0222
12308027	MICROPTERUS SALMOIDES	3.7037	0.041975	2.469	0.1160	2.469	3.1099	8.642	3.2679
12309029	POMOXIS ANNULARIS	.	.	19.753	1.0099	29.630	3.4901	49.383	4.5000
12405097	STIZOSTEDION CANADENSE	3.7037	0.130864	.	.	.	.	3.704	0.1309
19000801		0.0000	0.000000	.	.	.	.	0.000	0.0000

------------------------------ RESRV=7 YEAR=49 ------------------------------

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
10401003	LEPISOSTEUS PLATOSTOMUS	4.918	0.255738	.	.	.	.	4.918	0.2557
10604007	DOROSOMA CEPEDIANUM	44.262	0.240984	.	.	75.4098	6.74590	119.672	6.9869
10801002	HIODON TERGISUS	.	.	1.6393	0.1230	.	.	1.639	0.1230
11105012	CYPRINUS CARPIO	16.393	0.667213	24.5902	7.9279	13.1148	7.13934	54.098	15.7344
11125143	NOTROPIS SPILOPTERUS	77.049	0.113115	.	.	.	.	77.049	0.1131
11129166	PIMEPHALES NOTATUS	22.951	0.022951	.	.	.	.	22.951	0.0230
11201004	CARPIODES VELIFER	.	.	.	.	3.2787	0.89672	3.279	0.8967
11207000	ICTIOBUS SP.	.	.	75.4098	24.5344	8.1967	4.82295	83.607	29.3574
11301009	ICTALURUS PUNCTATUS	3.279	0.003279	8.1967	0.3623	1.6393	0.36721	13.115	0.7328
11303032	PYLODICTIS OLIVARIS	1.639	0.001639	.	.	.	.	1.639	0.0016
12201002	MORONE CHRYSOPS	1.639	0.008197	.	.	.	.	1.639	0.0082
12307012	LEPOMIS GULOSUS	14.754	0.016393	.	.	.	.	14.754	0.0164
12307014	LEPOMIS CYANELLUS	1.639	0.001639	.	.	.	.	1.639	0.0016
12307016	LEPOMIS HUMILIS	1.639	0.001639	.	.	.	.	1.639	0.0016
12307017	LEPOMIS MACROCHIRUS	404.918	0.760656	39.3443	0.6754	8.1967	0.47213	452.459	1.9082
12307019	LEPOMIS MEGALOTIS	3.279	0.004918	1.6393	0.0262	.	.	4.918	0.0311
12308027	MICROPTERUS SALMOIDES	24.590	0.068852	59.0164	3.2902	3.2787	1.56557	86.885	4.9246
12309029	POMOXIS ANNULARIS	.	.	32.7869	1.5279	24.5902	2.67869	57.377	4.2066
12501001	APLODINOTUS GRUNNIENS	6.557	0.068852	22.9508	1.5574	3.2787	0.40164	32.787	2.0279
12905002	LABIDESTHES SICCULUS	16.393	0.016393	.	.	.	.	16.393	0.0164

TABLE 3.5-4
COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

TABLE 3.5-5

COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

TOTAL NUMBERS AND WEIGHT BY SIZE CLASS -- YEARLY AVERAGE

RESRV=7 YEAR=50

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
10102002	ICHTHYOMYZON CASTANEUS	.	.	.	.	0.357	0.0032	0.357	0.0032
10401002	LEPISOSTEUS OSSEUS	0.882	0.00106	0.176	0.0302	.	.	1.058	0.0312
10601003	ALOSA CHRYSOCHLORIS	2.116	0.04074	4.881	0.3391	1.235	0.5014	8.232	0.8812
10604007	DOROSOMA CEPEDIANUM	52.484	0.77433	.	.	619.917	56.9258	672.401	57.7002
10604008	DOROSOMA PETENENSE	757.925	2.78074	.	.	0.353	0.0097	758.278	2.7904
10801000	HIODON SP.	.	.	0.353	0.0265	.	.	0.353	0.0265
10801002	HIODON TERGISUS	.	.	0.529	0.0616	.	.	0.529	0.0616
11102003	CAMPOSTOMA ANOMALUM	0.000	0.00000	.	.	.	.	0.000	0.0000
11105012	CYPRINUS CARPIO	8.344	0.04002	11.997	4.0324	11.116	6.4564	31.457	10.5288
11125073	NOTROPIS ATHERINOIDES	0.000	0.00000	.	.	.	.	0.000	0.0000
11129169	PIMEPHALES VIGILAX	0.000	0.00000	.	.	.	.	0.000	0.0000
11201000	CARPIODES SP.	.	.	.	.	2.880	1.4702	2.880	1.4702
11201002	CARPIODES CYPRINUS	.	.	.	.	2.482	1.0315	2.482	1.0315
11206028	HYPENTELIUM NIGRICANS	.	.	0.176	0.0284	.	.	0.176	0.0284
11207030	ICTIOBUS BUBALUS	0.882	0.08430	133.047	44.1975	25.518	14.8944	159.447	59.1762
11207031	ICTIOBUS CYPRINELLUS	.	.	.	.	0.714	0.5411	0.714	0.5411
11210000	MOXOSTOMA SP.	.	.	1.235	0.2310	2.351	0.8570	3.585	1.0880
11301002	ICTALURUS FURCATUS	.	.	.	.	0.353	0.3383	0.353	0.3383
11301009	ICTALURUS PUNCTATUS	31.929	0.37056	43.435	2.4516	17.581	4.3226	92.946	7.1448
11303032	PYLODICTIS OLIVARIS	0.768	0.00237	.	.	.	.	0.768	0.0024
12201002	MORONE CHRYSOPS	14.237	0.15449	1.584	0.0986	0.411	0.0776	16.232	0.3307
12307012	LEPOMIS GULOSUS	3.110	0.00516	0.768	0.0183	.	.	3.877	0.0235
12307014	LEPOMIS CYANELLUS	8.894	0.03930	.	.	.	.	8.894	0.0393
12307016	LEPOMIS HUMILIS	9.589	0.02208	2.545	0.0214	.	.	12.133	0.0435
12307017	LEPOMIS MACROCHIRUS	367.789	0.80131	69.276	1.4264	19.229	1.1853	456.294	3.4130
12307019	LEPOMIS MEGALOTIS	8.21:	0.03964	1.429	0.0229	.	.	9.643	0.0625
12307020	LEPOMIS MICROLOPHUS	.	.	0.176	0.0060	.	.	0.176	0.0060
12308024	MICROPTERUS DOLOMIEUI	1.786	0.01179	.	.	.	.	1.786	0.0118
12308026	MICROPTERUS PUNCTULATUS	25.062	0.15702	2.911	0.0886	0.534	0.0688	28.506	0.3144
12308027	MICROPTERUS SALMOIDES	146.349	0.38133	19.607	0.7700	3.361	1.3047	169.318	2.4560
12309029	POMOXIS ANNULARIS	2.173	0.00629	1.764	0.0735	6.864	0.9477	10.800	1.0276
12309030	POMOXIS NIGROMACULATUS	.	.	0.176	0.0074	0.234	0.0225	0.411	0.0299
12404077	PERCINA CAPRODES	0.176	0.00370	.	.	.	.	0.176	0.0037
12501001	APLODINOTUS GRUNNIENS	80.179	1.02992	44.185	2.3024	9.242	1.5119	133.606	4.8442
12905002	LABIDESTHES SICCULUS	0.000	0.00000	.	.	.	.	0.000	0.0000
19000801		541.285	0.78583	.	.	.	.	541.285	0.7858

RESRV=7 YEAR=51

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
10601003	ALOSA CHRYSOCHLORIS	.	.	8.1967	0.53934	1.6393	0.57049	9.836	1.1098
10604007	DOROSOMA CEPEDIANUM	122.951	1.71639	.	.	75.4098	8.31475	198.361	10.0311
10604008	DOROSOMA PETENENSE	339.344	1.76721	.	.	.	.	339.344	1.7672
11100801	UNIDENTIFIED SHINER	0.000	0.00000	.	.	.	.	0.000	0.0000
11105012	CYPRINUS CARPIO	.	.	.	.	1.6393	0.95246	1.639	0.9525
11129169	PIMEPHALES VIGILAX	0.000	0.00000	.	.	.	.	0.000	0.0000
11207030	ICTIOBUS BUBALUS	.	.	1.6393	0.64590	6.5574	3.98033	8.197	4.6262
11210045	MOXOSTOMA ERYTHRURUM	.	.	.	.	1.6393	0.61639	1.639	0.6164
11301002	ICTALURUS FURCATUS	.	.	.	.	1.6393	0.66557	1.639	0.6656

TABLE 3.5-6

COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

TOTAL NUMBERS AND WEIGHT BY SIZE CLASS -- YEARLY AVERAGE

RESRV=7 YEAR=51

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
11301009	ICTALURUS PUNCTATUS	1.639	0.013115	39.3443	2.40164	13.1148	4.45410	54.098	6.86885
11303032	PYLODICTIS OLIVARIS	1.639	0.001639	.	.	.	.	1.639	0.00164
12201002	MORONE CHRYSOPS	27.869	0.385246	8.1967	0.82295	18.0328	3.32787	54.098	4.53607
12307012	LEPOMIS GULOSUS	1.639	0.001639	.	.	.	.	1.639	0.00164
12307014	LEPOMIS CYANELLUS	3.279	0.008197	1.6393	0.06066	.	.	4.918	0.06885
12307016	LEPOMIS HUMILIS	8.197	0.022951	.	.	.	.	8.197	0.02295
12307017	LEPOMIS MACROCHIRUS	285.246	0.716393	40.9836	0.70000	4.9180	0.28197	331.148	1.69836
12307019	LEPOMIS MEGALOTIS	.	.	.	.	1.6393	0.10656	1.639	0.10656
12308027	MICROPTERUS SALMOIDES	6.557	0.073770	40.9836	2.14918	1.6393	0.30656	49.180	2.52951
12309029	POMOXIS ANNULARIS	1.639	0.006557	1.6393	0.09180	1.6393	0.14754	4.918	0.24590
12405097	STIZOSTEDION CANADENSE	1.639	0.000000	.	.	.	.	1.639	0.00000
12501001	APLODINOTUS GRUNNIENS	40.984	0.511475	24.5902	1.29016	4.9180	0.75246	70.492	2.55410
19000801		488.525	0.511475	.	.	.	.	488.525	0.51148

RESRV=7 YEAR=52

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
10601003	ALOSA CHRYSOCHLORIS	.	.	2.2131	0.183689	7.678	4.6977	9.891	4.8814
10604007	DOROSOMA CEPEDIANUM	21.564	0.29746	.	.	103.835	12.3677	125.400	12.6652
10604008	DOROSOMA PETENENSE	275.846	0.96732	.	.	1.667	0.0458	277.513	1.0132
10801002	HIODON TERGISUS	0.546	0.01803	.	.	.	.	0.546	0.0180
11105012	CYPRINUS CARPIO	.	.	.	.	1.626	1.7813	1.626	1.7813
11201000	CARPIODES SP.	.	.	.	.	0.546	0.3120	0.546	0.3120
11207030	ICTIOBUS BUBALUS	.	.	.	.	2.186	1.3158	2.186	1.3158
11301002	ICTALURUS FURCATUS	.	.	.	.	0.546	0.1880	0.546	0.1880
11301009	ICTALURUS PUNCTATUS	1.093	0.00601	.	.	1.093	0.1661	2.186	0.1721
11303032	PYLODICTIS OLIVARIS	4.065	0.01301	0.5464	0.119126	.	.	4.611	0.1321
12201002	MORONE CHRYSOPS	9.290	0.15847	2.1858	0.156831	.	.	11.475	0.3153
12307012	LEPOMIS GULOSUS	13.008	0.03252	2.4390	0.052033	.	.	15.447	0.0846
12307014	LEPOMIS CYANELLUS	4.898	0.02280	.	.	.	.	4.898	0.0228
12307017	LEPOMIS MACROCHIRUS	339.344	0.80883	18.8205	0.336416	5.718	0.4710	363.882	1.6163
12307019	LEPOMIS MEGALOTIS	43.150	0.17252	3.2724	0.066179	.	.	46.423	0.2387
12307020	LEPOMIS MICROLOPHUS	19.906	0.10224	1.0929	0.019672	3.252	0.2894	24.251	0.4113
12308026	MICROPTERUS PUNCTULATUS	43.764	0.31732	9.5162	0.220232	0.546	0.0705	53.827	0.6080
12308027	MICROPTERUS SALMOIDES	11.449	0.07272	13.3553	0.478268	8.943	2.3163	33.748	2.8673
12309029	POMOXIS ANNULARIS	3.825	0.01257	.	.	.	.	3.825	0.0126
12309030	POMOXIS NIGROMACULATUS	0.813	0.00407	.	.	.	.	0.813	0.0041
12501001	APLODINOTUS GRUNNIENS	4.372	0.06885	1.0929	0.062842	2.452	0.3874	7.917	0.5191
19000801		610.444	1.01083	.	.	.	.	610.444	1.0108

TABLE 3.5-7
COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

TOTAL NUMBERS AND WEIGHT BY SIZE CLASS -- YEARLY AVERAGE

RESRV=7 YEAR=54

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
10601003	ALOSA CHRYSOCHLORIS	4.94	0.0735	31.481	3.16296	1.235	0.3698	37.65	3.6062
10604007	DOROSOMA CEPEDIANUM	1.23	0.0160	.	.	485.185	82.1988	486.42	82.2148
10604008	DOROSOMA PETENENSE	3319.14	17.0846	.	.	57.407	2.2840	3376.54	19.3685
10801002	HIODON TERGISUS	.	.	0.617	0.11296	.	.	0.62	0.1130
11103005	CARASSIUS AURATUS	0.00	0.0000	.	.	.	.	0.00	0.0000
11105012	CYPRINUS CARPIO	.	.	.	.	4.321	3.4710	4.32	3.4710
11201000	CARPIODES SP.	.	.	.	.	10.494	6.4753	10.49	6.4753
11206028	HYPENTELIUM NIGRICANS	.	.	0.617	0.09938	.	.	0.62	0.0994
11207030	ICTIOBUS BUBALUS	.	.	0.617	0.24321	67.901	53.5457	68.52	53.7889
11210000	MOXOSTOMA SP.	.	.	.	.	1.235	0.5265	1.23	0.5265
11210035	MOXOSTOMA ANISURUM	.	.	.	.	2.469	2.1117	2.47	2.1117
11301002	ICTALURUS FURCATUS	6.79	0.1068	100.000	8.16481	2.469	0.3802	109.26	8.6519
11301009	ICTALURUS PUNCTATUS	47.53	0.2216	56.790	3.46852	16.667	4.8691	120.99	8.5593
11303032	PYLODICTIS OLIVARIS	0.62	0.0130	1.852	0.30988	1.852	0.9821	4.32	1.3049
12201002	MORONE CHRYSOPS	12.35	0.1383	0.617	0.06173	.	.	12.96	0.2000
12307012	LEPOMIS GULOSUS	11.73	0.0272	1.235	0.01852	0.617	0.0438	13.58	0.0895
12307014	LEPOMIS CYANELLUS	.	.	1.235	0.02469	.	.	1.23	0.0247
12307017	LEPOMIS MACROCHIRUS	782.72	1.7593	129.012	2.90864	36.420	2.5006	948.15	7.1685
12307019	LEPOMIS MEGALOTIS	116.67	0.4414	37.037	0.73951	.	.	153.70	1.1809
12307020	LEPOMIS MICROLOPHUS	.	.	.	.	4.321	0.3846	4.32	0.3846
12308024	MICROPTERUS DOLOMIEUI	0.62	0.0074	.	.	.	.	0.62	0.0074
12308026	MICROPTERUS PUNCTULATUS	154.94	0.9506	24.074	1.16235	0.617	0.0796	179.63	2.1926
12308027	MICROPTERUS SALMOIDES	22.84	0.1543	11.728	0.77840	3.086	0.5772	37.65	1.5099
12309029	POMOXIS ANNULARIS	0.62	0.0025	6.173	0.20988	1.852	0.2358	8.64	0.4481
12309030	POMOXIS NIGROMACULATUS	.	.	0.617	0.04012	.	.	0.62	0.0401
12404077	PERCINA CAPRODES	0.00	0.0000	.	.	.	.	0.00	0.0000
12405097	STIZOSTEDION CANADENSE	.	.	1.235	0.15370	3.086	0.7469	4.32	0.9006
12501001	APLODINOTUS GRUNNIENS	275.93	2.0975	83.951	4.20617	60.494	10.6599	420.37	16.9636
12905002	LABIDESTHES SICCULUS	0.00	0.0000	.	.	.	.	0.00	0.0000
19000801		425.31	1.3599	.	.	.	.	425.31	1.3599

RESRV=7 YEAR=55

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
10601003	ALOSA CHRYSOCHLORIS	1.80	0.0369	12.613	1.1045	18.018	6.635	32.43	7.777
10604007	DOROSOMA CEPEDIANUM	28.83	0.4333	.	.	729.730	107.668	758.56	108.101
10604008	DOROSOMA PETENENSE	4357.66	13.8811	.	.	59.459	1.643	4417.12	15.524
10801002	HIODON TERGISUS	.	.	0.901	0.1649	.	.	0.90	0.165
11105012	CYPRINUS CARPIO	.	.	.	.	11.712	7.685	11.71	7.685
11206028	HYPENTELIUM NIGRICANS	0.90	0.0081	.	.	.	.	0.90	0.008
11207030	ICTIOBUS BUBALUS	.	.	.	.	99.099	80.732	99.10	80.732
11207032	ICTIOBUS NIGER	.	.	.	.	0.901	1.517	0.90	1.517
11210044	MOXOSTOMA DUQUESNEI	.	.	.	.	1.802	0.666	1.80	0.666
11210045	MOXOSTOMA ERYTHRURUM	.	.	2.703	0.4306	22.523	7.371	25.23	7.802
11301002	ICTALURUS FURCATUS	.	.	.	.	0.901	0.566	0.90	0.566
11301009	ICTALURUS PUNCTATUS	21.62	0.2982	46.847	3.3009	37.838	9.162	106.31	12.761
11303032	PYLODICTIS OLIVARIS	.	.	.	.	4.505	1.816	4.50	1.816
12201002	MORONE CHRYSOPS	27.93	0.5532	36.937	2.9207	11.712	2.761	76.58	6.235
12307017	LEPOMIS MACROCHIRUS	490.99	1.3631	129.730	2.7405	27.027	1.759	647.75	5.862

TABLE 3.5-8
COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

TOTAL NUMBERS AND WEIGHT BY SIZE CLASS -- YEARLY AVERAGE

RESRV=7 YEAR=55

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
12307020	LEPOMIS MICROLOPHUS	2.703	0.01532	11.712	0.3856	29.7297	1.8514	44.144	2.2523
12308026	MICROPTERUS PUNCTULATUS	136.937	0.93333	36.036	1.0360	0.9009	0.1162	173.874	2.0856
12308027	MICROPTERUS SALMOIDES	68.468	0.51532	55.856	2.6378	11.7117	7.5577	136.036	10.7108
12501001	APLODINOTUS GRUNNIENS	43.243	0.69459	281.982	16.1613	95.4955	15.3333	420.721	32.1892
19000801		937.838	1.67658	.	.	.	.	937.838	1.6766

RESRV=7 YEAR=56

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
10601003	ALOSA CHRYSOCHLORIS	2.34	0.04299	57.943	4.6503	13.778	4.5287	74.06	9.2220
10604007	DOROSOMA CEPEDIANUM	76.58	1.16348	.	.	540.161	74.0906	616.74	75.2541
10604008	DOROSOMA PETENENSE	3265.75	8.84267	.	.	12.346	0.6568	3278.10	9.4995
10801002	HIODON TERGISUS	.	.	1.657	0.3605	.	.	1.66	0.3605
11100801	UNIDENTIFIED SHINER	0.00	0.00000	.	.	.	.	0.00	0.0000
11103005	CARASSIUS AURATUS	.	.	0.552	0.0497	0.276	0.3525	0.83	0.4022
11105012	CYPRINUS CARPIO	.	.	.	.	1.722	1.5972	1.72	1.5972
11129000	PIMEPHALES SP.	0.00	0.00000	.	.	.	.	0.00	0.0000
11201000	CARPIODES SP.	.	.	1.852	0.3759	1.170	0.6384	3.02	1.0143
11207030	ICTIOBUS BUBALUS	.	.	.	.	15.940	13.9905	15.94	13.9905
11210039	MOXOSTOMA CARINATUM	.	.	.	.	0.276	0.2674	0.28	0.2674
11210044	MOXOSTOMA DUQUESNEI	.	.	.	.	0.276	0.1489	0.28	0.1489
11210045	MOXOSTOMA ERYTHRURUM	0.28	0.00635	.	.	3.315	1.3790	3.59	1.3854
11301002	ICTALURUS FURCATUS	.	.	.	.	0.276	0.0657	0.28	0.0657
11301009	ICTALURUS PUNCTATUS	15.92	0.16216	15.112	1.0212	4.468	1.4886	35.50	2.6719
11303032	PYLODICTIS OLIVARIS	0.62	0.00247	.	.	0.276	0.0776	0.89	0.0801
11506000	FUNDULUS SP.	0.00	0.00000	.	.	.	.	0.00	0.0000
12201002	MORONE CHRYSOPS	22.19	0.65182	36.594	2.7260	5.249	1.5544	64.04	4.9322
12307012	LEPOMIS GULOSUS	1.51	0.00302	.	.	.	.	1.51	0.0030
12307014	LEPOMIS CYANELLUS	1.10	0.00635	0.829	0.0166	.	.	1.93	0.0229
12307016	LEPOMIS HUMILIS	.	.	0.552	0.0047	0.829	0.0149	1.38	0.0196
12307017	LEPOMIS MACROCHIRUS	131.30	0.46697	99.379	1.7888	16.247	1.3684	246.93	3.6242
12307020	LEPOMIS MICROLOPHUS	1.17	0.00846	3.867	0.1323	10.010	0.7345	15.05	0.8753
12308026	MICROPTERUS PUNCTULATUS	59.03	0.51811	40.673	0.9442	2.486	0.7746	102.19	2.2369
12308027	MICROPTERUS SALMOIDES	52.21	0.49111	42.166	1.5707	5.378	1.8547	99.75	3.9165
12309029	POMOXIS ANNULARIS	67.28	0.29259	30.864	0.3883	1.235	0.1802	99.38	0.8611
12309030	POMOXIS NIGROMACULATUS	0.62	0.00309	.	.	.	.	0.62	0.0031
12404077	PERCINA CAPRODES	0.00	0.00000	.	.	.	.	0.00	0.0000
12405097	STIZOSTEDION CANADENSE	2.83	0.18998	5.102	0.5456	6.173	1.7037	14.10	2.4393
12501001	APLODINOTUS GRUNNIENS	60.00	0.82049	168.969	10.0137	160.368	26.7625	389.34	37.5967
12905002	LABIDESTHES SICCULUS	0.00	0.00000	.	.	.	.	0.00	0.0000
19000801		504.43	0.39244	.	.	.	.	504.43	0.3924

TABLE 3.7-4

COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

TOTAL NUMBERS AND WEIGHT BY SIZE CLASS -- YEARLY AVERAGE

RESRV=7 YEAR=57

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
10601003	ALOSA CHRYSOCHLORIS	0.00	0.0000	1.240	0.1194	45.46	21.776	46.70	21.895
10604007	DOROSOMA CEPEDIANUM	7.02	0.1153	.	.	1806.42	264.218	1813.44	264.334
10604008	DOROSOMA PETENENSE	4291.83	15.7939	.	.	286.23	8.547	4578.05	24.341
10801002	HIODON TERGISUS	.	.	7.562	1.6477	1.65	0.636	9.22	2.284
11100801	UNIDENTIFIED SHINER	0.00	0.0000	.	.	.	.	0.00	0.000
11105012	CYPRINUS CARPIO	.	.	.	.	7.40	7.279	7.40	7.279
11129169	PIMEPHALES VIGILAX	0.00	0.0000	.	.	.	.	0.00	0.000
11201000	CARPIODES SP.	0.41	0.0215	.	.	6.66	4.280	7.07	4.302
11206028	HYPENTELIUM NIGRICANS	.	.	.	.	0.54	0.116	0.54	0.116
11207030	ICTIOBUS BUBALUS	.	.	.	.	55.68	55.093	55.68	55.093
11207031	ICTIOBUS CYPRINELLUS	.	.	.	.	1.08	1.246	1.08	1.246
11207032	ICTIOBUS NIGER	.	.	.	.	0.54	1.346	0.54	1.346
11210035	MOXOSTOMA ANISURUM	.	.	.	.	3.76	1.736	3.76	1.736
11210045	MOXOSTOMA ERYTHRURUM	0.41	0.0095	.	.	8.26	4.222	8.68	4.232
11301002	ICTALURUS FURCATUS	3.23	0.0742	2.688	0.2473	6.66	1.859	12.57	2.180
11301009	ICTALURUS PUNCTATUS	49.60	0.7100	28.184	2.0520	39.76	8.576	117.54	11.338
11303032	PYLODICTIS OLIVARIS	1.08	0.0048	4.879	0.6846	2.19	0.961	8.14	1.651
11506000	FUNDULUS SP.	0.00	0.0000	.	.	.	.	0.00	0.000
12201002	MORONE CHRYSOPS	46.78	1.1296	16.116	1.1467	103.02	29.921	165.92	32.198
12307012	LEPOMIS GULOSUS	25.02	0.0902	1.902	0.0387	1.36	0.132	28.28	0.261
12307014	LEPOMIS CYANELLUS	25.30	0.1446	5.621	0.1546	0.83	0.050	31.75	0.349
12307016	LEPOMIS HUMILIS	98.82	0.2943	52.315	0.4513	21.49	0.392	172.62	1.138
12307017	LEPOMIS MACROCHIRUS	1339.64	3.7985	345.530	7.2425	104.47	7.826	1789.63	18.867
12307019	LEPOMIS MEGALOTIS	18.28	0.0968	39.785	0.8425	.	.	58.06	0.939
12307020	LEPOMIS MICROLOPHUS	19.92	0.1453	32.729	1.1026	22.98	1.792	75.63	3.040
12308024	MICROPTERUS DOLOMIEUI	.	.	.	.	0.54	0.074	0.54	0.074
12308026	MICROPTERUS PUNCTULATUS	127.19	1.0379	62.783	1.8936	1.65	0.214	191.63	3.145
12308027	MICROPTERUS SALMOIDES	54.97	0.4620	68.982	4.6183	13.39	6.273	137.35	11.353
12309029	POMOXIS ANNULARIS	5.91	0.0247	14.018	0.2018	4.26	0.441	24.19	0.668
12404077	PERCINA CAPRODES	0.00	0.0000	.	.	.	.	0.00	0.000
12405097	STIZOSTEDION CANADENSE	.	.	.	.	0.54	0.246	0.54	0.246
12501001	APLODINOTUS GRUNNIENS	154.86	2.6287	187.003	10.3253	89.90	15.138	431.77	28.092
19000801		580.24	0.6924	.	.	.	.	580.24	0.692

RESRV=7 YEAR=58

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
10401001	LEPISOSTEUS OCULATUS	0.48	0.0290	.	.	.	.	0.48	0.0290
10601003	ALOSA CHRYSOCHLORIS	35.89	0.7405	32.7381	1.23488	0.476	0.4000	69.11	2.3754
10604007	DOROSOMA CEPEDIANUM	25.12	0.3807	.	.	241.310	39.5537	266.43	39.9344
10604008	DOROSOMA PETENENSE	1391.37	17.2331	.	.	3.155	0.1071	1394.52	17.3402
10801002	HIODON TERGISUS	.	.	3.9286	0.75726	.	.	3.93	0.7573
11100801	UNIDENTIFIED SHINER	0.00	0.0000	.	.	.	.	0.00	0.0000
11105012	CYPRINUS CARPIO	.	.	.	.	1.429	1.7514	1.43	1.7514
11201000	CARPIODES SP.	4.76	0.1762	.	.	1.429	1.1876	6.19	1.3638
11207030	ICTIOBUS BUBALUS	.	.	.	.	21.369	21.3231	21.37	21.3231
11210000	MOXOSTOMA SP.	2.38	0.0662	1.9048	0.35619	3.333	2.6395	7.62	3.0619
11301002	ICTALURUS FURCATUS	3.75	0.0575	6.1310	0.51101	5.714	1.9686	15.60	2.5371
11301009	ICTALURUS PUNCTATUS	.	.	9.6429	0.57310	4.286	1.0910	13.93	1.6640

TABLE 3.5-10
COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

TOTAL NUMBER AND WEIGHT BY SIZE CLASS -- YEARLY AVERAGE

RESRV=7 YEAR=58

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
11303032	PYLODICTIS OLIVARIS	.	.	2.5000	0.17750	0.4762	0.16952	2.976	0.34702
12201002	MORONE CHRYSOPS	5.357	0.10637	1.2500	0.12500	3.9286	0.74577	10.536	0.97714
12307012	LEPOMIS GULOSUS	29.762	0.08976	1.4286	0.03952	0.4762	0.03381	31.667	0.16310
12307013	LEPOMIS AURITUS	4.286	0.00952	.	.	.	.	4.286	0.00952
12307014	LEPOMIS CYANELLUS	18.155	0.06417	2.5000	0.07125	.	.	20.655	0.13542
12307017	LEPOMIS MACROCHIRUS	501.190	1.36661	85.0000	1.72470	38.3333	2.97280	624.524	6.06411
12307019	LEPOMIS MEGALOTIS	2.500	0.01125	33.0952	0.73173	0.9524	0.06238	36.548	0.80536
12307020	LEPOMIS MICROLOPHUS	5.060	0.02679	1.4286	0.03333	9.7024	0.80601	16.190	0.86613
12308026	MICROPTERUS PUNCTULATUS	34.286	0.29125	17.0238	0.83542	0.4762	0.06143	51.786	1.18810
12308027	MICROPTERUS SALMOIDES	7.619	0.06286	13.5714	1.04000	1.4286	0.30143	22.619	1.40429
12309029	POMOXIS ANNULARIS	9.524	0.04190	8.0357	0.32869	2.6786	0.57631	20.238	0.94690
12404077	PERCINA CAPRODES	0.000	0.00000	.	.	.	.	0.000	0.00000
12405097	STIZOSTEDION CANADENSE	0.476	0.02190	0.4762	0.07714	0.9524	0.61238	1.905	0.71143
12501001	APLODINOTUS GRUNNIENS	82.917	1.02256	26.4881	1.60077	23.9286	4.49554	133.333	7.11887
12905002	LABIDESTHES SICCULUS	0.000	0.00000	.	.	.	.	0.000	0.00000
19000801		240.595	0.24226	.	.	.	.	240.595	0.24226

RESRV=7 YEAR=59

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
10601003	ALOSA CHRYSOCHLORIS	.	.	12.381	1.22190	1.905	0.4790	14.286	1.7010
10604007	DOROSOMA CEPEDIANUM	.	.	.	.	407.619	63.3371	407.619	63.3371
10604008	DOROSOMA PETENENSE	144.762	1.05429	.	.	100.952	4.4762	245.714	5.5305
10801002	HIODON TERGISUS	.	.	0.952	0.17429	.	.	0.952	0.1743
11105012	CYPRINUS CARPIO	.	.	.	.	8.571	9.8352	8.571	9.8352
11201000	CARPIODES SP.	.	.	.	.	3.810	5.3200	3.810	5.3200
11207030	ICTIOBUS BUBALUS	.	.	4.762	1.05429	52.381	53.0019	57.143	54.0562
11209034	MINYTREMA MELANOPS	.	.	2.857	0.40667	.	.	2.857	0.4067
11210039	MOXOSTOMA CARINATUM	.	.	.	.	4.762	4.7933	4.762	4.7933
11210045	MOXOSTOMA ERYTHRURUM	.	.	.	.	1.905	0.5676	1.905	0.5676
11301002	ICTALURUS FURCATUS	1.905	0.05524	20.000	1.79143	4.762	0.9743	26.667	2.8210
11301009	ICTALURUS PUNCTATUS	2.857	0.00952	.	.	3.810	0.8143	6.667	0.8238
11303032	PYLODICTIS OLIVARIS	1.905	0.00476	0.952	0.03429	0.952	0.2676	3.810	0.3067
12201002	MORONE CHRYSOPS	1.905	0.01429	0.952	0.09524	0.952	0.1476	3.810	0.2571
12307012	LEPOMIS GULOSUS	78.095	0.25048	26.667	0.51905	1.905	0.3067	106.667	1.0762
12307014	LEPOMIS CYANELLUS	2.857	0.02571	.	.	.	.	2.857	0.0257
12307017	LEPOMIS MACROCHIRUS	504.762	1.53333	124.762	2.71619	30.476	2.0543	660.000	6.3038
12307019	LEPOMIS MEGALOTIS	0.952	0.00667	11.429	0.28476	.	.	12.381	0.2914
12307020	LEPOMIS MICROLOPHUS	3.810	0.02952	3.810	0.06857	3.810	0.3867	11.429	0.4848
12308024	MICROPTERUS DOLOMIEUI	.	.	.	.	0.952	0.3886	0.952	0.3886
12308026	MICROPTERUS PUNCTULATUS	50.476	0.28190	9.524	0.50952	0.952	0.1857	60.952	0.9771
12308027	MICROPTERUS SALMOIDES	18.095	0.11238	9.524	0.80857	8.571	4.8162	36.190	5.7371
12309029	POMOXIS ANNULARIS	20.000	0.09143	125.714	3.94667	15.238	3.2371	160.952	7.2752
12309030	POMOXIS NIGROMACULATUS	.	.	1.905	0.02381	.	.	1.905	0.0238
12405097	STIZOSTEDION CANADENSE	.	.	.	.	0.952	0.1962	0.952	0.1962
12501001	APLODINOTUS GRUNNIENS	178.095	2.01810	143.810	8.89429	228.571	39.7943	550.476	50.7067
19000801		569.571	0.49333	.	.	.	.	568.571	0.4933

TABLE 3.5-11
COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

TOTAL NUMBERS AND WEIGHT BY SIZE CLASS -- YEARLY AVERAGE

RESRV=7 YEAR=70

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
10401001	LEPISOSTEUS OCULATUS	.	.	1.685	0.5297	.	.	1.69	0.5297
10401002	LEPISOSTEUS OSSEUS	1.33	0.00371	0.370	0.0428	.	.	1.70	0.0465
10601003	ALOSA CHRYSOCHLORIS	7.92	0.06419	0.477	0.0515	0.845	0.4781	9.24	0.5938
10604007	DOROSOMA CEPEDIANUM	694.37	1.97368	.	.	645.340	73.1215	1339.71	75.0952
10604008	DOROSOMA PETENENSE	2453.61	3.23736	.	.	0.309	0.0151	2453.92	3.2525
10604801	MIXED DOROSOMA	766.72	1.92787	.	.	.	.	766.72	1.9279
10801002	HIODON TERGISUS	0.80	0.00801	.	.	.	.	0.80	0.0080
11103005	CARASSIUS AURATUS	0.09	0.00139	.	.	.	.	0.09	0.0014
11105012	CYPRINUS CARPIO	0.84	0.00215	0.152	0.0574	4.772	6.7791	5.77	6.8387
11124061	NOTEMIGONUS CRYSOLEUCAS	4.36	0.16987	.	.	.	.	4.36	0.1699
11201002	CARPIODES CYPRINUS	.	.	.	.	0.731	0.7723	0.73	0.7723
11207000	ICTIOBUS SP.	.	.	0.595	0.1164	6.616	8.8615	7.21	8.9779
11207030	ICTIOBUS BUBALUS	1.96	0.01349	3.041	0.7638	23.280	34.2239	28.28	35.0011
11207031	ICTIOBUS CYPRINELLUS	.	.	.	.	8.005	13.8933	8.01	13.8933
11207032	ICTIOBUS NIGER	.	.	.	.	0.170	0.2626	0.17	0.2626
11209034	MINYTREMA MELANOPS	18.02	0.10330	0.681	0.0676	0.471	0.2253	19.17	0.3962
11210000	MOXOSTOMA SP.	0.15	0.00697	.	.	0.878	0.5169	1.03	0.5239
11210038	MOXOSTOMA MACROLEPIDOTUM	.	.	0.298	0.0345	.	.	0.30	0.0345
11210044	MOXOSTOMA DUQUESNEI	0.27	0.03019	0.546	0.0851	3.362	1.5102	4.18	1.6255
11210045	MOXOSTOMA ERYTHRURUM	5.27	0.04800	0.507	0.0765	6.356	3.5511	12.13	3.6756
11301002	ICTALURUS FURCATUS	0.30	0.00030	2.865	0.2205	2.516	0.9639	5.68	1.1847
11301009	ICTALURUS PUNCTATUS	3.27	0.02428	10.096	0.6399	5.711	2.1658	19.07	2.8299
11303032	PYLODICTIS OLIVARIS	3.51	0.01332	0.427	0.0748	1.363	0.5120	5.30	0.6002
12201002	MORONE CHRYSOPS	47.30	0.22204	0.121	0.0121	.	.	47.42	0.2341
12302003	AMBLOPLITES RUPESTRIS	.	.	.	.	0.170	0.0155	0.17	0.0155
12307012	LEPOMIS GULOSUS	7.18	0.02858	4.442	0.0944	2.299	0.1893	13.92	0.3123
12307014	LEPOMIS CYANELLUS	7.41	0.04233	4.859	0.1092	0.455	0.0274	12.73	0.1790
12307016	LEPOMIS HUMILIS	.	.	2.864	0.0218	0.550	0.0308	3.41	0.0526
12307017	LEPOMIS MACROCHIRUS	1243.26	2.27349	193.311	4.5759	70.031	5.3723	1506.60	12.2217
12307019	LEPOMIS MEGALOTIS	47.16	0.29390	24.340	0.5245	2.711	0.1777	74.21	0.9961
12307020	LEPOMIS MICROLOPHUS	9.09	0.02532	15.225	0.4134	16.654	1.5886	40.97	2.0274
12308026	MICROPTERUS PUNCTULATUS	148.87	0.37294	2.432	0.1164	0.561	0.0754	151.86	0.5647
12308027	MICROPTERUS SALMOIDES	263.10	0.87446	22.412	1.8576	9.579	2.8174	295.09	5.5494
12309029	POMOXIS ANNULARIS	81.58	0.12086	26.132	0.9563	18.953	2.6918	126.66	3.7690
12309030	POMOXIS NIGROMACULATUS	.	.	.	.	0.893	0.0860	0.89	0.0860
12403075	PERCA FLAVESCENS	16.94	0.08346	.	.	.	.	16.94	0.0835
12404077	PERCINA CAPRODES	0.27	0.00369	.	.	.	.	0.27	0.0037
12405097	STIZOSTEDION CANADENSE	.	.	.	.	0.748	0.2127	0.75	0.2127
12501001	APLODINOTUS GRUNNIENS	109.45	0.81746	211.628	12.4508	96.912	15.7896	417.99	29.0579
19000801		694.77	0.84765	.	.	.	.	694.77	0.8476

TABLE 3.5-12

COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

TOTAL NUMBERS AND WEIGHT BY SIZE CLASS -- YEARLY AVERAGE

RESRV=7 YEAR=71

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
10401001	LEPISOSTEUS OCULATUS	0.27	0.00887	.	.	.	.	0.27	0.0089
10604007	DOROSOMA CEPEDIANUM	327.74	2.25516	.	.	525.051	60.2051	852.79	62.4603
10604008	DOROSOMA PETENENSE	3315.89	7.09360	.	.	.	.	3315.89	7.0936
11104011	CLINOSTOMUS FUNDULOIDES	4.17	9.95714	.	.	.	.	4.17	9.9571
11105012	CYPRINUS CARPIO	.	.	.	.	17.045	30.6302	17.05	30.6302
11124061	NOTEMIGONUS CRYSOLEUCAS	0.00	0.00000	.	.	.	.	0.00	0.0000
11129169	PIMEPHALES VIGILAX	0.00	0.00000	.	.	.	.	0.00	0.0000
11206028	HYPENTELIUM NIGRICANS	0.27	0.00591	0.269	0.0258	.	.	0.54	0.0317
11207030	ICTIOBUS BUBALUS	6.40	1.94884	30.236	69.2021	.	.	36.63	71.1509-
11207032	ICTIOBUS NIGER	.	.	0.780	2.5143	.	.	0.78	2.5143
11209034	MINYTREMA MELANOPS	21.16	0.30033	.	.	7.217	2.0803	28.37	2.3807
11210000	MOXOSTOMA SP.	.	.	1.613	0.1220	2.688	1.6231	4.30	1.7452
11210038	MOXOSTOMA MACROLEPIDOTUM	.	.	.	.	0.198	0.2341	0.20	0.2341
11210045	MOXOSTOMA ERYTHRURUM	5.23	0.06744	0.581	0.1320	5.946	3.3101	11.76	3.5095
11301009	ICTALURUS PUNCTATUS	0.99	0.00635	10.149	0.6629	18.131	8.2531	29.27	8.9224
11303032	PYLODICTIS OLIVARIS	2.37	0.00825	1.659	0.2981	0.467	0.2032	4.50	0.5096
12201002	MORONE CHRYSOPS	4.07	0.07558	.	.	.	.	4.07	0.0756
12201003	MORONE MISSISSIPPIENSIS	0.65	0.00321	0.269	0.0204	.	.	0.92	0.0236
12307012	LEPOMIS GULOSUS	36.84	0.08559	8.851	0.2027	.	.	45.69	0.2883
12307014	LEPOMIS CYANELLUS	5.95	0.06065	2.536	0.0294	.	.	8.49	0.0901
12307016	LEPOMIS HUMILIS	5.12	0.00983	.	.	0.581	0.0047	5.70	0.0145
12307017	LEPOMIS MACROCHIRUS	1586.16	3.02149	277.420	7.4848	76.582	5.4508	1940.16	15.9570
12307019	LEPOMIS MEGALOTIS	90.22	0.37082	48.312	1.2887	2.477	0.0805	141.01	1.7400
12307020	LEPOMIS MICROLOPHUS	72.54	0.22128	21.691	0.5890	23.321	3.2692	117.55	4.0794
12308026	MICROPTERUS PUNCTULATUS	74.01	0.35234	5.375	0.0827	2.117	0.3235	81.50	0.7586
12308027	MICROPTERUS SALMOIDES	58.44	0.31432	27.734	1.5835	18.526	5.9447	104.70	7.8425
12309029	POMOXIS ANNULARIS	7.90	0.04785	13.428	1.0152	17.180	2.9552	38.51	4.0182
12403075	PERCA FLAVESCENS	24.27	0.38464	.	.	.	.	24.27	0.3846
12404077	PERCINA CAPRODES	0.00	0.00000	.	.	.	.	0.00	0.0000
12501001	APLODINOTUS GRUNNIENS	71.68	0.92124	130.995	7.8048	53.175	7.2933	255.85	16.0193
12905002	LABIDESTHES SICCULUS	0.00	0.00000	.	.	.	.	0.00	0.0000
19000801		921.09	1.30537	.	.	.	.	921.09	1.3054

RESRV=7 YEAR=72

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
10401002	LEPISOSTEUS OSSEUS	.	.	0.198	0.02321	0.198	0.6845	0.40	0.708
10601003	ALOSA CHRYSOCHLORIS	1.05	0.0069	12.304	1.03448	0.397	0.1440	13.75	1.185
10604007	DOROSOMA CEPEDIANUM	0.26	37.3549	.	.	275.805	67.3381	276.06	104.693
10604008	DOROSOMA PETENENSE	1087.88	41.6605	.	.	22.093	0.5924	1109.97	42.253
10604801	MIXED DOROSOMA	0.00	15.6317	.	.	.	.	0.00	15.632
11105012	CYPRINUS CARPIO	.	.	.	.	14.659	31.4700	14.66	31.470
11124061	NOTEMIGONUS CRYSOLEUCAS	6.98	0.1221	.	.	.	.	6.98	0.122
11125073	NOTROPIS ATHERINOIDES	44.28	0.0765	.	.	.	.	44.28	0.076
11129166	PIMEPHALES NOTATUS	906.23	0.9008	.	.	.	.	906.23	0.901
11129169	PIMEPHALES VIGILAX	72.67	0.0302	.	.	.	.	72.67	0.030
11201001	CARPIODES CARPIO	.	.	.	.	0.198	0.2341	0.20	0.234
11206028	HYPENTELIUM NIGRICANS	.	.	0.269	0.02177	0.725	0.2117	0.99	0.233
11207030	ICTIOBUS BUBALUS	8.68	0.6446	2.528	0.97997	26.482	41.4328	37.69	43.057
1120[illegible]034	MINYTREMA MELANOPS	38.06	0.8060	2.002	0.32439	19.790	6.6612	59.85	7.79[illegible]

TABLE 3.5-13
COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

TOTAL NUMBERS AND WEIGHT BY SIZE CLASS — YEARLY AVERAGE

RESRV=7 YEAR=72

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
11210000	MOXOSTOMA SP.	0.269	0.00403	0.269	0.04032	2.151	1.4153	2.69	1.4597
11210039	MOXOSTOMA CARINATUM	.	.	0.198	0.03373	0.538	0.1602	0.74	0.1939
11210044	MOXOSTOMA DUQUESNEI	.	.	.	.	2.551	1.0392	2.55	1.0392
11210045	MOXOSTOMA ERYTHRURUM	0.258	0.00593	.	.	4.937	2.9199	5.19	2.9258
11301002	ICTALURUS FURCATUS	0.258	0.00747	.	.	3.488	2.0971	3.75	2.1046
11301004	ICTALURUS MELAS	.	.	0.581	0.03488	.	.	0.58	0.0349
11301009	ICTALURUS PUNCTATUS	1.051	0.00762	12.315	0.80117	23.201	7.1503	36.57	7.9591
11303032	PYLODICTIS OLIVARIS	0.780	0.00292	1.064	0.07590	1.646	0.9587	3.49	1.0375
11506024	FUNDULUS NOTATUS	32.558	0.00000	.	.	.	.	32.56	0.0000
11602001	GAMBUSIA AFFINIS	1.744	0.00000	.	.	.	.	1.74	0.0000
12201002	MORONE CHRYSOPS	3.301	0.05871	0.269	0.02204	.	.	3.57	0.0807
12201003	MORONE MISSISSIPPIENSIS	26.026	0.21217	0.258	0.01753	0.538	0.0586	26.82	0.2883
12300801	MIXED SUNFISHES	0.000	2.41127	.	.	.	.	0.00	2.4113
12307012	LEPOMIS GULOSUS	35.926	0.12372	14.264	0.35452	1.877	0.1909	52.07	0.6692
12307014	LEPOMIS CYANELLUS	1.421	0.01072	2.200	0.05389	0.773	0.0436	4.39	0.1082
12307016	LEPOMIS HUMILIS	6.620	0.01534	2.709	0.01542	0.839	0.0118	10.17	0.0425
12307017	LEPOMIS MACROCHIRUS	899.328	3.76388	495.253	8.60292	171.224	11.9087	1565.81	24.2755
12307019	LEPOMIS MEGALOTIS	59.421	0.15133	76.934	1.35618	5.842	0.7093	142.20	2.2168
12307020	LEPOMIS MICROLOPHUS	23.565	0.10959	40.654	1.14979	62.423	6.7324	126.64	7.9918
12308026	MICROPTERUS PUNCTULATUS	110.357	0.58993	12.060	0.25937	0.864	0.1617	123.28	1.0110
12308027	MICROPTERUS SALMOIDES	21.164	0.16678	60.900	3.86799	14.617	4.9630	96.68	8.9978
12309029	POMOXIS ANNULARIS	29.799	0.10410	13.330	0.44790	12.554	2.5449	55.68	3.0969
12309030	POMOXIS NIGROMACULATUS	1.786	0.00873	.	.	0.397	0.0968	2.18	0.1056
12400802	UNIDENTIFIED DARTER (NOT STIZOSTEDION)	0.000	0.00000	.	.	.	.	0.00	0.0000
12403075	PERCA FLAVESCENS	32.254	0.53801	.	.	.	.	32.25	0.5380
12404077	PERCINA CAPRODES	27.239	0.33653	.	.	.	.	27.24	0.3365
12405097	STIZOSTEDION CANADENSE	0.538	0.03253	0.806	0.07500	0.269	0.0849	1.61	0.1925
12501001	APLODINOTUS GRUNNIENS	305.069	3.87306	153.908	9.72385	127.070	24.9868	586.05	38.5837
12905002	LABIDESTHES SICCULUS	6.602	0.01059	.	.	.	.	6.60	0.0106
19000801		0.000	1.13357	.	.	.	.	0.00	1.1336

RESRV=7 YEAR=73

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
10401001	LEPISOSTEUS OCULATUS	.	.	0.198	0.0230	.	.	0.20	0.023
10401002	LEPISOSTEUS OSSEUS	.	.	0.198	0.0119	.	.	0.20	0.012
10601003	ALOSA CHRYSOCHLORIS	6.48	0.0666	19.024	1.3435	.	.	25.50	1.410
10604007	DOROSOMA CEPEDIANUM	0.65	0.0116	.	.	1034.97	123.704	1035.63	123.715
10604008	DOROSOMA PETENENSE	6897.23	44.0884	.	.	6.21	0.211	6903.44	44.300
10801002	HIODON TERGISUS	0.58	0.0116	.	.	0.27	0.065	0.85	0.076
11100000	CYPRINIDAE	233.20	0.2711	.	.	.	.	233.20	0.271
11102003	CAMPOSTOMA ANOMALUM	0.46	0.0027	.	.	.	.	0.46	0.003
11105012	CYPRINUS CARPIO	.	.	.	.	21.49	48.339	21.49	48.339
11124061	NOTEMIGONUS CRYSOLEUCAS	13.26	0.6902	.	.	.	.	13.26	0.690
11125000	NOTROPIS SP.	0.77	0.0010	.	.	.	.	0.77	0.001
11125073	NOTROPIS ATHERINOIDES	99.19	0.2425	.	.	.	.	99.19	0.242
11125143	NOTROPIS SPILOPTERUS	5.95	0.0230	.	.	.	.	5.95	0.023
11129000	PIMEPHALES SP.	358.96	0.9767	.	.	.	.	358.96	0.977
11129169	PIMEPHALES VIGILAX	0.00	0.0000	.	.	.	.	0.00	0.000
11201001	CARPIODES CARPIO	.	.	.	.	0.20	0.389	0.20	0.389

TABLE 3.5-14
COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

TOTAL NUMBERS AND WEIGHT BY SIZE CLASS -- YEARLY AVERAGE

RESRV=7 YEAR=73

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
11206028	HYPENTELIUM NIGRICANS	.	.	0.397	0.0647	0.397	0.1542	0.79	0.2188
11207030	ICTIOBUS BUBALUS	1.74	0.15814	1.388	0.4061	21.207	40.7401	24.34	41.3043
11209034	MINYTREMA MELANOPS	162.46	3.27802	7.131	1.0710	17.556	5.8903	187.14	10.2393
11210000	MOXOSTOMA SP.	.	.	1.882	0.2927	0.269	0.1524	2.15	0.4452
11210038	MOXOSTOMA MACROLEPIDOTUM	.	.	0.538	0.0524	.	.	0.54	0.0524
11210045	MOXOSTOMA ERYTHRURUM	0.72	0.03170	.	.	4.784	3.3460	5.30	3.3777
11301002	ICTALURUS FURCATUS	.	.	0.515	0.0464	.	.	0.52	0.0464
11301009	ICTALURUS PUNCTATUS	1.23	0.00833	12.072	0.7240	29.678	9.3957	42.98	10.1281
11303032	PYLODICTIS OLIVARIS	1.03	0.00825	0.773	0.1332	4.104	2.1100	5.91	2.2515
11500000	CYPRINODONTIDAE	154.57	0.20108	.	.	.	.	154.57	0.2011
11506026	FUNDULUS OLIVACEUS	0.20	0.00020	.	.	.	.	0.20	0.0002
11602001	GAMBUSIA AFFINIS	2.33	0.00465	.	.	.	.	2.33	0.0047
12201002	MORONE CHRYSOPS	13.96	0.14743	1.333	0.0665	1.119	0.2403	16.42	0.4543
12201003	MORONE MISSISSIPPIENSIS	16.65	0.19050	4.651	0.2721	.	.	21.30	0.4626
12302003	AMBLOPLITES RUPESTRIS	1.29	0.00490	3.351	0.0214	0.258	0.0080	4.90	0.0343
12307000	LEPOMIS SP.	0.00	0.00000	.	.	.	.	0.00	0.0000
12307012	LEPOMIS GULOSUS	195.94	0.97824	9.398	0.2331	8.172	0.7832	213.51	1.9945
12307014	LEPOMIS CYANELLUS	20.22	0.15254	1.892	0.0452	0.269	0.0183	22.38	0.2160
12307016	LEPOMIS HUMILIS	21.45	0.05833	13.822	0.1182	.	.	35.27	0.1765
12307017	LEPOMIS MACROCHIRUS	2214.82	5.82335	374.952	6.9739	186.171	12.1325	2775.94	24.9297
12307019	LEPOMIS MEGALOTIS	312.39	0.88415	59.204	1.1195	3.295	0.2100	374.89	2.2136
12307020	LEPOMIS MICROLOPHUS	614.75	4.17152	36.641	0.9053	43.595	5.1702	694.98	10.2470
12308026	MICROPTERUS PUNCTULATUS	49.31	0.27022	5.749	0.2253	0.806	0.1220	55.87	0.6175
12308027	MICROPTERUS SALMOIDES	66.45	0.46356	69.086	4.5632	26.925	6.5372	162.46	11.5639
12309029	POMOXIS ANNULARIS	24.31	0.07568	15.290	0.6483	16.301	2.8708	55.90	3.5948
12403075	PERCA FLAVESCENS	23.41	0.82621	.	.	.	.	23.41	0.8262
12404077	PERCINA CAPRODES	67.31	0.84742	.	.	.	.	67.31	0.8474
12405097	STIZOSTEDION CANADENSE	2.23	0.14021	0.581	0.0866	2.594	0.5862	5.40	0.8130
12501001	APLODINOTUS GRUNNIENS	228.57	1.96002	307.132	15.6923	125.745	21.2718	661.45	38.9242
12905002	LABIDESTHES SICCULUS	184.75	0.24037	.	.	.	.	184.75	0.2404
19000801		11.08	0.01392	.	.	.	.	11.08	0.0139

RESRV=7 YEAR=74

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
10401001	LEPISOSTEUS OCULATUS	0.46	0.1481	.	.	.	.	0.46	0.148
10401002	LEPISOSTEUS OSSEUS	.	.	0.397	0.04921	.	.	0.40	0.049
10601003	ALOSA CHRYSOCHLORIS	0.47	0.0037	2.348	0.29912	4.166	1.027	6.98	1.330
10604007	DOROSOMA CEPEDIANUM	5.23	0.0715	.	.	736.932	105.825	742.16	105.897
10604008	DOROSOMA PETENENSE	1989.11	27.6819	.	.	3.102	0.137	1992.22	27.819
10801002	HIODON TERGISUS	.	.	0.269	0.05645	.	.	0.27	0.056
11102003	CAMPOSTOMA ANOMALUM	0.27	0.0013	.	.	.	.	0.27	0.001
11105012	CYPRINUS CARPIO	.	.	0.515	0.09536	8.277	20.152	8.79	20.248
11114052	HYBOPSIS STORERIANA	2.86	0.0143	.	.	.	.	2.86	0.014
11124061	NOTEMIGONUS CRYSOLEUCAS	5.81	0.2721	.	.	.	.	5.81	0.272
11125073	NOTROPIS ATHERINOIDES	4.33	0.0085	.	.	.	.	4.33	0.008
11125084	NOTROPIS BUCHANANI	2.42	0.0022	.	.	.	.	2.42	0.002
11125143	NOTROPIS SPILOPTERUS	3.63	0.0081	.	.	.	.	3.63	0.008
11125160	NOTROPIS CHRYSOCEPHALUS	5.91	0.0156	.	.	.	.	5.91	0.016
[illegible]	[illegible]	[illegible]76	0.76[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	73[illegible]	[illegible]768

TABLE 3.5-15 COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

TOTAL NUMBERS AND WEIGHT BY SIZE CLASS -- YEARLY AVERAGE

RESRV=7 YEAR=74

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
11207030	ICTIOBUS BUBALUS	.	.	.	.	6.398	12.3070	6.40	12.3070
11209034	MINYTREMA MELANOPS	23.706	0.35461	26.160	3.52120	39.104	13.0238	88.97	16.8996
11210039	MOXOSTOMA CARINATUM	0.258	0.01186	.	.	.	.	0.26	0.0119
11210045	MOXOSTOMA ERYTHRURUM	7.460	0.11353	0.538	0.05860	5.729	4.6027	13.73	4.7748
11301009	ICTALURUS PUNCTATUS	0.515	0.00593	3.210	0.19554	8.411	3.8707	12.14	4.0722
11303032	PYLODICTIS OLIVARIS	.	.	0.736	0.08160	2.403	1.2323	3.14	1.3139
11506026	FUNDULUS OLIVACEUS	4.205	0.00633	.	.	.	.	4.21	0.0063
12201002	MORONE CHRYSOPS	2.611	0.03706	.	.	0.850	0.1628	3.46	0.1998
12201003	MORONE MISSISSIPPIENSIS	6.630	0.11248	1.917	0.13787	.	.	8.55	0.2504
12307000	LEPOMIS SP.	0.000	1.12887	.	.	.	.	0.00	1.1289
12307012	LEPOMIS GULOSUS	4.023	0.01204	3.587	0.06572	0.978	0.0734	8.59	0.1511
12307014	LEPOMIS CYANELLUS	0.853	0.00466	1.647	0.02563	.	.	2.50	0.0303
12307016	LEPOMIS HUMILIS	0.581	0.00116	.	.	.	.	0.58	0.0012
12307017	LEPOMIS MACROCHIRUS	633.678	1.04119	296.850	4.52192	105.549	5.5246	1036.08	11.0877
12307019	LEPOMIS MEGALOTIS	123.020	0.29732	73.492	1.07917	3.701	0.1698	200.21	1.5463
12307020	LEPOMIS MICROLOPHUS	42.925	0.15168	62.884	1.40557	61.856	6.6856	167.67	8.2429
12308026	MICROPTERUS PUNCTULATUS	69.780	0.29878	7.849	0.31774	4.709	0.7684	82.34	1.3849
12308027	MICROPTERUS SALMOIDES	27.572	0.12698	20.435	1.72374	19.070	4.9037	67.08	6.7544
12309029	POMOXIS ANNULARIS	0.595	0.00179	2.141	0.06711	7.148	1.1300	9.88	1.1989
12402012	ETHEOSTOMA CAERULEUM	0.773	0.00077	.	.	.	.	0.77	0.0008
12403075	PERCA FLAVESCENS	8.305	0.43428	.	.	.	.	8.30	0.4343
12404077	PERCINA CAPRODES	23.129	0.30299	.	.	.	.	23.13	0.3030
12405097	STIZOSTEDION CANADENSE	1.388	0.07047	0.258	0.01985	0.850	0.1920	2.50	0.2823
12501001	APLODINOTUS GRUNNIENS	27.104	0.22472	165.604	7.71236	62.017	10.2732	254.72	18.2103
12905002	LABIDESTHES SICCULUS	12.570	0.01939	.	.	.	.	12.57	0.0194
19000801		0.000	0.76160	.	.	.	.	0.00	0.7616

RESRV=7 YEAR=75

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
10401001	LEPISOSTEUS OCULATUS	0.60	0.0405	0.595	0.05833	.	.	1.19	0.0988
10401002	LEPISOSTEUS OSSEUS	.	.	0.258	0.03814	.	.	0.26	0.0381
10601003	ALOSA CHRYSOCHLORIS	.	.	0.715	0.06196	1.675	0.3908	2.39	0.4528
10604007	DOROSOMA CEPEDIANUM	109.44	1.4094	.	.	946.200	89.0993	1055.64	90.5087
10604008	DOROSOMA PETENENSE	2068.04	22.5759	.	.	122.961	4.0684	2191.00	26.6443
11100000	CYPRINIDAE	20.43	0.0204	.	.	.	.	20.43	0.0204
11105012	CYPRINUS CARPIO	.	.	.	.	12.648	28.9335	12.65	28.9335
11114052	HYBOPSIS STORERIANA	3.79	0.0201	.	.	.	.	3.79	0.0201
11124061	NOTEMIGONUS CRYSOLEUCAS	12.25	0.1522	.	.	.	.	12.25	0.1522
11125000	NOTROPIS SP.	48.06	0.0601	.	.	.	.	48.06	0.0601
11125073	NOTROPIS ATHERINOIDES	54.04	0.1281	.	.	.	.	54.04	0.1281
11125143	NOTROPIS SPILOPTERUS	11.84	0.0190	.	.	.	.	11.84	0.0190
11125159	NOTROPIS EMILIAE	0.91	0.0009	.	.	.	.	0.91	0.0009
11125160	NOTROPIS CHRYSOCEPHALUS	1.61	0.0030	.	.	.	.	1.61	0.0030
11129169	PIMEPHALES VIGILAX	3397.45	3.5568	.	.	.	.	3397.45	3.5568
11206028	HYPENTELIUM NIGRICANS	.	.	0.258	0.02448	.	.	0.26	0.0245
11207030	ICTIOBUS BUBALUS	1.79	0.1548	0.783	0.16159	6.386	18.7095	8.96	19.0259
11207031	ICTIOBUS CYPRINELLUS	.	.	.	.	0.188	1.1203	0.19	1.1203
11209034	MINYTREMA MELANOPS	10.71	0.1667	10.983	1.40267	19.720	8.7838	41.42	10.3531
11210000	MOXOSTOMA SP.	42.90	0.7754	.	.	.	.	42.90	0.7754

TABLE 3.5-16
COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

TOTAL NUMBERS AND WEIGHT BY SIZE CLASS -- YEARLY AVERAGE

RESRV=7 YEAR=75

SPECIES	SCNAME	YNGNUM	YNGWT	INTNUM	INTWT	ADTNUM	ADTWT	TOTNUM	TOTWT
11210045	MOXOSTOMA ERYTHRURUM	.	.	1.053	0.12253	0.457	0.17041	1.51	0.2929
11301002	ICTALURUS FURCATUS	0.26	0.00129	.	.	.	.	0.26	0.0013
11301005	ICTALURUS NATALIS	.	.	.	.	0.258	0.10284	0.26	0.1028
11301009	ICTALURUS PUNCTATUS	1.03	0.00593	2.390	0.11345	10.266	4.13267	13.69	4.2521
11303032	PYLODICTIS OLIVARIS	0.77	0.00309	1.567	0.24101	0.864	0.35741	3.20	0.6015
11506026	FUNDULUS OLIVACEUS	1.08	0.00108	.	.	.	.	1.08	0.0011
12201002	MORONE CHRYSOPS	.	.	.	.	0.269	0.06022	0.27	0.0602
12201003	MORONE MISSISSIPPIENSIS	19.37	0.33274	12.011	0.93732	2.014	0.26403	33.39	1.5341
12307000	LEPOMIS SP.	6.73	0.00778	.	.	.	.	6.73	0.0078
12307012	LEPOMIS GULOSUS	38.28	0.06906	4.671	0.07518	2.824	0.28072	45.77	0.4250
12307014	LEPOMIS CYANELLUS	0.60	0.00179	.	.	.	.	0.60	0.0018
12307016	LEPOMIS HUMILIS	.	.	0.258	0.00129	.	.	0.26	0.0013
12307017	LEPOMIS MACROCHIRUS	4073.41	5.43524	237.889	3.92611	108.316	5.80495	4419.62	15.1663
12307019	LEPOMIS MEGALOTIS	488.19	0.93568	48.231	0.80394	0.645	0.03818	537.07	1.7778
12307020	LEPOMIS MICROLOPHUS	160.80	0.54351	17.086	0.40452	62.773	6.80495	240.66	7.7530
12307801	HYBRID LEPOMIS SPP.	0.38	0.00226	0.752	0.01071	.	.	1.13	0.0130
12308026	MICROPTERUS PUNCTULATUS	73.26	0.22877	2.309	0.06657	1.337	0.27835	76.91	0.5737
12308027	MICROPTERUS SALMOIDES	65.56	0.26275	23.820	1.65685	17.354	6.29605	106.74	8.2157
12309029	POMOXIS ANNULARIS	1.13	0.00399	4.309	0.27160	7.803	1.05249	13.25	1.3281
12309030	POMOXIS NIGROMACULATUS	.	.	.	.	0.752	0.12632	0.75	0.1263
12402000	ETHEOSTOMA SP.	0.80	0.00080	.	.	.	.	0.80	0.0008
12402060	ETHEOSTOMA SPECTABILE	0.75	0.00075	.	.	.	.	0.75	0.0008
12403075	PERCA FLAVESCENS	4.36	0.08787	.	.	.	.	4.36	0.0879
12404077	PERCINA CAPRODES	19.70	0.17169	.	.	.	.	19.70	0.1717
12405097	STIZOSTEDION CANADENSE	0.27	0.01505	1.459	0.20889	0.188	0.03346	1.92	0.2574
12501001	APLODINOTUS GRUNNIENS	33.86	0.29906	68.257	3.97296	37.145	8.04076	139.26	12.3128
12905002	LABIDESTHES SICCULUS	73.02	0.10522	.	.	.	.	73.02	0.1052

TABLE 3.5-17
COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

SIZE DISTRIBUTION PER HECTARE For Chickamauga Reservoir, 1976

SPECIES	COMMON NAME	NUMBER YOUNG-OF-YEAR	WEIGHT YOUNG-OF-YEAR	NUMBER INTER-MEDIATE	INTER-MEDIATE WEIGHT	ADULT NUMBER	ADULT WEIGHT	TOTAL NUMBERS	TOTAL WEIGHT
12307017	BLUEGILL	5,812.9	7.74	674.5	9.07	186.8	11.16	6,674.2	27.97
10604008	THREADFIN SHAD	3,401.9	10.91	.0	.00	.0	.00	3,401.9	10.91
10604007	GIZZARD SHAD	1,140.3	9.78	.0	.00	844.9	103.45	1,985.2	113.23
11129169	BULLHEAD MINNOW	1,974.2	1.72	.0	.00	.0	.00	1,974.2	1.72
12307019	LONGEAR SUNFISH	867.5	1.85	188.9	2.61	4.7	.22	1,061.2	4.68
12307020	REDEAR SUNFISH	187.5	.60	62.8	1.50	93.8	9.15	344.1	11.25
12501001	FRESHWATER DRUM	77.8	.55	125.6	7.13	119.9	18.85	323.3	26.53
12905002	BROOK SILVERSIDE	216.6	.23	.0	.00	.0	.00	216.6	.23
11125143	SPOTFIN SHINER	212.0	.22	.0	.00	.0	.00	212.0	.22
12308026	SPOTTED BASS	124.5	.55	9.4	.28	1.3	.21	135.2	1.04
11124061	GOLDEN SHINER	87.3	1.45	.0	.00	.0	.00	87.3	1.45
12308027	LARGEMOUTH BASS	38.8	.21	34.6	1.30	13.5	5.87	86.9	7.38
11125073	EMERALD SHINER	80.8	.19	.0	.00	.0	.00	80.8	.19
12307000		77.6	.09	.0	.00	.0	.00	77.6	.09
12307012	WARMOUTH	54.6	.08	12.3	.23	5.7	.44	72.6	.75
12201003	YELLOW BASS	48.1	.19	8.8	.59	3.8	.45	60.7	1.24
11209034	SPOTTED SUCKER	15.3	.28	3.1	.51	35.1	17.41	53.6	18.20
12309029	WHITE CRAPPIE	26.5	.08	14.7	.23	7.6	1.21	48.9	1.51
10604000		48.5	.01	.0	.00	.0	.00	48.5	.01
12404077	LOGPERCH	47.8	.36	.0	.00	.0	.00	47.8	.36
12403075	YELLOW PERCH	32.2	.47	.0	.00	.0	.00	32.2	.47
11301009	CHANNEL CATFISH	1.6	.00	6.3	.32	17.7	11.98	25.6	12.30
11105012	CARP	.0	.00	.2	.05	22.2	46.31	22.4	46.36
11506024	BLACKSTRIPE TOPMINNO	20.4	.02	.0	.00	.0	.00	20.4	.02
12307013	REDBREAST SUNFISH	15.6	.03	2.3	.03	.0	.00	17.9	.06
11602001	MOSQUITOFISH	16.8	.02	.0	.00	.0	.00	16.8	.02
11125152	MIMIC SHINER	14.7	.01	.0	.00	.0	.00	14.7	.01
11114052	SILVER CHUB	14.7	.30	.0	.00	.0	.00	14.7	.30
11207030	SMALLMOUTH BUFFALO	.6	.01	.0	.00	12.4	28.93	13.0	28.94
10401001	SPOTTED GAR	.0	.00	2.4	.68	9.7	6.87	12.1	7.55
11125154	STEELCOLOR	9.2	.02	.0	.00	.0	.00	9.2	.02
12402012	RAINBOW DARTER	7.0	.01	.0	.00	.0	.00	7.0	.01
11210044	BLACK REDHORSE	.4	.00	1.3	.17	4.8	2.33	6.5	2.50
12201002	WHITE BASS	3.9	.08	1.4	.09	.5	.06	5.7	.23
11210045	GOLDEN REDHORSE	.0	.00	.0	.00	3.5	2.16	3.5	2.16
10601003	SKIPJACK HERRING	1.2	.01	.0	.00	2.3	.58	3.5	.60
12405097	SAUGER	.0	.00	.0	.00	3.4	.75	3.4	.75
11301002	BLUE CATFISH	3.0	.02	.0	.00	.0	.00	3.0	.02
11201001	RIVER CARPSUCKER	2.8	.18	.0	.00	.0	.00	2.8	.18
11303032	FLATHEAD CATFISH	1.2	.00	.0	.00	1.5	.81	2.7	.81
12307014	GREEN SUNFISH	1.8	.00	.8	.01	.0	.00	2.6	.01
11206028	NORTHERN HOG SUCKER	.4	.00	.4	.02	1.3	.50	2.1	.52
11102003	STONEROLLER	1.5	.02	.0	.00	.0	.00	1.5	.02
11125000		1.2	.00	.0	.00	.0	.00	1.2	.00
12307016	ORANGESPOTTED SUNFIS	.7	.00	.0	.00	.2	.01	.9	.01
11506026	BLACKSPOTTED TOPMINN	.9	.00	.0	.00	.0	.00	.9	.00
11129166	BLUNTNOSE MINNOW	.6	.00	.0	.00	.0	.00	.6	.00
10801002	MOONEYE	.0	.00	.4	.08	.0	.00	.4	.08
10401002	LONGNOSE GAR	.4	.02	.0	.00	.0	.00	.4	.02
12308024	SMALLMOUTH BASS	.0	.00	.4	.01	.0	.00	.4	.01
11123035	RIVER CHUB	.2	.01	.0	.00	.0	.00	.2	.01

TABLE 3.5-18
COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

COMMON AND SCIENTIFIC NAMES OF FISHES IN ROTENONE SAMPLES

FGROUP	SPECIES	FISH GROUP	COMMON NAME	SCIENTIFIC NAME
1	12201002	GAME	WHITE BASS	MORONE CHRYSOPS
1	12201003	GAME	YELLOW BASS	MORONE MISSISSIPPIENSIS
1	12307000	GAME		LEPOMIS SP.
1	12307012	GAME	WARMOUTH	LEPOMIS GULOSUS
1	12307013	GAME	REDBREAST SUNFISH	LEPOMIS AURITUS
1	12307014	GAME	GREEN SUNFISH	LEPOMIS CYANELLUS
1	12307017	GAME	BLUEGILL	LEPOMIS MACROCHIRUS
1	12307019	GAME	LONGEAR SUNFISH	LEPOMIS MEGALOTIS
1	12307020	GAME	REDEAR SUNFISH	LEPOMIS MICROLOPHUS
1	12308024	GAME	SMALLMOUTH BASS	MICROPTERUS DOLOMIEUI
1	12308026	GAME	SPOTTED BASS	MICROPTERUS PUNCTULATUS
1	12308027	GAME	LARGEMOUTH BASS	MICROPTERUS SALMOIDES
1	12309029	GAME	WHITE CRAPPIE	POMOXIS ANNULARIS
1	12403075	GAME	YELLOW PERCH	PERCA FLAVESCENS
1	12405097	GAME	SAUGER	STIZOSTEDION CANADENSE
2	10401001	ROUGH	SPOTTED GAR	LEPISOSTEUS OCULATUS
2	10401002	ROUGH	LONGNOSE GAR	LEPISOSTEUS OSSEUS
2	10601003	ROUGH	SKIPJACK HERRING	ALOSA CHRYSOCHLORIS
2	10601002	ROUGH	MOONEYE	HIODON TERGISUS
2	11105012	ROUGH	CARP	CYPRINUS CARPIO
2	11201001	ROUGH	RIVER CARPSUCKER	CARPIODES CARPIO
2	11206028	ROUGH	NORTHERN HOG SUCKER	HYPENTELIUM NIGRICANS
2	11207030	ROUGH	SMALLMOUTH BUFFALO	ICTIOBUS BUBALUS
2	11209034	ROUGH	SPOTTED SUCKER	MINYTREMA MELANOPS
2	11210044	ROUGH	BLACK REDHORSE	MOXOSTOMA DUQUESNEI
2	11210045	ROUGH	GOLDEN REDHORSE	MOXOSTOMA ERYTHRURUM
2	11301002	ROUGH	BLUE CATFISH	ICTALURUS FURCATUS
2	11301009	ROUGH	CHANNEL CATFISH	ICTALURUS PUNCTATUS
2	11303032	ROUGH	FLATHEAD CATFISH	PYLODICTIS OLIVARIS
2	12501001	ROUGH	FRESHWATER DRUM	APLODINOTUS GRUNNIENS
3	10604000	FORAGE		DOROSOMA SP.
3	10604007	FORAGE	GIZZARD SHAD	DOROSOMA CEPEDIANUM
3	10604008	FORAGE	THREADFIN SHAD	DOROSOMA PETENENSE
3	11102003	FORAGE	STONEROLLER	CAMPOSTOMA ANOMALUM
3	11114052	FORAGE	SILVER CHUB	HYBOPSIS STORERIANA
3	11123035	FORAGE	RIVER CHUB	NOCOMIS MICROPOGON
3	11124061	FORAGE	GOLDEN SHINER	NOTEMIGONUS CRYSOLEUCAS
3	11125000	FORAGE		NOTROPIS SP.
3	11125073	FORAGE	EMERALD SHINER	NOTROPIS ATHERINOIDES
3	11125143	FORAGE	SPOTFIN SHINER	NOTROPIS SPILOPTERUS
3	11125152	FORAGE	MIMIC SHINER	NOTROPIS VOLUCELLUS
3	11125154	FORAGE	STEELCOLOR	NOTROPIS WHIPPLEI
3	11129166	FORAGE	BLUNTNOSE MINNOW	PIMEPHALES NOTATUS
3	11129169	FORAGE	BULLHEAD MINNOW	PIMEPHALES VIGILAX
3	11506024	FORAGE	BLACKSTRIPE TOPMINNOW	FUNDULUS NOTATUS
3	11506026	FORAGE	BLACKSPOTTED TOPMINNOW	FUNDULUS OLIVACEUS
3	11602001	FORAGE	MOSQUITOFISH	GAMBUSIA AFFINIS
3	12307016	FORAGE	ORANGESPOTTED SUNFISH	LEPOMIS HUMILIS
3	12402012	FORAGE	RAINBOW DARTER	ETHEOSTOMA CAERULEUM
3	12402036	FORAGE	STRIPETAIL DARTER	ETHEOSTOMA KENNICOTTI
3	12404077	FORAGE	LOGPERCH	PERCINA CAPRODES
3	12905002	FORAGE	BROOK SILVERSIDE	LABIDESTHES SICCULUS

TABLE 3.5-19
COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

SAMPLE SITE DESCRIPTIONS

SECTION=AREA 1

COVE	RMILE	GRID	MONTH	DAY	YEAR
1	475.7	358522099075	9	14	76
2	478.0	358522090115	9	16	76

SECTION=AREA 2

COVE	RMILE	GRID	MONTH	DAY	YEAR
1	495.0	358531017066	9	21	76
2	508.0	358448057072	9	23	76

SECTION=AREA 3

COVE	RMILE	GRID	MONTH	DAY	YEAR
1	524.6	358457053076	9	8	76

TABLE 3.5-20

COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

FISH POPULATION BY COVE

SECTION=AREA 1

Sample	COVE	HECTAR	ACRES	METER	FEET	FISH_HA	FISH_AC	KG_HA	LB_AC
734	1	0.9	0.4	1.9	6.2	18333.3	7419.3	209.7	187.1
735	2	0.6	0.2	1.2	3.9	23060.7	9332.4	192.9	172.1

SECTION=AREA 2

	COVE	HECTAR	ACRES	METER	FEET	FISH_HA	FISH_AC	KG_HA	LB_AC
736	1	0.5	0.2	1.2	3.9	15300.0	6191.8	237.1	211.5
737	2	0.4	0.2	0.9	3.0	19795.3	8011.0	502.4	448.2

SECTION=AREA 3

	COVE	HECTAR	ACRES	METER	FEET	FISH_HA	FISH_AC	KG_HA	LB_AC
738	1	0.3	0.1	0.3	1.0	9715.2	3931.6	522.7	466.3

SECTION=ALL AREA

COVE	HECTAR	ACRES	METER	FEET	FISH_HA	FISH_AC	KG_HA	LB_AC
.	2.7	1.1	1.1	3.6	17240.9	6977.2	332.9	297.0

SIZE DISTRIBUTION PER HECTARE BY SAMPLE

SAMPLE	SPECIES	COMMON NAME	NUMBER YOUNG-OF-YEAR	WEIGHT YOUNG-OF-YEAR	NUMBER INTER	WEIGHT INTER	NUMBER HARVEST	WEIGHT HARVEST	NUMBER TOTAL	WEIGHT TOTAL
734	10401002	LONGNOSE GAR	2.2	.12	.0	.00	.0	.00	2.2	.12
734	10604007	GIZZARD SHAD	4.3	.03	.0	.00	552.7	82.70	557.0	82.73
734	10604008	THREADFIN SHAD	1,060.2	2.88	.0	.00	.0	.00	1,060.2	2.88
734	11102003	STONEROLLER	1.1	.01	.0	.00	.0	.00	1.1	.01
734	11105012	CARP	.0	.00	1.1	.26	4.3	4.87	5.4	5.14
734	11123035	RIVER CHUB	1.1	.03	.0	.00	.0	.00	1.1	.03
734	11124061	GOLDEN SHINER	119.4	.75	.0	.00	.0	.00	119.4	.75
734	11125073	EMERALD SHINER	49.5	.11	.0	.00	.0	.00	49.5	.11
734	11125143	SPOTFIN SHINER	11.8	.01	.0	.00	.0	.00	11.8	.01
734	11125152	MIMIC SHINER	54.8	.03	.0	.00	.0	.00	54.8	.03
734	11129166	BLUNTNOSE MINNO	3.2	.00	.0	.00	.0	.00	3.2	.00
734	11129169	BULLHEAD MINNOW	205.4	.19	.0	.00	.0	.00	205.4	.19
734	11206028	NORTHERN HOG SU	.0	.00	.0	.00	4.3	2.09	4.3	2.09
734	11207030	SMALLMOUTH BUFF	.0	.00	.0	.00	1.1	.49	1.1	.49
734	11209034	SPOTTED SUCKER	1.1	.03	.0	.00	23.7	17.29	24.7	17.32
734	11210044	BLACK REDHORSE	.0	.00	.0	.00	2.2	.91	2.2	.91
734	11301009	CHANNEL CATFISH	.0	.00	19.4	1.05	17.2	7.00	36.6	8.05
734	11602001	MOSQUITOFISH	1.1	.00	.0	.00	.0	.00	1.1	.00
734	12201003	YELLOW BASS	226.9	.73	9.7	.49	4.3	.43	240.9	1.65
734	12307000		319.4	.46	.0	.00	.0	.00	319.4	.46
734	12307012	WARMOUTH	1.1	.00	3.2	.07	9.7	.82	14.0	.89
734	12307013	REDBREAST SUNFI	53.8	.09	2.2	.04	.0	.00	55.9	.13
734	12307016	ORANGESPOTTED S	.0	.00	.0	.00	1.1	.03	1.1	.03
734	12307017	BLUEGILL	11,314.0	14.93	1,163.4	14.01	273.1	14.91	12,750.5	43.85
734	12307019	LONGEAR SUNFISH	1,264.5	2.33	311.8	4.79	18.3	.87	1,594.6	7.99
734	12307020	REDEAR SUNFISH	91.4	.29	8.6	.18	68.8	7.49	168.8	7.96
734	12308026	SPOTTED BASS	311.8	1.27	14.0	.52	4.3	.82	330.1	2.61
734	12308027	LARGEMOUTH BASS	122.6	.59	48.4	1.56	10.8	3.71	181.7	5.86
734	12309029	WHITE CRAPPIE	5.4	.02	6.5	.05	2.2	.39	14.0	.45
734	12402012	RAINBOW DARTER	33.3	.04	.0	.00	.0	.00	33.3	.04
734	12402036	STRIPETAIL DART	1.1	.00	.0	.00	.0	.00	1.1	.00
734	12403075	YELLOW PERCH	15.1	.24	.0	.00	.0	.00	15.1	.24
734	12404077	LOGPERCH	74.2	.53	.0	.00	.0	.00	74.2	.53
734	12405097	SAUGER	.0	.00	.0	.00	1.1	.30	1.1	.30
734	12501001	FRESHWATER DRUM	132.3	.95	154.8	8.55	44.1	6.24	331.2	15.73
734	12905002	BROOK SILVERSID	65.6	.09	.0	.00	.0	.00	65.6	.09
SAMPLE TOTAL			15,547.7	26.75	1,743.1	31.57	1,043.3	151.36	18,333.7	209.67

TABLE 3.5-21 COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

TABLE 3.5-22 COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

SIZE DISTRIBUTION PER HECTARE BY SAMPLE

SAMPLE	SPECIES	COMMON NAME	NUMBER YOUNG-OF-YEAR	WEIGHT YOUNG-OF-YEAR	NUMBER INTER	WEIGHT INTER	NUMBER HARVEST	WEIGHT HARVEST	NUMBER TOTAL	WEIGHT TOTAL
735	10604007	GIZZARD SHAD	.0	.00	.0	.00	519.6	79.81	519.6	79.81
735	10604008	THREADFIN SHAD	162.5	.28	.0	.00	.0	.00	162.5	.28
735	10801002	MOONEYE	.0	.00	1.8	.38	.0	.00	1.8	.38
735	11124061	GOLDEN SHINER	76.8	.33	.0	.00	.0	.00	76.8	.33
735	11125073	EMERALD SHINER	305.4	.72	.0	.00	.0	.00	305.4	.72
735	11125143	SPOTFIN SHINER	669.6	.66	.0	.00	.0	.00	669.6	.66
735	11125152	MIMIC SHINER	3.6	.00	.0	.00	.0	.00	3.6	.00
735	11125154	STEELCOLOR	37.5	.06	.0	.00	.0	.00	37.5	.06
735	11129169	BULLHEAD MINNOW	6,455.4	5.30	.0	.00	.0	.00	6,455.4	5.30
735	11206028	NORTHERN HOG SU	.0	.00	1.8	.12	.0	.00	1.8	.12
735	11207030	SMALLMOUTH BUFF	.0	.00	.0	.00	7.1	10.20	7.1	10.20
735	11209034	SPOTTED SUCKER	.0	.00	1.8	.22	14.3	4.97	16.1	5.19
735	11301009	CHANNEL CATFISH	1.8	.01	8.9	.47	7.1	3.42	17.9	3.90
735	11303032	FLATHEAD CATFIS	1.8	.00	.0	.00	.0	.00	1.8	.00
735	12201003	YELLOW BASS	.0	.00	1.8	.17	1.8	.20	3.6	.37
735	12307000		62.5	.01	.0	.00	.0	.00	62.5	.01
735	12307012	WARMOUTH	110.7	.16	10.7	.18	5.4	.35	126.8	.69
735	12307013	REDBREAST SUNFI	3.6	.00	.0	.00	.0	.00	3.6	.00
735	12307014	GREEN SUNFISH	8.9	.02	1.8	.02	.0	.00	10.7	.03
735	12307016	ORANGESPOTTED S	3.6	.01	.0	.00	.0	.00	3.6	.01
735	12307017	BLUEGILL	9,732.1	10.43	594.6	8.86	221.4	12.51	10,548.2	31.80
735	12307019	LONGEAR SUNFISH	2,351.8	4.75	217.9	3.11	5.4	.25	2,575.0	8.10
735	12307020	REDEAR SUNFISH	335.7	.74	10.7	.32	178.6	17.38	525.0	18.44
735	12308024	SMALLMOUTH BASS	.0	.00	1.8	.03	.0	.00	1.8	.03
735	12308026	SPOTTED BASS	80.4	.35	8.9	.37	.0	.00	89.3	.72
735	12308027	LARGEMOUTH BASS	55.4	.34	60.7	1.79	17.9	6.90	133.9	9.04
735	12309029	WHITE CRAPPIE	.0	.00	1.8	.01	.0	.00	1.8	.01
735	12402012	RAINBOW DARTER	1.8	.00	.0	.00	.0	.00	1.8	.00
735	12403075	YELLOW PERCH	32.1	.72	.0	.00	.0	.00	32.1	.72
735	12404077	LOGPERCH	35.7	.29	.0	.00	.0	.00	35.7	.29
735	12501001	FRESHWATER DRUM	.0	.00	62.5	3.78	48.2	11.37	110.7	15.15
735	12905002	BROOK SILVERSID	517.9	.56	.0	.00	.0	.00	517.9	.56
SAMPLE TOTAL			21,046.6	25.74	987.5	19.83	1,026.8	147.36	23,060.9	192.92

TABLE 3.5-23 COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

SIZE DISTRIBUTION PER HECTARE BY SAMPLE

SAMPLE	SPECIES	COMMON NAME	NUMBER YOUNG-OF-YEAR	WEIGHT YOUNG-OF-YEAR	NUMBER INTER	WEIGHT INTER	NUMBER HARVEST	WEIGHT HARVEST	NUMBER TOTAL	WEIGHT TOTAL
736	10601003	SKIPJACK HERRIN	.0	.00	.0	.00	2.1	.53	2.1	.53
736	10604007	GIZZARD SHAD	.0	.00	.0	.00	904.3	128.99	904.3	128.99
736	10604008	THREADFIN SHAD	7,053.2	27.60	.0	.00	.0	.00	7,053.2	27.60
736	11102003	STONEROLLER	6.4	.07	.0	.00	.0	.00	6.4	.07
736	11114052	SILVER CHUB	10.6	.31	.0	.00	.0	.00	10.6	.31
736	11124061	GOLDEN SHINER	2.1	.00	.0	.00	.0	.00	2.1	.00
736	11125073	EMERALD SHINER	48.9	.13	.0	.00	.0	.00	48.9	.13
736	11125143	SPOTFIN SHINER	378.7	.41	.0	.00	.0	.00	378.7	.41
736	11125152	MIMIC SHINER	14.9	.02	.0	.00	.0	.00	14.9	.02
736	11125154	STEELCOLOR	8.5	.02	.0	.00	.0	.00	8.5	.02
736	11129169	BULLHEAD MINNOW	1,214.9	.94	.0	.00	.0	.00	1,214.9	.94
736	11206028	NORTHERN HOG SU	2.1	.01	.0	.00	2.1	.39	4.3	.40
736	11209034	SPOTTED SUCKER	14.9	.29	.0	.00	4.3	1.85	19.1	2.14
736	11210044	BLACK REDHORSE	2.1	.02	6.4	.83	17.0	7.45	25.5	8.30
736	11301009	CHANNEL CATFISH	6.4	.02	.0	.00	.0	.00	6.4	.02
736	11303032	FLATHEAD CATFIS	4.3	.01	.0	.00	2.1	1.31	6.4	1.32
736	11506024	BLACKSTRIPE TOP	102.1	.12	.0	.00	.0	.00	102.1	.12
736	11506026	BLACKSPOTTED TO	4.3	.01	.0	.00	.0	.00	4.3	.01
736	12201003	YELLOW BASS	2.1	.01	2.1	.18	.0	.00	4.3	.19
736	12307000		6.4	.00	.0	.00	.0	.00	6.4	.00
736	12307012	WARMOUTH	12.8	.01	19.1	.34	6.4	.40	38.3	.75
736	12307013	REDBREAST SUNFI	2.1	.00	.0	.00	.0	.00	2.1	.00
736	12307017	BLUEGILL	2,487.2	4.49	446.8	6.27	142.6	9.31	3,076.6	20.07
736	12307019	LONGEAR SUNFISH	721.3	2.17	414.9	5.13	.0	.00	1,136.2	7.30
736	12307020	REDEAR SUNFISH	157.4	.41	57.4	1.27	117.0	13.76	331.9	15.44
736	12308026	SPOTTED BASS	72.3	.38	17.0	.41	2.1	.23	91.5	1.03
736	12308027	LARGEMOUTH BASS	2.1	.02	21.3	1.11	12.8	3.89	36.2	5.01
736	12309029	WHITE CRAPPIE	.0	.00	2.1	.09	.0	.00	2.1	.09
736	12403075	YELLOW PERCH	102.1	1.23	.0	.00	.0	.00	102.1	1.23
736	12404077	LOGPERCH	112.8	.87	.0	.00	.0	.00	112.8	.87
736	12405097	SAUGER	.0	.00	.0	.00	4.3	.85	4.3	.85
736	12501001	FRESHWATER DRUM	.0	.00	17.0	1.08	55.3	11.32	72.3	12.40
736	12905002	BROOK SILVERSID	470.2	.50	.0	.00	.0	.00	470.2	.50
SAMPLE TOTAL			13,023.2	40.07	1,004.1	16.71	1,272.4	180.28	15,300.0	237.06

SIZE DISTRIBUTION PER HECTARE BY SAMPLE

SAMPLE	SPECIES	COMMON NAME	NUMBER YOUNG-OF-YEAR	WEIGHT YOUNG-OF-YEAR	NUMBER INTER	WEIGHT INTER	NUMBER HARVEST	WEIGHT HARVEST	NUMBER TOTAL	WEIGHT TOTAL
737	10601003	SKIPJACK HERRIN	.0	.00	.0	.00	9.3	2.39	9.3	2.39
737	10604007	GIZZARD SHAD	39.5	.51	.0	.00	1,981.4	199.29	2,020.9	199.80
737	10604008	THREADFIN SHAD	7,188.4	22.20	.0	.00	.0	.00	7,188.4	22.20
737	11105012	CARP	.0	.00	.0	.00	18.6	63.74	18.6	63.74
737	11114052	SILVER CHUB	62.8	1.18	.0	.00	.0	.00	62.8	1.18
737	11124061	GOLDEN SHINER	214.0	6.10	.0	.00	.0	.00	214.0	6.10
737	11129169	BULLHEAD MINNOW	1,955.8	2.14	.0	.00	.0	.00	1,955.8	2.14
737	11201001	RIVER CARPSUCKE	14.0	.91	.0	.00	.0	.00	14.0	.91
737	11207030	SMALLMOUTH BUFF	.0	.00	.0	.00	2.3	6.86	2.3	6.86
737	11209034	SPOTTED SUCKER	60.5	1.10	14.0	2.30	69.8	29.32	144.2	32.73
737	11210044	BLACK REDHORSE	.0	.00	.0	.00	4.7	3.30	4.7	3.30
737	11210045	GOLDEN REDHORSE	.0	.00	.0	.00	2.3	.54	2.3	.54
737	11301009	CHANNEL CATFISH	.0	.00	.0	.00	48.8	40.47	48.8	40.47
737	11303032	FLATHEAD CATFIS	.0	.00	.0	.00	2.3	1.00	2.3	1.00
737	11602001	MOSQUITOFISH	25.6	.03	.0	.00	.0	.00	25.6	.03
737	12201002	WHITE BASS	16.3	.34	7.0	.47	2.3	.28	25.6	1.09
737	12201003	YELLOW BASS	2.3	.08	30.2	2.13	7.0	.87	39.5	3.07
737	12307012	WARMOUTH	120.9	.18	25.6	.50	7.0	.61	153.5	1.29
737	12307013	REDBREAST SUNFI	18.6	.04	9.3	.11	.0	.00	27.9	.15
737	12307014	GREEN SUNFISH	.0	.00	2.3	.04	.0	.00	2.3	.04
737	12307017	BLUEGILL	5,127.9	8.30	1,107.0	15.21	200.0	10.93	6,434.9	34.44
737	12307020	REDEAR SUNFISH	325.6	1.48	237.2	5.72	104.7	7.12	667.4	14.32
737	12308026	SPOTTED BASS	118.6	.50	7.0	.09	.0	.00	125.6	.59
737	12308027	LARGEMOUTH BASS	14.0	.12	39.5	2.00	23.3	9.83	76.7	11.94
737	12309029	WHITE CRAPPIE	.0	.00	11.6	.56	20.9	2.93	32.6	3.49
737	12403075	YELLOW PERCH	11.6	.13	.0	.00	.0	.00	11.6	.13
737	12404077	LOGPERCH	16.3	.09	.0	.00	.0	.00	16.3	.09
737	12405097	SAUGER	.0	.00	.0	.00	11.6	2.61	11.6	2.61
737	12501001	FRESHWATER DRUM	32.6	.43	230.2	12.17	179.1	33.15	441.9	45.74
737	12905002	BROOK SILVERSID	14.0	.01	.0	.00	.0	.00	14.0	.01
SAMPLE TOTAL			15,379.3	45.87	1,720.9	41.30	2,695.4	415.24	19,795.4	502.39

TABLE 3.5-24
COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

TABLE 3.5-25

COMPUTER OUTPUT OF COVE ROTENONE SAMPLES

SIZE DISTRIBUTION PER HECTARE BY SAMPLE

SAMPLE	SPECIES	COMMON NAME	NUMBER YOUNG-OF-YEAR	WEIGHT YOUNG-OF-YEAR	NUMBER INTER	WEIGHT INTER	NUMBER HARVEST	WEIGHT HARVEST	NUMBER TOTAL	WEIGHT TOTAL
738	10401001	SPOTTED GAR	.0	.00	12.1	3.38	48.5	34.36	60.6	37.74
738	10601003	SKIPJACK HERRIN	6.1	.07	.0	.00	.0	.00	6.1	.07
738	10604000		242.4	.05	.0	.00	.0	.00	242.4	.05
738	10604007	GIZZARD SHAD	5,657.6	48.36	.0	.00	266.7	26.45	5,924.2	74.81
738	10604008	THREADFIN SHAD	1,545.5	1.59	.0	.00	.0	.00	1,545.5	1.59
738	11105012	CARP	.0	.00	.0	.00	87.9	162.94	87.9	162.94
738	11124061	GOLDEN SHINER	24.2	.05	.0	.00	.0	.00	24.2	.05
738	11125000		6.1	.00	.0	.00	.0	.00	6.1	.00
738	11129169	BULLHEAD MINNOW	39.4	.02	.0	.00	.0	.00	39.4	.02
738	11207030	SMALLMOUTH BUFF	3.0	.03	.0	.00	51.5	127.12	54.5	127.15
738	11209034	SPOTTED SUCKER	.0	.00	.0	.00	63.6	33.63	63.6	33.63
738	11210045	GOLDEN REDHORSE	.0	.00	.0	.00	15.2	10.26	15.2	10.26
738	11301002	BLUE CATFISH	15.2	.08	.0	.00	.0	.00	15.2	.08
738	11301009	CHANNEL CATFISH	.0	.00	3.0	.08	15.2	8.99	18.2	9.07
738	11303032	FLATHEAD CATFIS	.0	.00	.0	.00	3.0	1.72	3.0	1.72
738	11602001	MOSQUITOFISH	57.6	.07	.0	.00	.0	.00	57.6	.07
738	12201002	WHITE BASS	3.0	.05	.0	.00	.0	.00	3.0	.05
738	12201003	YELLOW BASS	9.1	.15	.0	.00	6.1	.76	15.2	.92
738	12307012	WARMOUTH	27.3	.07	3.0	.07	.0	.00	30.3	.14
738	12307017	BLUEGILL	403.0	.55	60.6	1.00	97.0	8.16	560.6	9.71
738	12307020	REDEAR SUNFISH	27.3	.10	.0	.00	.0	.00	27.3	.10
738	12308026	SPOTTED BASS	39.4	.25	.0	.00	.0	.00	39.4	.25
738	12308027	LARGEMOUTH BASS	.0	.00	3.0	.05	3.0	5.00	6.1	5.05
738	12309029	WHITE CRAPPIE	127.3	.36	51.5	.44	15.2	2.72	193.9	3.52
738	12501001	FRESHWATER DRUM	224.2	1.37	163.6	10.06	272.7	32.20	660.6	43.63
738	12905002	BROOK SILVERSID	15.2	.01	.0	.00	.0	.00	15.2	.01
SAMPLE TOTAL			8,472.9	53.23	296.8	15.08	945.6	454.31	9,715.3	522.63

Question Number 3.6:

Provide a copy of detailed drawings of the intake systems showing the relationship of source water interception, with bottom contour map.

Response:

See Figure 3.6-1 (included with this response) for a drawing of the intake systems which shows the contours along the intake channel out into the river. The response to Question Number 3.7 provides a contour map of the river bottom adjacent to the plant site.

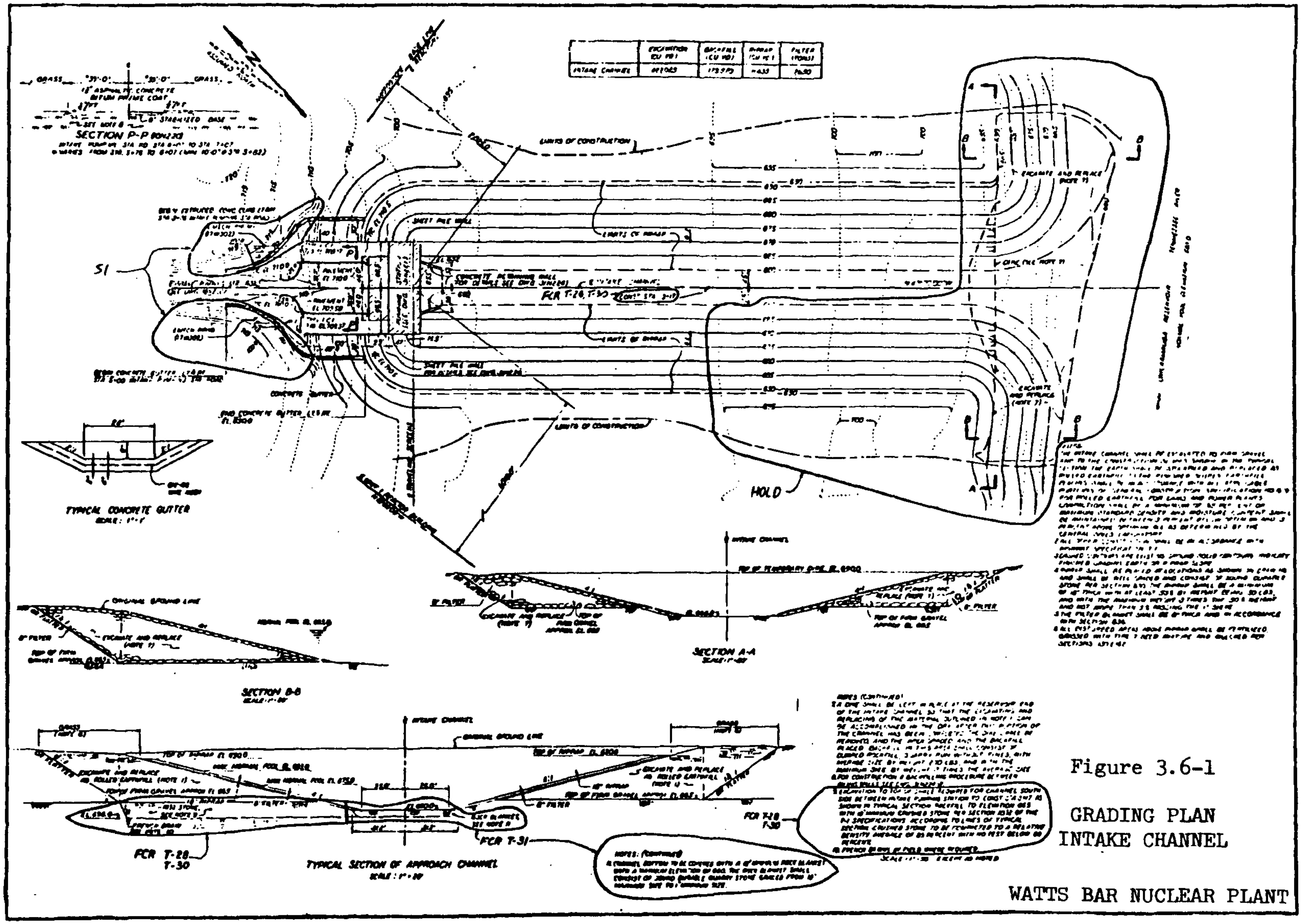


Figure 3.6-1

GRADING PLAN
INTAKE CHANNEL

WATTS BAR NUCLEAR PLANT

Question Number 3.7:

Provide a legible copy of bottom contour map presented in TVA's Environmental Information (page A-12).

Response:

See Figure 3.7-1 (included with this response).

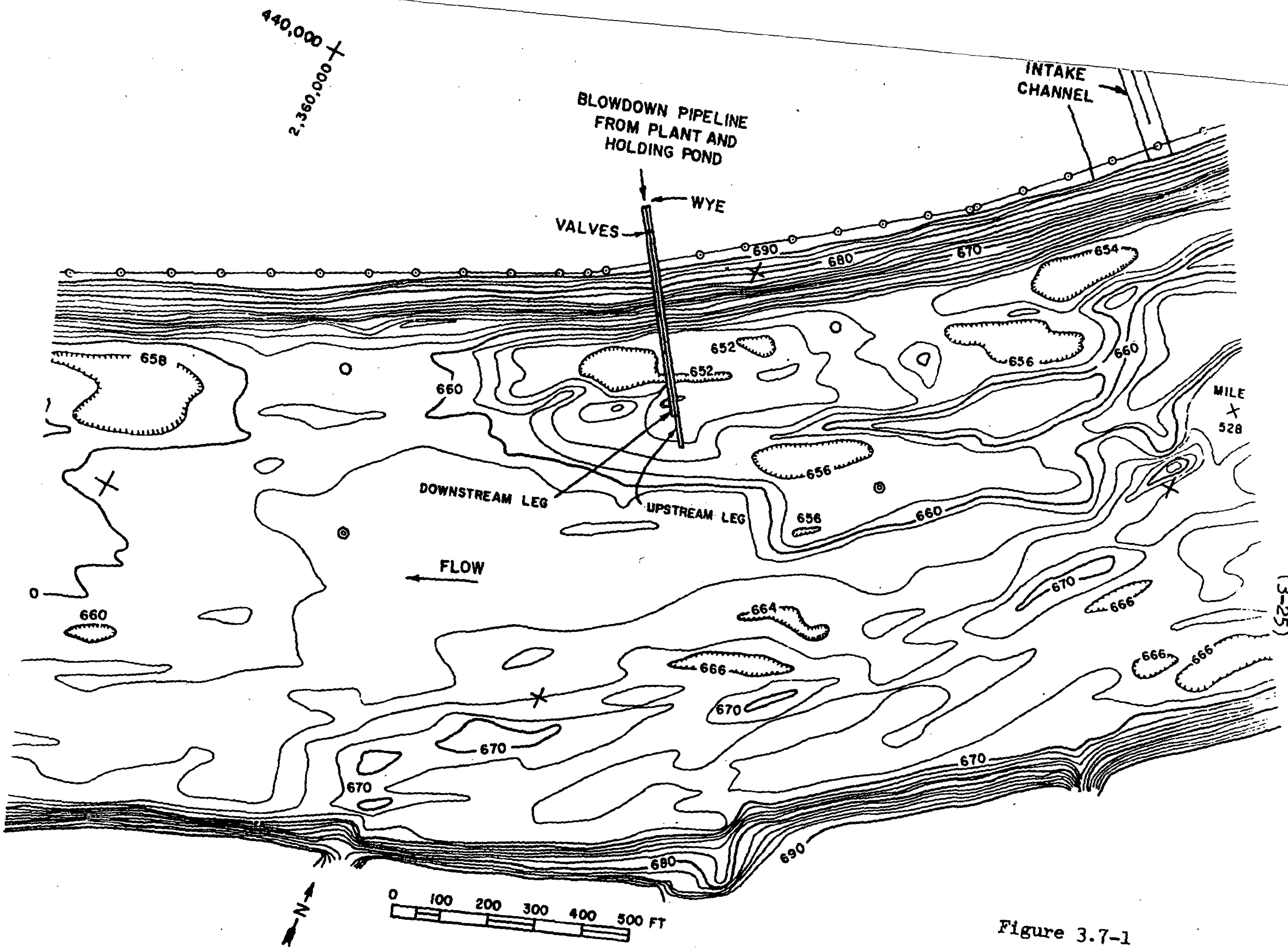


Figure 3.7-1

LOCATION OF MULTIPORT
DIFFUSER SYSTEM

WATTS BAR NUCLEAR PLANT

Question Number 3.8:

Discuss status of diffuser construction. Describe control and monitoring programs used to minimize and detect dredging effects during intake and discharge systems construction. Describe the role of TVA in supervision of the dredging operations.

Response:

Status of Diffuser Construction & Monitoring Program

The dredging contractor has completed excavation in the river for the diffuser pipes. A thick limestone rock lens was encountered in the last 75 feet of the upstream diffuser foundation. The contractor utilized a rock drill to line drill through the lens, a battering ram to further fracture the rock, and the customary shovel front to complete the excavation of rock. Although this procedure is more costly than would be expected for blasting, TVA has consistently pursued effective methods of construction which would result in minimal adverse environmental impacts at the Watts Bar Nuclear Plant.

At the NRC site visit on February 23 & 24, 1977, TVA indicated that dredging of such a small volume of material (approximately 1600 cu. yds.) would normally be a three day job. The NRC staff agreed that an extensive monitoring program for such a small volume dredge operation would be impractical. Although, the total time spent (nearly two months) on the dredging operation was longer than TVA had initially anticipated, the volume removed was unchanged. The greater length of time required to complete the job was due to the following delays:

(a) The last 75 feet of the upper diffuser has a limestone lens that ran from 4 to 7 feet thick and the contractor had to line drill and ram the limestone to remove it with the shovel front. The time spent drilling and removing the rock was responsible for the major portion of the delay in excavation. At any given time the amount removed was extremely small and materials handling was very limited.

(b) High rainfall caused a delay of approximately 7 to 10 days while waiting for reservoir pool levels to recede.

(c) The contractor had to modify his line drill operation even after water level recession (added approximately 11 feet to the length) because of unusually high rainfall in the Chickamauga and Watts Bar reservoir watersheds.

TVA has started excavation on the riverbank portion (approximately 50 feet) of the diffuser. This work will require approximately ten working days to complete, but only two days will be required for actual dredging.

The precast panels are ready, all pipe has been received, and all miscellaneous hardware with the exception of the turn buckles has been received.

The observation of the dredging effects during excavation of the diffuser discharge was included in the routine preoperational water quality surveys. Experienced TVA personnel evaluated the conditions and determined that the dredging effects were held to a minimum because of the nature of the substrate (rock) and the small volume of spoil material handled at any given time.

The spoil material from the dredging operation was loaded onto barges and taken to the upper side of the coal docking facility at the Watts Bar Steam Plant. It was then loaded onto TVA trucks and used for fill and grading at the site.

Proposed Intake Monitoring:

Monitoring the removal of the intake channel plug will be performed by TVA personnel and will be more extensive than that performed on the diffuser excavation. The monitoring will involve observations, pictures, and sampling of the potential plume resulting from breeching and clam shell or bucket excavation from the river side. Controls will be through the project management inspector and Division of Environmental Planning consultation.

Role of TVA in Supervision of Dredging Operation:

TVA is monitoring the contractor's operation (both discharge diffuser and intake channel) by providing a full time inspector who (1) verifies contractor's lines and grades, (2) coordinates between the contractor and TVA, and (3) prepares progress reports and pay estimates. TVA divers visually inspect for conformance with design requirements all underwater areas along the river bottom where the dredging operations take place.

Question Number 3.9:

Are any reports available on results of TVA's investigation into "...methods of increasing the DO levels in the releases from its headwater (storage) reservoirs" (FES, page 1.1-24 and Environmental Information, page B-12)? If so, provide a copy. If not, indicate when such reports will be available.

Response:

Six copies of the following reports have been included in a separate package that is being transmitted directly to the NRC staff Environmental Project Manager (on Watts Bar Nuclear Plant) for distribution to the appropriate NRC staff technical reviewer(s).

"Investigation of Oxygen Injection Using Small-Bubble Diffusers at Fort Patrick Henry Dam, " by William R. Nicholas and Richard J. Ruane, TVA, Division of Environmental Planning, Water Quality and Ecology Branch, Chattanooga, Tennessee, October 24, 1975. Presented at Symposium on Reaeration Research, ASCE Hydraulics Division, Gatlinburg, Tennessee, October 28-30, 1975.

"Oxygenation of Turbine Discharges from Fort Patrick Henry Dam," by R. J. Ruane, TVA, Division of Environmental Planning, Water Quality and Ecology Branch, Chattanooga, Tennessee, and Dr. Svein Vigander, TVA, Division of Water Management, Water Systems Development Branch, Norris, Tennessee. Applications of Commercial Oxygen to Water and Wastewater Systems, Water Resources Symposium No. 6, Center for Research in Water Resources, edited by Speece and Malina, page 291 (1973).

Preliminary Draft of Report "Oxygenation System Cost Estimates, Fort Patrick Henry Dam, Advance Report No. 28," Tennessee Valley Authority, Division of Water Management, Water Systems Development Branch, Norris, Tennessee, February 1977. Report No. 24-48.

4. HYDROLOGY

Question Number 4.1:

The ES states that there are four public water supplies taken from the Watts Bar and Chickamauga Reservoirs within the reach from Lenoir City, 73 miles upstream of the site, to the Daisy-Soddy-Falling Water Utility District 45 miles downstream of the site; yet you list only three. Provide a list of the four public water supplies.

TVA's Response:

There was no inconsistency in the water use information provided in the Environmental Information. All public water supplies within a 20-mile radius of the site including supplies taken from the Tennessee River between Fort Loudoun and Chickamauga Dams were listed on Table 1.1-13. Four of the supplies listed (Lenoir City, Spring City, Dayton, and Daisy-Soddy-Falling Water Utility District) are taken from Watts Bar and Chickamauga Reservoir, as stated in the text.

Specific comments on three of the above four supplies were included in the text, along with comments on two other supplies outside the area included on Table 1.1-13. This additional information was included because of its particular pertinence to the relationship between the Watts Bar Nuclear Plant and these particular public water supplies.

An updated and revised table of public water supplies within a 20-mile radius of the plant, and supplies taken from the Tennessee River between Fort Loudoun and Chickamauga Dams, is included here as Table 4.1-1. Also see Figure 4.1-1 of this response.

Table 4.1-1

Water Supplies Within a 20 Mile Radius of The Watts Bar Nuclear Plant

	Name	Approx. Radial Distance From Site[a] Miles	Est. Population Served	Average Daily Use Gallons	Source and Location
	PUBLIC GROUND WATER SUPPLIES				
	TENNESSEE				
	McMinn Co.				
1	E. K. Baker School	9.2	340	8,500	Well
2	Idlewild Elem. School	8.6	170	4,300	Well
3	Niota	17.1	2,500	290,000	Spring
4	Riceville U.D.	17.0	580	18,000	Spring
	Meigs Co.				
5	Cedar Valley Elem. School	12.5	190	47,000	Well
6	Decatur	3.3	1,500	117,000	Spring
7	Eastview Elem. School	19.7	130	3,200	Well
8	Fairview Elem. School	3.0	180	4,600	Well
9	Ten Mile Elem. School	7.9	170	4,200	Well
	Monroe Co.				
10	Sweetwater	17.5	5,000	700,000	Spring (90%); Sweetwater Cr. 21.6 (10%)
	Rhea Co.				
11	Cedine Bible Camp	7.0	120	6,000	Well
12	Evensville Elem. School	12.3	125	3,100	Well
13	Frazier Elem. School	11.7	150	3,800	Well
14	Spring City	7.6	2,300	300,000	Spring (67%); Piney River 5.7 (33%)
	Roane Co.				
15	Kingston	40.3	5,000	315,000	Spring (91%); TRM 568.3 (9%)
16	Midway High School	19.2	290	7,200	Spring
17	Paint Rock Elem. School	18.9	195	4,900	Well
18	Rockwood	17.6	10,000	1,420,000	Spring (99%); King Creek 1.3 (1%)

a. Radial distance to all supplies except those which take water directly from the Tennessee River which are shown as river mile distance from TRM 528.0.

Table 4.1-1, (cont'd)

Water Supplies Within a 20-Mile Radius of The Watts Bar Nuclear Plant Including Supplies Taken From the Tennessee River Between Ft. Loudoun and Chickamauga Dams

	Name	Approx. Water Route Distance From Site Miles	Est. Population Served	Average Daily Use Gallons	Source and Location
			PUBLIC SURFACE WATER SUPPLIES		
	TENNESSEE				
1	Hamilton Co. Daisy-Soddy-Falling Water U.D.	44.7	8,500	400,000	Soddy Cr.-emb. 4.2 (67%) and Well (33%)
2	Loudon Co. Lenoir City	73.3	6,600	950,000	TRM 601.3
3	Loudon	64.3	5,200	576,000	TRM 592.3 (50%) and Spring (50%)
4	McMinn Co. Athens	13.7	15,000	1,852,000	Oostanaula Cr. 35.2 (50%) and Spring (50%)
5	Englewood	19.2	1,810	253,000	Middle Cr. 1.8
	Rhea Co.				
6	Dayton	24.2	6,150	1,366,000	TRM 503.8
7	Ozone Presbyterian Church	18.4	100	5,000	Fall Branch 1.4
	Roane Co.				
8	Camp John Knox	27.7	130	4,500	TRM 555.7

Table 4.1-1, (cont'd)

Water Supplies Within a 20-Mile Radius of The Watts Bar Nuclear Plant Including Supplies Taken From the Tennessee River Between Ft. Loudoun and Chickamauga Dams

	Name	Approx. Water Route Distance From Site Miles	Est. Population Served	Average Daily Use Gallons	Source and Location
	INDUSTRIAL SURFACE WATER SUPPLIES				
	Hamilton Co.				
1-I	C. F. Industries[a]	55.0	210	3,140,000[b]	TRM 473.0
2-I	I.C.I. America (VAAP)[c]	55.0	2,000	50,000,000	TRM 473.0
3-I	TVA - Sequoyah Nuclear Plant[d]	43.5	300	$1,616.5X10^{6}$[e]	TRM 484.5
	Loudon Co.				
4-I	Union Carbide Corp.	64.0	430	3,272,000	TRM 592.0 (70%); Spring (29%); M (1%)
	Monroe Co.				
5-I	Carolyn Products, Inc.	19.2	150	655,000	Sweetwater Cr. 20.8 (95%); M (5%)
	Rhea Co.				
6-I	Southern Silk Mills	9.2	850	300,000	Piney River 7.8 (84%); M (16%)
7-I	TVA - Watts Bar Nuclear Plant	-0-	300	111,166,500[e]	TRM 528.0
8-I	TVA - Watts Bar Steam Plant	1.9	100	449,726,000[f]	TRM 529.0

a. Water is also used for potable water within the plant.
b. Does not include approximately 81.0 MGD recirculation.
c. Plant is presently closed.
d. Plant presently under construction.
e. Cooling water and cooling tower makeup.
f. Primarily cooling water.

Table 4.1-1, (cont'd)

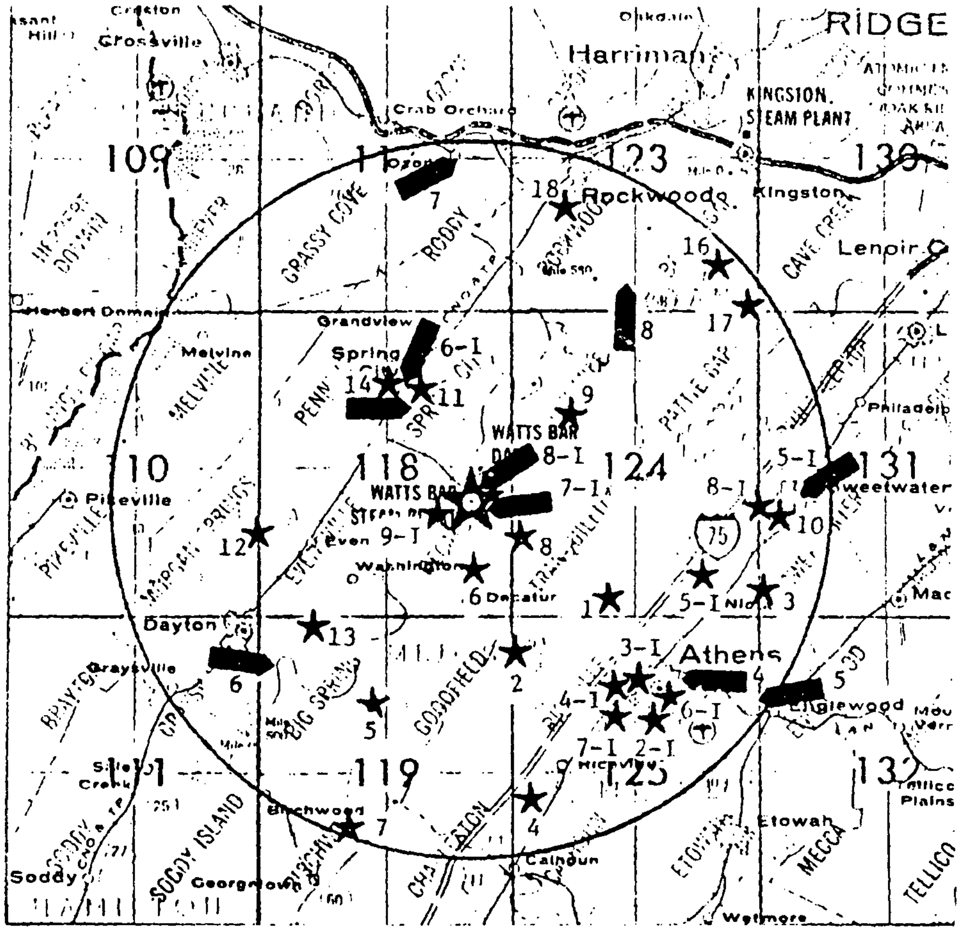
Water Supplies Within a 20-Mile Radius of The
Watts Bar Nuclear Plant

	Name	Approx. Radial Distance From Site[a/] Miles	Est. Population Served	Average Daily Use Gallons	Source and Location
		INDUSTRIAL GROUND WATER SUPPLIES			
	Loudon Co.				
1-I	Charles H. Bacon Co. (Loudon)	63.4	600	350,000	Spring (75%); TRM 591.4 (20%); M (5%)
	McMinn Co.				
2-I	Athens Hosiery Mill, Inc.	13.0	170	239,000	Well
3-I	Athens Stove Works	13.8	400	160,000	Well
4-I	Cherokee Photo Finishers	12.7	50	59,000	Well
5-I	Crescent Hosiery Mill	15.6	125	25,000	Well
6-I	Mayfield Dairy Farm, Inc.	15.0	345	290,000	Well
7-I	Plastic Industries, Inc.	13.4	210	10,000	Well
	Monroe Co.				
8-I	Sweetwater Hosiery Mills	16.6	90	24,000	Spring (97%); M(3%)
	Rhea Co.				
9-I	TVA - Watts Bar Reservation[b/]	1.0	480	44,980	Wells[c/]

a. Radial distance to all supplies except those which take water directly from the Tennessee River which are shown as river mile distance from TRM 528.0

b. Supplies potable water to nuclear plant, steam plant, hydro plant, and resort area.

c. The Watts Bar Reservation potable ground water supply is not completely operational at this time. Most of the water requirements are being supplied by two wells. However, this is supplemented, as needed, by surface water treated in the old reservation water plant which withdraws water from Watts Bar Reservoir at the dam. The surface water plant is operated approximately once each week, regardless of need, to maintain plant readiness. A third well is being developed which will provide sufficient capacity for the ground water supply to meet all the reservation needs. This well is expected to be integrated into the system by December 1977, at which time the old surface water plant will be retired.



WATTS BAR NUCLEAR PLANT

Plant Site

Surface Water Supply

Ground Water Supply

NOTE: The number associated with the symbol corresponds to the numbering in tables

FIGURE 4.1-1

Public Water Supplies Within a 20-Mile Radius of the plant site

Scale of Miles

10 0 10 20

Question Number 4.2:

Discuss the potential scouring associated with the discharge section of the heat-dissipation system.

Response:

If the angle of discharge for the diffuser jets were less than 20°, scouring of the river bottom by the jets would probably occur. However, as indicated in the response to Question Number 4.5, the ports of the diffuser system at the Watts Bar Nuclear Plant will discharge at an angle of 45° from the horizontal; therefore, no scouring of the river bottom is expected.

Question Number 4.3:

Provide the cross-sectional area of the intake channel and how it varies along the channel length.

Response:

See Figure 3.6-1 (included with response to Question Number 3.6) for a drawing of the intake channel showing cross-sectional area variations along the channel length.

Question Number 4.4:

Provide a detailed diagram of the intake structure. Show the location of the trash racks; wave barriers, and traveling screens and provide plans and cross sections of the intake structure with all pertinent elevations. Describe the systems for handling the debris and the fish return.

Response:

See Figures 4.4-1 thru 4.4-5 (included with this response).

The intake structure provides trash racks and vertical traveling screens for handling debris. Large debris is retained on the trash racks while small debris passes through the trash racks and is retained on the vertical traveling screens. The screens are rotated and debris is removed by spray washing. The washwater and debris flows into a trash sluice which discharges into a catch basin located on the west end of the Intake Pumping Station. The washwater and debris ultimately reaches the Yard Drainage Holding Pond where the debris is retained.

The planned operation does not provide for separation of fish and debris. There are no wave barriers associated with the Intake Pumping Station.

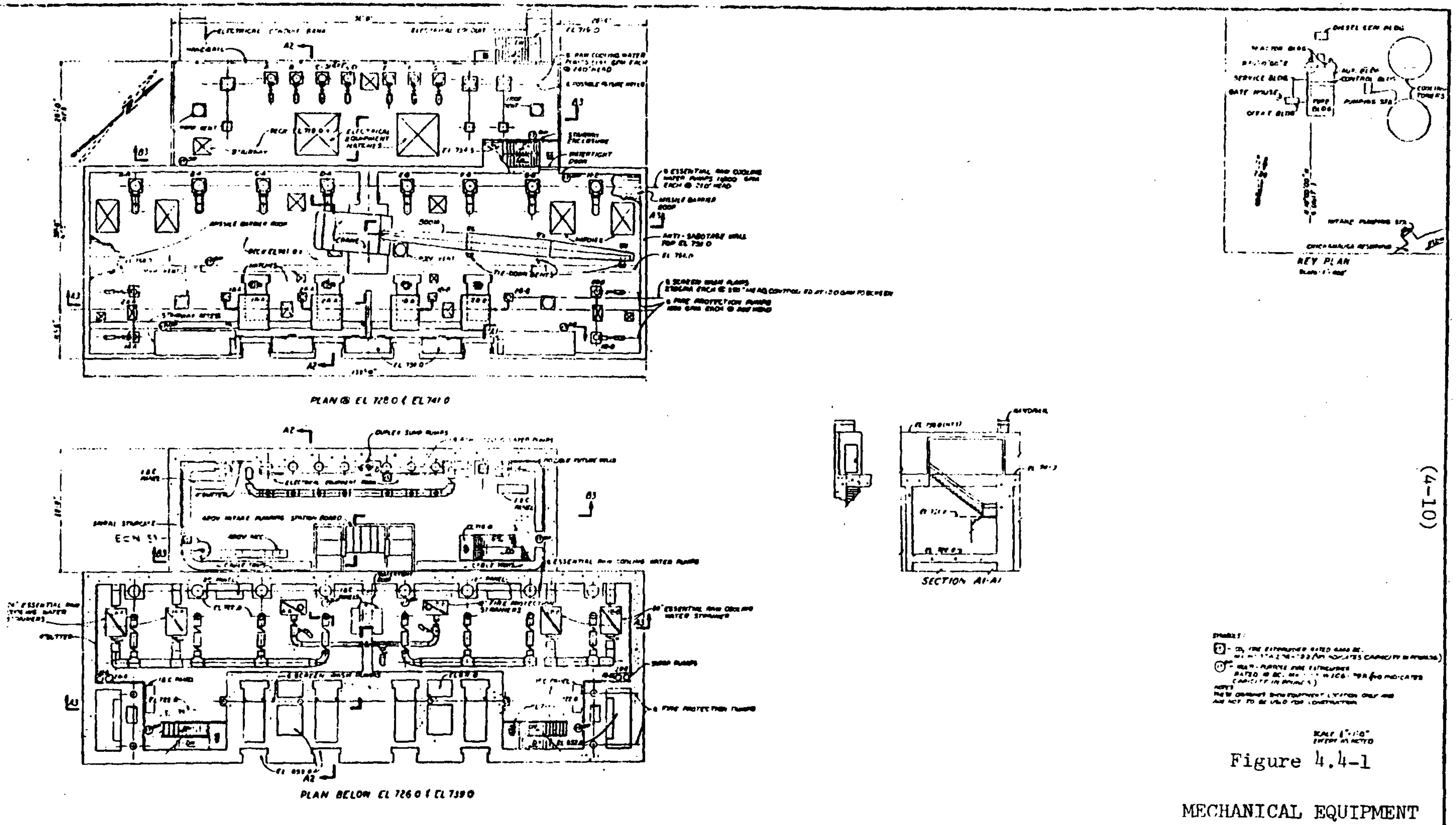
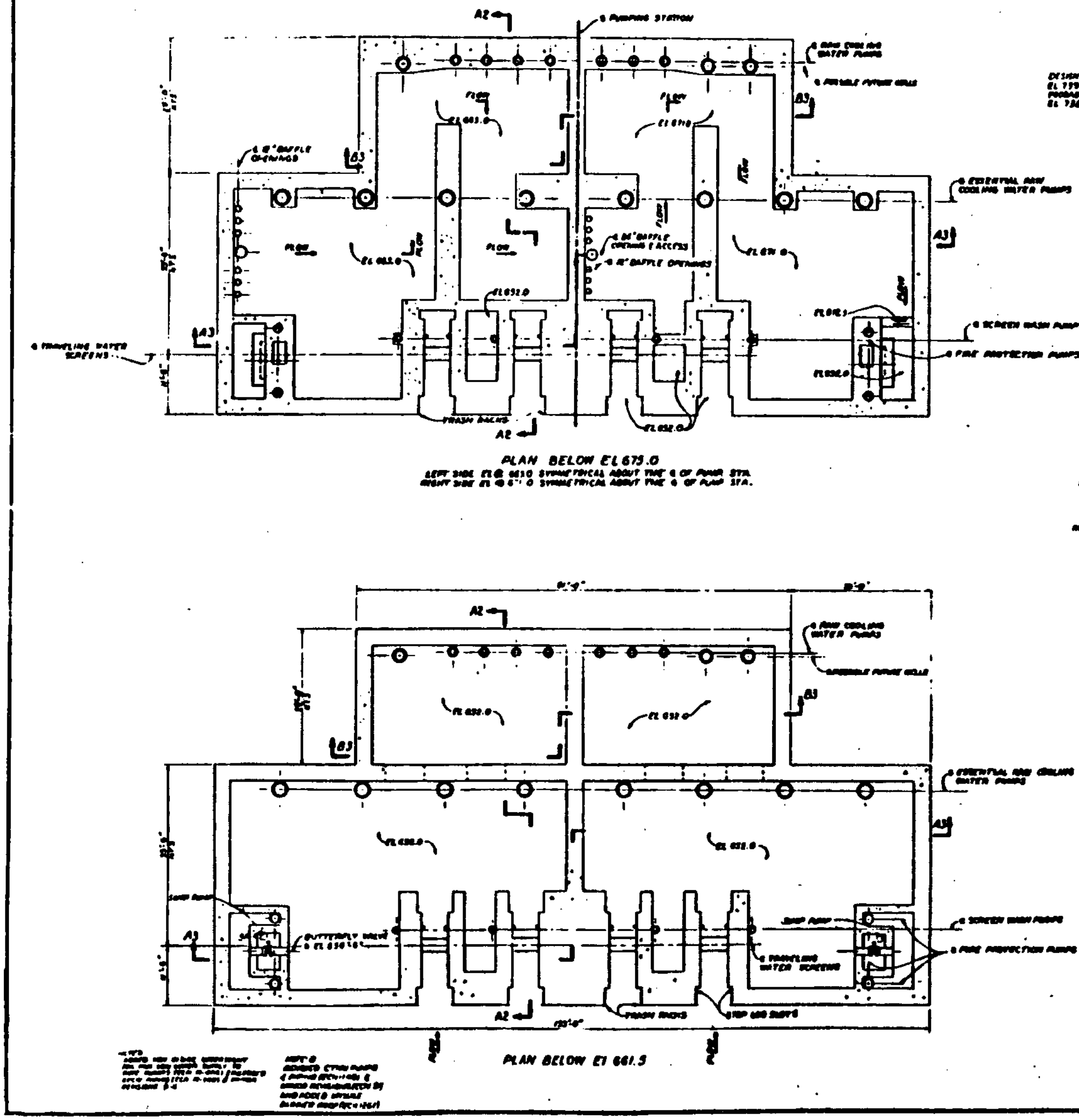


Figure 4.4-1

MECHANICAL EQUIPMENT
INTAKE PUMPING STATION

Watts Bar Nuclear Plant



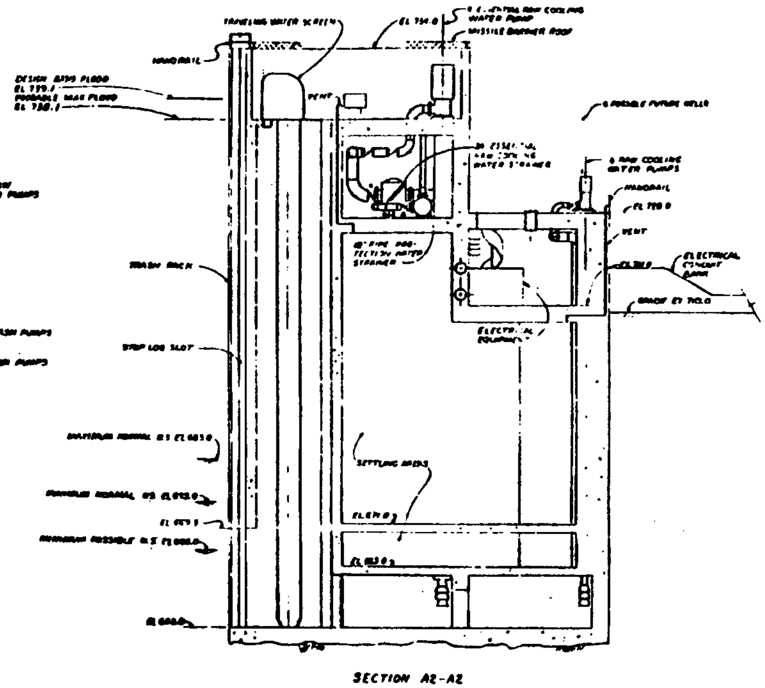
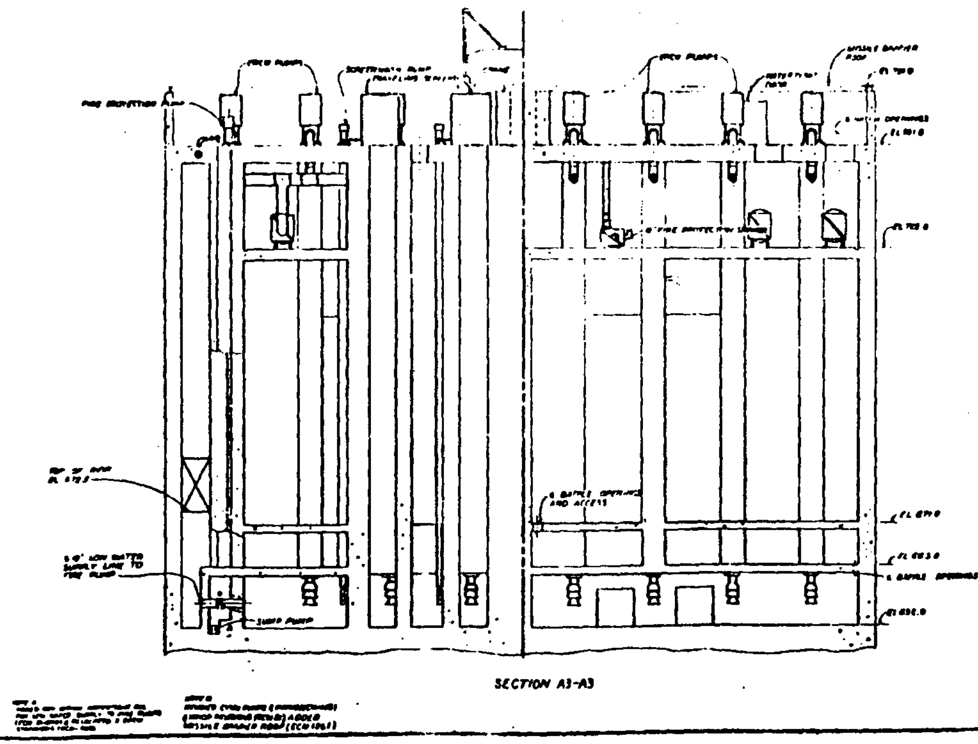


Figure 4.4-2

MECHANICAL EQUIPMENT
INTAKE PUMPING STATION

Watts Bar Nuclear Plant



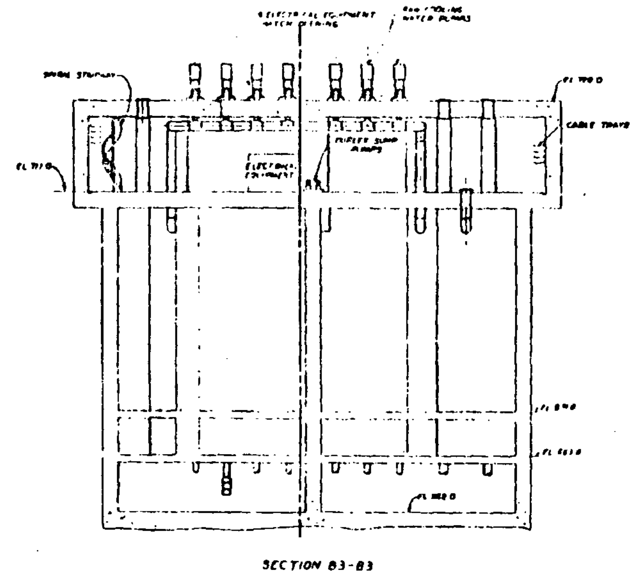


Figure 4.4-3

MECHANICAL EQUIPMENT
INTAKE PUMPING STATION

Watts Bar Nuclear Plant

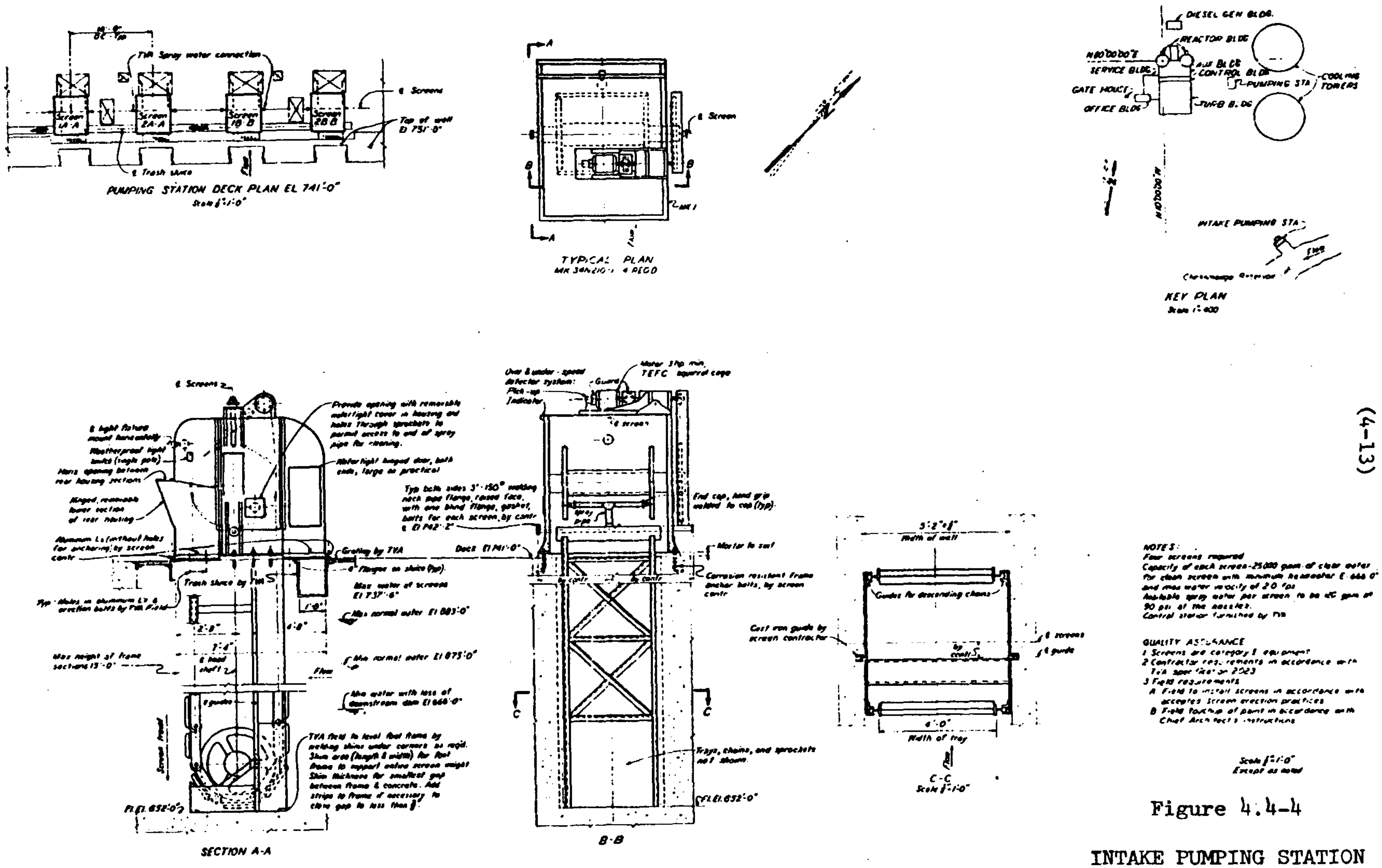
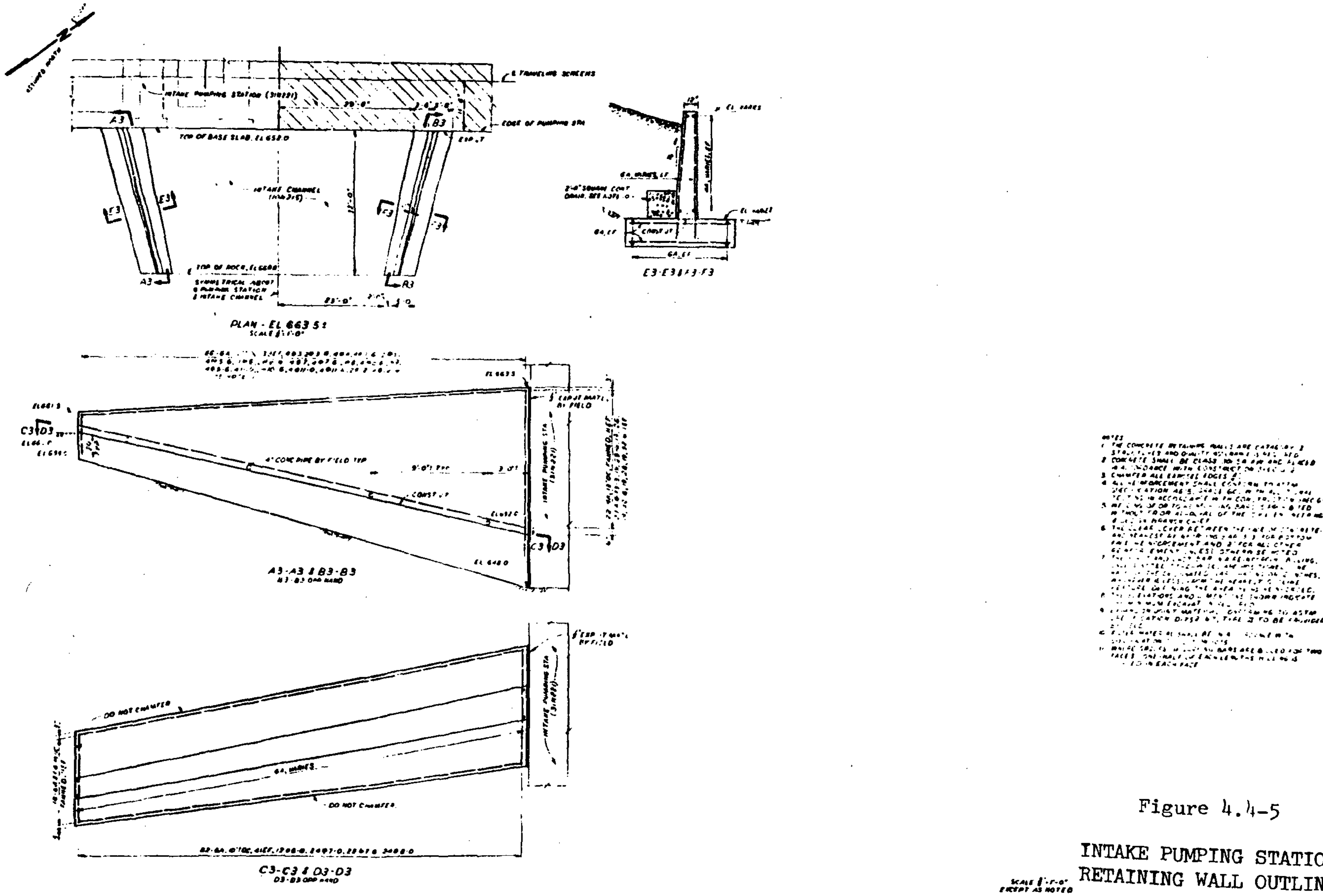


Figure 4.4-4

INTAKE PUMPING STATION
TRAVELING SCREENS ARRANGEMENT

WATTS BAR NUCLEAR PLANT



(4-14)

Figure 4.4-5

INTAKE PUMPING STATION
RETAINING WALL OUTLINE

Watts Bar Nuclear Plant

Question Number 4.5:

Provide a detailed description of the diffuser to supplement the information provided in the Environmental Information Report. Include such information as the type, angle of discharge, etc.

Response:

Included with this response is a report entitled "Results of Hydrothermal Model Studies of the Multiport Diffuser System, Watts Bar Nuclear Plant." This report provides the detailed information requested. With the exception of reference 2, all the references in this report are generally available in the literature. Six copies of reference 2, entitled "Effect of Orientation to Flow Direction on Diffuser-Induced Dilution and Plume Structure in a Shallow River," have been included in a separate package that is being transmitted directly to the NRC staff Environmental Project Manager (on Watts Bar Nuclear Plant) for distribution to the appropriate NRC staff technical reviewer(s).

TENNESSEE VALLEY AUTHORITY

RESULTS OF
HYDROTHERMAL MODEL TESTS
OF THE
MULTIPORT DIFFUSER SYSTEM
WATTS BAR NUCLEAR PLANT

TVA
ENGINEERING
LABORATORY

WATER SYSTEMS DEVELOPMENT BRANCH
NORRIS, TENNESSEE

DIVISION OF WATER MANAGEMENT

TECHNICAL REPORT

Tennessee Valley Authority
Division of Water Management
Water Systems Development Branch

RESULTS OF HYDROTHERMAL MODEL TESTS OF THE MULTIPORT DIFFUSER SYSTEM WATTS BAR NUCLEAR PLANT

Report No. 9-2013

Prepared by
Christopher D. Ungate
Norris, Tennessee
May 1977

DESCRIPTION OF MULTIPORT DIFFUSER SYSTEM
WATTS BAR NUCLEAR PLANT

INTRODUCTION

The Tennessee Valley Authority is constructing a two-unit nuclear generating plant in Rhea County, Tennessee, on the right bank of Chickamauga Lake adjacent to the Watts Bar Dam Reservation near Tennessee River Mile (TRM) 528 (Figure 1). One closed cycle, natural draft cooling tower per unit is utilized as the primary means of heat dissipation. Blowdown will be discharged at a rate of between 28.3 and 32.5 cubic feet per second (cfs) from each cooling tower basin so as to maintain the concentration of solids in the cooling towers at approximately twice that found in the Tennessee River. Since the blowdown cannot be continuously discharged during periods of no releases from Watts Bar Dam without violating applicable thermal standards, blowdown can be discharged into a holding pond of approximately 190 acre-feet capacity during these periods. When sufficient water is released from Watts Bar Dam, blowdown may be again discharged to the river. This occurs at the minimum release from Watts Bar Hydro Plant of 3500 cfs. In addition, blowdown from the holding pond can be discharged to the river at a rate of approximately 60 cfs.

This report presents the results of hydrothermal physical model tests of the plant's multiport diffuser system. The diffuser system is described and the analytical theory used for the diffuser design is given and compared to the results of the physical model tests. Conclusions concerning the performance of the diffuser and the size of the area of diffuser-induced mixing are given. Previous studies resulted in the choice of a diffuser system oriented perpendicularly to the river flow (Reference 1). Additional hydrothermal physical model tests were conducted as part of these studies (Reference 2).

DIFFUSER DESIGN

Diffuser Dimensions and Geometry

A physical description of the recommended diffuser system is given in Table 1 and depicted in Figure 2. The diffuser system will consist of two pipes branching from a central conduit at the right bank of Chickamauga Lake and extending in a direction perpendicular to the river flow into the Tennessee River. Each pipe will be controlled by a 54-inch diameter butterfly valve, located a short distance from the wye with the central conduit.

The downstream leg will consist of approximately 297 feet of 4.5-foot diameter paved corrugated steel approach pipe connected to 150 feet of unpaved 1- x 3-inch corrugated steel diffuser pipe of the same diameter. The diffuser pipe section will be half buried in the river bottom and will contain two 1-inch diameter port per corrugation. The centroid of the ports will be oriented at an angle of 45^{o} from the horizontal in a downstream direction.

The upstream leg will consist of approximately 447 feet of 3.5-foot diameter paved corrugated steel approach pipe connected to 75 feet of unpaved 1- x 3-inch corrugated steel diffuser pipe of the same diameter. The upstream diffuser pipe section will also be half buried in the river bottom and will extend its entire length of 75 feet beyond the dead end of the downstream diffuser pipe section. The port diameter, spacing and orientation of the upstream leg will be the same as that of the downstream leg.

Diffuser Location

The location of the diffuser system is shown in Figure 3. Both the upstream and downstream legs are located beneath the navigation channel, as indicated by buoy markers on Figure 3. The location of the diffuser was chosen so that the depth of water above the diffuser will be sufficient to allow for the safe passage of barges.

Operational Modes and Characteristics

Modes of Operation

A mode of operation for the diffuser system is defined as any one of the possible combinations of diffuser pipe sections which may discharge blowdown under particular circumstances. Thus, for the Watts Bar Nuclear Plant diffuser system, the first mode consists of only the upstream leg discharging blowdown, the second mode consists of only the downstream leg discharging blowdown, and the third mode consists of both the upstream and downstream legs discharging blowdown. Mode 1 is used when either unit 1 or unit 2 is operated alone. Mode 2 is used when only both units are operated simultaneously or when only stored blowdown is discharged from the holding pond. Mode 3 is used when either or both of the units is operated at the same time as stored blowdown is discharged from the holding pond. Table 2 summarizes the minimum and maximum blowdown flow rates that can be expected for each mode.

Operational Characteristics

The operational characteristics for the minimum and maximum flows of each mode are summarized in Table 3. The average jet exit velocity, approach pipe velocity and the required head at three locations in the pipe are presented.

Table 3 shows that the average jet exit velocity varies from 8.6 to 12.7 feet per second (fps) for all the operational modes, which will provide ample mixing.

Analysis of Diffuser Performance

An analytical expression for the dilution induced by a submerged slot diffuser in shallow water was developed by Adams (Reference 3):

$$S = 1/2(V \sin \gamma + (V^2 \sin^2\gamma + 2\frac{h}{B} \cos \theta)^{1/2}) \qquad (1)$$

where S = dilution

$$= \frac{\text{entrained river flow + diffuser flow}}{\text{diffuser flow}}$$

$$V = \frac{u_a h}{u_o B} = \frac{Q_R L}{Q_B w} = \text{volume flux ratio}$$

u_a = average river velocity across diffuser

u_o = jet exit velocity

h = average river depth

B = slot width

Q_R = river flow at diffuser site = $u_a wh$

Q_B = diffuser flow = $u_o LB$

L = diffuser length

w = average river width

γ = orientation angle of diffuser in river ($\gamma = 90^\circ$; perpendicular to river flow)

θ = discharge angle from river bottom ($\theta = 0^\circ$; parallel to river bottom)

This theory is applicable as long as $L/H \geq 5$. Table 4 shows the values of these parameters for the Watts Bar Nuclear Plant diffusers. Equation 1 is applicable because $L/H \approx 10$. The predicted dilution of the Watts Bar diffuser system is 17 at a minimum Tennessee River flow of 3500 cfs.

The two dimensional structure of the discharge plume was predicted using the method of Jirka which is based on the theory of Adams (Reference 4). Full vertical mixing of the discharge plume and the receiving water was predicted for the following criterion:

$$F_T \, V^{3/2} \geq 1.0$$

where

$$F_T = \frac{F_s}{h/_B{}^{3/2}} = \text{diffuser load}$$

F_s = slot densimetric Froude number

$$= \frac{u_o}{\sqrt{g'B}}$$

$$g' = \frac{(\rho_o - \rho_a)g}{\rho_a}$$

ρ_o = density of discharge

ρ_a = density of ambient river water

g = gravitational constant

In general, stratified conditions downstream of the discharge were predicted when this criterion was not met. For the Watts Bar Nuclear Plant diffuser system, the variety of discharge conditions can result in either fully mixed or stratified conditions downstream of the discharge.

MODEL DESCRIPTION

Because the theory used to predict the dilution of the diffuser system was two-dimensional, the final design of the diffuser was evaluated in hydrothermal model studies, where three-dimensional effects were simulated. A detailed description of the physical model is presented in Reference 2 and is summarized herein. The physical model studies were conducted according to geometric, kinematic and Froude scaling criteria in the 8-foot wide, 60-foot long flume at TVA's Engineering Laboratory in Norris, Tennessee. An undistorted model (length/scale ratio 1:60) of approximately 45 percent of the 1100-foot wide river was constructed because of the limited width of the flume. Figure 4 shows that the section of the river modeled was the area of practical interest on the plant side of the river. Because the river exhibited a fairly rectangular cross-section, only a general schematization of the river geometry was necessary (Figure 5). The use of a false wooden floor in the flume eliminated the need for insulation of the bottom of the flume. The equivalent of a river flow (Q_R) of 3500 cfs was used in the model studies, which was the minimum river flow during which blowdown from the plant would be discharged (Reference 1).

Submerged multiport diffusers were modeled using the concept of an equivalent slot width. A series of submerged discharge ports were assumed to be equivalent to a submerged slot of equal length and port area, provided the port spacing was less than the water depth. Diffuser jets discharged at a prototype velocity of 9.5-15.1 fps. The effect of the buoyancy of the discharge was modeled using heat as the source of density differences between the discharge and receiving water body. Density differences between the discharge and the receiving water corresponding to temperature differences of -5^{o}C to 25^{o}C were tested. These density differences were characterized by the parameter g', which was defined earlier. The density of the discharge can be less than the receiving water at the Watts Bar plant site because of the concentration of dissolved solids in the blowdown compared to the river and because of the quicker response of natural draft cooling towers to cooler ambient air temperatures in the autumn months compared to the response of the river at the plant site.

TEST RESULTS

Data Interpretation

Test results for the Watts Bar Nuclear Plant diffuser system are presented in Figures 6-11. Results are presented in the form of discharge concentration isoquants at prototype water depths of 5 and 12 feet.

Comparison of concentration plots for tests of the same river and diffuser flow, discharge buoyancy and geometry indicated that plume structure was generally reproducable. Plume areas, discharge concentrations and other quantifiable data were always of the same order of magnitude for each replicate test but differed substantially enough that the use of such data was justifiable only in a comparative order of magnitude analysis. These variations were probably caused by the stochastic nature of turbulent mixing and the low density and slow scanning rate of the temperature probes compared to the length scales and frequency of turbulent mixing.

Comparison of concentration plots for tests of the same equivalent slot diffuser composed of different port diameter and spacings indicated good agreement. Some tests with large diffuser flow rates showed the effects of boundary layers on the mid-river boundary of the model. Concentration data in these areas were interpreted with caution because viscosity is not scaled correctly in models developed according to Froude scaling criteria; however, these effects were apparent outside areas of jet-induced mixing and did not affect overall results.

Diffuser-Induced Dilution and Plume Structure

Maximum Diffuser Length

Figures 6 through 8 show diffuser discharge concentration plots for the test values of diffuser design parameters given in Table 4. The concentration plots are shown for a diffuser length of 194 feet and three discharge buoyancies: g' = -0.05, 0.05 and 0.20. For g' = -0.05, the negatively buoyant case, the discharge plume was fully mixed over the depth and did not concentrate near the right bank (Figure 6). This showed that a negatively buoyant discharge acting in the opposite direction of vertical jet momentum increased dilution. For g' = 0.05, the discharge buoyancy was slightly positive (Figure 7). High concentration measurements particularly near the bottom boundary of the model indicated that warmer water was retained in the boundary layers because of the greater effect of viscosity in the model as compared to the prototype. At the five-foot depth, Figure 7 shows the entrainment of cooler ambient river water by the diffuser and the contraction of the mixed diffuser flow downstream mentioned by Adams (References 3 and 4). For g' = 0.20, the discharge plume was mixed over the depth, but tended to concentrate near the surface because of the high discharge buoyancy (Figure 8). Boundary effects were evident, particularly at the 12-foot depth, but the discharge plume did not concentrate near the right bank.

A diffuser-induced dilution of 13 was predicted by Equation 1 for the test results in Figures 6-8 (Table 4). This corresponded to a discharge concentration of 0.08. Figures 6-8 show that discharge concentrations one diffuser length downstream along the longitudinal centerline of the diffuser were equal to or less than 0.08. The discharge plume was predicted to be fully mixed over the depth for $g' = \pm 0.05$, and to be stratified outside the area of diffuser-induced mixing for $g' = 0.20$. Figures 6-8 show that the plume structure for these tests was fairly well predicted.

Minimum Diffuser Length

Figures 9 through 11 show discharge concentration plots for a diffuser length of 102 feet and the same discharge buoyancies evaluated previously. For $g' = -0.05$, the discharge plume was fairly well mixed over the entire depth and did not concentrate near the right bank (Figure 9). For $g' = 0.05$, the discharge plume was fully mixed over the entire depth (Figure 10). Boundary layer effects were evident, particularly at the 12-foot depth, and were caused by the greater effect of viscosity in the model. For $g' = 0.20$, the discharge plume became stratified outside of the area of diffuser-induced mixing and did not concentrate near the right bank (Figure 11). In Figures 9-11 boundary layer and viscosity effects were not as important because of the smaller ratio of diffuser length to modeled river width as compared to Figures 6-8.

A diffuser-induced dilution of 13 was predicted by Equation 1 for the test results in Figures 9-11 (Table 4). This corresponded to a discharge concentration of 0.08 (Table 4). Figures 9-11 show that discharge concentrations one diffuser length downstream along the longitudinal centerline of the diffuser were equal to or less than 0.08. The discharge plume was predicted to be fully mixed over the depth for $g' = \pm 0.05$ and to be stratified outside the area of diffuser-induced mixing for $g' = 0.20$. Figures 9-11 show that the plume structure for these tests was well predicted.

APPLICATION OF TEST RESULTS

As noted previously, quantifiable data from replicate tests differed substantially enough that the use of such data was justifiable only in a comparative order of magnitude analysis. Comparison of predicted dilutions for the model diffuser using the two-dimensional theory of Adams and measured dilutions for the model diffuser showed reasonable agreement for both the 194-foot and 102-foot diffuser lengths. This agreement indicated that the mixing from a submerged slot diffuser in shallow water was primarily a two-dimensional phenomenon and the resulting dilution could be reasonably predicted by a two-dimensional theory. Because the predicted dilutions based on the two-dimensional theory of Adams never overestimated the measured dilutions in the model, the two-dimensional theory of Adams can be used to conservatively predict the performance of the multiport diffuser system at the Watts Bar Nuclear Plant.

A comparison of design and test values of diffuser design parameters is given in Table 4. Average river velocity and discharge velocity were larger in the model compared to the prototype diffuser, while river depth and the maximum diffuser length were smaller. Values of other parameters in the model and the prototype were in close agreement. Table 4 shows that the theory of Adams predicts a dilution of 17 for the actual diffuser design and a dilution of 13 for the diffuser model at a minimum Tennessee River flow of 3500 cfs. Figures 6-11 show reasonable agreement between predicted and measured values of dilution for the diffuser model. Therefore, the actual multiport diffuser system at the Watts Bar Nuclear Plant should achieve a dilution of approximately 17 when either the upstream, downstream or both legs of the diffuser system are in operation at a minimum Tennessee River flow of 3500 cfs.

The results of the hydrothermal model tests indicated that concentration of the discharge near the right bank did not occur. In addition, the discharge plume did not form a thermal wedge upstream of the diffuser even at the highest discharge buoyancy. The tendency of the discharge plume in the model to form vertically mixed conditions downstream of the diffuser was well predicted by the theory of Adams. Similar plume structure is predicted for the actual diffuser design.

Mixing Zone

The results of the model tests showed that the expected diffuser-induced dilution was achieved approximately one diffuser length downstream. Thus the area of diffuser-induced mixing extends approximately 150 feet downstream when the downstream leg of the diffuser system is discharging; approximately 75 feet downstream when the upstream leg of the diffuser system is discharging; and 225 feet downstream when both legs of the diffuser system are discharging. The proposed mixing zone should encompass all of these modes of operation and should extend 225 feet downstream over the entire river depth and diffuser system width (225 feet).

REFERENCES

1. Tennessee Valley Authority, Environmental Information, Watts Bar Nuclear Plant, Units 1 and 2, November 18, 1976.

2. Ungate, C. D., and E. E. Driver, "Effect of Orientation to Flow Direction on Diffuser-Induced Dilution and Plume Structure in a Shallow River," Water Systems Development Branch, TVA Division of Water Management, to be presented at the XVII Congress of the International Association for Hydraulic Research, Baden-Baden, Germany, August 1977.

3. Adams, E. E., "Submerged Multiport Diffusers in Shallow Water With Current," Master's Thesis, Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts, May 1972.

4. Jirka, G., and D.R.F. Harleman, "The Mechanics of Submerged Multiport Diffusers for Buoyant Discharges in Shallow Water," Ralph M. Parsons Laboratory Report No. 169, Massachusetts Institute of Technology, Cambridge, Massachusetts, March 1973.

TABLE 1

DIMENSIONS OF RECOMMENDED DIFFUSERS

WATTS BAR NUCLEAR PLANT

	Upstream Leg	Downstream Leg	Total
Diffuser			
Pipe Length (ft) (unpaved 1- x 3-inch corrugated steel pipe)	75.0	150.0	225.0
Pipe Diameter (ft)	3.5	4.5	
Port Diameter (in)	1.0	1.0	
Number of Ports Per Corrugation	2	2	
Port Spacing Normal to Corrugation (in)	3.0	3.0	
Port Spacing Parallel to Corrugation (in)	3.0	3.0	
Friction Factor	0.0948	0.0841	
Approach Pipe			
Pipe Length (ft) (paved corrugated steel pipe)	447.0	297.0	474.0
Pipe Diameter (ft)	3.5	4.5	
Friction Factor	0.0191	0.0148	

TABLE 2

SUMMARY OF MODES OF OPERATION
BLOWDOWN DIFFUSER SYSTEM
WATTS BAR NUCLEAR PLANT

Mode of Operation	Diffuser System Flow Rate		Distribution of Flow			
			Minimum		Maximum	
	Minimum (cfs)	Maximum (cfs)	Upstream Leg (cfs)	Downstream Leg (cfs)	Upstream Leg (cfs)	Downstream Leg (cfs)
1 One Unit only	28.3	32.5	28.3	----	32.5	----
2 Two Units only or Holding Pond Discharge only	56.6	65.1	----	56.6	----	65.1
3 Either or Both Units + Holding Pond Discharge	88.5	125.3	29.1	59.4	41.2	84.1

Blowdown Rate per unit: 28.3 - 32.5 cfs
Holding Pond Discharge Rate: 60.2 cfs

TABLE 3

OPERATING PROPERTIES OF RECOMMENDED DIFFUSERS

WATTS BAR NUCLEAR PLANT

	Individual Operation of Diffuser Legs				Combined Operation of Diffuser Legs			
	Mode 1		Mode 2		Mode 3			
	Upstream Leg		Downstream Leg		Minimum		Maximum	
	Minimum	Maximum	Minimum	Maximum	Upstream	Downstream	Upstream	Downstream
Blowdown Rate (cfs)	28.3	32.5	56.6	65.1	29.3	59.2	41.5	83.8
Port Velocity (fps)	8.6	9.9	8.6	9.9	9.0	9.0	12.7	12.7
Approach Pipe Velocity (fps)	2.9	3.4	3.6	4.1	3.1	3.7	4.3	5.3
Dead End Head (ft)	2.6	3.4	2.6	3.4	2.8	2.8	5.6	5.7
Diffuser Head Req'd (ft)	2.7	3.5	2.8	3.7	2.9	3.0	5.8	6.1
Total Head Req'd (ft) from Wye	3.0	4.0	3.0	4.0	3.2	3.2	6.5	6.5

TABLE 4

DESIGN AND TEST VALUES
OF DIFFUSER DESIGN PARAMETERS

Symbol Primary	Parameter	Units	Design Value	Test Value
u_o	Discharge Velocity (max)	m/s (fps)	3.9 (12.7)	4.5 (14.8)
u_a	Average River Velocity	cm/s (fps)	4.9 (0.16)	7.0 (0.23)
B	Equivalent Slot Width	cm (ft)	1.33 (0.0436)	1.44 (0.0471)
h	River Depth (min)	m (ft)	6.7 (22)	4.3 (14)
Secondary				
γ	Orientation Angle to River Flow	deg	90	90
Θ	Discharge Angle	deg	45	45
g'	Buoyancy (max)	--	0.20	0.20
	(min)	--	-0.05	-0.05
L	Diffuser Length (max)	m(ft)	69(225)	59(194)
	(min)	m(ft)	23(75)	31(102)
Analytical Theory (References 3 and 4)				
h/B	Submergence	--	505	297
V	Volume Flux Ratio	--	6.4	4.6
S	Dilution	--	17	13

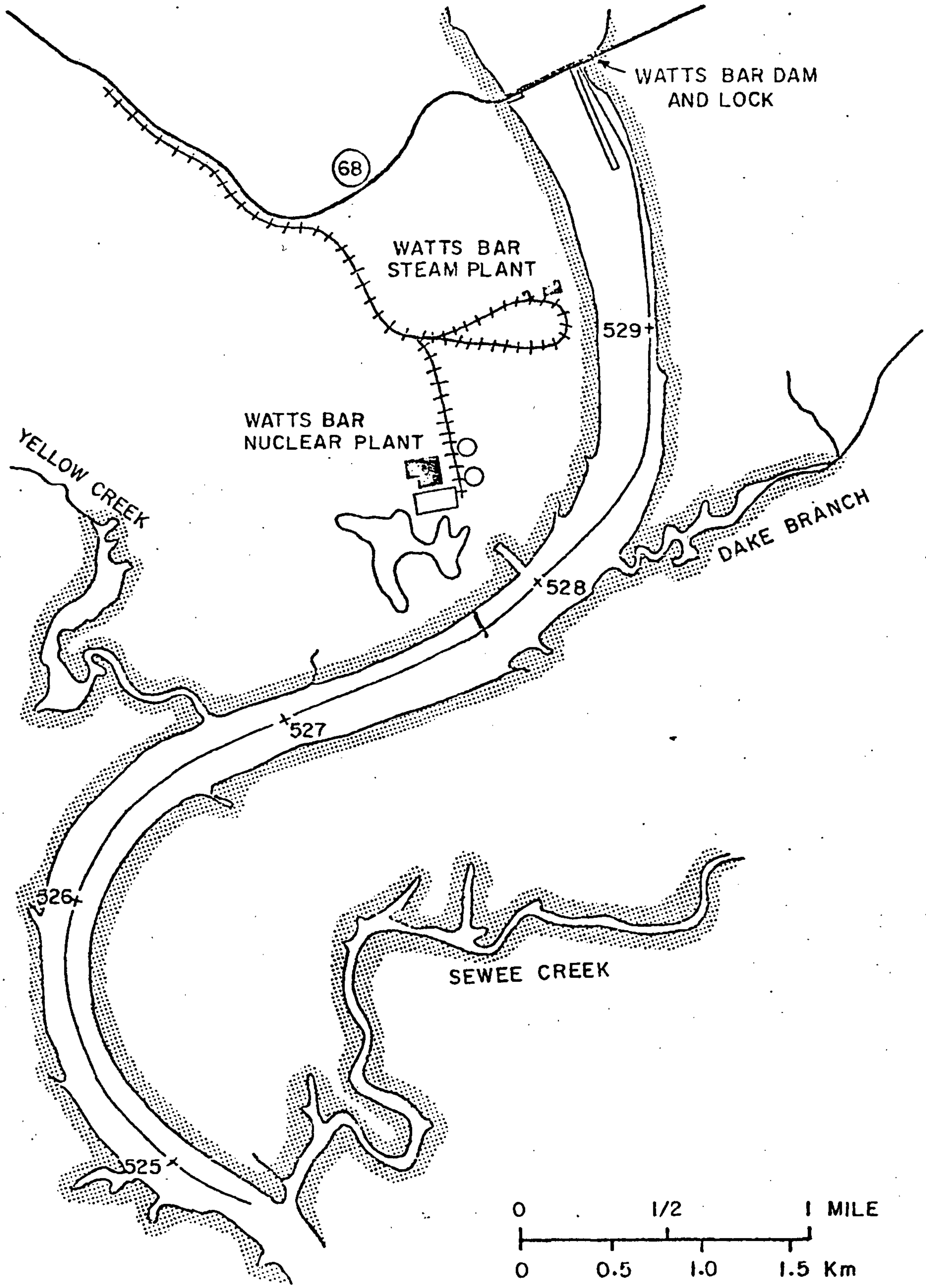


Figure 1: Tennessee River Near Watts Bar Dam

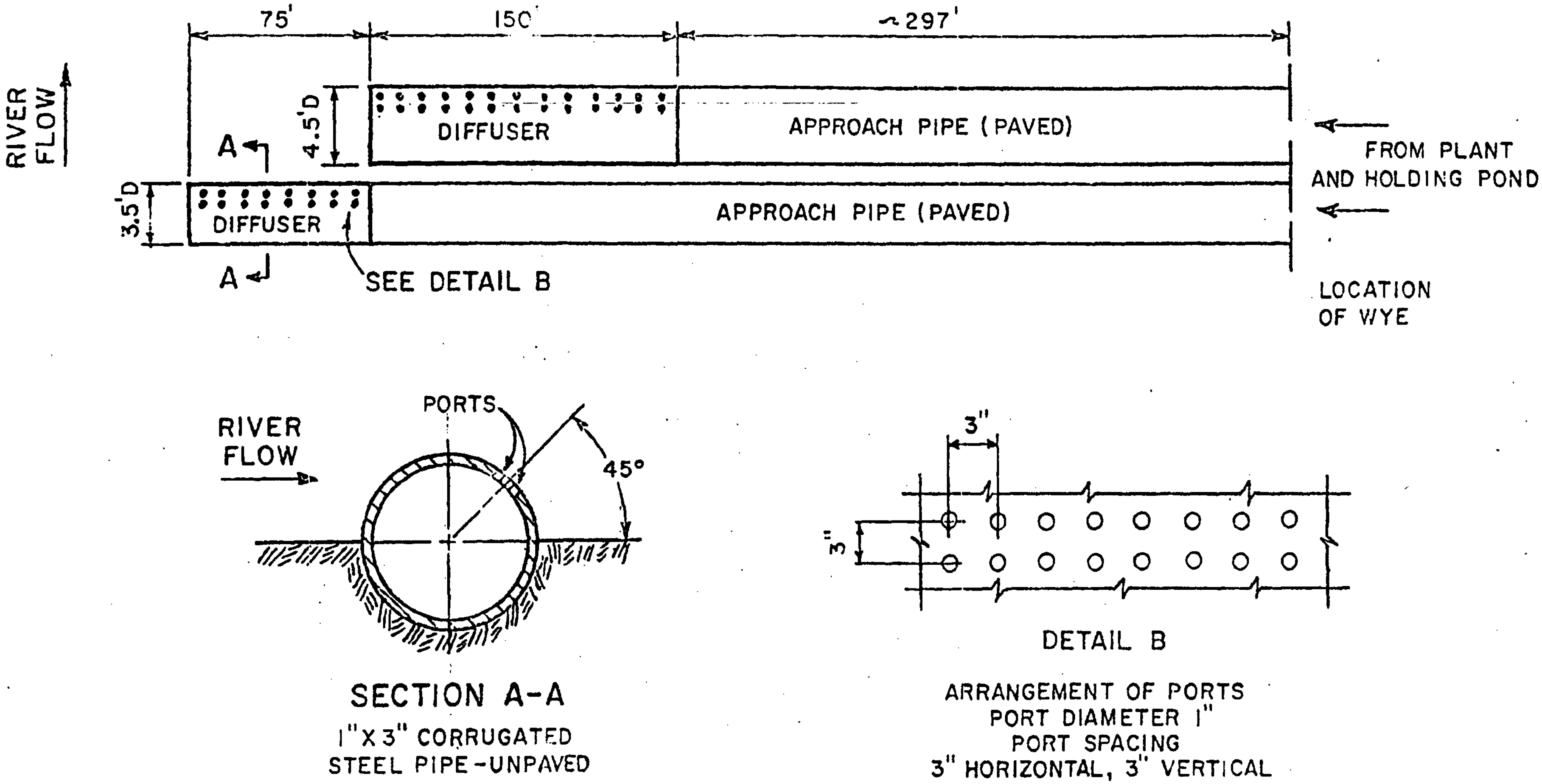


Figure 2: Recommended Diffuser Geometry

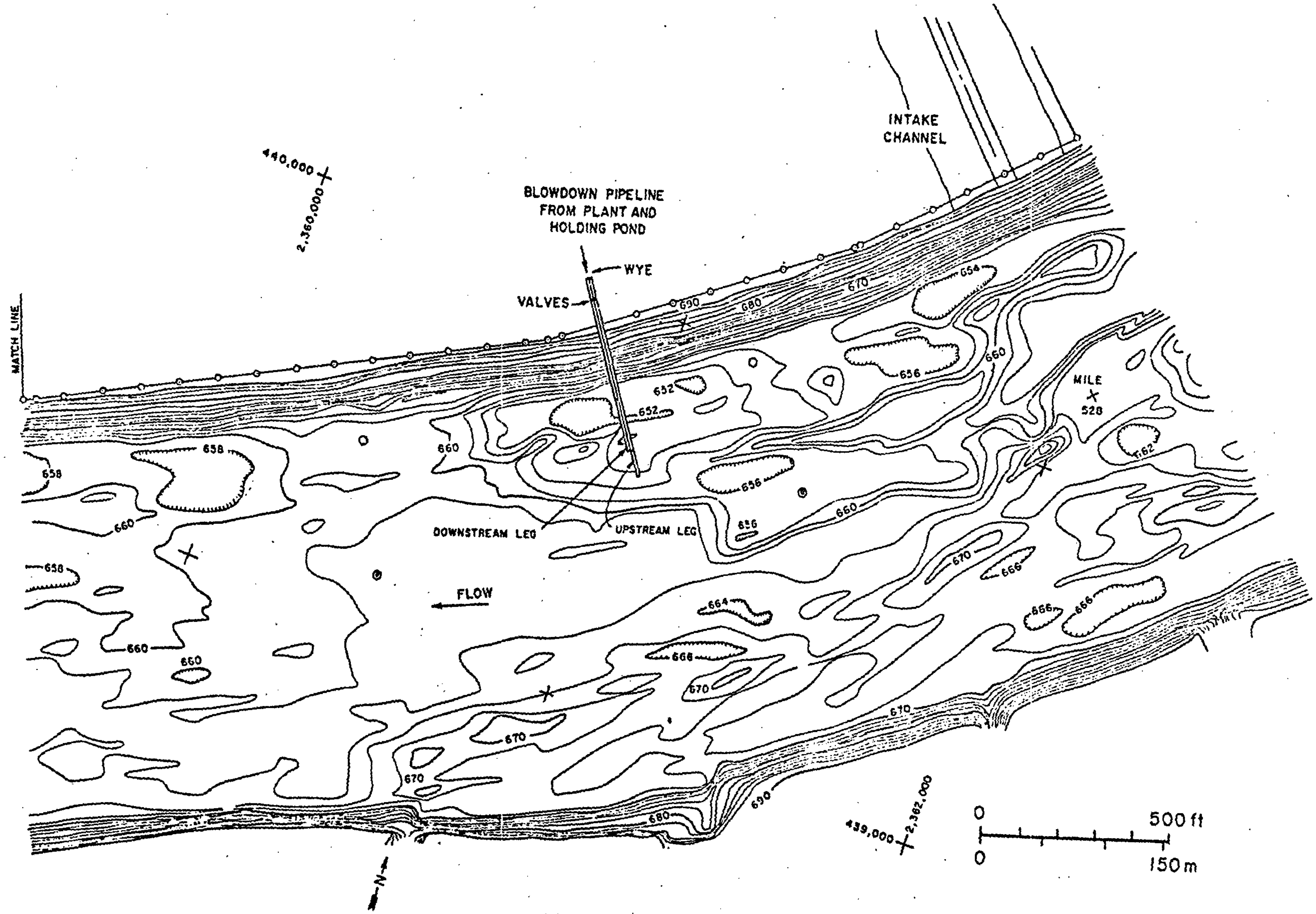


Figure 3 – Location of Multiport Diffuser System

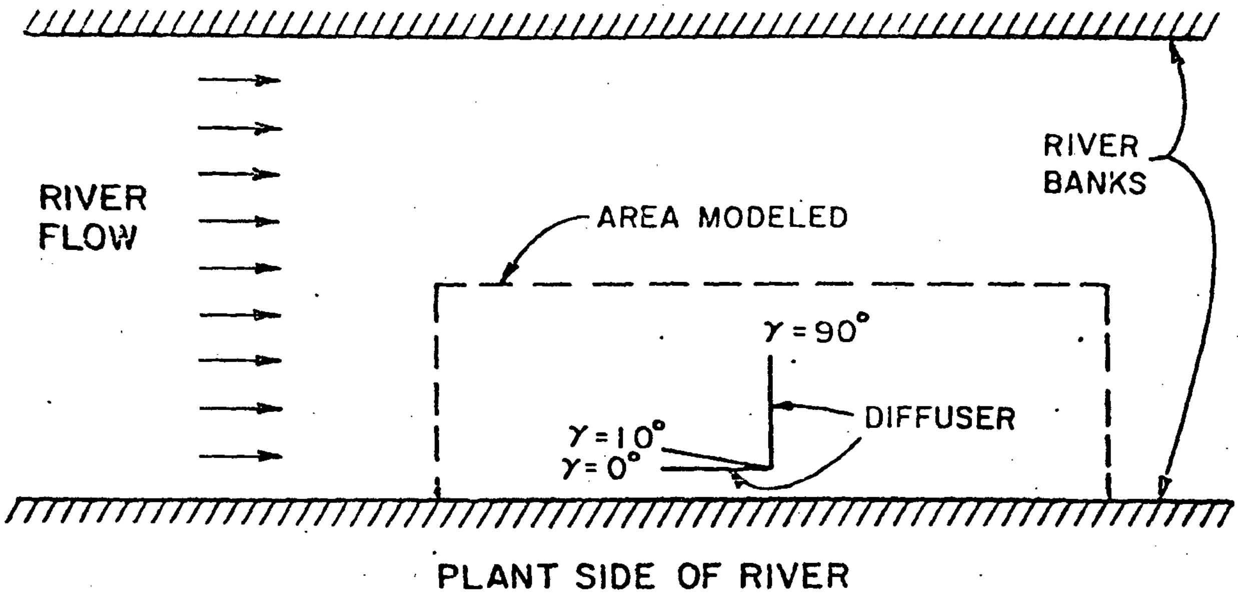


Figure 4 - Plan of Diffuser Model

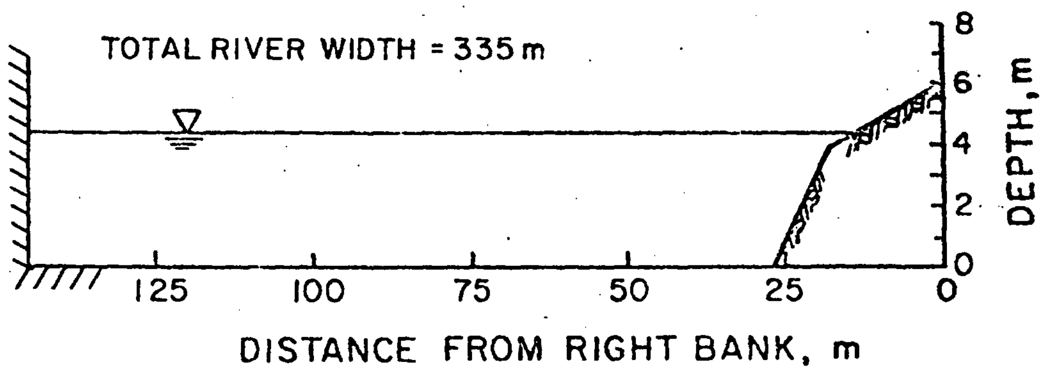
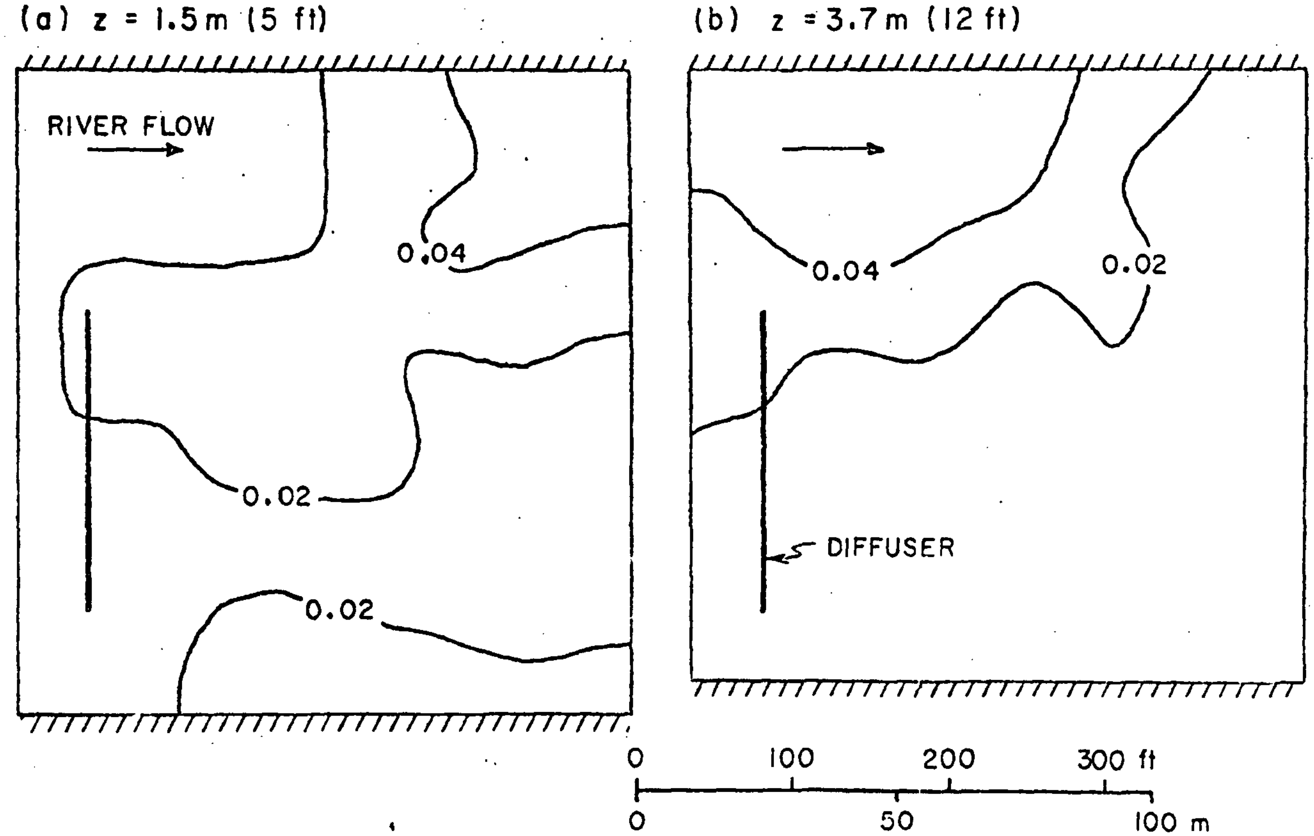


Figure 5 - Model of Prototype River Cross-Section



$\gamma = 90°$

$h = 4.3$ m (14 ft)

$Q_R = 99\ m^3/s$ (3500 cfs)

$B = 1.44$ cm (0.0471 ft)

$\theta = 45°$

Figure 6 - Diffuser Discharge Concentration Plots, L = 59 m (194 ft), g' = -0.05

$\gamma = 90°$

$h = 4.3$ m (14 ft)

$Q_R = 99$ m^3/s (3500 cfs)

$B = 1.44$ cm (0.0471 ft)

$\theta = 45°$

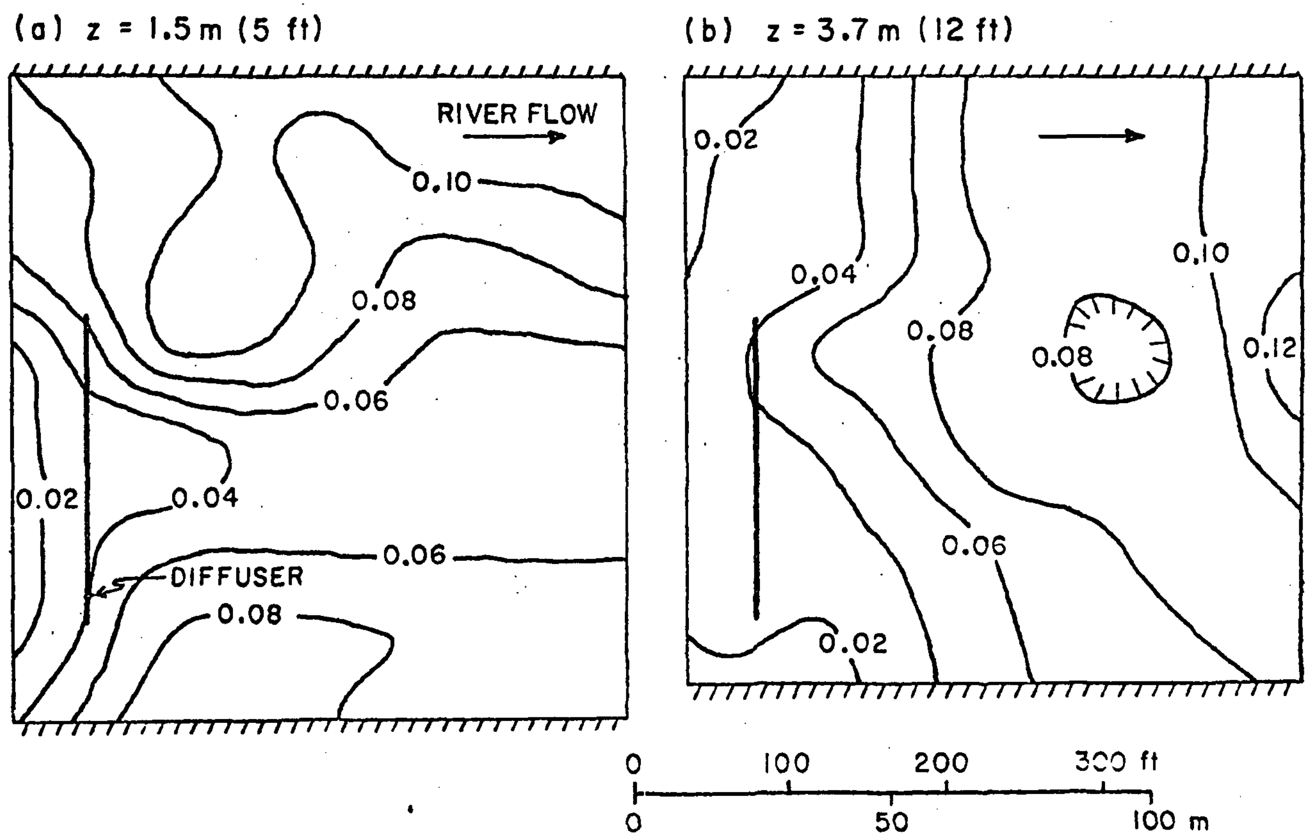


Figure 7 - Diffuser Discharge Concentration Plots, L = 59 m (194 ft), g' = 0.05

$\gamma = 90°$

h = 4.3 m (14 ft)

Q_R = 99 m^3/s (3500 cfs)

B = 1.44 cm (0.0471 ft)

θ = 45°

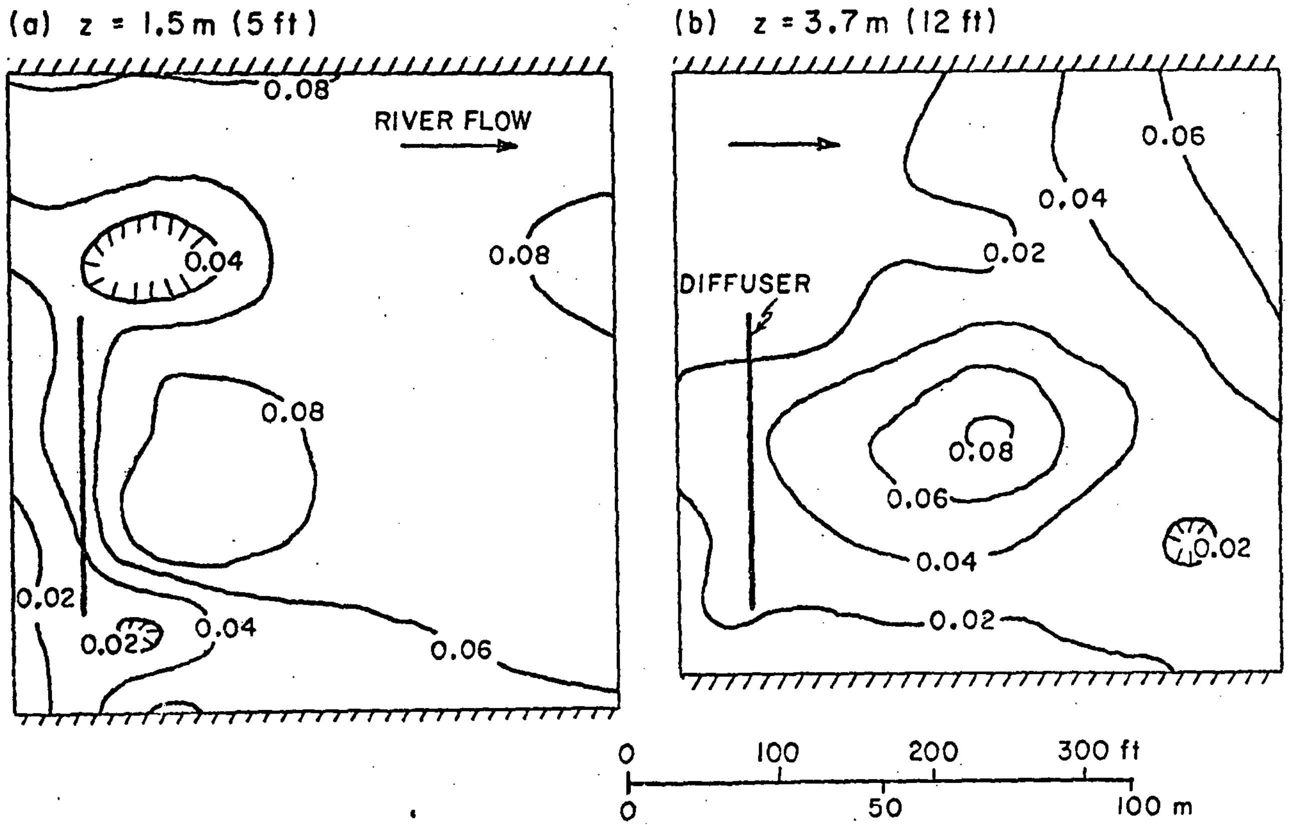


Figure 8 - Diffuser Discharge Concentration Plots, L = 59 m (194 ft), g' = 0.20

$\gamma = 90°$
$h = 4.3m$ (14 ft)
$Q_R = 99 m^3/s$ (3500 cfs)
$B = 1.44$ cm (0.0471 ft)
$\theta = 45°$

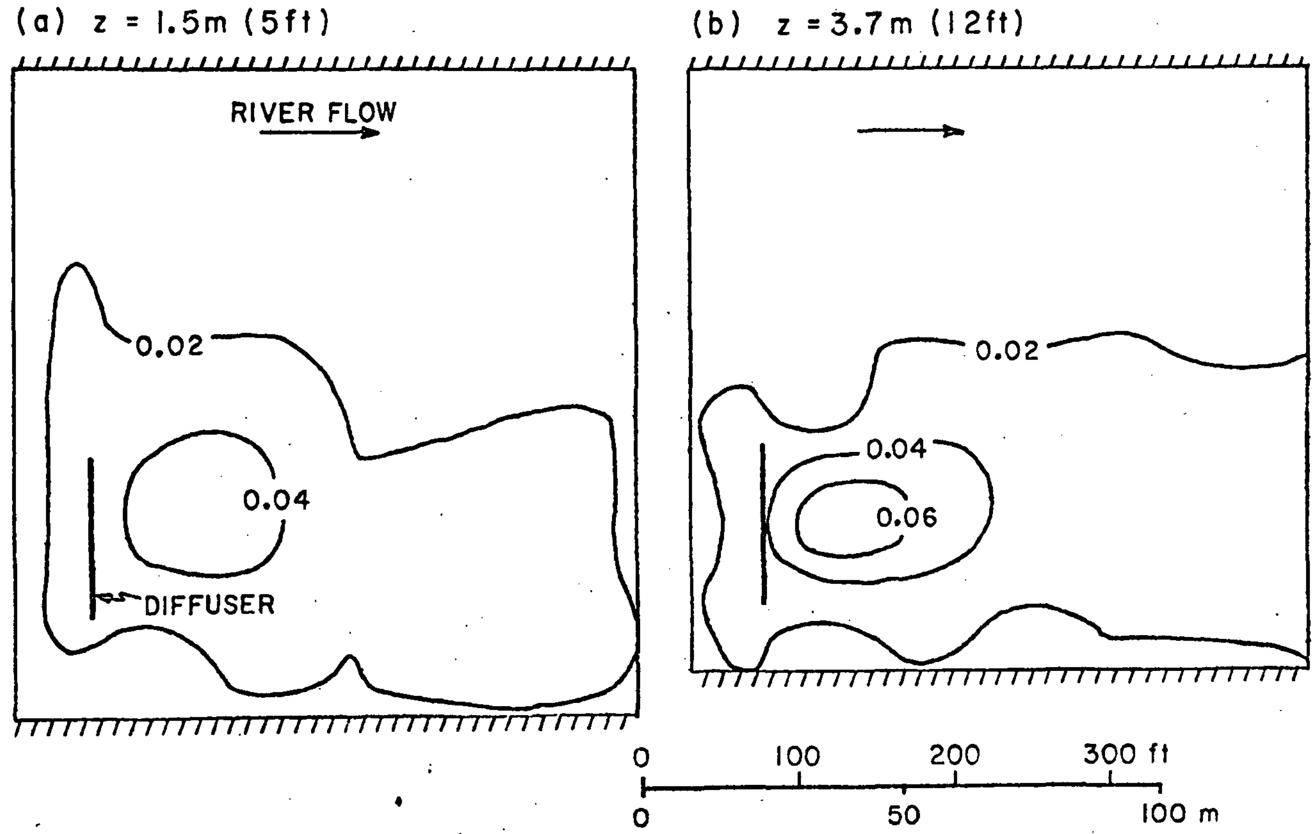


Figure 9 - Diffuser Discharge Concentration Plots, L=31m (102 ft), g'=-0.05

$\gamma = 90°$

$h = 4.3$ m (14 ft)

$Q_R = 99\ m^3/s$ (3500 cfs)

$B = 1.44$ cm (0.0471 ft)

$\theta = 45°$

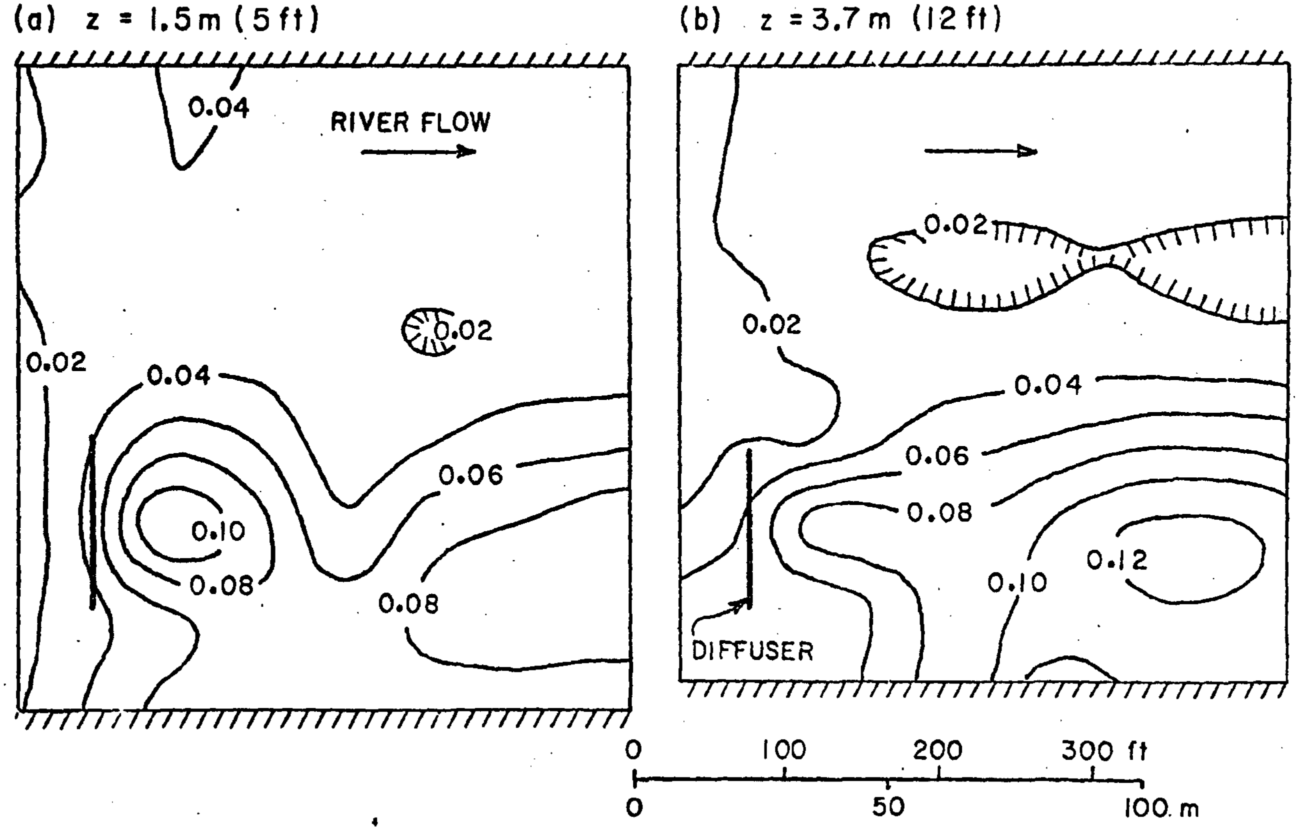


Figure 10 - Diffuser Discharge Concentration Plots, L = 31m (102 ft), g' = 0.05

$\gamma = 90°$
h = 4.3 m (14 ft)
Q_R = 99 m^3/s (3500 cfs)
B = 1.44 cm (0 0471 ft)
θ = 45°

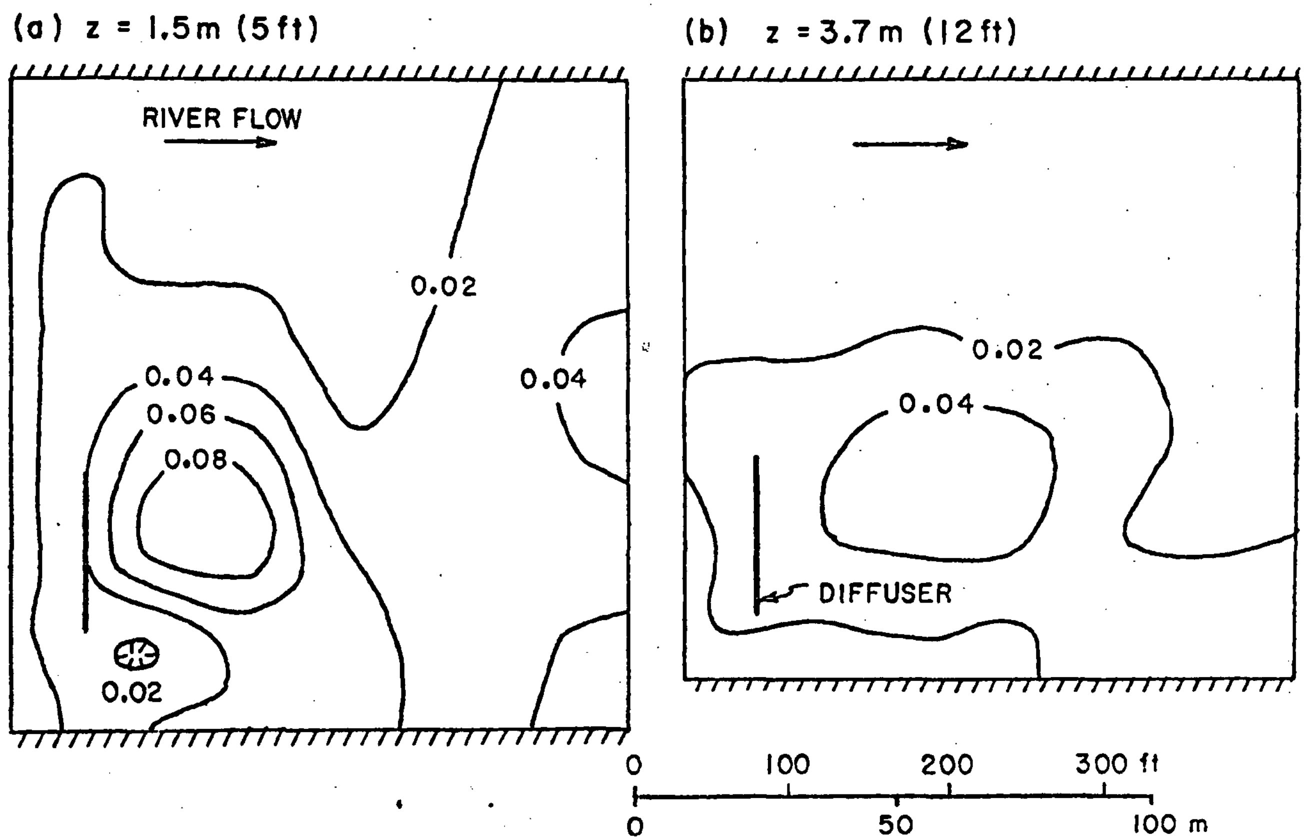


Figure 11 - Diffuser Discharge Concentration Plots, L=31m (102 ft), g'= 0.20

Question Number 4.6:

a. Describe the extent and behavior of the thermal plume under both normal and extreme conditions.

b. Discuss the effects of changes in source and receiving waters attributable to season, winds, unusual weather, currents, etc.

c. Compare the effects of the plume to Tennessee state thermal standards for the water body and to existing thermal conditions of the water body.

d. Include the effects of the plume on the circulation patterns in the receiving water.

e. Define and describe the thermal mixing zone.

f. Discuss the possibility of a thermal barrier or block to fish passage.

Question Number 4.7:

Discuss the thermal models used to evaluate the thermal plume.

Response to Questions 4.6 and 4.7:

It has been found convenient to divide question 4.6 into parts (above) and address these parts and question 4.7 in the same discussion.

The responses to questions 4.6 (parts a,b,d,e) and 4.7 are given in the report entitled "Results of Hydrothermal Model Tests of the Multiport Diffuser System, Watts Bar Nuclear Plant," which is included in the response to Question Number 4.5. This report discusses the models used to evaluate the physical effect of the discharge, the extent and behavior of the discharge plume for normal and extreme conditions, and the proposed thermal mixing zone. The model results indicate that the discharge will have little effect on the lateral or vertical flow pattern of the receiving water. The proposed mixing zone would block approximately 35 percent of the river cross section at the diffuser site and would not cause a barrier to fish passage.

TVA's Final Environmental Statement (FES) on the Watts Bar Nuclear Plant determined that, based on conservative assumptions, the maximum temperature difference between the blowdown and the receiving water before mixing was 49°F. Thus, with a diffuser with the capability of achieving dilution of 10, the FES concluded that the maximum temperature rise outside the area of diffuser-induced mixing due to the blowdown discharge of the plant would be less than the maximum water temperature change of 5.4°F allowed by State of Tennessee temperature standards. The above referenced report (included in the response to Question Number 4.5) shows that the multiport diffuser system at the Watts Bar Nuclear Plant is capable of achieving a dilution of approximately 17 at a minimum Tennessee River flow of 3500 cfs, and thus supports this conclusion.

TVA's FES also found that water temperature records for releases from Watts Bar Dam for 1967-1971 showed a maximum water temperature of 80.6°F. Thus, even with a maximum allowable temperature rise of 5.4°F, the maximum water temperature outside the area of diffuser-induced mixing due to the blowdown discharge from the plant would be less than the maximum water temperature of 86.9°F allowed by State of Tennessee standards.

Because changes in the rate of power production of nuclear plants are gradual (approximately 10 percent per hour), except for emergency situations, changes in the amount of heat in the blowdown will also be gradual. Mixed temperature rises under almost all conditions will be less than 3.6°F because average temperature rises between the blowdown and the river before mixing range from 3°F in October to 20°F in February (see response to Question Number 4.12) and the miltiport diffuser system is capable of achieving a dilution of approximately 17 at minimum Tennessee River flow of 3500 cfs. Therefore the rate of change of the mixed temperature outside the area of diffuser-induced mixing due to the blowdown discharge from the plant will not exceed the maximum rate of temperature change of 3.6°F per hour allowed by State of Tennessee thermal standards, even during a startup or shutdown of the diffuser system.

Question Number 4.8:

It is stated that a ground water system was developed to serve the nuclear plant. Estimate the impact of water consumption by the plant and provide the bases for the estimate. Discuss the effects on nearby groundwater wells.

Response:

The Watts Bar Nuclear Plant maximum ground-water consumption will occur during the final phases of construction; it is expected to be 300,000 gallons per day (GPD) for boiler startup, etc. This use is 42 percent of the system's maximum capacity of 720,000 GPD from two wells. A standy well adds another 144,000 GPD capacity. The Watts Bar Hydro plant and a nearby resort will be furnished a maximum of 200,000 GPD (or 28 percent of the system capacity.

Records during a 72-hour aquifer test indicate that there will be no effect on neighboring wells. At a pumping rate of 400 gallons per minute, the water-level drawdown in the larger yield well was stable at 28 feet. The radius of pumpage effect around the well is estimated to be considerably less than 400 feet, based on measurements in observation wells, and will be confined to TVA property. The nearest domestic well is 1,000 feet to the south of the nearest pumped well.

Features of the ground water supply wells are provided in Table 4.8-1. Locations of these water supply wells is shown in Figure 4.8-1.

TABLE 4.8-1

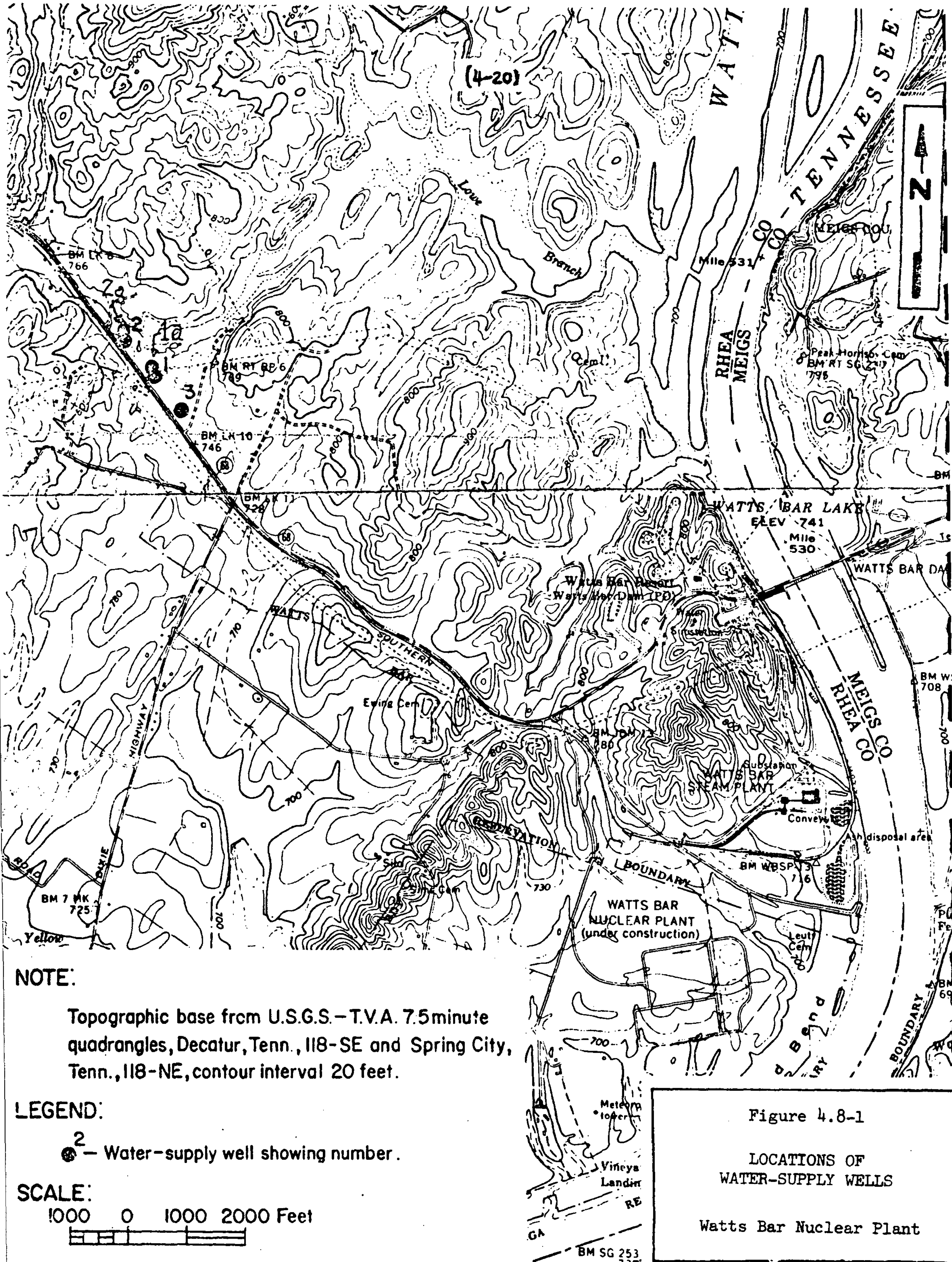
WATER SUPPLY WELLS
(1977 Tests)

WATTS BAR NUCLEAR PLANT

Well No.	Depth ft.	Dia. ft.	Yield GPM	Depth to Static W.L., ft.	Depth to Pumping W.L.,ft.	Water-Bearing Zone Depth, ft.	Depth of Casing ft.	Pump Capacity gpm	Intake Depth ft.
1	(abandoned, replaced by well 1a)								
1a*	250	.7	100	21	89	77-81	60	100	--
2	(abandoned, replaced by well 2a which was completed in January 1977)								
2a	250	.7	400	14	42	230-235	137	400	100+
3**	286	.7	100	15	100	192-193.5	36	100	154

*Standby well

**Currently used for plant supply



NOTE:

Topographic base from U.S.G.S.–T.V.A. 7.5 minute quadrangles, Decatur, Tenn., 118-SE and Spring City, Tenn., 118-NE, contour interval 20 feet.

LEGEND:

$\bullet^2$ — Water-supply well showing number.

SCALE:

1000 0 1000 2000 Feet

Figure 4.8-1

LOCATIONS OF
WATER-SUPPLY WELLS

Watts Bar Nuclear Plant

Question Number 4.9:

Provide a detailed description of the operational monitoring water quality program as outlined in Reg. Guide 4.8.

Response:

In accordance with the requirements of the Federal Water Pollution Control Act Amendments of 1972, TVA on October 19, 1976, filed a Section 402 NPDES permit application (standard form C) with the Regional Administrator, EPA, Region IV, Atlanta, Georgia, for the operational discharges from the Watts Bar Nuclear Plant. The operational NPDES permit, which is expected to be developed and issued by EPA during the present NRC-EPA environmental review process, will be the basis for the development of operational aquatic monitoring programs for the Watts Bar Nuclear Plant. The final NPDES permit will specify the specific effluent limitations for thermal, chemical, and sanitary waste discharges originating from the facilities as well as specific effluent and instream (abiotic and biotic) monitoring and reporting requirements necessary to determine compliance with the effluent limitations. The instream monitoring program will be based upon the results of the pre-operational monitoring program and monitoring requirements associated with the assessment of intake technology under Section 316(b) of the FWPCA.

Because of the comprehensive aquatic monitoring and reporting requirements which will be included in the NPDES permit, TVA has no plans to develop or implement a separate operational monitoring program as suggested in NRC's Regulatory Guide 4.8. This position has already been addressed in the "applicability statement" included in chapter 16, Appendix A, of the Watts Bar Nuclear Plant FSAR.

Question Number 4.10:

Provide detailed information (e.g., location, type, formation groundwater taken from) on the series of monitoring wells that you stated would be installed to provide baseline data. Also, provide all groundwater level data collected to date.

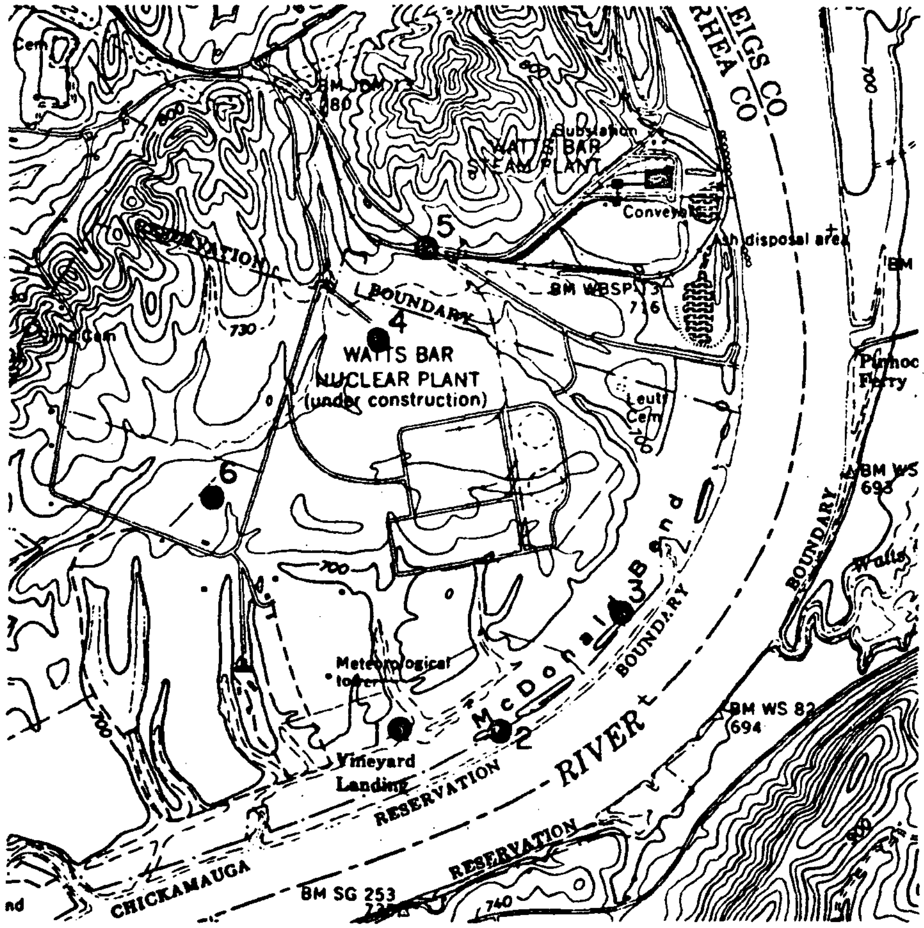
Response:

Locations (and other features) of the groundwater observation wells are specified in Table 4.10-1. Figure 4.10-1 presents these well locations in relation to the Watts Bar Nuclear Plant. Groundwater level data is provided in Figure 4.10-2.

TABLE 4.10-1

DATA ON WATTS BAR NUCLEAR PLANT OBSERVATION WELLS
(See Attached Figure for Ground-water Levels)

Well No.	Location	Well Diameter	Well Depth	Elevation Top of Casing	Aquifer	Remarks
1	530+37 WB+22	.5	150	693.1	Conasauga Shale	Ground-water level records begin January 1973
2	532+21 E2+47	.5	150	680.9	"	"
3	522+30 E18+13	.5	150	683.0	"	"
4	N12+02 W2+48	.5	150	725.4	"	"
5	N20+56 E3+61	.5	150	733.5	"	"
6	S2+09 N23+87	.5	150	720.7	"	Used for temporary water supply from January 1973 through March 1976. Ground-water levels July 1976 to present.
6A	84°47'51" 35°36'04"	.5	150	727.8	"	Ground-water levels, January 1973 through February 1974. Well destroyed by construction in March 1974.



NOTE:

Topographic base from U.S.G.S – T.V.A. 7.5 minute quadrangle, Decatur, Tenn., 118-SE, Contour interval 20 feet.

LEGEND:

●2 – Ground-water observation well showing number.

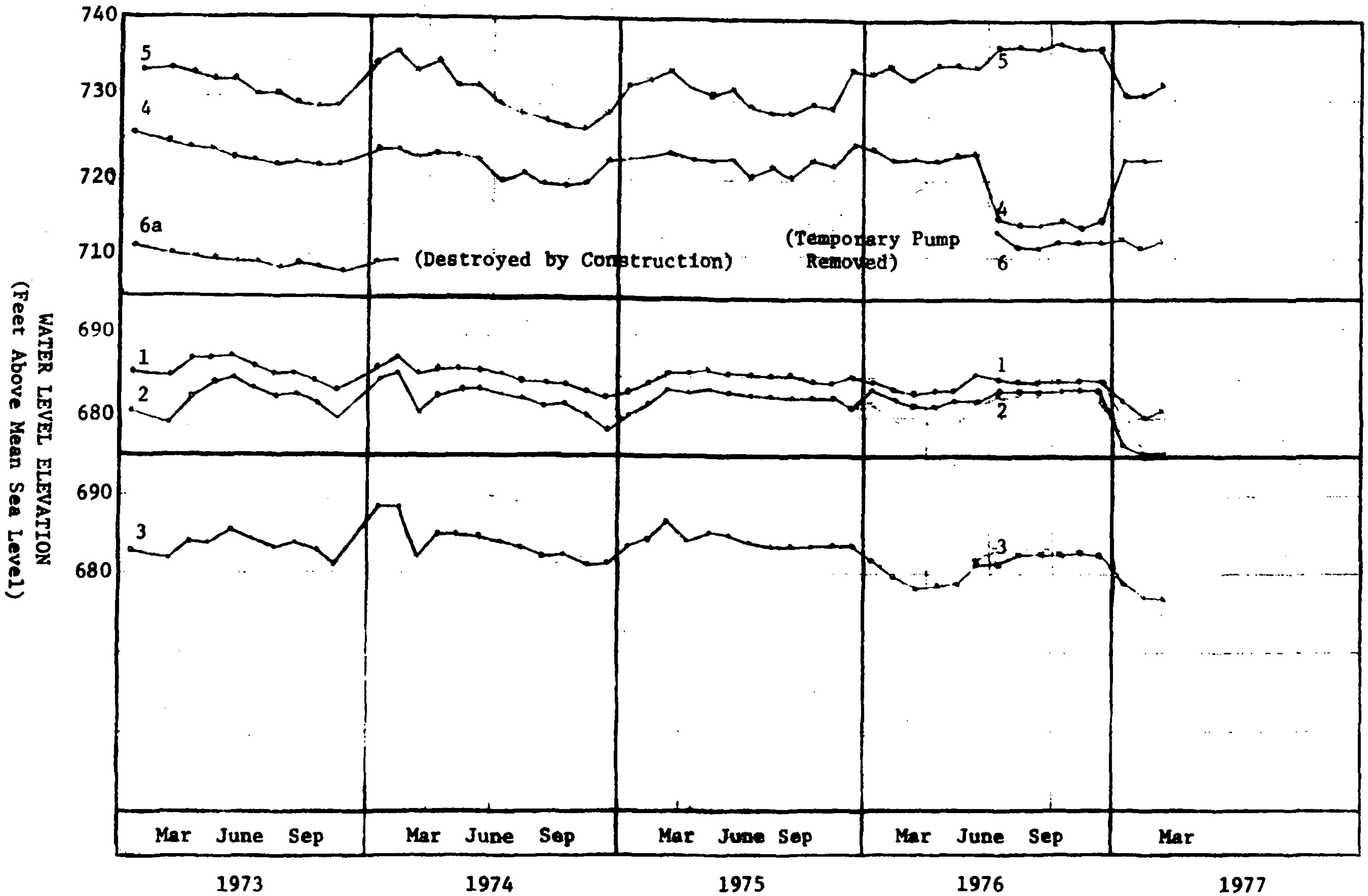
SCALE:

1000 0 1000 2000 Feet

Figure 4.10-1

LOCATIONS OF GROUND-WATER OBSERVATION WELLS

Watts Bar Nuclear Plant



(4-25)

Figure 4.10-2
OBSERVATION WELL GROUNDWATER LEVELS
WATTS BAR NUCLEAR PLANT

Question Number 4.11:

Provide a more detailed discussion on the operational groundwater monitoring program. Show the location of the 5 wells that will be sampled and state the aquifer that the samples will be taken from.

Response:

A well downgradient from the plant will be equipped with an automatic sequential-type sampler from which a composite sample will be analyzed monthly for radioactivity. At least one sample from a groundwater source upgradient from the plant will also be collected on a monthly basis.

Locations of the observation wells are shown in Figure 4.10-1 in the response to Question Number 4.10. As stated in the response to Question Number 4.10, the aquifer is Conasauga Shale.

Question Number 4.12:

Provide the following estimates of the discharge temperatures expected for Units 1 and 2 operating at 100% load:

a. Monthly average discharge temperature.

b. Maximum daily average discharge temperature (for each month).

c. Maximum instantaneous discharge temperature (for each month).

d. Monthly average ambient surface temperature.

e. Maximum daily average ambient surface temperature (for each month).

Table 4.12-1 (included with this response) provides the requested information. Blowdown temperatures rather than discharge temperatures have been provided. The discharge temperature should be equal to the blowdown temperature except when the holding pond contents are discharged. The discharge temperature should be lower than the blowdown temperature when the holding pond contents are discharged because the blowdown stored in the holding pond should lose heat to the atmosphere. The monthly average blowdown temperature plus one standard deviation has been provided in place of the maximum daily average blowdown temperature, which is not available.

The monthly average and maximum temperatures of the releases from Watts Bar Hydro Plant have been given (Table 2.6-1, TVA Final Environmental Statement (FES)). As noted in the TVA-FES, no stratification is expected in Chickamauga Lake in the first 20 miles below Watts Bar Dam. Therefore, Watts Bar Hydro Plant discharge temperatures should give an adequate estimate of surface temperatures at the plant site.

The thermal discharge from the Watts Bar Steam Plant will affect water temperatures at the plant site. Field surveys of the effects of the thermal discharge from Watts Bar Steam Plant show that during periods of releases from Watts Bar Hydro Plant, water temperatures at the plant site will be increased 0-1°F by the thermal discharge from Watts Bar Steam Plant. During and immediately following periods of no releases from Watts Bar Hydro Plant, water temperature at the plant site will be increased 1-3°F by the thermal discharges from Watts Bar Steam Plant.

Table 4.12-1

Summary of Blowdown and River Temperatures
Watts Bar Nuclear Plant

	Blowdown Temperature[1]			River Temperature[2]	
	Monthly Average (°F)	Monthly Average +σ (°F)	Trihourly Maximum (°F)	Monthly Average (°F)	Weekly Maximum (°F)
January	63	69	81	44	46
February	64	68	80	44	47
March	68	74	84	49	52
April	74	79	87	59	62
May	78	83	89	66	68
June	82	86	91	73	75
July	85	87	92	76	78
August	84	88	93	77	81
September	81	85	90	76	78
October	74	80	87	71	78
November	68	75	85	59	72
December	66	71	83	50	54

Notes:

1. Based upon National Weather Service data at Chattanooga 1963-1973.

2. Based upon Watts Bar Hydro Plant releases, weekly observations 1967-1971, Table 2.6-1, TVA FES.

Question Number 4.13:

Provide the bases for statements, on page 2.10-2 of the Watts Bar Nuclear Plant Environmental Statement, that the plant water use will not affect recreational use of the Chickamauga Reservoir, nor will it affect known or projected industrial water use downstream.

Also, assess the impact of water consumption on downstream consumers and on competing demands (i.e., agriculture, drinking, sewage, etc.) for available water.

Response:

TVA bases its conclusion regarding the impact of the Watts Bar Nuclear Plant upon recreational and industrial use of the Chickamauga Reservoir (stated on page 2.10-2 of the FES) on: (1) total water supply availability, (2) reservoir pool elevations, and (3) chemical and physical characteristics. It is concluded that neither the water use nor the water consumption associated with the Watts Bar Nuclear Plant would have a significant impact on other downstream uses.

With respect to the insignificances of plant water use, an evaluation of the data presented in the third paragraph on page 2.10-2 would show that on a year-round basis the plant water use if entirely consumed (86 MGD) would be approximately 0.5 percent of the mean annual flow (17.2 BGD) past the site. In actuality, plant water consumption by evaporation would only be about 43 MGD. Correspondingly, the plant water consumption, i.e., water not ultimately returned to the river, would be about 0.25 percent of the mean annual flow. Therefore, neither the plant water use nor the plant water consumption are significant portions of the total streamflow available at the site and remaining streamflow available downstream from the site.

The accuracy of the streamflow measured is at best within ±2 percent of the total streamflow. Thus on a long-term basis, neither the total water use nor the consumptive use at Watts Bar Nuclear Plant could be detected by direct streamflow measurement.

Chickamauga Reservoir is a multipurpose reservoir which is operated in accordance with an established rule curve for purposes of navigation, flood control, and hydroelectric power generation. Consumptive water use at Watts Bar Nuclear Plant *per se* would have no measurable impact on the streamflow through, or the pool elevation of, Chickamauga Reservoir as it is operated in accordance with its statuatory purposes.

As stated in Sections 2.4, 2.5, and 2.6, the discharges from the Watts Bar Nuclear Plant would have only minimum effects on the chemical and physical characteristics of Chickamauga Reservoir.

5. RADIOLOGICAL

Question Number 5.1:

Provide a discussion of the agricultural productivity of the region within fifty miles of the Watts Bar site. Indicate to what extent these activities are typical of the State of Tennessee.

Response:

Table 5.1-1 provides a summary of agriculture in counties within a 50-mile radius of the Watts Bar Nuclear Plant using 1974 data. Within a 50-mile radius of the Watts Bar Plant there is a total of 30 counties of which five are located in Georgia, one in North Carolina, and the remainder in Tennessee.

The agriculture in the area is typical of that of east Tennessee. There is a total of almost 20,000 farms in the 30-county area, which represents 19 percent of the farms in the State of Tennessee. Farms within the area sold a total of $194.9 million worth of farm products in 1974 or an average of $9,838 per farm. Comparable data for the State of Tennessee was a total of $926.1 million where the average value of farm products sold per farm was $9,038. The area thus produced 21 percent of the value of agricultural products sales of the State of Tennessee.

Average size of farm is 117 acres compared to 130 acres for the State of Tennessee. Land in farms in the 30-county area accounted for 17.5 percent in farms in Tennessee. A greater proportion of cropland was used for pasture in the area than was true for the State of Tennessee.

Cattle and calves and milk cows were more important in the area than were feeder pigs and market hogs. The attached table shows that broilers are extremely important in the area within a 50-mile radiusof the Watts Bar Plant. Broilers sold within 50 miles are produced in counties in Tennessee, North Carolina, and north Georgia. The north Georgia counties have a high concentration of broiler production. The total broiler production within a 50-mile radius of the plant amounts to 118 percent of the total broilers sold within the entire State of Tennessee. Excluding the broilers produced in north Georgia and North Carolina, the region around Watts Bar solely contained within Tennessee would produce 65 percent of all broilers produced in Tennessee. Hence, broilers are a much more important product in the area at Watts Bar than they are in the remainder of Tennessee. On a productivity basis the area is thus more dependent on livestock and livestock products than it is on crops and it is slightly more concentrated in its production per farm or per acre in terms of dollars than the State of Tennessee.

The table also shows acreages of various crops produced. Hay, vegetables, and orchard crops are important crops in the area and account for from 23 to almost 50 percent of these crops produced in Tennessee.

Response to Question Number 5.1 (continued)

Tabacco is an important crop in the area. However, the yield is lower than the Tennessee average. Corn is a much more important crop than soybeans or wheat, which are the other two crops produced in the area. The average yield of corn is the same as the Tennessee average while the yield of soybeans and wheat is higher than the average for Tennessee.

The area is more dependent on specialty crops and livestock or livestock products than is true for the State of Tennessee and therefore it compares more favorably in terms of dollar volume than would the State of Tennessee as a whole.

TABLE 5.1-1
A Summary of Agriculture in Counties Within a 50-Mile Radius of the Watts Bar Nuclear Plant

Item	Area within 50-Mile radius	State of Tenn.	Area as a % of State of Tenn.
Number of farms	19,811	102,474	19.3
Tot. value of farm products sold (1974)	$194,911,000	$926,132,000	21.0
Ave. value of farm product sales/farm	$9,838	$9,038	-
Land in farms (acres)	2,328,050	13,314,243	17.5
Average size of farm (acres)	117.5	129.9	-
Total cropland (acres)	1,204,620	7,783,829	15.5
Ave. amount of cropland/farm (acres)	60.8	76.0	-
Tot. acres of cropland harvested	437,982	3,727,190	11.8
Ave. amount of cropland harvested/farm (acres)	22.1	36.4	-
Total acres of cropland used for pasture	696,661	3,534,009	19.7
Ave. amount of cropland used for pasture/ farm (acres)	35.2	34.5	-
Number of all cattle and calves on farms	585,338	2,745,893	21.3
Ave. number of cattle and calves/farm	29.5	26.8	-
Number of milk cows on farms	62,096	238,528	26.0
Number of hogs and pigs on farms	102,758	696,873	14.7
Number of chickens 3 months old or older on farms	2,229,433	4,759,696	46.8
Number of broilers sold	38,965,421	32,966,544	118.0
Crop Production			
Acres of hay	247,664	1,043,861	23.7
Acres of vegetables	14,564	29,824	48.8
Land in orchards (acres)	1,276	5,620	22.7
Acres of tobacco harvested	5,303	56,540	9.4
Ave. yield of tabacco (pounds/acre)	1,945	1,960	-
Total pounds of tabacco produced	10,315,800	110,945,000	9.3
Acres of corn harvested	101,720	570,000	17.8
Average yield of corn (bushels/acre)	61	61	-
Total production of corn (bushels)	6,299,140	34,770,000	18.1
Acres of soybeans harvested	42,510	1,520,000	2.7
Ave. yield of soybeans (bushels/acre)	24.4	21	-
Total production of soybeans (bushels)	1,037,600	31,920,000	3.2
Acres of wheat harvested	23,180	325,000	7.1
Ave. yield of wheat (bushels/acre)	31.3	29	-
Total production of wheat (bushels)	726,990	9,425,000	7.7

Data Sources: 1974 U.S. Census of Agriculture (Preliminary) and State Corp Reporting Services, 1974, (for Tennessee, Georgia, and North Carolina).

6. SOCIOECONOMIC EFFECTS

Question Number 6.1:

The TVA-FES for the Watts Bar Nuclear Plant was published in November 1972. No updated socioeconomic data was provided to the staff in the November 1976 Environmental Information Watts Bar Nuclear Plant, Unit Nos. 1 and 2, ER Supplement. We therefore require an update of any change in the data and/or the analysis of the information presented in the following sections of the TVA-FES: 1.1.3(8), 2.2.5(3), 2.10, 8.2.4(7), (8), (10).

Response:

Provided in this response are updates discussing any information relevant to operation of the facility that is different from that contained in the FES.

FES Section 1.1.3(8)

(b) Transportation--I-75, which is 12 miles east of the plant, is now completed.

(c) Farming--First paragraph, there has been no significant change in the land cover statistics.

Second paragraph, according to the 1974 Census of Agriculture (Preliminary), there were 790 farms in Rhea and Meigs Counties with gross sales of $6,701,000. Of these, 313 were classified as commercial and 477 as subsistence farms. The commercial farms accounted for gross sales of $6,389,000, while the subsistence farms had gross sales of only $312,000. Information is not yet available regarding dairy farms.

(g) Population Distribution--See response to Question Number 1.1.

(h) Waterways--In 1975, traffic through the Watts Bar Lock was 375 thousand tons while for the Tennessee River, the total was 28.3 million tons.

FES Section 8.2.4(8)

Since November 9, 1972, options have been taken on about 2,200 acres of land within the five-mile study area. This locale is identified as Smith Bend on Chickamauga Reservoir between river miles 520 and 525. A Chattanooga Times news story from Dayton, Tennessee, dated February 26, 1976, reported that Exxon Corporation had acquired the options for the purpose of creating a new industrial site. The higher values per acre reflected in the options indicate industrial real estate market price levels. These options have since been exercised.

FES Section 8.2.4(10)

This section stated that 967 acres of land would be committed for the use of power production during the lifetime of the plant and that restricted use of 3,165 acres of transmission line rights of way would result during the lifetime of those lines. Instead, the land commitment for the plant is 970 acres while restricted use of approximately 2,008 acres of new transmission line rights of way are expected to result.

Question Number 6.2:

For both the construction and operating forces directly associated with the facility, provide current estimates for the following:

(a) Total employment (update Tables 2.9-2 and 2.9-3),
(b) Breakdown of workers' residential characteristics as follows:

1. Average annual population of relocating workers. Differentiate between plant employees who change place of residence for the project ("relocatees") and those residing in the area during the week and returning to permanent place of residence on weekends ("transients");

2. Family characteristics of "relocatees" (Marital status, average number of school age children and the average age of same);

3. Housing preferences of "transients" and "relocatees", and

4. Probable residential location of "transients" and "relocatees".

Response:

(a) Update Table 2.9-2 is as follows:

Projected Construction Employment

Watts Bar Nuclear Plant

Month	Employment	Month	Employment
December 1972	24	June 1977	3275
June 1973	738	December 1977	2925
December 1973	1170	June 1978	2450
June 1974	1594	December 1978	1925
December 1974	1940	June 1979	1200
June 1975	2231	December 1979	775
December 1975	2579	June 1980	525
June 1976	2766	December 1980	350
December 1976	3161	June 1981	0

Updated Table 2.9-3 is as follows:

Projected Permanent Employment

Watts Bar Nuclear Plant

Month	Projected Employment
December 1976	30
March 1977	85
June 1977	125
September 1977	135
December 1977	170
March 1978	180
June 1978	190
September 1978	200

Average annual 1975 wage for plant staff was approximately $14,500.

(b) The only available information regarding construction workers is contained in construction employee survey reports. Three of these reports (six copies of each) have been included in a separate package that is being transmitted directly to the NRC Staff Environmental Project Manager (on Watts Bar Nuclear Plant) for distribution to the appropriate NRC staff technical reviewer(s).

With respect to operating employees, no data have been gathered regarding their family characteristics or housing choices. The distribution of the present operating force at the Watts Bar Steam Plant is 23 percent in or around Spring City, 16 percent in or around Dayton, 8 percent in or around Decatur, and 6 percent in or around Athens. The remainder was spread among approximately 20 other towns, none of which contained 5 percent or more of the total.

Question Number 6.3:

Describe past, present and proposed efforts in the provision of technical and financial assistance to the local and regional jurisdictions impacted by Watts Bar Nuclear Plant.

Response:

Impact assessments during the project planning phase revealed that local school systems were likely to be adversely affected by the in-moving work force. In anticipation of this impact, TVA provided two portable classrooms to Rhea County for use beginning in the 1973-74 school year. Also, the financial equivalent of three classrooms and one school bus ($75,000) was provided to Meigs County for use beginning in the 1975-76 school year. Recently, one bus was provided to Rhea County for use in the 1976-77 school year. Monitoring will continue and future actions will be based upon the level of impacts identified. Because of the interest expressed by the project workers, TVA is assisting in developing an employee transporation program utilizing buses and van pools. Assessments during the project planning stage and experience during the construction phase have revealed no other project impacts requiring mitigation.

Question Number 6.4:

Provide current population distribution data and updated population projections within a 10-mile radius.

Response:

See response to Question Number 1.1.

Question Number 6.5:

Supply staff with maps illustrating current land use within a 10-mile radius of the site.

Response:

Six copies of a map and accompanying overlay showing the currently available land cover and ownership information in the vicinity of the plant site have been included in a separate package that is being transmitted directly to the NRC staff Environmental Project Manager (on Watts Bar Nuclear Plant) for distribution to the appropriate NRC staff technical reviewer(s).

8. METEOROLOGY

Question Number 8.1:

Provide diurnal and monthly averages and extremes of temperatures, dew point, and relative humidity based on recent long term (e.g., 30 years) climatic data. This information should be fully documented and substantiated as to the validity of its representation of expected long-term conditions at and near the site.

Response:

The response to this question is provided in the Watts Bar Nuclear Plant FSAR Section 2.3.2 and Tables 2.3-2, 2.3-3, 2.3-7, 2.3-8, 2.3-9, 2.3-10, and 2.3-11.

Question Number 8.2:

Provide at least two annual cycles (preferably three or more whole years), including the most recent one-year period, of monthly and annual onsite wind speed and direction data in joint frequency form at all heights of measurement representative of wind characteristics for points of effluent release to and transported within, the atmosphere.

Response:

The response to this question is provided in the TVA response to NRC Item B.1.a on Appendix I.

Question Number 8.3:

Provide monthly and annual joint frequencies of wind direction and speed by atmospheric stability class at heights and intervals relevant to atmospheric transport of effluents within 50 miles of the site. These data may be supplemented by nearby representative stations.

Response:

The response to this question is provided in the TVA response to NRC Item B.1.b on Appendix I.

Question Number 8.4:

Provide information concerning the number of hours with precipitation, rainfall rate distributions and monthly precipitation wind roses.

Response:

The response to this question is provided in the TVA responses to NRC Item B.1.c on Appendix I and NRC Request Item 5 on Appendix I meteorological information acceptance review.

Question Number 8.5:

Discuss the impact of existing levels of air pollution and station operation.

Response:

Existing levels of air pollution in the Watts Bar Nuclear Plant area are so low that no impact on operation of the Watts Bar Nuclear Plant is expected.

Question Number 8.6:

Discuss the relationship of the meteorological data gathered on a regional basis to onsite data.

Response:

The response to this question is provided in the Watts Bar Nuclear Plant FSAR Sections 2.3.1.3, 2.3.2, and 2.3.3.3 and the TVA response to NRC Item 1 on Appendix I meteorological information acceptance review.

Question Number 8.7:

Provide a discussion of the effect of local topography on meteorological conditions in the Watts Bar area.

Response:

The response to this question is provided in the Watts Bar Nuclear Plant FSAR Sections 2.3.1.2, 2.3.2.2 (pages 2.3-7 and 2.3-8), 2.3.3.3, and 2.3.4.2 and the TVA response to NRC B.2.e and Appendix I.

Question Number 8.8:

Provide monthly mixing height data.

Response:

The response to this question is provided in the Watts Bar Nuclear Plant FSAR Section 2.3.2.2 (pages 2.3-8) and the TVA response to NRC Item B.2.c on Appendix I.

Note: These are seasonal and annual values that were readily available. The latter (for Appendix I) had values interpolated with lesser precision, only to the nearest 50 meters, than the former.

Question Number 8.9:

For assessment of the impact of station operation on the environment, provide data summaries (e.g., moisture deficit, visibility, solar radiation) to support your conclusions of the frequency and extent of fogging and icing conditions as a result of the use of natural draft cooling towers and of other impacts on the environment.

Response:

Solar radiation data are not applicable to analysis of shading effects from the cooling tower plume(s) because there is a high incidence and much variability of natural cloudiness related to temporal variations of synoptic conditions in the site area. Data on fog are presented in FES section 2.6.2(2) and in FSAR section 2.3.2.2 and table 2.3-12. Atmospheric moisture deficit values were calculated from Nashville rawinsonde data from the FES analysis of natural draft cooling tower plume behavior. Onsite atmospheric moisture deficit values can be calculated from the dew point and dry bulb temperature data for the 4-foot level which are recorded on the magnetic data tape provided to the NRC in response to Item B.1.b on Appendix I. As a result of March 2 and March 7, 1977, telephone discussions between Norris Nielsen, TVA Meteorologist, and Leta Andrews, NRC meteorologist, NRC use of only the onsite moisture data is planned for the operating license stage EIS.

Question Number 8.10:

Provide appropriate summaries of joint humidity data along with the joint wind speed, stability category, and the wind direction frequencies for heights related to the estimation of cooling tower moisture dispersion for at least one annual cycle in order to provide a basis for the estimation of the impact of tower operation on the environment. If detailed site-specific meteorological data as described above are not available, you may present information applicable to the general site area from the National Weather Service or other authoritative sources.

Response:

Nashville rawinsonde data were used in lieu of onsite data for the FES analysis of natural draft cooling tower plume behavior. However, as is stated in the response to NRC Question 10, the two-year onsite data tape provided previously will be used as the source of data for NRC's evaluation relative to preparation of the operating license stage EIS. It should be noted that use of 4-foot level dry bulb and dew point temperature data will provide somewhat conservative results (i.e., longer visible plumes on the average) due to higher average moisture content of the air at the level than at plume heights. Wind data for the 300-foot level of the onsite meteorological tower should be used as it will better respresent air flow at plume height than will the 33-foot wind data. However, compared to the FES plume direction frequencies based on the Nashville rawinsonde data, the plume direction frequencies based on 300-foot onsite onsite wind data can be expected to show greater upvalley and downvalley frequencies and less crossvalley frequencies.

Question Number 8.11:

Discuss the techniques used to estimate the change in cooling tower plume width as a function of distance and direction from the cooling tower.

Response:

The analysis of cooling tower plume impact was concerned exclusively with plume length. Explanation of the method of analysis is stated in FES Section 2.6.2(2). As stated in the text, plume lenths were computed for sixteen $22\frac{1}{2}^{o}$ compass point sectors. The plume was assumed to fill the sector, and plume width was not computed.

Question Number 8.12:

Compare the Paradise Steam Plant site (which was used in making estimates of cooling tower plume length for Watts Bar) and the Watts Bar site with respect to parameters (e.g., wind, stability, humidity) related to cooling tower plume dispersion.

Response:

The Watts Bar Nuclear Plant site is located in the Great Valley of the Tennessee River, between the Cumberland Plateau and the Great Smoky Mountains. The valley-ridge orientations are roughly northeast-southwest. Within 15 miles, the significant topographical features in the Watts Bar area include Walden Ridge (200 to 1100 feet above plant grade) to the west and a series of lower ridges (100 to 300 feet above plant grade) to the east. The Paradise Steam Plant site is located in the Green River Valley in western Kentucky, where there are no major valley-ridge terrain features. Within a 15-mile radius of the Paradise site, the topographic features consist of rolling hills (generally [illegible] to 200 feet above plant grade).

Response: (continued)

The climate at both sites is primarily temperate continental and dominated much of the year by the Azores-Bermuda anticyclonic circulation. This circulation is most pronounced in the late summer and fall and produces extended periods of fair weather. In the winter and early spring, the circulation patterns become diffuse with relatively more frequent passage of high and low pressure systems and associated air mass fronts. This causes frequent changes in the local winds, stability, precipitation, and other meteorological variables. The values of meteorological parameters related to cooling tower plume dispersion (wind, stability, temperature, and humidity) can be affected by both local and regional topographic features. Temperature and humidity patterns provide information on atmospheric moisture content and absolute humidity deficit.

The wind at the Paradise site is most frequently from the south and southwest, with a secondary maximum from the northwest. This wind direction frequency distribution is representative of regional flow patterns in western Kentucky.[1] At the Watts Bar site, onsite data show the most frequent wind directions are southwesterly (upvalley) and northeasterly (downvalley), roughly parallel to the local valley-ridge terrain. The winds at and above the level of release from the cooling towers (approximately 500 feet high) are less affected by the topographic channeling. Therefore, it is expected that frequencies of southwest and northeast wind directions will be reduced and frequencies of south and west through north wind directions will be significantly greater. However, Paradise probably has a more uniform frequency distribution of wind direction and somewhat higher wind speeds than Watts Bar at cooling tower plume heights.

There is a significantly greater potential for air stagnation conditions in the Watts Bar area than in the Paradise area.[2,3] This is coincident with a somewhat greater frequency of stable atmospheric conditions, including limited layer mixing.

The differences in the topographic features and the air stagnation potential at these two sites, the greater evapotranspiration in the Watts Bar area, and the similarity of the temperature patterns at both sites appear to contribute to slightly greater relative moisture content in the atmosphere and consequent slightly smaller absolute humidity deficits, on the average, at Watts Bar.

REFERENCES

1. U.S. Department of Commerce. Climatic Atlas of the United States, ESSA, EDS, 1968. (Reprinted by NOAA, 1974).

2. Korshover, J. "Synoptic Climatology of Stagnating Anticyclones East of the Rocky Mountains, 1936-1970," NOAA Technical Memorandum ERL ARL-34, U.S. Department of Commerce, Air Resources Laboratories, Silver Spring, Maryland, October 1971.

3. Holzworth, G. C. Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States, Environmental Protection Agency, Research Triangle Park, North Carolina, January 1972.

Question Number 8.13:

Provide information describing the locations and elevations of observation stations, instrumentation, and frequency and duration of meteorological data provided to describe the local air quality and local regional meteorology near the Watts Bar site. This information should include descriptions of instruments, performance specifications, calibration and maintenance procedures, data output and recording systems and locations, and data analysis procedures.

Response:

The Watts Bar onsite meteorological measurements program is presented in Section 2.3.3 of the Watts Bar Nuclear Plant Final Safety Analysis Report (FSAR).

TVA/ONR/PCS-81/2

Tennessee Valley Authority

FINAL

ENVIRONMENTAL IMPACT STATEMENT

WATTS BAR
WASTE HEAT PARK
RHEA COUNTY, TENNESSEE

VOLUME I

Index No: 87

COVER SHEET
ENVIRONMENTAL IMPACT STATEMENT

WATTS BAR WASTE HEAT PARK
RHEA COUNTY, TENNESSEE

[ ] Draft [X] Final environmental impact statement prepared by the Tennessee Valley Authority. For additional information contact:

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1-800-362-9250 (Tennessee)
1-800-251-9242 (Other areas)

1. [X] Administrative action [ ] Legislative action

2. Lead Agency - Tennessee Valley Authority
Cooperating Agency - United States Army Corps of Engineers

3. Contingent upon availability of funds, TVA is proposing to promote large-scale commercial waste heat utilization by constructing a waste heat distribution system on a site adjacent to TVA's Watts Bar Nuclear Plant in Rhea County, Tennessee. The distribution system would be used to transport heated water (condenser circulating water) from the nuclear plant to an agro-industrial park which would use the heated water as an energy source and return the water to the plant for reuse in the CCW system. An easement (contract) would be used to convey the site to a park management organization which would be responsible for developing and operating the waste heat park. Conditions would be placed on the park to protect the health and safety of the public, the environment, and other interests of the United States. Environmental impacts associated with construction and operation of the waste heat park include: (1) a change in land use, including altering terrestrial habitat; (2) minor impacts to floodplains and wetlands; (3) potential socioeconomic, cultural, and aesthetic impacts; and (4) potential discharge of pollutants to the air and water. Development of the waste heat park would have fewer adverse impacts than would be expected from similar developments utilizing conventional heat sources.

4. Alternative sites for locating a waste heat facility and alternative actions which would effectively demonstrate the waste heat park concept are evaluated. This proposal was found to be the only practical and reasonable alternative available.

5. The draft statement was sent to the Environmental Protection Agency and made available to the public on October 20, 1980. The final statement was sent to the Environmental Protection Agency and made available to the public on July 31, 1981.

6. No action will be taken on this matter until 30 days after the notice of availability for the final statement appears in the Federal Register

EXECUTIVE SUMMARY

Introduction

TVA is considering granting a 400-acre easement at the Watts Bar Nuclear Plant site to establish a waste heat park. A waste heat park is an agricultural, aquacultural, and/or industrial area that uses power plant waste heat to save energy and improve the commercial viability of the park's businesses. The park is envisioned to include a number of facilities in a spectrum of industrial classes. The easement would be granted to a local public-oriented development organization which would be responsible for park operation and maintenance. Conditions would be placed on park to protect the health and safety of the public, the environment, and other interests of the United States. The purpose of the Environmental Impact Statement (EIS) is to inform TVA decision makers and the public of the significant environmental impacts and the reasonable alternatives which would avoid or minimize adverse impacts or enhance the quality of the environment. While this document must, to fulfill its purpose, discuss all significant adverse impacts associated with the proposed project; it should be emphasized that these impacts are less than would be expected from similar development at this site or elsewhere utilizing a conventional heat source. The use of coal, uranium, or another fuel in lieu of waste heat would have significant impacts associated with resource exploration, mining, transportation, energy production, and waste management that are avoided through the use of waste heat. The EIS will also serve to facilitate environmental review of specific park applicants and aid park occupants in acquiring their own permits by providing an assessment of the existing environment and mitigative needs.

This EIS assesses the project alternatives, including the no-action alternative (not granting the easement). Five candidate sites for the facility are assessed in the EIS. The document evaluates 21 potential Standard Industrial Classification code agricultural, aquacultural, or industrial businesses that are believed to show promise for waste heat applications. In addition to the evaluation of project alternatives, the EIS provides a more detailed analysis of environmental effects should the preferred Watts Bar alternative be implemented. The purpose of this treatment is to facilitate the environmental review of and permitting processes for potential park users.

Purpose and Need

The need to which TVA is responding is that of demonstrating the feasibility of large-scale waste heat utilization.

TVA's statutory responsibilities include the generation of electrical power, flood control, navigation improvement on the Tennessee River, and agricultural and industrial development in the seven State Tennessee Valley region. As a regional resource agency, TVA is committed to development of the resources in the Tennessee Valley region in a manner that conserves and enhances the environment. TVA operates the Nation's largest power system, supplying an ample amount of electric energy at the lowest feasible cost. In meeting this objective, TVA conducts research on new, economical ways to provide or use energy in a manner consistent with this Nation's policy to protect and enhance the natural environment. The proposed project is a step toward meeting these obligations for the future.

The recent history of conventional energy supplies indicates that they may be subject to supply interruptions, shortages, and rapid price escalation. With the increasing cost of and rising demand for energy, the Nation can no longer afford the wasteful consumption of resources. A national energy effort, which includes major conservation measures, the development of alternative energy sources, and the more efficient use of existing resources, has been implemented.

TVA is considering a number of energy use proposals with an emphasis on developing near-term technology to begin a substantive improvement in energy-use patterns as soon as possible. This includes proposals for substituting the use of coal in an environmentally acceptable fashion to reduce industrial and commercial dependence on natural gas and petroleum, reducing dependence of the transportation sector on petroleum, using waste heat and energy discharged from steam-electric generating plants or contained in municipal and industrial wastes, and developing energy conversion technology and environmental controls. The waste heat park concept, as proposed for demonstration at the Watts Bar site, is one means of implementing energy use goals by utilizing what would otherwise be a lost energy resource, thus conserving existing fuel supplies. While the immediate benefit of this project would accrue to the TVA region, ultimately this demonstration will assist in reducing this Nation's need for costly and undependable foreign energy supplies.

From 50 to 65 percent of the raw fuel energy input for conventional steam-electric generating plants is transferred to condenser circulating water and discharged to the environment as high-volume, low-grade "waste heat." It has been estimated that TVA's annual production of waste heat in the 1990's may exceed 1.5×10^{15} Btu's. The utilization of even a portion of the energy from waste heat would result in a corresponding savings of existing fuel sources, thus providing a positive incentive for development of waste heat use. Other factors within the TVA system, including higher operating temperatures, increased plant sizes, and the use of cooling towers in closed mode, contribute to the quality and reliability of the waste heat source and provide additional incentives for TVA to develop waste heat use.

TVA has been involved in waste heat research and development since the late 1960's. In 1978 TVA initiated a 5-year research and development study on waste heat use, the emphasis of which was to accelerate technology development for transfer to commercial users for widespread application at power plants. Efforts were focused on advancing a balance of multiple waste heat uses--including agricultural, aquacultural, and industrial application--and developing power plant interface systems which could adequately handle large-scale complexes of these multiple uses. Initial research indicates that only through widespread application of large-scale multiple use complexes can power plant waste heat become a significant usable energy resource on a national basis.

In addition, large-scale multiple use complexes or "waste heat parks" offer a variety of advantages over small-scale applications which are conceived and dealt with individually as each new potential user appears. Some of these advantages include:

1. Development and use of common service facilities (raw water, sewers, waste disposal, roads, etc.);

2. Reduced individual user capital and operating costs for waste heat supply and return system;

3. Planning for total needs of large multiple-use complexes developed over time so first users do not adversely affect those following; and

4. Opportunity to integrate waste heat applications to achieve more efficient use of the waste heat.

Moreover, due to these advantages, a well-planned and staged large-scale development should reduce individual user product cost.

TVA is proposing to convey a site of approximately 400 acres adjacent to the Watts Bar Nuclear Plant to demonstrate commercial waste heat concepts. An easement with appropriate development restrictions would convey the site to a park management organization for development.

In carrying out its responsibilities under the TVA Act, TVA follows a policy designed to develop and enhance a quality environment. As a result of this policy, TVA has long considered environmental matters in its decisionmaking. Offices and divisions within TVA employ personnel with a wide diversity of experience and academic training which enables TVA to utilize a systematic, interdisciplinary approach to ensure the integrated use of the natural and social sciences and the environmental design arts in planning and decisionmaking. As a Federal agency, TVA is subject to the requirements of the National Environmental Policy Act of 1969 (NEPA).

This statement discusses the environmental considerations relating to the granting of easements for the Watts Bar Waste Heat Park consistent with interests of the United States, including those identified by NEPA and TVA's implementing procedures. In preparing this statement, TVA has been particularly conscious of CEQ's guidance to avoid highly technical and specialized analyses and data in the body of the statement. This document is being sent to local, State, and Federal agencies.

This environmental impact statement generally evaluates the impacts from potential users of waste heat at the Watts Bar site. When specific uses are identified, they will be evaluated by TVA under NEPA and TVA's implementing procedures. If necessary, conditions will be placed on easement agreements to protect the health and safety of the public, the environment, and other interests of the United States.

Alternatives

The environmental impacts associated with the construction and operation of a waste heat park, considering alternative sites and alternative actions to demonstrate the waste heat park concept, have been evaluated in this statement. Alternatives include no action, the development of a waste heat park at an alternate site, alternative management schemes, and the proposed action of granting an easement for the development of a waste heat park at Watts Bar.

The implementation of the no-action alternative would result in the temporary maintenance of the existing resources of the TVA-owned site and the surrounding area, but would also result in the continued loss of a potentially valuable energy resource. Locating the initial large-scale demonstration of waste heat use at an alternate site would not appear to reduce or offset significantly any of the environmental impacts anticipated at Watts Bar, but could delay or limit the application of waste heat concepts. Alternative management options--entities responsible for park development and waste heat use demonstration, land conveyance methods, management requirements, and pricing policies--exercised in a manner other than that proposed could result in less than optimum utilization of the waste heat resources through reduced local participation, fewer sources of funding, and pricing that might discourage user participation in a proof-of-concept venture. No environmental advantages could be identified for any of the rejected options.

Granting an easement to a public park management organization for the waste heat park development at Watts Bar was selected as the most practical alternative based in part on site evaluation criteria which included schedules, accessibility of piping, mode of cooling tower operation, operating temperatures, minimal conflict with health and safety systems, availability of suitable nearby land, local economic potential, adverse impacts which could practicably be minimized, and local capability to form a park development corporation. The easement would include appropriate conditions to protect the health and safety of the public, the environment, and other interests of the United States.

Affected Environment and Environmental Consequences - Alternatives

Sites evaluated and found most feasible as candidates for a large-scale waste heat park demonstration are Bellefonte, Hartsville, Phipps Bend, Watts Bar, and Yellow Creek Nuclear Plants. Major engineering and environmental characteristics are summarized and evaluated; there would not appear to be any environmental issues which would preclude park development at any of the alternative sites.

Generic descriptions of park development and operations are presented and evaluated. Services which probably would be provided for park users regardless of the site selected or the entity sponsoring park development include paved roads, railroad access, utilities, landscaping, stormwater runoff management, and a raw water supply. The potential for central backup and heat augmentation systems is being investigated; conservative assumptions on the location, fuel requirements, sizing, and materials handling are used in evaluating the potential impacts of these systems. Agricultural, aquacultural, and industrial uses suitable for waste heat applications are described.

Impacts resulting from the no-action alternative would include exercising other options for long-term land use changes, the loss of the waste heat energy resource, and the continued or increased consumption of existing fuel supplies. The no-action alternative would also increase the total adverse environmental impacts by forcing industries to use other energy sources with the much greater potential for environmental effects associated with energy production and use from the associated fuel cycle. Many impacts associated with the development of a waste heat park at an alternative site would be similar regardless of location, except that potential radiological impacts of boiling water reactors and pressurized water reactors would differ slightly. Impacts that could result from management schemes other than those proposed could result in less than optimum utilization of the waste heat resources; no environmental advantages could be identified for any of the rejected management options.

Affected Environment and Environmental Consequences - Watts Bar Site

More detailed evaluations of the Watts Bar site and of site-specific environmental impacts and mitigative measures are presented as appendices to the EIS to assist regulatory agencies and potential park occupants in licensing procedures. This document incorporates related studies under the Endangered Species Act, the National Historic Preservation Act, and other environmental review laws and executive orders. Studies indicate that two species of endangered freshwater mussels and one endangered fish species occur in the vicinity of the proposed site. One archaeological site, 40RH64, within park boundaries has been determined by TVA to be eligible for the National Register of Historic Places. Wetlands are present on and adjacent to the site, and a significant portion of the proposed park property lies below base floodplain elevation.

Potential construction impacts include loss of soil productivity, fugitive dust emissions resulting from grading and clearing operations and construction traffic, minor increases in combustion emissions from construction vehicles, alteration of natural drainage patterns, increased sediment loads in surface water bodies, temporary increases in nearby community sound levels, alteration of terrestrial habitat, displacement of wildlife, visual effects, and noncritical development in floodplain and wetland areas.

Potential operational effects evaluated include a minor change in the quality of the nuclear plant condenser circulating water; increased SO_2, particulate, and NO_x emissions; microclimate modifications; increased withdrawal of surface water; possible thermal effects from discharges; reduced flow from springs in the area; pumpage interference between existing and new water supply wells; discharges to surface or ground water sources; increased noise levels; increased population radiological dose commitments due to an increased working force in proximity to the nuclear plant; loss of open space; entrainment of larval fish; accidental industrial spills; land use changes; operation of facilities in floodplain or wetlands areas; and disturbance of cultural resources.

Mitigative measures which may reduce or minimize impacts include: best management practices during construction to reduce soil erosion and sedimentation potential, revegetating disturbed areas, installing control equipment on potential air pollution sources such as augmentation and backup systems, treatment of discharges to receiving streams, disposal of solid wastes in an approved sanitary landfill, implementation of spill prevention control and countermeasures plans, the protection of ground water quality, revision of the Radiological Emergency Plan, careful selection of facility locations, timing of activities, and recovery or protection of cultural resources.

Some unavoidable adverse impacts would remain after application of the planning and mitigative measures discussed above. However, these represent minor increases in impacts already created by nuclear plant construction and operation.

Short-Term Uses vs Long-Term Productivity

The site to be developed is adjacent to an established waste heat source. Successfully utilizing this source would contribute to the immediate goal of demonstrating the feasibility of waste heat utilization and to the long-term consequences of conserving fuel supplies, developing otherwise wasted resources, and advancing related production and process technologies.

One long-term, secondary benefit would be the expansion of employment opportunities by providing additional jobs. Most of the jobs would be permanent, which would contribute long-term employment stability to the area. Another gain would be the increased economic activity resulting from the increase in local incomes. The development of the waste heat park could have some positive effect on the loss of area employment when the Watts Bar Nuclear Plant is completed. However, because of the time lag between plant completion and the staged development of the park, the sizeable pay differential between the two types of jobs, and the difference in skill demand, this effect should be minimal.

The area could be restored to other uses at the termination of the waste heat park project, which represents a short-term commitment of land use. The preclusion of other site uses associated with the nuclear plant could be a long-term effect. Land occupied by expanded urban areas or by transportation facilities would be considered a long-term use. Productivity in relation to soils, vegetation, and wildlife habitat would be altered but would be expected to be restored over the long term. Disturbance of cultural resources, even with salvage, would represent an irreversible commitment, although present researchers would have the benefit of information gained from material exposed during site preparation.

The operation of the waste heat park should not result in significant long-term environmental degradation. All effluents discharged to the air, water, and land will be in compliance with applicable regulatory requirements and within levels which are considered acceptable for the short-term uses of the environment.

Irreversible and Irretrievable Commitments of Resources

Building materials would be committed for the construction of park facilities, as well as for roads and buildings to accommodate the expected trade growth. Energy, in the form of petroleum products and electricity, would be consumed for development activities and for park operations. Manpower would be committed to this project in lieu of utilizing the work force elsewhere. From undisturbed areas, wildlife habitat, open space, and some soil quantity and quality would be lost for the life of the project. Cultural resources in areas designated for surface disturbance would be committed to destruction, protection, or salvage.

Conclusion

The successful demonstration of commercial waste heat utilization will benefit the Tennessee Valley region and the Nation. The preferred alternative, granting an easement for the development of a waste heat park at Watts Bar, is the best available means of demonstrating large-scale waste heat concepts. Implementing this action at the Watts Bar site should facilitate the demonstration of waste heat technology and should provide sufficient assurance that the park does not adversely affect the nuclear plant. This document generally evaluates the impacts and specifies constraints for a number of potential users of waste heat that could be expected to locate at the Watts Bar facility. When specific uses are identified, they will be evaluated by TVA under NEPA and TVA's implementing procedures, and if necessary, conditions will be placed in easements to ensure the protection of the health and safety of the public, the environment, and other interests of the United States.

It is concluded that granting an easement to a park management organization for the development of a waste heat park at Watts Bar is an environmentally sound action, with fewer adverse impacts than would be expected from similar development elsewhere utilizing conventional heat sources. Development of the waste heat park at Watts Bar is the most reasonable (perferred) alternative and should be implemented.

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1. PURPOSE AND NEED

The need to which TVA is responding, that of demonstrating the feasibility of large-scale waste heat utilization, is described in this chapter.

1.1 ENERGY USE GOALS

The Tennessee Valley Authority (TVA) is a corporate agency of the United States created by the Tennessee Valley Authority Act of 1933 (48 Stat. 58, as amended, 16 U.S.C. §§ 831-831dd [1976; Supp. III, 1979]). TVA's statutory responsibilities include the generation of electrical power, flood control, navigation improvement on the Tennessee River, and agricultural and industrial development in the seven-State Tennessee Valley region. As a regional resource agency, TVA is committed to development of the resources in the Tennessee Valley region in a manner that conserves and enhances the environment. TVA operates the Nation's largest power system supplying an ample amount of electric energy at the lowest feasible cost. In meeting this objective, TVA conducts research on new, economical ways to provide or use energy in a manner consistent with this Nation's policy to protect and enhance the natural environment. The proposed project is a step toward meeting these obligations for the future.

The recent history of conventional energy supplies indicates that they may be subject to supply interruptions, shortages, and rapid price escalation. With the increasing cost of and rising demand for energy, the nation can no longer afford the wasteful consumption of resources. A national energy effort, which includes major conservation measures, the development of alternative energy sources, and the more efficient use of existing resources, has been implemented.

TVA is considering a number of energy use proposals with an emphasis on developing near-term technology to begin a substantive improvement in energy use patterns as soon as possible. This includes proposals for substituting the use of coal in an environmentally acceptable fashion to reduce industrial and commercial dependence on natural gas and petroleum, reducing dependence of the transportation sector on petroleum, using waste heat and energy discharged from steam-electric generating plants or contained in municipal and industrial wastes, and developing energy conversion technology and environmental controls. The waste heat park concept, as proposed for demonstration at the Watts Bar site, is one means of implementing energy use goals by utilizing what would otherwise be a lost energy resource, thus conserving existing fuel supplies.

1.2 WASTE HEAT UTILIZATION

From 50 to 65 percent of the raw fuel energy input for conventional steam-electric generating plants is transferred to condenser circulating water and discharged to the environment as high-volume low-grade "waste heat." It has been estimated that TVA's annual production of waste heat in the 1990's may exceed 1.5×10^{15} Btu's. The utilization of even a portion of the energy from waste heat would result in a corresponding savings of existing fuel sources, thus providing a positive incentive for development of waste heat use. Other factors within the TVA system, including higher operating temperatures, increased plant sizes, and the use of cooling towers in closed mode, contribute to the quality and reliability of the waste heat source and provide additional incentives for TVA to develop waste heat use.

TVA has been involved in waste heat research and development since the late 1960's. In 1978, TVA initiated a 5-year research and development study on waste heat use, the emphasis of which was to accelerate technology development for transfer to commercial users for widespread application at power plants. Efforts were focused on advancing a balance of multiple waste heat uses--including agricultural, aquacultural, and industrial applications--and developing power plant interface systems which could adequately handle large-scale complexes of these multiple uses. Initial research indicates that only through widespread application of large-scale multiple use complexes can power plant waste heat become a significant useable energy resource on a national basis.

In addition, large-scale multiple use complexes or "waste heat parks" offer a variety of advantages over small-scale applications which are conceived and dealt with individually as each new potential user appears. Some of these advantages include:

1. development and use of common service facilities (raw water, sewers, waste disposal, roads, etc.);

2. reduced individual user capital and operating costs for waste heat supply and return system;

3. planning for total needs of large multiple use complex developed over time so first users do not adversely affect those following; and

4. opportunity to integrate waste heat applications to achieve more efficient use of the waste heat.[1]

Moreover, due to these advantages, a well-planned and staged large-scale development should reduce individual user product cost.

TVA is proposing to make available a site of approximately 400 acres adjacent to the Watts Bar Nuclear Plant to demonstrate commercial waste heat concepts. When fully developed the waste heat park would use approximately 12 percent of the total waste heat produced by the 2-unit nuclear plant. An easement with appropriate development conditions would be granted under provisions of Public Law No. 87-852 (40 U.S.C. §§ 319-319c [1976]) for the use of the site.

1.2 REFERENCES

1. Tennessee Valley Authority. Watts Bar Waste Heat Park Feasibility Analysis. January 1979.

1.3 ENVIRONMENTAL POLICY

In carrying out its responsibilities under the TVA Act, TVA follows a policy designed to develop and enhance a quality environment. As a result of this policy, TVA has long considered environmental matters in its decisionmaking. Offices and divisions within TVA employ personnel with a wide diversity of experience and academic training which enables TVA to utilize a systematic, interdisciplinary approach to ensure the integrated use of the natural and social sciences and the environmental design arts in planning and decisionmaking. As a Federal agency, TVA is subject to the requirements of the National Environmental Policy Act of 1969 (NEPA), 42 U.S.C. §§ 4321 *et seq*. (1976), which became effective on January 1, 1970.

This statement discusses the environmental considerations relating to the granting of easements for the Watts Bar Waste Heat Park consistent with Section 102(2)(C) of NEPA, the Council on Environmental Quality (CEQ) NEPA implementing procedures (40 CFR Parts 1500-1508), and TVA's procedures for implementing NEPA (45 FR 54, 511-15). In preparing this statement, TVA has been particularly conscious of CEQ's guidance to avoid highly technical and specialized analyses and data in the body of the statement. While this EIS must, to fulfill its purpose, evaluate all significant adverse impacts associated with the proposed project, it should be emphasized that these impacts are less than would be expected from similar development at this site or elsewhere utilizing a conventional heat source. The overall environmental effects of energy conversion and use from a conventional fuel cycle would include effects from exploration, mining, transportation, energy conversion, and waste management. This document is being sent to local, State, and Federal agencies and is available to the public.

This environmental impact statement generally evaluates the impacts from potential users of waste heat at the Watts Bar site. When specific uses are identified, they will be assessed by TVA under NEPA and TVA's implementing procedures, and if necessary, conditions will be placed in easements to ensure the protection of the health and safety of the public, the environment, and other interests of the United States.

2. ALTERNATIVES

This chapter discusses alternative actions, including the proposed action (granting an easement) and the no-action alternative, which are available to TVA in meeting its statutory responsibilities and in implementing national energy use goals by demonstrating waste heat utilization concepts.

2.1 NO ACTION

Exercising this alternative would result in no change in the status of the property adjacent to Watts Bar Nuclear Plant. TVA would retain title to the approximately 400-acre site and would not demonstrate commercial waste heat concepts at this time. Because there is recognized economic potential for the geographic area, it may be feasible for a multiple-use complex, similar to the one proposed but utilizing conventional energy sources, to be developed near the proposed site. A park using conventional energy sources would generate about the same impacts as those assessed in Appendix B, in addition to increasing the consumption of existing energy forms and associated impacts.

TVA is pursuing several different new technologies such as solar and biomass conversion. These are still in the formulative stages. TVA is proceeding with conservation and load management measures which should reduce overall power needs in the region. Long-term projections indicate that these measures alone cannot be used to fulfill the system's requirements. Rather, a mix of conservation, conventional power generation, and new technology-based generation will likely be needed to meet future load growth. Waste heat is one of the Valley's and the Nation's abundant, but as yet untapped, resources that can be utilized to help meet tomorrow's energy requirements.

Failure to take action would result in the maintenance, at least temporarily, of the existing environmental resources of the TVA-owned site and the surrounding area. However, other land-use options for this site may be evaluated by TVA which could result in a change in the site's present condition. No action on the proposal would also result in the waste of a potentially valuable energy resource. The opportunity to develop waste heat utilization techniques would be lost or delayed to the detriment of the region and the nation.

In light of this, it is not reasonable to ignore or delay development of a potentially significant energy source. Consequently, the no-action alternative must be rejected.

2.2 WASTE HEAT PARKS AT OTHER TVA POWER PLANTS

Waste heat parks similar to the one proposed in this statement could be located at other TVA power plants. Site development potential would depend on such factors as mode of cooling system operation, availability of suitable land, accessibility of tie-in piping, operating temperatures, availability of flow, size and number of generating units, compatibility with health- and safety-related systems and with other uses of the site, economic potential for the area, and plant operation (start-up) schedules. The application of these types of criteria to plants within the TVA system and the descriptions of existing environments of suitable sites are presented in Chapter 3.

In general, the acceptability and economic feasibility of waste heat uses will vary from site to site. The three areas of waste heat application that appear to be feasible for any site that might be chosen are agriculture, aquaculture, and industrial uses. Descriptions of these applications and a generic assessment of their impacts are provided in Chapter 4.

From initial evaluations, all the sites appear to be generally acceptable and comparable from an environmental standpoint; therefore, locating a waste heat park at an alternate site would not appear to reduce or offset to a significant degree any of the environmental impacts addressed in Chapter 4 and Appendix B. Waste heat park development must be coordinated with plant operation schedules, health and safety systems, and alternative land uses at other plants to avoid impacts. The selection of a site with less than optimum potential for the demonstration of waste heat use would not result in the fullest utilization of waste heat technology. The Watts Bar site was chosen as the only practical site for the initial demonstration of a waste heat park, according to the criteria listed in Section 2.4. Environmental impacts, including the minimal floodplain and wetland effects, would be similar at alternative sites (see Table 4.3-1).

Based on all factors, TVA concludes that a site other than Watts Bar could delay or limit the application of waste heat concepts, and no significant countervailing benefit has been identified with such a delay. Consequently, location at other TVA plant sites is not deemed to be the perferred alternative.

No non-Federally owned sources of conventional steam-electric power plant waste heat are available in the Tennessee Valley to support such a waste heat park.

2.3 ALTERNATIVE MANAGEMENT SCHEMES

One alternative is to have the interfacing system between the plant and the waste heat park installed by TVA, but total responsibility for the demonstration of waste heat technology and for park development assumed by a private profit-making organization. Such development could result in fewer opportunities for local participation than would be possible if TVA took an active role in park planning and development. Furthermore, it is doubtful that sufficient private capital could be amassed for this "proof-of-concept" project, and the possibility of attracting capital from alternate sources such as State, regional, or Federal agencies would be reduced. Moreover, the stringent contractual arrangements required to assure that the waste heat park would not have an adverse impact on the generating plant while assuring that the waste heat park concept was successfully demonstrated might also, as a practical matter, eliminate any interest by private concerns. Because of these potentially negative features, conditions would be less than optimum for the successful large-scale demonstration of waste heat utilization by a private profit-making organization, and this alternative was rejected.

The overriding general requirement will be to reserve to TVA sufficient legal authority to assure that the waste heat park does not have an adverse impact upon the nuclear plant and to assure a successful demonstration of the waste heat park concept. These dual requirements can be accomplished by providing TVA with (1) final review authority over such important decisions as selecting occupants for the park, (2) the right of prior review and approval of the intermediary's contracts, and (3) placing appropriate conditions in any instruments used to convey landrights.

Two cost-based methods can be applied to establish the price of waste heat: the value-of-service concept, considering the cost of competitive or alternative energy sources, and the cost-of-service concept, in which the price is determined by the actual cost of supplying the waste heat to the user. Because the lack of a current market for waste heat would require the establishment of an arbitrary value for the waste heat, the application of the value-of-service approach may not be as desirable as the cost-of-service concept for the method to set the waste heat rates. Pricing units would most likely be measured in gallons of water. Pricing the energy on the basis of water flow would provide an incentive for extraction of energy as well as simplifying measurement of product usage. Other considerations in determining the pricing policy would be capital investment, operation and maintenance costs, and electricity charges for the distribution system incurred by TVA. These charges would be transferred to the intermediary group who would, in turn, pass them on to individual users, along with charges for site development.

2.4 GRANTING AN EASEMENT FOR A WASTE HEAT PARK AT WATTS BAR

This alternative was chosen as the most practical and reasonable one available to demonstrate and evaluate waste heat as an energy resource in a timely fashion based on the following criteria:

A. Time schedule for Watts Bar startup coincides with a near-term time schedule for commercial waste heat use.

B. The plant has easily accessible tie-in piping and has substantial available flow.

C. The plant has full-time closed-loop cooling tower operation.

D. The temperatures available are less subject to variation and are among the highest in the TVA system.

E. There are no identifiable conflicts with nuclear safety-related systems.

F. Land suitable for waste heat uses is located nearby and is owned by TVA.

G. There is recognized economic potential in the local communities.

H. Commercial parties have already expressed an interest in the waste heat at this site.

I. The adverse environmental impacts associated with this proposal can be minimized.

J. County government structure is compatible with the creation of a park development corporation.

K. Granting the easement would allow TVA to retain appropriate authority to ensure the successful demonstration of commercial waste heat concepts with proper regard given to safety, health, and environmental matters.

The basis for proposing the preferred alternative is summarized in Table 2.4-1. The waste heat uses described in Section 4.2 (agriculture, aquaculture, and industry) are feasible at this location. A summary evaluation of the impacts of this preferred alternative is presented in Section 4.3.4. A detailed evaluation of this proposal is presented in Appendices A and B.

TABLE 2.4-1

The basis for proposing the preferred alternative, which is a combination of several options, is summarized below

Alternative	Advantages	Disadvantages
(1) No action	Maintenance of existing resources and options for future site uses.	Loss or delay of utilization of waste heat. A conventional industrial park would increase consumption of existing fuels.
(2) Alternate Sites (A) Existing fossil-fired plants (except Paradise)		Wrong mode of cooling system operation; lower temperatures and flows; extended shutdown required to install waste heat systems.
(B) Browns Ferry		No full-time, closed-cycle cooling system operation; shutdown required.
(C) Sequoyah		Same as Browns Ferry.
(D) Paradise		Only one unit with closed-cycle operation; shutdown required; lack of suitable land; site use conflicts.
(E) Bellefonte	Capable of supporting a waste heat park.	Commercial operation is three years later than Watts Bar. Park development could limit plant expansion. Cumulative entrainment could be a problem to fisheries. Additional evaluation would be required to determine extent of cultura resources.
(F) Hartsville	Capable of supporting a waste heat park.	Less accessible tie-in piping, later commercial operation, lower temperatures. Park development could limit plant expansion. Open-system use of CCW could concentrate chemicals present in Cumbe land River. Additional evaluation would be required to determine extent of cultural resourc

Alternative	Advantages	Disadvantages
(G) Phipps Bend	Capable of supporting a waste heat park.	Questionable land availability; lower temperatures; later schedule. Park development could limit plant expansion. Lack of sufficient water volumes could necessitate additional treatment of chemical discharges. Additional involvement of SHPO and ACHP would be required to evaluate impacts to sites nominated to National Register.
(H) Watts Bar	Capable of supporting a waste heat park; higher temperatures; near-term start-up schedule.	Park development could limit plant expansion. Pumping wells for waste heat park supply could decrease flows of springs feeding Yellow Creek impoundment. Low dissolved oxygen levels may necessitate additional treatment of discharges. Mitigative measures for any impacts to springs would be needed. Additional involvement of SHPO and ACHP would be required.
(I) Yellow Creek	Capable of supporting a waste heat park.	Lower temperatures, commercial operation is six years later than Watts Bar. Park development could limit plant expansion. Cumulative entrainment would be primary concern to fisheries.
(3) Alternate Management		
(A) TVA sponsorship	Could sell waste heat through a not-for-profit industrial development corporation. This would enhance local participation and could improve the possibility of attracting capital from alternate sources.	
(B) Private sponsorship		Could result in fewer opportunities for local participation. Assurance that the waste heat park would not adversely impact the nuclear plant and assuring waste heat concepts were successfully demonstrated may eliminate interest by private concerns.

Alternative	Advantages	Disadvantages
(C) Easement	Would restrict the use of the land to a waste heat park development, retain TVA restrictions regarding floodplain development and the right to flood, ensure the protection of the health and safety of the public, the environment, and other interests of the United States.	
(D) Other conveyance method		A fee simple interest or a lease would be too inflexible.
(E) General management requirements	Provides TVA with final review authority over such important decisions as selecting occupants for the park, the right of prior review and approval of the intermediary's contracts, and placing appropriate conditions in any instruments used to convey landrights.	
(F) Cost-of-service pricing	Price would be determined by the actual cost of supplying waste heat to the user. Pricing the energy on the basis of water flow would provide an incentive for extraction of energy as well as simplifying measurement of product usage.	
(G) Value-of-service pricing		Would have to consider the cost of competive or alternative energy sources. Lack of a current market for waste heat would require the establishment of an arbitrary value for waste heat.

3. AFFECTED ENVIRONMENT - ALTERNATE SITES

This chapter summarizes the physical, biological, and cultural features of alternative sites considered.

3.1 SITE EVALUATION CRITERIA

Criteria for selecting a site for the near-term, large-scale demonstration of waste heat technology include:

1. mode of cooling system operation, with full-time, closed-cycle operation preferable so that the water used as the waste heat source is subjected as little as possible to the ambient thermal conditions of a surface water body;

2. suitable land, with no preclusive environmental conditions, available adjacent to the waste heat producer;

3. accessible tie-in piping to minimize any conflicts with health and safety systems or plant operations caused by the installation of piping to the waste heat park;

4. increased temperature rises in the main condenser, with higher condenser circulating water temperatures resulting in more heat available for use in a waste heat park;

5. availability of flow;

6. multiple unit operation to provide an adequate supply of waste heat and to decrease the potential for a loss of supply due to a plant outage;

7. minimal conflicts with health- and safety-related systems and with current or projected uses of the site such as plant expansion;

8. sufficient economic potential in the area to support a multiple-use complex as visualized for a waste heat park; and

9. start-up schedule which would not delay the demonstration of a waste heat park or which would not result in unwarranted shutdown of an operating plant if the demonstration of an unproven technology was unsuccessful.

Generating plants which did not meet the initial criteria were Browns Ferry and Sequoyah Nuclear Plants and all existing fossil-fired plants, with the exception of Paradise Unit 3. The Paradise plant was excluded from further study because it had only one unit with closed-cycle cooling, it was already in operation and would require shutdown to install the waste heat distribution system, suitable nearby land was lacking, and the potential existed for limiting other uses of the site, such as plant facility expansion. However, although these sites did not exhibit characteristics necessary for the optimum demonstration of a waste heat park, they have not been precluded from future development of suitable waste heat applications.

The following sites conformed to sufficient criteria to be considered suitable candidates for the location of a waste heat park:

1. Bellefonte
2. Hartsville
3. Phipps Bend
4. Watts Bar
5. Yellow Creek

The evaluation of criteria for waste heat park development, as applied to these locations, are presented in Table 3.1-1. Descriptions of the existing environments of these sites are summarized in Section 3.2 and are presented in detail in individual environmental statements.[1-5] Impacts associated with the development of a waste heat park at alternative locations are presented in Chapter 4. These projected impacts are based on the assumption that a waste heat park would be developed inside existing reservation boundaries. Impacts anticipated at the Watts Bar site are presented in Appendix B.

3.1 REFERENCES

1. Tennessee Valley Authority. Final Environmental Statement - Bellefonte Nuclear Plant Units 1 and 2. May 24, 1974.

2. Tennessee Valley Authority. Final Environmental Statement - Hartsville Nuclear Plants. May 23, 1975.

3. Tennessee Valley Authority. Final Environmental Statement - Phipps Bend Nuclear Plant Units 1 and 2. September 17, 1976.

4. Tennessee Valley Authority. Final Environmental Statement - Watts Bar Nuclear Plant Units 1 and 2. November 9, 1972.

5. Tennessee Valley Authority. Final Environmental Statement - Yellow Creek Nuclear Plant Units 1 and 2. January 30, 1978.

TABLE 3.1-1

APPLICATION OF WASTE HEAT PARK DEVELOPMENT CRITERIA

	Bellefonte	Hartsville	Phipps Bend	Watts Bar	Yellow Creek
Type of Cooling System	Closed cycle	Closed cycle	Closed cycle	Closed cycle	Closed cycle
Suitable Land Within Reservation Boundary	Available	Available	Question-able	Available	Available
Accessibility of Piping	Easily Accessible	Less Accessible	Accessible	Easily Accessible	Accessible
Condenser Temperature Increases	35.2°F	32°F	32°F	38°F	34.5°F
Number of Units	2	4	2	2	2
Compatability with Site Uses	Favorable	Favorable	Favorable	Favorable	Favorable
Area Economic Potential	Favorable	Favorable	Favorable	Favorable	Favorable
Projected Commercial Operation	6/84 3/85	7/87,4/88 4/95,4/96	2/88 4/94	3/82 9/82	7/86 4/93

Earliest possible dates as stated in NRC Status Report 1/81.

3.2 SITE CHARACTERISTICS

Locations of the sites found most feasible as candidates for a large-scale waste heat park demonstration (Bellefonte, Hartsville, Phipps Bend,* Watts Bar, and Yellow Creek*) are shown in Figure 3.2-1.

From initial evaluations, all the sites appear to be capable of supporting a waste heat park and to be generally acceptable from an environmental standpoint. Major engineering and environmental characteristics at each of the alternative sites, which determine the site's ability to support a waste heat park, are summarized in Table 3.2-1. As indicated in the table and as further evaluated in Chapter 4, there would not appear to be any environmental issues which would preclude park development.

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*Deferred nuclear units at Phipps Bend and Yellow Creek may impact the desirability of those sites for waste heat part development in the near future.

TABLE 3.2-1. SUMMARY OF SITE CHARACTERISTICS

	Bellefonte	Hartsville	Phipps Bend	Watts Bar	Yellow Creek
Location					
State	Alabama	Tennessee	Tennessee	Tennessee	Mississippi
County	Jackson	Smith, Trousdale	Hawkins	Rhea	Tishomingo
Land Area, ha (acres)	658 (1625)	788 (1947)	514 (1270)	826 (2040)	457 (1130)
Land Use					
Agriculture	No active agricultural production because use of the site is committed to the generating plant	See Bellefonte	See Bellefonte	See Bellefonte	See Bellefonte
Recreation	A recreation area is proposed for Shipp Chapel Peninsula	No important recreational facilities exist in vicinity of the site	See Hartsville	Watts Bar Resort is located to the north of the site	See Hartsville
Other	The site is being evaluated for plant expansion	See Bellefonte	See Bellefonte	See Bellefonte	
Engineering Considerations					
Geology	For structures requiring rock foundations, a normal amount of excavation may be necessary. No mineral resources of commercial value have been identified at the site.	Foundation treatment may be required for any structures with rock foundations. There are no conflicts with mineral resources.	Geologic conditions are suitable. No mineral resources have been identified.	See Bellefonte	For structures requiring rock foundations, a greater than normal amount of excavation may be necessary. No mineral resources of commercial value have been identified at the site.
Soils	Soils are suitable for engineering and agronomic uses.	See Bellefonte	See Bellefonte	See Bellefonte	Fewer uses available than at other sites, but still suitable for park development.

TABLE 3.2-1. SUMMARY OF SITE CHARACTERISTICS (Continued)

	Bellefonte	Hartsville	Phipps Bend	Watts Bar	Yellow Creek
Hydrology					
Water Availability	A ground water source of up to 1000 gpm can probably be developed within 2 miles of the site; surface water source is adequate	Insufficient ground water supplies would necessitate use of surface water source	Adequate surface water supplies can be developed, but ground water sources may be insufficient	See Bellefonte	See Bellefonte
Floodplain Elevations					
1% chance flood	601	468.5	1120, 1113.5	697	420 (preliminary)
0.2% chance flood	602	474	1123, 1117	701	422 (preliminary)
Structure profile	606	---	--	708	423
Water Quality	Existing conditions should not limit uses of the site but may restrict park discharges or open-system use of CCW	Concentration of chemicals in Cumberland River may present some use and discharge limitations	Chemical concentrations in Holston River and Cherokee Reservoir may present some use and discharge limitations	Dissolved oxygen levels may present some use and stringent discharge limitations for sources of oxygen-demanding pollutants	See Bellefonte
Ecology					
Terrestrial	Several terrestrial vertebrate "species of special concern" have been reported in site vicinity	Several species in site vicinity are listed as sensitive by State of Tennessee	Two State-listed threatened species have been reported from the site	Sensitive species have been identified in the immediate vicinity, i.e., bald eagle, osprey, and sandhill crane	No sensitive species have been identified on the site or in the immediate vicinity
Aquatic (Waterfowl)	Town Creek embayment adjacent to site, provides habitat for wetland wildlife	Dixon Creek provides habitat for wetland wildlife resources	The site provides habitat for wood duck production;	Yellow Creek Wildlife Management Area is adjacent to this site	Yellow Creek embayment supports extensive waterfowl use
(Fisheries)	Town Creek is a good spawning and nursery area for fish	A limited mixing zone is available in the river	A very limited mixing zone and severe raw water intake constraints exist	Migratory spawning species are present; limited dissolved oxygen resources	Yellow Creek is a productive fisheries spawning and nursing area
(Nonfisheries)	No sensitive species identified	Endangered species of mussel is present in site vicinity	A minimal mixing zone exists; no sensitive species have been identified	Two endangered mussel species are present in site vicinity	See Bellefonte

TABLE 3.2-1. SUMMARY OF SITE CHARACTERISTICS (Continued)

	Bellefonte	Hartsville	Phipps Bend	Watts Bar	Yellow Creek
Wetlands	Two wetlands areas, one unique to the region, are found within reservation boundaries	One wetlands area, a mud flat, exists on site	One emergent wetlands area, created by construction activities, is located at this stie	Three scrub/shrub wetlands areas have been identified	None within site boundaries
Air Quality	PSD Class II, with possible limited increment availability; proximity to high terrain and nonattainment area could be a problem for large sources	Near nonattainment area for O_3, with possible limited increment availability anticipated	See Bellefonte	PSD Class II, coal-fired steam plant modeling may indicate no increment availability; proximity to high terrain is potential problem	PSD Class II, with full increment availability anticipated
Radiological Considerations	Assuming similar conditions, doses from Bellefonte's PWR units should be less than those from BWR (see discussion in Section 4.3.2)	BWR units at this site would result in slightly higher population doses than similar PWR units (see Section 4.3.2)	See Hartsville	See Bellefonte	See Bellefonte
Cultural Resources	Historic preservation and clearance conflicts appear to be minimal	Ongoing historic preservation and clearance proceedings may be complicated by park development	Several sites eligible for the National Register are within reservation boundaries	One site within reservation boundaries appears to be eligible for National Register nomination	All significant cultural resources have been recovered and removed from the site
Socioeconomics	A sufficient socioeconomic base exists to support park construction and operation	See Bellefonte	See Bellefonte	See Bellefonte	See Bellefonte
Access	Highway, rail, and barge access are available	Rail access may not be available	There are no barge facilities	See Bellefonte	See Bellefonte

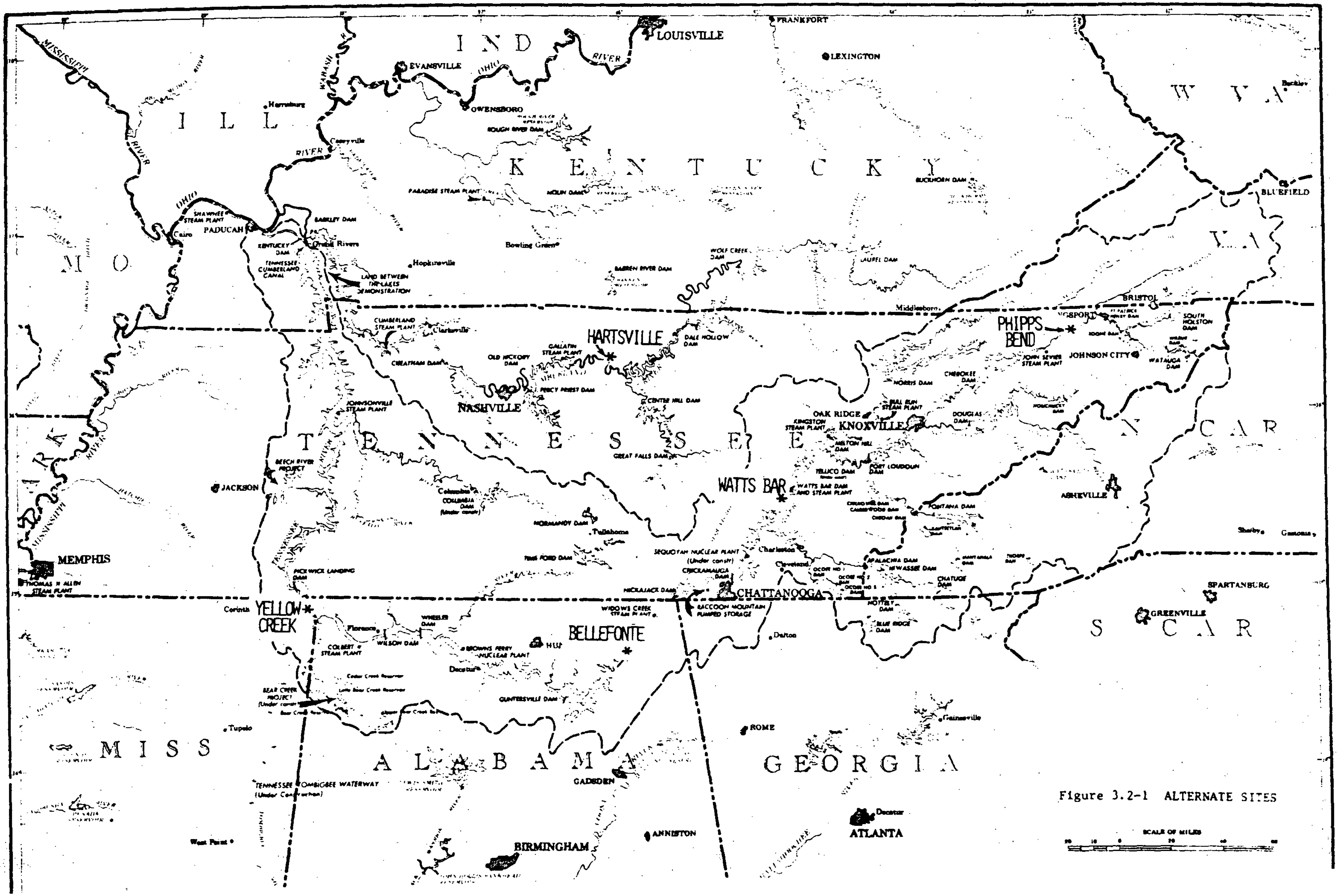

Figure 3.2-1 ALTERNATE SITES

4. ENVIRONMENTAL CONSEQUENCES ALTERNATIVES

General descriptions of park development and operations are presented in Sections 4.1 and 4.2. A summary evaluation of the effects of these actions on the alternatives under consideration is presented in Section 4.3.

4.1 GENERAL WASTE HEAT PARK CHARACTERISTICS

It is anticipated that the following services would be provided for park users regardless of which site is selected or who sponsors the development of the park:

1. Paved roads
2. Railroad spur
3. Potable water supply, preferably from a ground water source
4. Wastewater treatment for sanitary and some amenable industrial wastes, possibly using a biological recycling system
5. Electricity
6. Landscaping of open areas
7. Stormwater runoff management
8. Raw water supply, approximately 170,000 l/min (45,000 gpm)

The feasibility of providing central back-up and heat augmentation systems, as an alternative to individual units for each park user, is being evaluated. For assessment purposes, it is conservatively assumed that central systems would be provided and operated by the park management organization. Siting considerations for these systems would include accessibility to waste heat piping and proximity to users most likely to need augmentation or back-up capabilities. Two coal-fired facilities would be used as back-up units for operation during a plant outage. The initial unit would provide 95,000 l/min (25,000 gpm) of heated water and would consume about 7.2 t (8 tons) of coal per hour of operation. A 30-day coal stockpile, covering 1.6 ha (4 acres), would be maintained. The second back-up system would have a 284,000 l/min (75,000 gpm) capacity, with a coal consumption rate of approximately 20 t (22 tons) per hour. The 30-day stockpile would occupy about 5 ha (12 acres). Ash handling, utilizing mechanical collection, temporary onsite storage, and shipment to an offsite disposal area, would probably be used.

The augmentation system would increase the waste heat temperature from its average of 44°C (112°F) to a range of 60°-93°C (140°-200°F) for use in industrial processes. The 90,000,000 Btu unit would consume about 3.6 t (4 tons) of coal/hour. It is expected that a 30-day coal stockpile, occupying about 0.8 ha (2 acres), would be maintained; and ash handling, similar to that for the backup system, would be used. Alternatives to onsite central systems include using nearby steam plant coal pile and ash storage, other fuels such as gas or fuel oil, alternate sizes, and alternate locations.

TVA probably would sell the waste heat through public-oriented intermediaries (park management) rather than assume full responsibility at the waste heat source for park operation. The intermediary would be structured as a general not-for-profit corporation and/or an Industrial Development Corporation (IDC). This would allow citizens of the county to participate as members of the board of directors. IDC directors would be elected by the county government and would be qualified electors of and taxpayers in that county. Use of a public-oriented group should enhance local participation in the project and could improve the possibility of attracting capital from alternate sources.

The intermediary would be responsible for park development and operation, including obtaining necessary permits for park facilities such as a central wastewater treatment plant and augmentation and back-up systems, if utilized. Individual industries would obtain their own discharge permit and be responsible for their own fire protection and security, unless other arrangements can be made with the county.

4.2 WASTE HEAT APPLICATIONS

The waste heat park currently envisioned would probably include a "mix" of industries. This section describes some typical industries which could be anticipated to locate at a waste heat park. It is not the intent of this document to describe all potential industries suitable for location at a waste heat park or to predetermine the mix of industries that may wish to locate there. As industries express desire to locate at the park, they will be evaluated by TVA under NEPA and TVA's implementing procedures, and if necessary, conditions will be placed on easement agreements to protect the health and safety of the public, the environment, and other interests of the United States. The descriptions in this section present evaluations that assume compliance by the occupants with common industrial practices and existing laws and regulations. Industries proposing to locate at the park will be responsible for meeting at a minimum all applicable environmental regulations and standards. Interest to date in the waste heat park has been expressed by greenhouses, tanning, and ethanol industries.

4.2.1 Agricultural Applications

4.2.1.1 Greenhouses and Soil Warming

The following estimates have been prepared for a typical greenhouse or soil warming area.

Physical Facilities--Approximately 20-40 ha (50-100 acres) of greenhouses could be eventually built, with 2-8 ha (5-20 acres) being constructed within 5 years after a park opens. The two types of greenhouses would be those using a soil or pot culture and those using a hydroponic production system. Greenhouse structures would be aluminum- or steel-framed and would be glazed with polyethlene, fiberglass or glass. Approximately 1160 m^2 of service building area would be needed per hectare (5000 ft^2/acre) of greenhouse. Service buildings would be primarily prefabricated open-span steel buildings with concrete floors. Approximately the same amount of total land area would be needed for access roads, service buildings, and outside storage areas as that required for greenhouses.

Approximately 20 percent of the total greenhouse acreage is expected to use some form of hydroponic production system and would require a lagoon to hold excess nutrient solution. A lagoon with 344 m^2 surface area would be sufficient to accommodate discharges from 1 ha of greenhouses (1500 ft^2 of lagoon/acre of greenhouse). No storage area for hazardous materials would be needed. Approved pesticides would be stored in a locked storage room in the greenhouse service buildings in compliance with applicable regulations.

Approximately 10 ha (25 acres) of land may be used for a proof-of-concept demonstration of open field soil warming with waste heat. A 465 m^2 (5000 ft^2) metal storage building would be sufficient to store equipment and supplies for this demonstration project. The soil warming grid would consist of 2.54 cm (1 in.) PVC pipe buried approximately 46 cm (18 in.) deep and spaced on 46 cm (18 in.) centers over the 10 ha (25 acre) field.

Work Force--The manpower requirements for construction would vary considerably, depending upon the type of greenhouse used (glass, fiberglass, or double polyethylene) and the crops to be produced. Five to eight men could erect 0.4 ha (1 acre) of greenhouses in six months. Operating labor would vary considerably by crop. Six to ten full-time employees plus three to five additional peak season workers should be sufficient for 0.4 ha (1 acre) of most crops.

Operating Procedures--Only pesticides approved by the Environmental Protection Agency (EPA) would be used. Common insecticides and fungicides approved for greenhouse use are listed in Table 4.2-1. Fungicides and insecticides would normally be applied at 7- to 14-day intervals. The specific fungicide and/or insecticide used at each application would be dependent upon the crop, pest and label instruction. If individual back-up heating systems are used, the fuel storage capacity required would be about 7570 l (2000 gal) of LP gas or fuel oil per 0.4 ha (1 acre). Soil warming areas would require two to four cultivations each year. There should be no odor problems associated with greenhouses or soil warming. Fertilizer applications at the rate of about 168 kg nitrogen, 112 kg phosphorus, 112 kg potassium per ha (150 lb N, 100 lb P, 100 lb K per acre) would be made to the soil warming area annually. There would be no excessive noise or extensive use of ground water associated with these uses.

Approximately 10 ha (25 acres) of greenhouses are expected to use direct contact (evaporative pad) heat exchangers. The remainder will use dry-type heat exchangers. Approximately 4670 l/min (500 gpm/acre) of condenser circulating water (CCW) would be used per hectare of greenhouse. The only effect these exchangers are expected to have on the CCW, other than a cooling effect, is a slight increase in the concentration of total dissolved solids, similar to that expected if the water had passed through the cooling towers.

Discharges--Total application of irrigation water in hydroponic greenhouses would be approximately 28,050 l/ha (3000 gal/acre) per day. Irrigation drainage is expected to be less than 3806 l/ha (300 gal/acre) per day occurring over a 12- to 14-hour period. The approximate nutrient concentration in both irrigation water and drainage is shown below.

Nutrient	Applied (mg/l)	Drainage (mg/l)
Total N	145	120
NO_3-N	120	45
P	60	45
K	260	160
Ca	130	110
Mg	64	60
Mn	0.2	0.2

Pesticides could also be present in the drainage but should not cause a significant impact when applied at recommended rates. Irrigation drainage could be routed to a lagoon capable of a minimum 30-day retention. Typical lagoon design would call for an average depth of 1 m and a surface area of 344 m^2 per ha of greenhouse (3 ft depth with 1500 ft^2 of surface area per acre of greenhouse). Approximately 168 kg N, 112 kg P, 112 kg K per ha (150 lb N, 100 lb P, 100 lb K per acre) will be applied annually to the 10 ha (25 acre) soil heating area, which is subject to storm runoff.

Materials Flow--During the construction of the greenhouses, up to 124 truck trips delivering materials could be required per ha (50 trips/acre) of greenhouse over a 6-month construction period. During operation, an average of approximately 2 truck loads (1 load/acre) of material in and 2-7 truck loads (1-3 loads/acre) of products out per week would occur for each hectare of greenhouses. There would be no transportation of hazardous material and only a minimal movement of pesticides.

Solid Waste--Crop residues would compose most of the solid wastes from vegetable greenhouses. Approximately 11 t of dry matter per ha (5 tons/acre) would need to be disposed of twice annually. Waste from vegetable and ornamental greenhouses would include plant clippings, cull fruit, plastic plant containers, packing crates, paper and plastic bags, cardboard boxes, etc. Quantity would not exceed 560 kg/week/ha (500 lb/week/acre) of greenhouses. Twelve empty pesticide drums (one 5-gal drum/acre) and two empty pesticide bags per week per hectare (1 bag/acre) of greenhouse would need disposal. A new polyethylene covering will probably be installed at least every other year on each greenhouse. These materials would be disposed of in an approved landfill.

Crop residues from soil warming areas would be disposed of by plowing into soil on the soil warming plots where they were grown. Other solid waste such as fertilizer bags and pesticide containers would be disposed of in an approved sanitary landfill. Approximately 49 fertilizer bags/ha (20/acre) would need disposal after planting in early spring each year. No more than twelve pesticide drums per ha (one 5-gal drum/acre) of crop would need disposal each week between April 1 and October 1 each year.

Revenue Flows--Construction material costs would be \$185,000-\$618,000/ha (\$75,000-\$250,000/acre), dependent upon the type of structure. Construction labor costs would be \$123,000-\$371,000/ha (\$50,000-\$150,000/acre). Production costs for vegetables would range from \$99,000-\$198,000/ha (\$40,000-\$80,000/acre), and production costs for ornamentals would be \$74,000-\$371,000/ha (\$30,000-\$150,000/acre). Revenues from vegetables would be \$173,000-\$297,000/ha (\$70,000-\$120,000/acre), and from ornamentals about \$247,000-\$865,000/ha (\$100,000-\$350,000/acre). These figures, as are all cost projections in this section, are in 1979 dollars.

4.2.1.2 Livestock Production and Animal Waste Reclamation

The following discussion is based on a multiple unit concept for the proposed industry. The major components are: (1) finishing facility, (2) farrowing facility, (3) fish production (*Tilapia*) and marketing, (4) plant production (water chestnuts) and marketing, (5) fingerling production and marketing, and (6) anaerobic digester. Components shown in Table 4.2-2 can be combined in a number of ways; however, only certain combinations appear to be justified from an operational, biological, and possibly economic standpoint. The minimum combination would be a finishin facility with an aquaculture waste treatment system (1 + 3) or with the addition of a farrowing facility (1 + 2 + 3). However, for assessment purposes, all of the six possible components will be considered for their inclusion into a waste heat facility. Convective heat exchangers would be used in the livestock facilities and anaerobic digester. Plant and fish production would be direct-contact users of the CCW.

Swine Growing-Finishing

For a 1000-hog finishing operation and associated components, approxi mately 28 ha (70 acres) would be required (Table 4.2-2). This would inclu hog housing, feed storage, and waste disposal facilities for a controlled operation. The temperature range most often recommended for growing-finishing swine is from 7°-18°C (45°-65°F), depending upon the type structure and other factors. High animal densities in swine growing-finishing phases can contribute heat sufficient to maintain acceptable temperatures in enclosed buildings so that supplemental heat is not usually needed to maintain barn air temperatures. When direct heating has been used, fuel energy consumptions reported range from as low as 34,200 Btu's per pig for a low-temperature, environmentally controlled structure to as much as 1.5×10^6 Btu's per pig in a zone-heated, modified open-front structure.

Broiler Production

There is also potential for using waste heat for supplementally heating broiler production facilities, supplying 4000 to 5000 Btu's/bird/year. Heat is required for successful production the first few weeks of production throughout the year, and for the entire production cycle during winte months. The facility cost, operational requirements, access areas, materials flow, odors, etc., would be similar to the estimates for the swine finishing facility. The same size facility, 929 m^2 (10,000 ft^2), could be used to produce 5 crops of 12,500 birds per year. Dry-type heat exchangers would probably be used. The waste generated in a broiler facility is different than in swine production, and a floor litter is normally used. This broiler litter waste offers potential for direct sale as a livestock feed or a soil amendment. Broiler waste, unlike caged-layer waste, offers little potential as a feedstock for anaerobic fermentation.

The following unit sizes are based on the swine finishing facility and all of the support components (farrowing, fish and plant production, anaerobic digestion) to maintain a 1000-hog capacity finishing facility. The farrowing facility is sized to produce 10,000 feeder pigs per year. Excess feeder pigs not used in the finishing facility would be sold.

Swine Farrowing

Most crate dimensions for swine farrowing would be 1.5 m (5 ft) wide by 2 m (7 ft) long. The width includes a 46 cm- (18 in.-) wide pig area on both sides of a 61 cm- (24 in.-) wide sow area. Supplemental heat is required for swine farrowing throughout most of the year. However, heating requirements in summer months are minimal, and wintertime heat requirements are relatively low compared to greenhouses. If the power plant shuts down during a period when heat is required, alternate means must be provided for warming animals. During winter, when air is recirculated within animal shelters, high dust levels may accumulate. Heating this facility with waste heat would probably require the use of dry heat exchangers. This would probably be in the form of pipes or ducts in the floor for creep area heat and additional heating of ventilation air.

The heating capacity required for supplemental air heating is about 2000-3000 Btu's/hr/sow and litter. Normally a heat lamp (250 watts/litter) or electric resistance floor heat (320-430 watts/m^2) (30-40 watts/ft^2) is also used to furnish creep area heat. The total supplemental heat capacity required is about 3000-4000 Btu's/hr per sow and litter.

Fish Production

Disposal of confined livestock wastes would be handled as a slurry and diluted sufficiently to fertilize and support production of algae, which is a source of high-quality protein for livestock and fish. Two species of Asiatic carp and several species of the tropical *Tilapia* would be used to filter the microscopic algae from the organically fertilized water. By stocking these filter-feeding fish and other fish species of different feeding habits, it would be possible to use the available nutrients most efficiently. Ponds occupying about 14 ha (35 acre), would be stocked at a rate of 584 kg of fish/ha (520 lb/acre). A water flow rate of at least 107 l/min/ha (70 gal/min/acre) and 1 m (3 ft) deep would be required for fish production.

Plant Production

Water from fish culture ponds would be applied to drainable sand filtration beds in which Chinese waterchestnuts (*Eleocharis dulcis*) are growing. These plants would provide additional nutrient uptake, thus sufficiently improving the water quality to allow discharge to a receiving stream, reuse in the livestock rearing facility, or return to the cooling system. Waste heat would provide longer growing seasons and harvesting periods, reduce storage problems, and permit off-season marketing.

Fingerling Production

Intensive production of tilapia and silver carp fingerlings could be conducted using CCW during the winter months when ambient water temperatures would not sustain sufficient algae growth for fish production. Fingerlings would provide nutrient uptake for the recycling system and would also supply stock for the fish polyculture. Marketing channels have not been developed for tilapia or carp, but the potential exists.

Anaerobic Digester

Approximately 2400 m^3 (85,000 ft^3)/day of biogas would be produced from livestock wastes in an anaerobic digester, which would be housed in a 255 m^3 (9000 ft^3) sealed tank. The retention time of 10-15 days and the bacteriological processes in the digester also serve to pretreat the manure before its introduction into the fish culture ponds as a food source Waste heat would be used to maintain digester temperatures in the range for optimum gas production. The biogas, which would require handling procedures as a combustible gas, could be used as fuel to operate equipment in the livestock housing facility.

Physical Facilities--The building would probably be wood-framed, with plastic or wooden vents on the upper portion of the underwalls. The exterior covering and roof would be sheet metal and the building would be located on a concrete floor with provisions for manure collection and removal. There would probably be an associated feed storage bin and automatic feeding equipment. Some area would be required for access for loading and unloading, and roads should be capable of withstanding all weather traffic.

Work Force--Construction would require about 20 workers for 3 months. There would be 4 full-time and 1 at 1/4 time operational employees. Four temporary workers would be needed for 2 periods of 2 weeks during spring and fall.

Operating Procedures--Some odors would be anticipated from the livestock facility. These odors would not constitute a health hazard to persons in the vicinity. Periodic odor may be detected due to temporary operating conditions (i.e. draining lagoons, washing down facility, etc.). Properly implemented waste-handling methods (manure collection and removal aerobic conditions of fish production) should minimize the potential for detecting odors offsite.

The pesticides and fungicides used in any proposed livestock industry would be approved substances that are standard in the industry, including general categories of insecticides, rodenticides, bactericides, and antibiotics. Ground water or river water would be used to supply 37,850 l (10,000 gal) per day for livestock drinking water in the farrowing barn and other miscellaneous activities.

Discharges--The resultant discharges of the open-system-use CCW would be cooled by the convection and evaporational losses from the water surfaces of associated waste treatment lagoons. As a result of using livestc manures as the sole source of fertilizer and routing wastewater through the successive steps of the facility, the treatment of the waste-produced products would be designed for maximum resource recovery and minimal effe on water quality.

Solid Wastes--The solid waste generated by the livestock operation would consist mainly of organic waste that may result from accidental spillage of feeds, settleable solids that resist decomposition by natural processes, accidental fish kills in the facility due to uncontrollable factors, and possible spoilage of plant products during storage. Proxima waste fish poundage could be 113,000 kg (250,000 pounds). Water chestnuts could spoil in processing if not stored or shipped appropriately. The bulk of the chestnut solid waste would be fed to the finish hogs. Minimal office solid waste would be generated.

Materials Flow--Truck traffic to the site would consist mainly of the livestock shipments into and out of the park on a regular basis. Approximately 25 percent of the 1000-head herd of swine would be shipped to market approximately once a month. If this facility was only a finishing unit, then small feeder-pigs would be shipped into the facility as replacer pigs. Access areas and truck traffic would also be required for shipment of bulk feeds to the industry. Access roads should accommodate tractor trailer traffic.

Revenue Flows--Construction materials costs would range from $200,000 to $250,000. Construction labor costs are estimated at $100,000 to $150,000. Production costs would be about $650,000 to $800,000. Revenues from the following products could total $1.0 to $1.5 million:

	Units
Hogs Finished	3,000 hogs
Feeder Pigs	5,600 pigs
Food Fish	95,000 kg (210,000 lbs)
Fingerling Fish	500,000 fish
Chestnuts	408,000 kg (900,000 lbs)
Chestnut Hay	159,000 kg (350,000 lbs)
Methane Gas	8.4×10^5 m^3 (3×10^7 ft^3)

4.2.1.3 Grain Drying

Waste heat could be used for drying grain in units sized for a typical farmer or small farmer cooperative. These systems would probably involve the use of prefabricated grain bins with a capacity of 1060 hl (hectoliter)-3520 hl (3,000-10,000 bushels) for drying and storing grain on the site, with the most likely users being farmers in the vicinity. Use of waste heat would be seasonal, with drying occurring primarily in the fall and early winter. Some drying of spring wheat is also anticipated.

The following estimates are based on one 1760 hl- (5000 bushel-) capacity round grain bin. One such bin would serve about 24 ha (60 acres) of corn production or about 61-81 ha (150-200 acres) of soybean or wheat production. Once a grain is dried at the park, it would probably remain in the bin until sold or used. Several units on a site would allow better utilization of access areas, loading and unloading equipment, and waste heat supply systems.

Physical Facilities--The bin would be constructed of heavy gauge galvanized sheet metal with steel supports where required. A concrete footing would be required, and the bin would have a false floor supported by concrete or concrete blocks to form an air plenum. Bin dimensions would be a diameter of 6.3 m (21 feet) and a height of 7.3 m (24 feet) with an inverted conical cover. Truck access to each bin would be required and a single blower and dryer could serve either one or two units. Access areas should be paved to withstand truck traffic during adverse weather conditions. Each bin would require about 93 m^2 (1000 ft^2) of area which includes the bin, a concrete pad for the blower and dryer, and access areas for loading and unloading. No facilities for wastewater treatment would be required. If no central backup heating system is provided, propane gas storage (one 1900 l [500 gal] tank per bin) would be needed. Electric service required would probably be about 10 kW at 480 V, 3 phase. Blower size would be 5-10 hp, and the dryer size would be from 350,000 to 1,000.000 Btu/h. Design features such as the concrete footing and conical cover would provide protection from rodents and insects.

Work Force--During construction, about 100 hours of labor would be required to assemble the bin, including all footings, structural components, and blower and dryer mounting and connections (three people working for less than one week). During operation, two people would be needed during loading and unloading (for about two days). During drying and storage, infrequent inspections only would be required.

Operating Procedure--One to three drying cycles per year could be expected, with most bins used for one cycle. Waste heat via convective heat exchangers would provide the energy for drying one cycle from about 25 percent moisture to 15 percent moisture, which would require 1900-2800 l (500-700 gal) of LP gas in a conventional bin. One drying cycle could last from one week to four weeks, depending on the grain, initial moisture content, and amount of heat available. Intermittent ventilation of grain would be required during storage. Unmuffled blowers could emit a high frequency noise that could be heard up to 1.6 km (1 mile) from the facility during operation. Pesticides are not normally used. Because of the relatively small bin size and the ventilation requirements, the possibility of explosion should be negligible.

Discharges--Particulate emissions could result from loading and unloading grain. Air flow rates of 420-700 m^3/min (15,000 to 25,000 cfm) would be discharged from the top of the bin and some dust could be discharged in this airstream. The amount and type of dust would depend on the type and condition of the grain, but is usually negligible in terms of pollution from a bin of this size.

Solid Waste--Any solid wastes generated would be grain dust or residues from loading or unloading. These are usually "composted in place," but could be hauled to a landfill. Normally, less than one ton of waste including a small volume of office waste would be associated with one cycle in a bin of this size.

Materials Flow--Approximately two truck loads of material and personnel traffic for three people would be sufficient during a construction period of less than one week. Construction materials would include sheet metal, cement, steel supports, and concrete blocks. About 15-20 truck loads of grain would be required for loading or unloading grain, with about 88-106 hl (250-300 bushels) per load. One load of propane (for a 1900 l [500 gal] truck) would be required monthly for each bin during drying cycles, if no central backup system is provided.

Revenue Flows--Materials cost for one bin with blower and propane dryer would be approximately $2000. Labor cost for construction would be about $1000. Electric usage for one crop would be about 1000 to 1500 kWh during drying and storage, or about $0.01 per bu. Propane cost for a conventional system would be about $350, or about $0.07 per bu., for one cycle. Less than 10 man-hours per week would be required during drying and storage. The value of the dried grain would be about $16,000 for corn or $35,000 for soybeans.

4.2.2 Aquacultural Applications

Potential aquaculture development would include commercial production of edible-size fish, commercial production of seed stock, or a public fish hatchery.

Physical Facilities--Concrete raceways partially imbedded in the ground would be used to rear fish. Water could be cascaded from section to section to improve oxygen levels. Some operations or portions could be covered with open span steel structures or pole barn-type covers for protection from weather. Access areas need to be sufficient for tractor-trailer trucks moving in and out of area for hauling fish and feed. This would probably require one hectare of additional area for each hectare of water surface (acre/acre). A security fence would be required around individual operations to prevent poaching. Holding ponds would be required with retention times of 15-30 minutes to settle solid wastes. Extensive downstream aquaculture ponds may be utilized to further improve water quality. Detailed pond system engineering remains to be developed, but the system could be similar to the concepts described in Section 4.2.1.2 for the livestock waste recycling system.

Work Force--Construction activities would require about 60-80 workers for six months. Operational manpower would range from 10 to 15 employees.

Operating Procedures--The aquaculture system involves the mixing of CCW and ambient surface water. This is one of three uses identified for direct contact use. The following pesticide and fungicide treatments may be used:

1. Formalin - 250 ppm for 1 hour
2. Potassium Permanganate - 10 ppm for 1 hour
3. Salt - 3% solution
4. Terramycin - 2-4 1/2 gram/100 lb fish/day for 7 days

Cleaning cycles would be needed approximately 1 percent of total operating time. There would not be a need for fuel storage, cultivation, irrigation or fertilizer application. No odor problems are anticipated under normal operations. An approved landfill will be required to dispose of any mass fish die-offs. No excessive noise is expected. About 114,000 l/min (30,000 gpm) of CCW will be used directly with no heat exchangers. The facility would be using raw water to moderate wastewater temperature. The maximum raw water flow rate would be about 114,000 l/min (30,000 gpm).

Discharges--Wastewater from raceways normally have a BOD_5 ranging from less than 10 mg/l during normal operations to 200 mg/l during cleaning Removal of low concentrations of solids could be accomplished in a settling pond; phytoplankton may build up but could be harvested to a certain extent in downstream ponds by extensive aquaculture means similar to those describ in Section 4.2.1.2. Wastewater from the system would be treated to meet applicable performance standards (at a minimum) as well as water quality criteria and/or levels of discharge commensurate with the assimilative capacity of the receiving stream.* Treated effluents would be returned to the condenser cooling system and the river in the same proportions as initially received.

Solid Waste--Dead fish disposal would need an approved landfill. Feces, etc., should settle in settling pond and decompose.

Materials Flow--Traffic during construction would involve about 250-370 truck loads of material per hectare (100-150/acre), including some dirt moving. Cement, structural steel, and fencing would be the only construction materials. Operational traffic would be 2-5 trucks per day per hectare (1-2/ acre), plus employment traffic. There would not be any transportation of hazardous materials.

Revenue Flows--Construction materials cost, including dirt moving, would be about $3.1-$4.3 million/ha ($1.25-$1.75 million/acre). Construction labor cost at $8/hr would be $1.1-$1.5 million/ha ($450,000-$600,000/acre). Production cost would range from $500,000-$620,000/ha ($200,000-$250,000/acre). Production revenues are estimated at $0.9-$1.2 million/ha ($350,000-$500,000/acre).

4.2.3 Industrial Applications

4.2.3.1 Selection Criteria

The primary criterion for selection of a particular industry is its compatibility with the nuclear plant systems. Transportation methods and types of cargo; the processing, manufacturing, or utilization of potentially hazardous materials; and types of structures associated with the facility are factors to be considered to ensure that no park users would impact the safe operation of the plant. Additional selection criteria include technical feasibility, space requirements, production demand labor requirements and availability, energy requirements, environmental acceptability, and materials availability. All industries will comply with applicable Federal, State, and local rules and regulations.

Several industries have been identified as feasible candidates for location at a waste heat park. Characteristics of these industries are presented in Table 4.2-3.

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*This criterion is applicable to all wastewater discharges from any of the potential facilities. Mitigation will be site, industry, and process specific, commensurate with probable impacts.

Descriptions of these industries are provided below. The first group of applications (meat, soybean, and vegetable processing) are the most likely candidates for location in the park because of their relation to other park uses already identified. This is a tentative identification of broad categories of potential industries; specific details for some industrial uses are so site- or process-dependent that they cannot be provided at this time.

Standard Industrial Classification*	Industry
201	Meat Products
203	Canned and Preserved Fruits and Vegetables
204	Grain Mill Products
2065	Candy and Confectionary Products
2066	Chocolate and Cocoa Products
2075	Soybean Processing
2098	Macaroni, Spaghetti, Vermicelli, and Noodles
2491	Wood Preserving
2833	Medicinal Chemicals and Bontanical Products
2865	Cyclic Crudes and Intermediates; Dyes and Organic Pigments
2869	Distillation of Industrial Alcohol
2891	Adhesives
311-319	Leather Tanning and Products
327	Concrete Products
3471	Electroplating
3713	Truck and Bus Bodies

4.2.3.2 Fish Processing Plant

The following characteristics describe a typical fish processing facility.

Physical Facilities--The structure would be open-span prefabricated steel with metal sides. The floors and loading platforms should be constructed of materials easily cleaned such as concrete or tile which would not become water-soaked and contaminated with organic substances. Windows, doors, and other entry areas would be screened. A plant capable of processing 2300 kg (5000 lbs) of dressed fish per day [913,000 kg (2 million lbs) annual live weight] would require a building about 9 by 18 m (30 by 60 ft). Access areas would be sufficient to accommodate tractor-trailer truck traffic to the plant and to the holding ponds. A concrete holding tank adjacent to the plant would be required to hold 2300-3200 kg (5000-7000 lb) of fish. A structure 12 by 1.2 by 1 m (40 by 4 by 3.5 ft) with features allowing easy harvesting would be ample. There would be no storage of hazardous materials.

Work Force--Construction would require about 8 workers for 6 months. An operation work force of 15-20 employees, including management, would be needed.

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*Identification codes from Standard Industrial Classification Manual, 1972.

Operating Procedures--Approximately 76-114 l/min (20-30 gpm) of potable water would be needed. The only use of CCW would be to heat the building. Noise would not be excessive. Waste products including scales, bones, and internal organs (offal) must be continuously removed from the processing area to prevent breeding of flies or development of offensive odors. An approved landfill for offal would be required. The offal could be used to make fertilizer or feed if volume warranted this. Fish processors would comply with applicable State and Federal health standards.

Discharges--Approximately 38-76 l/min (10-20 gpm) of process water with some offal would be generated. This would require an aerated lagoon with about a 10-day retention time, with approximate dimensions of 15x15x1 m to 21x21x1 m (50x50x3 ft to 70x70x3 ft). Any discharges would comply with State and Federal water quality regulations.

Solid Waste--About 1360-1588 kg (3000-3500 lbs) of offal would be generated daily by a 2300 kg (5000 lb) per day (dressed fish weight) plant. A small quantity of office solid waste would be produced. All solid waste would be taken to an approved landfill for disposal.

Materials Flow--During construction, 20-25 loads of material and equipment would be needed. There is potential for some dirt moving for holding tank and lagoon construction. Operational traffic would be composed of 2-3 trucks per day delivering materials and shipping products, daily trips to approved landfill, and normal employee and visitor traffic. If central back-up and augmentation systems are provided, there would be no transport of hazardous materials.

Revenue Flows--Construction materials cost would be $100,000-$150,000. Construction labor cost would be about $50,000-$70,000. Annual production cost would range from $300,000-$400,000. Gross annual revenue is expected to be about $1.75-$2.5 million. Production revenues less cost of fish purchased would yield about $0.75-$1.1 million/annually.

4.2.3.3 Beef Slaughtering Plant

The following estimates for a beef slaughtering plant are based on a 60-head-per-hour, single shift, 8-hour day.

Physical Facilities--The building would be a single-story structure, requiring about 1.2 ha (3 acres) of land. This area includes holding pens with concrete floors and open sides, but does not include any waste treatment facilities. Slaughter facility would include kill floor, dressing and chill rooms, coolers, boilers, and storage area. Structure should be brick or tile which would not become water-soaked and contaminated with organic substances. Floors would be rough-finished concrete and well-drained. Approximately one drain would be required for each 37 m^2 (400 ft^2) of floor space.

The slaughter building would need to be about 1950 m^2 (21,000 ft^2), and the holding pens and alleyways about 2400 m^2 (26,000 ft^2). Access areas would be sufficient to accommodate tractor-trailers to and from the processing plant and to the holding area. There would be no storage of hazardous material if central back-up and augmentation units are used.

Work Force--Construction would require about 25 employees for one year. There would be an operational work force of 90-100 employees, full time, including management, with little or no seasonal variation.

Operating Procedures--About 760-1130 l/min (200-300 gpm) of water would be needed for washing in the kill room and up to the point where carcasses are hung in the chill room. Odor would be generated only in the holding area and kill room. Proper handling of wastes would minimize odors and confine them to the immediate vicinity. Noise levels would not be anticipated to be a problem.

Discharges--Because closed heat exchange system will be used to heat water, no change would be experienced in the quality of CCW. About 870-900 l (230-240 gal) of raw process water would be required per head slaughtered. If a lagoon were used for water treatment, about 1.2-2 ha (3-5 acres) of land would be required. Most of the solid waste would be removed and used for recycling into livestock feed. About 2.7 kg (6 lbs) of manure would be produced per head per day for animals held in the holding area. This waste could be removed and used as fertilizer, or it could be suspended and treated in the water treatment facility.

Materials Flow--Construction materials would include concrete, concrete blocks, glazed brick or tile, structural steel, and wood. Roads would need to accommodate tractor-trailer trucks and large concrete transport equipment. During operation, live beef cattle would be the major input material received, and at least part would be shipped in by tractor-trailer. Materials out would be beef carcasses and parts and dehydrated solid waste material. Most would be shipped out by tractor-trailer.

Revenue Flows--Construction costs for pens and alleyways would be about $650,000. The building construction would be expected to cost about $735,000 and labor costs would be about $500,000. Wages would average about $1-$1.5 million annually. Operating costs would be $500,000-$800,000 annually, in addition to a yearly expenditure for cattle of about $85 million. Gross annual revenue would be expected to be about $90 million.

4.2.3.4 Broiler Processing

The broiler processing facility is based on a 10,000 bird-per-hour plant. Live birds will weigh 1.6 kg (3.5 lbs). The plant will operate 8 hours per day for about 250 days per year.

Physical Facilities--The broiler processing facility would consist of two buildings. One would have a pole frame with open sides, a concrete drive-through floor, and fans located to circulate air through chicken coops stacked on tractor-trailer trucks. The other building would house the slaughter-processing operation, which would include a weigh station, unloading docks, a kill floor, and rooms for scalding, picking, pinning, drawing, cutting up, cooling, weighing, ice-packing or freezing, plus load-out facilities. The slaughter plant would have a concrete floor with drains, concrete block walls with an impervious surface, and drip-proof ceilings. The structure for holding birds would be 550 m^2 (6000 ft^2) and the slaughter facility would be 2800 m^2 (30,000 ft^2). The access area would need to be sufficient to accommodate tractor-trailer truck traffic for shipping in live birds and for shipping out ice-packed processed birds.

Work Force--A construction force of about 20 workers would be needed for a year. Operations would require 300-325 employees per year, full time, including management.

Operating Procedures--CCW would be used for preheating process water and for space heating. Temperatures would have to be augmented. No fuel storage would be required unless natural gas was used for augmentation.

Discharges--About 30 l (8 gal) of water per bird is used for processing broilers, producing about 8250 l (2200 gal) of waste water per 454 kg (1000 lbs) of birds processed. The BOD level per 454 kg (1000 lbs) of birds processed would be 3 kg (8.2 lbs), and suspended solid waste would be 2.3 kg (6.3 lbs). Most of this would be blood and grease that cannot be controlled for refining into animal feed.

Odors from rendering and dehydrating the offal, feathers, and blood would be confined to the vicinity of the cooking vats.

Solid Waste--Manure, feathers, dust, and other solid waste from the holding area would be collected by dry cleaning and rendered with the offal, feathers, and blood into high-protein feed for sale back to the feed industry. The quantity is small, for short holding periods. Almost all of the 386 kg of offal and 154 kg of feathers produced per 1000 kg (175 and 70 lbs/ 1000 lbs) of live weight slaughtered are recovered. About 85-90 percent of the 154 kg/1000 kg (70 lbs/1000 lbs) of blood is also recovered. There would be a small quantity of office solid waste generated.

Materials Flow--For construction, concrete trucks, tractor-trailers, and a crane for hauling concrete, cement blocks, structural steel, and building supplies would be needed. During operation live birds would be the only material shipped in, requiring about five 23 t (25 ton) tractor-trailer loads per day. Dressed birds and high protein animal feed ingredients would be shipped out, requiring six 23 t (25 ton) loads daily.

Revenue Flows--Construction costs would range from $1.2-$1.5 million, including construction wages amounting to about $500,000. Annual operating costs would be about $12 million (including purchase of broilers), with wages constituting an additional $6.3 million annually. Gross annual revenue would be about $20 million.

4.2.3.5 Hog Slaughtering Plant

The following estimates for a hog slaughtering plant are based on a 300-head-per-hour, single-shift, 8-hour day.

Physical Facilities--The building would be a single story structure requiring about 0.8 ha (2 acres) of land. The area would including holding pens with concrete floors and open sides. The slaughter facility would include a stunning area, a scalding vat and dehairer housed in a story-and-a-half room [4.5 m (15 ft)] to allow sufficient working room. Other space needed would be for a chill room, cooler room, boiler room, a smoking room for curing bacon and ham, plus a room for boxing parts. The structure should be glazed brick or tile which will not become water-soaked and contaminated with organic substances. The floors should be rough finished concrete and designed so that they are well drained. For areas where wet operations take place, one drain would be required for each 37 m^2 (400 ft^2) of floor space. The holding area would need to be about 185 m^2 (20,000 ft^2) for pens and alleyways. The building would need to be about 1395 m^2 (15,000 ft^2). Access areas would need to be sufficient to accommodate tractor-trailer truck traffic to and from the processing plant and to the holding area. There would not be any storage of hazardous material unless natural gas was used for augmentation.

Work Force--Construction would require about 20 employees for one year. For operations, 60-70 employees, including management, would be needed. There would be little seasonal variation in operational labor requirements.

Operating Procedures--The plant's raw water supply requirements would be about 345 l/min (91 gpm). Water in the scalding tub would need to be 71°C (160°F), which will require augmentation above CCW temperature. Water for washing would be needed throughout the kill area and to the point where carcasses are hung in the chill room. Odors would be generated from the holding area and in the kill room, particularly in the dehairing and the eviscerating operations. However, proper cleaning would minimize the odors and confine them to the immediate area where the operations are being performed. Noise levels would be within acceptable limits. CCW would be used to heat the building and to elevate the temperature of the hot water needed before it enters the boilers.

Discharges--A closed heat exchange system would be used to heat water, with no change experienced in the quality of CCW.

About 64-72 l (17-19 gal) of wastewater will be discharged per head slaughtered. The water would contain some offal, blood, and grease from processing. Although the inedible and waste portions amount to about 18 kg (37 lbs) per head, most of this inedible offal, blood, and grease would be dehydrated and recycled for livestock feed. Therefore, the amount of wastewater requiring treatment would be minimized. Discharges to the air would be minimal and would not be expected to be detectable beyond the plant area.

Solid waste would consist of a small quantity of office solid waste and about 1 kg (2 lbs) of manure produced per head per day held. Most hogs would be slaughtered the same day; few would be held over two days after receipt at the holding area.

Materials Flow--Construction materials would include concrete, concrete blocks, glazed brick or tile, structural steel, and wood. The road system would need to accommodate tractor-trailer trucks and large concrete transport equipment. During operations, live hogs would be the major input materialreceived, and at least part would be shipped in on tractor-trailer trucks. Materials out would be hog carcasses and parts and dehydrated solid waste. Most would be shipped out by tractor-trailer trucks.

Revenue Flows--Construction costs for pens and alleyways would be about $250,000. The building would cost $525,000 to construct. Labor (20 people for one year) costs would be about $400,000. Wages would range from $1.0-$1.5 million, including management, per year. Operating costs would be about $500,000 per year, plus $45-$55 million to purchase hogs. Gross annual revenue would be $50-$60 million.

4.2.3.6 Soybean Processing Facility

The following characteristics would apply for a soybean processing facility.

Physical Facilities--The facility would consist of storage capable of supplying processing requirements for 60 days. The processing facility would include a preparation facility, flaking operation and oil solvent extraction plant, and meal and oil storage. It is assumed that oil would be shipped out as crude oil.

Buildings would be concrete and steel. The extraction plant would be a multiple-story structure with concrete and wire floors on each level with open sides. Meal storage would have metal sides. Soybean storage would be in steel bins with concrete floors. Oil storage would be in stainless steel tanks. A plant capable of processing 2000 tons of soybeans per day would require building space of 3555 m^2 (38,250 ft^2). See Table 4.2-4 for area requirements by facility.

The facility would need access by road, rail, and water. Storage facility needs would be four 352,000 hl (1 hl = 2.842 bu) tanks.

Work Force--A construction crew of 100-150 employees would be needed for two years. For operations, 100-125 employees, including management, would be needed for 24 hours/day.

Operating Procedures--The CCW would be used to preheat the air by convection for use in drying beans in preparation process. Air used in drying process would need to be 76°C (169°F); therefore, supplemental heat would be required. Hot water would also be needed in the softening process, and the waste heat water can be used in the exchange process for heating water for that purpose. Approximately 30,000 l (8000 gal) of process water per hour is used, of which about 19,000 l (5000 gal) would be taken up by the process. The remainder is recycled. Natural gas would probably be used for dryer and boiler (unless other types of petroleum are used). Hexane, a solvent used in oil extraction, is highly flammable. Approximately 3785 l (1000 gal) of hexane is evaporated per day of operation. About 2.8 million l (75,000 gal) of hexane would generally be stored underground in metal tanks.

Discharges--Preliminary estimates indicate that a closed heat exchange system would be used, so that no water would be discharged. There would not be any solid waste, other than minimal office waste, produced. Accidental discharges of hexane or soybean oil could occur during transport, transfer, or storage. Odors could be confined to the plant area. Particulate emission could occur during materials transfer.

Materials Flow--Heavy-duty trucks would be required for bringing in concrete, structural steel, and equipment during construction phase. Soybeans would be delivered by rail, barge, or truck, requiring 85 23 t (25 ton)-truck loads per day for processing. About 1450 t (1600 ton) of meal would be produced per day, requiring 64 23 t (25 ton) loads and shipped out by rail, barge, or truck. About 318 t (350 ton) of oil per day would be available for shipping, primarily by barge and truck. The transportation of hexane would be conducted according to applicable regulations.

Revenue Flows--Construction labor costs would range from \$5-\$8 million. Construction materials would cost from \$5-\$10 million. Operating labor costs would be \$2-\$2.5 million annually. Processing machinery would cost about \$8-10 million. Production cost, excluding purchase cost of beans would be \$9-\$12 million annually. Bean acquisition cost would be \$120-\$160 million. Gross annual revenue would be from \$160-\$200 million.

4.2.3.7 Turkey Processing

The turkey processing facility is based on a 1000 turkey (heavy young hens) per hour plant. Live birds weigh about 8-9 kg (18-20 lbs) with a dressed weight average of 6 kg (13 lbs). The plant would operate 8 hours per day for about 250 days per year. Many turkey processing plants also process broilers.

Physical Facilities--The turkey processing facility is essentially the same structure as that for chicken processing, except that the structures will require approximately 3700 m^2 (40,000 ft^2) due to the larger-sized birds. The holding area will be a 558 m^2 (6000 ft^2) pole-framed building with a drive-through concrete floor. Access areas would be needed to accommodate tractor-trailer trucks for shipping live birds into the facility and ice-packed processed birds out of the plant.

Work Force--A construction crew of 22 workers would be needed for approximately one year. For operation, 100-110 full-time employees, including 10 management/supervisory, would be needed.

Operating Procedures--The temperature of process water would need to be increased to 71°C (160°F) for some operations. Odor would be confined to vicinity of cooking vats where offal is rendered. Water used in processing turkeys would be 3750 l per 1000 kg (1700 gal/1000 lbs) of live weight slaughtered.

Discharges--Solid waste (manure, feathers) would be collected by dry cleaning and rendered with the offal, feathers, and blood for sale back to feed industry. About 70 kg of feathers per 1000 kg of live weight (70 lbs/1000 lbs) and almost all of the 125 kg of offal would be recovered and would not require discharge. About 85-90 percent of the 70 kg of blood is recovered and would not be discharged. Solid waste materials are rendered as high protein feed and sold to the feed industry.

The BOD level would be 3.6 kg (8 lbs) and the suspended solid waste level would be 2.3 kg (5 lbs) per 1000 birds slaughtered; most of this is blood and grease that cannot be controlled and processed for feed.

Materials Flow--Construction materials would include concrete, cement blocks, structural steel, wood, and other building supplies.

Operational materials shipped in would be live birds, and materials shipped out would be dressed turkeys and high protein feed ingredients. Three incoming 23 t (25 ton) tractor-trailer loads daily would be needed, and 2-3 outgoing loads per day would be expected.

Revenue Flows--Construction costs would be about $1.5-$2 million, including $400,000-$500,000 for construction wages. Operating costs, including $2-$2.5 million for wages, would be $5-$6 million per year. Costs for purchasing turkeys to process would be $12-$15 million annually. Gross annual revenue would range from $15-$25 million.

4.2.3.8 Vegetable Processing Plant

The following estimates for a vegetable processing plant are based on a multiple-purpose plant capable of canning leafy greens, lima beans, and southern peas, and capable of producing 1500 cases of number 303 cans per hour. The canning season would be about 90 days for these products.

Physical Facilities--The building would be a single-story structure requiring about 0.8 ha (2 acre) of land, excluding wastewater treatment facilities. The building would be about 1670 m^2 (18,000 ft^2) of enclosed space. All floors should be concrete and ceilings should be drip-proof. Walls should be sealed so that they are moisture-proof; this could be tile, glazed brick, or sealed concrete.

Access areas should be sufficient to accommodate tractor-trailer truck traffic for receiving raw inputs and shipping canned vegetables.

Work Force--Construction would require an estimated 18 employees for one year. For operation during canning season 12-18 full-time employees, including management, would be needed. Seasonal work force needs would be 30-40 part-time employees to work during the 4-5 month canning season.

Operating Procedures--The operations include temporary storage at the unloading docks, cleaning, washing, flotation cleaning, inspecting, shelling, chopping or slicing, holding, blanching, cooling, brining, dewatering, filling cans, closing cans, processing, cooling, labeling, palletizing, storing, and loading. Process water requirements would be 380 l/min (100 gpm). It is possible that some of this water, used in cleaning and canning processes, could be treated and recycled. With proper waste disposal, odors should not be objectional and would be confined to the processing area. Some steam and exhaust would be emitted. Increases above background noise levels would be minimal.

Discharges--CCW quality would not be affected because a closed exchange system would be used to transfer heat. About 380 l/min (100 gpm) of process water would be generated, with the BOD level ranging from 1.2 to 3.6 g/l (.01 and .03 lbs per gal) of water. Most waste from vegetable processing plants is biodegradable. About 2540 t (2800 ton) of process solid waste would be produced annually, which includes pea hulls and other plant materials that would be discarded. A minimal quantity of office solid waste would be produced. These wastes would be disposed of in an approved landfill.

Materials Flow--Construction materials would include concrete block, glazed brick or tile, structural steel, and wood. Operations would involve the shipping in of raw vegetables, cans and lids, cases, labels, salt, and minor supplies used in processing. Shipments out would be canned vegetables.

Revenue Flows--Construction costs would be $700,000-$1,000,000, with construction wages comprising an additional $360,000-$500,000. Operational costs would be about $1.5-$2.0 million annually. Operating wages would be $400,000-$500,000. The cost of raw products would range from $1.5 to $2.0 million. Gross annual revenue would amount to $5-$5.5 million.

4.2.3.9 Other Food Products

Other food processing industries with the potential for locating at a waste heat park would be manufacturers of the following: candy and confectionary products; chocolate and cocoa products; chewing gum; pasta products; dried and dehydrated fruits, vegetables, and soup mixes; pickled fruits and vegetables, vegetable sauces and seasonings, and salad dressings; dog, cat, and other pet food; and prepared feeds and feed ingredients for animals. Operations and materials would be similar to those previously described for specific food products. CCW would be used in convective heat exchangers to preheat process and cleaning water and for space heating. Wastewater discharges could contain suspended solids, oxygen-demanding wastes, oil, and grease, and/or alkaline and acid wastes. Air effluents could include dust from grinding or handling flour, sugar, or cocoa.

Several of the food processing industries described in the previous sections have the potential to generate odoriferous solid wastes. These wastes will be disposed of in an environmentally acceptable manner meeting all applicable regulations. Landfills, if used for disposing of these wastes will not impact residential or recreational areas. If acceptable landfills are not located in the vicinity of the waste heat park, industries producing these wastes will be responsible for transporting them to acceptable landfills, reprocessing them, or disposing of them in other environmentally acceptable ways.

4.2.3.10 Medicinal Chemicals and Botanical Products

This manufacturer would be engaged in (1) manufacturing bulk organic and inorganic medicinal chemicals and their derivatives and (2) processing (grading, grinding and hulling) bulk botanical drugs and herbs. Establishments primarily engaged in manufacturing agar-agar and similar products of natural origin, endocrine products, manufacturing or isolating basic vitamins, and isolating active medicinal principals such as alkaloids from botanical drugs and herbs are also included in this industry.

Physical Facilities--Land requirements for this industry would be about 40 ha (100 acres). The plant itself would contain about 9290m^2 (100,000 ft^2). Highway access would be necessary.

Work Force--Approximately 500 operational workers, without specialized skills, would be needed.

Operational Procedures--Chemicals would be isolated or manufactured, then packaged for shipment.

Discharges--Wastewater could contain oxygen-demanding wastes, suspended solids, chromium, zinc, lead, and mercury. Solid waste that could be transported to an approved landfill would include plant residue, paper, and glass. Other wastes requiring special handling would depend on the type of drug manufactured, but could include heavy metals; antibiotics; recovery, purification, and extraction solvents; alkaloids; crude steroids; oil and organic residues; alcohols; activated carbon; blood plasma fractions; salts; and cyanides. Special care would be necessary to assure that significant amounts of toxic and hazardous substances from this source do not reach water sources or do not contaminate products produced at the park.

Material Flows--Incoming operational materials would include biological products, chemicals, herbs, and packaging materials.

4.2.3.11 Cyclic Crudes and Intermediates; Dyes and Organic Pigments

This industry would be engaged primarily in manufacturing coal tar crudes and cyclic organic intermediates, dyes, color lakes, and toner. Important products of this industry include: (1) Derivatives of benzene, toluene, naphthalene, anthracene, pyridine, carbazole and other cyclic chemical products, (2) synthetic organic dyes; (3) synthetic organic pigments; and (4) cyclic (coal tar) crudes, such as light oils and light oil products, coal tar crudes, and products of medium and heavy oil such as creosote oil, naphthalene, and tar.

Physical Facilities--Coal tar and other organics would be transported to the site by truck or rail. The industrial site would occupy 16-20 ha (40-50 acres). The processing plant itself would require from 280 to 920 m^2 (3,000-10,000 ft^2). Highway, rail, and barge access would be needed.

Work Force--Approximately 50 workers would be employed for plant operation.

Operating Procedures--The coal tar is heated to a desired level in which the lighter fractions are removed.

Discharges--The waste stream could contain oxygen-demanding wastes, suspended solids, heavy metals, metal oxides, aliphatic halides, alkylbenzene, amines, ammonia, arenes, benzene, carboxylic acid, chlorinated aromatics, cyclic aliphatics, ether, ketone, phenols, and sulfuric acid. Special handling procedures would be required for both liquid and solid wastes to assure that significant amounts of toxic and hazardous substances from this source do not reach watercourses or contaminate goods produced at the park. There would probably be no discharges. Odors could be generated.

4.2.3.12 Adhesives

Industrial and household adhesives, including glue, caulking compounds, sealants, and rubber cements from vegetable, animal, or synthetic materials, would be manufactured. The adhesives would then be sold to various industries such as tape producers and carpet manufacturers. The following information applies to a plant operating on a single shift, producing 8 million kg (18 million lbs) of adhesives annually.

Physical Facilities--Approximately 1 ha (2 acres) of land would be required for a plant occupying 1900 m^2 (20,000 ft^2).

Work Force--About 25 employees would be needed for plant operation.

Operating Procedures--The operation of an adhesives plant would depend on the type of adhesive being produced. For latex adhesives, bales of rubber would be cut into thin sheets and milled with chemical additives. Softeners, in the form of plasticizers, and polyvinyl acetate resins are added and mixed. Chlorinated solvents are added, and the material is agitated.

Discharges--Waste streams would vary according to the type of adhesive being produced. Process liquids could contain suspended solids, dissolved solids, oil and grease, oxygen-demanding wastes, vinyl alcohols, polyvinyl acetate, dextrins, and caustics. Effluents would require special handling and treatment in lieu of discharge to assure that significant amounts of toxic and hazardous substances from this source do not reach watercourses or contaminate products produced at the park. Manufacturing processes could produce odors.

Material Flows--Most of the raw materials and finished products would be transported by truck. Raw materials would include rubber, zinc oxide, crepe, paracoumarone resin, wood resin, and oil. Water consumption would be about 190 l/min (50 gpm).

4.2.3.13 Leather Tanning and Products

These related industries would involve leather tanning as well as manufacturing leather goods such as saddlery, riding tackle, embossed leather goods, desk sets, razor straps, beltry, shoes, gloves, luggage, and handbags.

Physical Facilities--Leather tanning facilities would require about 0.4 ha (1 acre) of land and a building with 1700 m^2 (18,000 ft^2) of floor space. Land requirements for leather products manufacturing range from less than 0.04 ha (0.1 acre) for handbags to 4-6 ha (10-15 acres) for luggage manufacturing. Buildings range from 55 m^2 (600 ft^2) to 13,000 m^2 (140,000 ft^2).

Work Force--A listing of employees according to skill levels is as follows:

Skilled: 2 (women's handbags) to 18 (luggage)
Unskilled/semiskilled: 2 (handbags) to 142 (luggage)
Indirect: 1 (handbags) to 15 (luggage or gloves)
TOTAL: 5 (handbags) to 175 (luggage)

Operating Procedures--For leather tanning, a chrome bath process would be used. Raw stock (light cattle hides) would be shipped in and processed by drying, soaking, liming, dehairing, fleshing, scudding, rounding, deliming, and bathing. For leather products finished hides are brought into the plant where they are trimmed, shaped, tooled, or decorated.

Discharges--For leather tanning, wastewater could contain varying concentrations of acidity, alkalinity, color, total solids, suspended solids, BOD, chloride, chromium, ammonia, organic nitrogen, total nitrogen sulfide, sulfate, polysaccharides, and tannin. Wastewater from leather products would be cleaning water. Solid wastes consist mostly of pieces of leather and wastewater treatment sludges. Finish residues, slurries containing 10 to 50 percent solids, and screenings could contain lime, copper, lead, zinc, chromium compounds, pieces of leather, hair and other protein-like substances. Floor sweepings are another source of process solid wastes and include twine, salt, and general plant debris. The primary source of solid waste for leather goods manufacturing would be from the trimmings of the finished hides. Office solid waste would be generated. Odors could be generated by tanning processes, but no unusual odors would be expected from the manufacturing of leather goods. Special care would be necessary to assure that significant amounts of toxic and hazardous substances from this source do not reach watercourses or contaminate products produced at the park.

4.2.3.14 Concrete Products

These industries would manufacture a variety of concrete products, including building block and brick, pipe, columns, joists, and tile from a combination of cement and aggregate.

Physical Facilities--Land requirements for concrete block and brick manufacturing would be about 2 ha (5 acres). The production building would be a single-story structure with about 185 m^2 (2,000 ft^2) of floor space. Miscellaneous concrete products manufacturing would require a 2200 m^2 (24,000 ft^2) building and approximately 3 ha (7 acres) of land.

Work Force--Less than 10 workers would be required for operations for block and brick manufacturing. Miscellaneous products require a work force of 30 employees.

Operating Procedures--Raw materials are mixed, poured into forms, allowed to set, and then removed and allowed to cure.

Discharges--Wastewater could include phosphorus, calcium, magnesium, and suspended solids (concrete particles that came from the curing process). There would also be dust emissions during materials handling. Office-related solid waste would also be produced.

Material Flows--Raw materials would include cement, gravel, sand, and water. Most of the materials would be transported by truck, requiring about 12 trips/day, although rail transportation may also be used.

Revenue Flows--Annual costs for materials would be about $100,000, with an additional $50,000 for wages.

4.2.3.15 Electroplating

The electroplating industry involves nickel plating, plating with other metals, and anodizing of various kinds of metals. Operation of a typical plant would consist of one shift which requires a fairly high percentage of skilled workers. The market is predominantly a local one, but the industry has a wide range of users. Therefore, developing areas should be able to support a plant, and as demand grows, production can be readily expanded at a small cost.

Physical Facilities--About 0.2 ha (1/2 acre) of land would be required. The building would be single-story with about 560 m^2 (6,000 ft^2).

Work Force--About 15 employees, with at least 5 skilled workers, would be needed.

Operating Procedures--Raw materials are brought in, cleaned, and stripped. The metals are then polished, anodized, and finished or plated, polished, and finished. The finished products are stored for shipping.

Discharges--Wastes from the electroplating industry could include water pollution control sludges, process chemical wastes such as copper, nickel, chromium, zinc, cyanide, fluoride, cadmium, lead, iron, tin, and phosphorus; grinding wastes; degreaser sludges; and salt precipitates from electroless nickel bath regeneration. These would probably not be discharged. Special care would be necessary to assure that significant amounts of toxic and hazardous substances from this source do not reach watercourses or contaminate products produced at the park.

Material Flows--Direct materials would include nickel sulfate, nickel chloride, boric acid, anodizing dyes, packing materials, and miscellaneous maintenance supplies.

4.2.3.16 Wood Preserving

Wood that has already been sawed or planed would be treated for protection against decay, fire, and insects.

Physical Facilities--Approximately 10 ha (25 acres) of land would be required for a plant occupying 4650-9300 m^2 (50,000-100,000 ft^2). Highway and rail access would be needed.

Work Force--About 35 employees, including 10 skilled workers, would be needed for plant operation.

Operating Procedures--Cut timber would be treated under pressure with creosote, penta, or other chemical preservatives. These preservatives would be recycled with no discharge.

Discharges--Since a closed system would be used, effluents would be limited to accidental discharges of preservatives. Process water could contain phenols, oil and grease, oxygen-demanding wastes, dissolved and suspended solids, phosphorus, ammonia, copper, chromium, zinc, arsenic, and fluorides. Solid waste could include bottom sediment sludge as well as wood scraps if poles, posts, or pilings are cut onsite. Odors could be generated. Special care would be necessary to assure that significant amounts of toxic and hazardous substances from this source do not reach watercourses or contaminate products produced at the park.

4.2.3.17 Truck and Bus Bodies

Truck and bus bodies would be manufactured for sale separately or for assembly on purchased chassis.

Physical Facilities--About 4 ha (10 acres) of land would be needed; the building would contain approximately 2800 m^2 (30,000 ft^2) of floor space. Highway and rail access would be required.

Work Force--About 200 employees would operate the plant. This would include 70 skilled workers, 80 semiskilled and unskilled laborers, and 50 indirect workers.

Operating Procedures--Materials are cut according to patterns, fitted, and posts connected. Bodies would be painted and undercoated, with interiors finished to specification. The bodies may then be shipped or may be mounted on chassis before shipment.

Discharges--Suspended solids, oxygen-demanding wastes, phenols, phosphorus, chromium, iron, lead, aluminum, zinc, oil, and grease could be present in process and clean-up water. Solid waste would include scraps not sorted and sold, paint, spent solvents, and office-related waste. Odors could result from the process. Special care would be necessary to assure that significant amounts of toxic and hazardous substances from this source do not reach watercourses or contaminate products produced at the park.

Material Flows--Aluminum, steel beams and posts, hardware, wheels, paint, and undercoatings would be transported to the plant, primarily by truck. Finished products would be shipped out by truck or rail.

4.2.3.18 Distillation of Industrial Alcohol

The industry would produce ethanol from fermentable vegetables (probably milo or corn) for gasohol. Yearly production would be 190 million liters (50 million gal) of ethanol. One hectoliter of vegetables would yield 31 liters (1 bu: 2.9 gal) of ethanol. The following description applies to 190 million l (50 million gal)/year. Any increase in production would result in a corresponding increase in facilities.

Physical Facilities--The plant would require about 20 ha (50 acres) for laboratory, administration, and other support facilities. Highway, rail, and barge access would be needed.

Work Force--A total of 120-125 employees would be needed. The plant would be operated 24 hours/day with three 8-hour shifts.

Operating Procedures--For grain, kernels would be loosened by steeping, then ground into meal. Further grinding would separate the starch and gluten, then the starch would be dried and cooked. The fermentation of other vegetables would be aided by cooking. After cooling, enzymes would be added to promote the conversion to glucose. Yeast would then be added to produce ethanol, which would undergo two distillation processes. The ethanol would be denatured by adding a contaminant such as gasoline or ketone; and as a final step, would be inspected before being shipped. Stillage, the nonfermentable residue, could be dried and used as a high-protein component in animal feed. Noncontact use of the waste heat would occur throughout the process, but temperatures would require augmentation.

Discharges--Grinding operations would produce some air emissions, but these could be controlled. Wastewater could contain yeast, carbohydrates, oxygen-demanding wastes, benzene, and hydrocarbons. Most of the treatment can be provided in settling ponds. Special care would be necessary to assure that significant amounts of toxic and hazardous substances from this source do not reach watercourses or contaminate products produced at the park. Solid wastes would include husks and stems, which could be recycled for use as fertilizer, and a small quantity of office waste. Odors could be generated.

Materials Flow--Vegetables, a denaturing agent such as gasoline or ketone, enzymes, yeast, and a water supply of 265-380 l/min (70-100 gpm) would be required. Ethanol would be shipped primarily to local markets via tanker truck, rail, or barge. Special handling procedures would be required for the denaturing agent and the ethanol.

Revenue Flows--Construction would cost approximately $70 million. Annual operating costs would be $80 million. Income would probably be dependent on gasoline prices.

TABLE 4.2-1

APPROVED PESTICIDES AND FUNGICIDES
USED IN ORNAMENTAL GREENHOUSES[1]

Insecticide	Formulation	Rate of Formulation/Acre[2]
Acephate (Orthene)	75 SP	300 g (2/3 lb)
Aldicarb (Temik)	10% granular	567-1134 g (20-40 oz)
*Bacillus Thuringiensis (Thuricide HPC, Dipel, Biotrol)	liquid	2 qt
Carbaryl (Sevin)	50% WP	454 g (1 lb)
Demeton (Systox)	28.5% EC	0.2-0.5 l (1/2 to 1 pt)
*Diazinon	50% WP	908 g (2 lb)
*Dichlovos (DDVP, VAPONA)	81% EC	vaporize 1 kg/1000 m^3) (1 oz/1000 ft^3)
*Dicofol (Kelthane)	18.5% EC	0.5 l (1 pt)
Dimethoate (Cygon)	30.5% EC	0.7 l (1-1/2 pt)
Disulfoton (Di-syston)	15% granular	6-12 kg/1000 m^2 (20-40 oz/1000 ft^2)
*Endosulfan (Thiodan)	25% WP	454 g (1 lb)
Fenthion (Baytex)	46% EC	0.9 l (2 pt)
Guthion	22.2% EC	0.9 l (2 pt)
*Malathion	50% EC	0.7 l (1-1/2 pt)
*Metaldehyde	90% SP bait	varies (use label rate) 227-454 g (1/2 to 1 lb)
*Lannate Methoxychlor	50% WP	0.9-1.4 kg (2-3 lb)
Oxydemeton Methyl (Meta-Systox R)	25% SC	0.7 l (1-1/2 pt)
Mexacarbate (Zectran)	25% WP	0.9-1.4 kg (2-3 lb)
Morestan	25% WP	454 g (1 lb)
*Naled (Dibrom)	60% EC	vaporize 1 kg/10,000 m^3 (1 oz/10,000 ft^3)
*Nicotine (Nicofume Liquid)	40%	follow label
Parathion	15% WP	681 g (1-1/2 lb)
Pentac	50% WP	681 g (1-1/2 lb)
Pirimicarb (Pirimor)	50% WP	113-227 g (1/4 to 1/2 lb)
Resmethrin (SPB-1582)	24.5% EC	0.5-0.9 l (1 to 2 pt)
TEPP	20% EC	0.2 l (1/2 pt)
Tetradition (Tedion)	25% WP	454 g (1 lb)
Trichlorfon (Dylox)	50% SP	681 g (1-1/2 lb)
Fungicides		
*Benomyl (Benlate)	50% WP	227-454 g (1/2 to 1 lb)
*Captan	50% WP	227-908 g (1/2 to 2 lb)
*Chlorthalonil (Bravo Daconil)	6F	227-1362 g (1 to 3 lb)
Dexon	35% WP	227 g (1/2 lb)
*Dinocap (Karathane)	18% WP	113-227 g (1/4 to 1/2 lb)
*DCNA (Botran)	75% WP	454-1210 g (1 to 2-2/3 lb
*Maneb	80% WP	1.36 kg (3 lb)
Terrazole (Truban)	35% WP	113 g (4 oz)

[1]Pesticides with an asterisk may also be used on certain vegetable crops.
[2]Rate per acre unless specified otherwise.

TABLE 4.2-2

LIVESTOCK HOUSING AND BIOLOGICAL RECLAMATION COMPONENTS SIZES: FLOW 9500 l/MIN (2500 GPM)

Component	Number of animals	Yield kg (lbs)	Area Required m^2 (ft^2)
Finishing	1,000	54,500 (120,000)	929 (10,000)
Farrowing (sows)	500	68,100 (150,000)	557 (6,000)
Nursery	300	5,500 (12,000)	186 (2,000)
Subtotal	1,800	128,000 (282,000)	1672 (18,000)
Fish Ponds	280,000	95,300 (210,000)	14 ha (35 acre)
Chestnut Beds		408,000 (900,000)	12 ha (30 acre)
Fingerlings Supply	817,000	18,200 (40,000)	650 (7,000)
Anaerobic Digester			21 (225)
Volume = 225 m^3 (9000 ft^3)			
Gas = 2400 m^3/day (84,600 ft^3/day)			
Btu = 5 x 10^7/day @ 60% methane			
Service Area and Roads			1.8 ha (4.5 acre)
Total Area			26.5 ha (65.5 acre)
Grand Total			28.3 ha (70.0 acre)

Table 4.2-3.

CHARACTERISTICS OF INDUSTRIAL USERS

SIC	Industry	Average Annual Wage[a]	Southeast Production Needed ($1,000)[b]	National Growth: Historic[c]	National Growth: Projected[d]	Water Intake (Billion Gallons/yr)[e]: Total Water Intake	Fresh Water: Total	Fresh Water: Process	Fresh Water: Cooling and Condensing	Other (includes Boiler Feed and Sanitary Service)	Electric Energy Use/ Employee (000 kWh)[f]
2011	Meat packing	13,260	87,418	23,003.4; 21,437.6; 22,994.1; 21,467.0; 24,614.4	1.5	69.3	68.1	36.1	D	9.3	22.55
2016	Poultry dressing	7,120	-1,384,405	3,254.1; 2,942.9; 3,390.7; 3,225.8; 3,726.3	3.0	28.5	28.5	22.8	D	3.5	18.21
2034	Dehydrated fruits, vegetables, soups	11,361	114,829	607.3; 602.4; 671.4; 684.7; 759.4	NA	6.3	D	5.3	D	D	34.06
2035	Pickles, sauces, and salad dressings	10,246	67,152	1,166.7; 1,144.0; 1,102.6; 1,104.5; 1,119.3	NA	2.7	D	D	D	D	12.87
2047	Dog, cat, and other pet food	12,753	296,772	1,401.9; 1,723.4; 1,565.7; 1,659.1; 1,908.4	NA	2.7	2.7	1.4	D	D	45.31
2048	Prepared feeds	11,800	-64,932	5,037.1; 4,225.1; 4,751.8; 4,711.5; 4,708.1	NA	2.6	2.6	0.5	1.9	0.2	34.89
2065	Confectionary products	9,377	196,834	2,472.5; 2,568.4; 2,674.4; 2,379.2, 2,429.2	NA	NA					18.43
2066	Chocolate and cocoa products	12,371	NA	735.5; 790.6; 787.0; 719.7; 746.9	NA	9.0	D	D	D	D	35.63
2067	Chewing gum	11,359	44,054	382.6; 404.2; 373.6; 303.0; 326.3	NA	NA	NA	NA	NA	NA	15.22
2075	Soybean products	13,455	21,781	3,357.2; 2,676.6; 4,089.5; 4,076.2; 4,385.0	NA	16.0	16.0	0.6	D	D	139.94
2092	Fish processing	7,013	NA	1,084.4; 1,059.9; 1,107.9; 1,092.3; 1,170.4	NA	2.7	2.2	1.9	0.1	0.2	14.21
2098	Macaroni and spaghetti	11,277	NA	348.3; 348.5; 350.0; 339.0; 370.8	NA	0.1	0.1	0.1	-	-	33.93
2491	Wood preserving	10,142	NA	475.8; 448.1; 607.0; 525.7; 474.6	NA	0.3	0.3	D	D	D	14.24

[a] U.S. Department of Labor, Bureau of Labor Statistics.
[b] Estimated by Office of Community Development, TVA.
[c] Value of Industry Shipments, Millions of Constant 1972 Dollars (yearly data, 1972-1976), U.S. Industrial Outlook, 1979.
[d] Real Growth Percent Change, 1978-1983, U.S. Industrial Outlook, 1979 (1978 dollars).
[e] "Water Use in Manufacturing," 1972 Census of Manufactures, Table 3A.
[f] "Fuels and Electric Energy Consumed," Annual Survey of Manufactures, 1976.
NA - not available
D - data withheld to avoid disclosure

Table 4.2-3. (Continued)

SIC	Industry	Average Annual Wage[a]	Southeast Production Needed ($1,000)[b]	National Growth: Historic[c]	National Growth: Projected[d]	Water Intake (Billion Gallons/yr)[e]: Total Water Intake	Fresh Water: Total	Fresh Water: Process	Fresh Water: Cooling and Condensing	Other (includes Boiler Feed and Sanitary Service)	Electric Energy Use/ Employee (000 kWh)[f]
2833	Medicinals and botanicals	18,411	NA	509.0; 647.1; 874.1; 930.4; 1,148.0	5.0	19.0	19.0	2.6	D	D	52.79
2865	Cyclic crudes and intermediates	18,040	NA	2,049.6; 2,358.0; 1,948.2; 1,777.2; 2,086.4	4.4	91.2	86.7	14.3	65.3	7.0	176.67
2891	Adhesives and sealants	14,296	NA	928.0; 1,099.6; 1,113.3; 944.5; 1,008.0	NA	6.5	6.5	1.1	4.4	0.9	23.34
3111	Leather tanning and finishing	10,802	NA	1,059.5; 955.4; 999.5 1,032.9; 1,003.8	-2.0	7.6	D	D	D	D	16.16
3151	Leather gloves and mittens	6,314	17,572	98.2; 107.0; 138.3; 102.8; 105.1	1.4	NA	NA	NA	NA	NA	3.32
3161	Luggage	8,121	31,070	364.5; 396.6; 381.7; 365.3; 412.9	1.5	NA	NA	NA	NA	NA	7.32
3171	Handbags and purses	6,921	18,090	365.0; 348.3; 346.7; 441.4; 485.2	-2.2	NA	NA	NA	NA	NA	7.35
3199	Leather goods	7,474	NA	161.3, 166.6; 161.6; 188.6; 191.3	NA	NA	NA	NA	NA	NA	6.21
3271	Concrete block and brick	11,016	-15,801	855.7; 863.3; 759.2; 758.1; 774.0	2.4	0.4	0.4	0.3	-	0.1	19.45
3272	Concrete products	11,377	NA	1,961.4; 2,071.1; 1,878.0; 1,723.4; 1,688.6	3.5	0.7	0.7	0.4	-	0.2	10.98
3471	Plating and polishing	10,178	NA	1,034.5; 1,208.1; 1,183.7; 1,092.8; 1,264.8	NA	11.6	D	D	D	D	24.28
3713	Truck and bus bodies	12,243	NA	1,564.4; 1,570.7; 1,304.3; 1,383.1; 1,724.9	3.1	D	D	D	D	D	7.95

TABLE 4.2-4

PHYSICAL FACILITIES FOR SOYBEAN PROCESSING PLANT
AT 1814 TONNES (2000 TONS) SOYBEANS PER DAY

	Area m^2 (ft^2)
Preparation House	1,015 (10,920)
Extraction Plant (Solvent)	605 (6,510)
Meal Bagging and Shipping Section	334 (3,600)
Meal Storage	290 (3,120)
Boiler House, Machine Shop, Storeroom and Office	1,171 (12,600)
Locker Room and Shower House	139 (1,500)
	3,553 (38,250)

4.3 EVALUATION OF IMPACTS ASSOCIATED WITH ALTERNATIVES

4.3.1 No Action

The no-action alternative would result in no near-term change in the status of the land now proposed for waste heat park use. This would make the property available for other TVA applications including future requirements for plant support facilities. If nonplant-related applications were permitted within the reservation boundary, the development of a multiple-use complex using conventional energy sources could be feasible. A park using conventional energy sources would generate impacts at the site and fuel cycle impacts offsite from using the alternative energy source in addition to the same impacts as those assessed for the waste heat park. This would also increase the consumption of existing fuel supplies. No action would also eliminate the environmental benefit of reducing the total thermal discharge from Watts Bar Nuclear Plant.

The most significant result of the no-action alternative would be the delay of development of waste heat as an energy source.

4.3.2 Alternative Sites

Potential impacts of waste heat park development at alternate sites are summarized in Table 4.3-1. For this summary, only the land area within plant reservation boundaries has been evaluated for development because of the necessity of locating a waste heat park near the waste heat source. Any additional land requirements would increase the likelihood of environmental impacts to a limited degree, and such land acquisition would be addressed in greater detail when it was proposed.

Many impacts are similar regardless of location. However, differences in potential radiological impacts of boiling water reactors (BWR) and pressurized water reactors (PWR) exist, because of the operation and steam-supply design of these systems. Also, the types of emissions control and site-specific meteorology will significantly influence the extent of these impacts. The material selected for this evaluation utilizes identical meteorological information and an operational efficiency of 80 percent for all facilities so that variables other than design differences can reasonably be eliminated.

The information presented in Table 4.3-2 indicates the order of magnitude of potential doses to waste heat park tenants and includes the type of reactor and the assumed radionuclide releases for each system. Doses reported should not be interpreted as being directly applicable for waste heat facilities, as all of the pathways considered are most unlikely. This evaluation is presented to provide an understanding of the different parameters to be considered and the characteristics of the different power generating systems.

In the Case 4 analysis the PWR emissions for iodine are less than those from the BWR while the noble gas emissions are greater. The result is that the doses from the BWR exceed those associated with the PWR. In addition, the BWR and PWR doses are presented when the 100 meter (m) stack is employed. It is apparent that with comparable gaseous release systems (e.g., a 100 m stack) the doses associated with a BWR facility will exceed those from a PWR.

It should be noted that the methodology used in the reference document[(1)] is considered by TVA to be "conservatively realistic" due to the tendency to overestimate the quantity of radioactive material released in the effluents. Furthermore, it is believed that dose estimates associated with PWR generating facilities have an additional conservative element inherently present in the model because releases from vents were not credited as being elevated releases even during periods of relative atmospheric stability.

4.3.3 Alternative Management

If exercised in a manner other than that proposed, the various options presented within this alternative (see Section 2.3)--the entity responsible for park development and waste heat use demonstration, land conveyance methods, management requirements, and pricing policy considerations--could result in less than optimum utilization of the waste heat resource through reduced local participation, fewer sources of funding, and pricing that might discourage user participation in a proof-of-concept venture. No environmental advantages could be identified for any of the rejected options.

4.3.4 Waste Heat Park at Watts Bar

A detailed evaluation of the impacts of this alternative is presented in Appendix B. The locations of significant features discussed in the following text are shown in Figure 4.3-1.

4.3.4.1 Site Development

No significant impacts to geologic features or to existing site facilities are expected, especially since a large portion of the site has already been disturbed.

Best management practices will be employed by PMO and industries during site preparation to minimize soil losses due to erosion. Material useful as plant growth media will be segregated and stockpiled, then redistributed for site landscaping.

Potential effects on normal operations of the nuclear plant would be related to a minor change in the quality of the CCW and the increased working force in proximity to the plant.

Park occupants would be required to provide adequate treatment of the CCW so that the water returned to the cooling system would be of acceptable quality.

The Radiological Emergency Plan for the nuclear plant would have to be revised to include provisions for the employees and activities of the waste heat park. The potential for waste heat park-related accidents to impact the safe operation of the nuclear plant will be evaluated by both TVA and the NRC if appropriate at such time specific uses are identified.

4.3.4.2 Air Quality

The primary construction-related air quality impacts are associated with fugitive dust resulting from grading and clearing operations and from construction traffic. These should be temporary, and most of the fugitive dust is expected to settle out within the plant site boundaries. Wet suppression techniques, including periodic application of water on unpaved access roads, will be employed to minimize the fugitive dust associated with these activities.

Most of the atmospheric emissions associated with operational activities and facilities of potential users, of the size considered for the waste heat park, are expected to be small. In addition, most of the processing activities would be regulated by process permit conditions. Consequently, no significant air quality impacts resulting from these emissions would be expected offsite. Qualitative assessments of the potential air pollutant emissions associated with the various activities are provided in Section B.2.2.1 of Appendix B.

Central coal-fired heat backup and heat augmentation systems at the Watts Bar site are assumed as opposed to individual units for each park user. Air quality modeling based upon "worst case" source engineering data and estimated allowable emission rates suggests that existing PSD class II SO_2 increments may be a limiting factor in locating these coal-fired facilities at the site. A more detailed discussion of air quality impacts from these facilities is presented in Section B.2.2.2 of Appendix B.

The potentially limited SO_2 increment availability at the Watts Bar site could preclude use of coal-fired backup and heat augmentation facilities at the park, and may preclude some types of industry, depending upon their air emissions. Consequently, although development of a waste heat park would not be precluded, certain types of industry could be precluded from locating at the park.

Air pollutants produced during the operation of waste heat park facilities will be regulated by NSPS, PSD permit specifications, and/or process permit specifications. The various permit requirements will ensure that air quality in the area is maintained at levels necessary to protect public health and welfare. Consequently, additional mitigative measures to protect air quality are not expected to be necessary during operation.

Operation of the waste heat park facilities will result in microclimatic modifications in an area which includes the meteorological monitoring facility for the nuclear plant. These modifications may include changes in local wind speed and wind direction near the ground, changes in the local thermodynamic stability of the atmosphere within about 100 m of the ground, and changes in the amount of water vapor in the air near the ground. Necessary modifications will be made to the existing meteorological monitoring program to ensure it continues to meet NRC requirements after the park commences operation. Criteria for locating buildings and conducting activities in the park will be established.

A more detailed discussion of air quality-related environmental consequences at Watts Bar is presented in Section B.2 of Appendix B.

4.3.4.3 Hydrology and Water Quality

Hydrology--Waste heat park development will alter the present natural drainage system within the site boundaries. Process water requirements will have a negligible effect on the Tennessee River; however, if existing wells are unable to meet the park's demand for potable water, additional wells may have to be drilled. Careful selection of well locations will be required to prevent impacting Yellow Creek impoundment which is fed by onsite springs, and to minimize pumpage interference with the existing potable water well field.

Water Quality--Existing thermal discharges from Watts Bar Nuclear and Steam Plants under variable conditions from Watts Bar Hydroelectric Plant will utilize most, if not all, of the maximum allowable temperature rise in the Tennessee River when the waste heat park begins operation. Also, at times in this reach of the river, natural temperatures exceeded and background concentrations of dissolved oxygen were below existing water quality criteria. Therefore, when users which could discharge significant levels of additional heat and/or oxygen consuming pollutants are proposed for the heat park, TVA will review their specific discharge schemes. In addition, when park users which have the potential for generating significant quantities of toxic pollutants or hazardous wastes are proposed, a similar review will be conducted. These reviews will be conducted under NEPA and TVA's implementing procedures, and if necessary, conditions will be placed on easement agreements to protect the health and safety of the public, the environment, and other interests of the United States. In addition, TVA will evaluate the effect of the proposal on the nuclear plant condenser circulating water system. Necessary mitigative measures will be required as appropriate. However, the central heat park (domestic sewage treatment, central back-up and heat augmentation, storm water management, domestic solid waste disposal, and process water intake systems), greenhouse and soil warming, grain drying, and concrete product facilities do not represent significant sources of these pollutants and have been assessed with respect to water quality.

Potential impacts to water quality from these facilities could result from the discharge of construction and operational wastewater and storm water runoff, the instream dredging for the process water intake and discharge structures, the storage of recyclable nutrient solutions, and the disposal of solid waste, including pesticide and fungicide containers. As previously specified for the other potential park users, mitigative measures for these potential impacts will be required as appropriate.

At a minimum, all wastewater will be treated as dictated by applicable new source performance standards and/or water quality standards. Also, the proposal for filling will be certified by the Tennessee Division of Water Quality Control prior to the issuance of a dredge and fill permit by the Army Corps of Engineers.

Specifically, during construction and operation of these facilities, storm water runoff will be managed by the use of best management practices which have been proven to be successful in limiting erosion and siltation losses to the aquatic environment. The required instream dredging should not significantly impact the water quality of the river due to the short-term and localized nature of the dredging, the characteristically gravel substrata of the river in the vicinity of the site, and the volume of water available for dispersion of suspended sediments. Conventional solid waste, if not recyclable, will be disposed of in a sanitary landfill. Pesticide and fungicide containers will be triple rinsed, with the rinse water used as make-up water, and also disposed of in a sanitary landfill. If oil or hazardous substances are stored onsite, an environmental evaluation will be performed and a Spill Prevention Control and Countermeasure (SPCC) plan will be developed and implemented for each storage facility if determined necessary.

Greenhouse, soil warming, and grain drying facilities will not require a discharge to surface waters. Nutrient solution storage lagoons will probably be lined and ground water quality may be monitored. Based on the relatively small size of the units, the intermittent operational requirement, the volume and characteristics of the heated discharges, and the applicable new source performance standards, effluents from the central back-up and heat augmentation system should not have a significant impact on the Tennessee River. Fly ash, bottom ash, and scrubber sludge will be disposed of in a manner designed to protect ground water quality consistent with applicable State and Federal requirements. Discharges from the other facilities (sewage treatment and concrete product) will have an insignificant effect on the quality of the Tennessee River.

4.3.4.4 Health and Safety

4.3.4.4.1 Noise

Temporary increases in nearby community sound levels will occur from construction work and from motor vehicle traffic.

Significant amounts of rock drilling and blasting are not anticipated. As a consequence, park construction should have lesser offsite effect than construction at Watts Bar Nuclear Plant had.

Operational noise will originate from truck deliveries, employee work traffic, and processing equipment.

Although there are no local or Federal noise regulations applicable to the Watts Bar Waste Heat Park at this time, park users will be required to be in compliance with any future noise control regulations. A maximum L_{eq} of 65 dB or less at the park boundary is considered to be acceptable at this time.

The area surrounding major transportation routes to the waste heat park are low density rural areas. Further, there will be less traffic along these routes associated with the waste heat park (estimated to be 1100 employees for full development) than was present during peak nuclear plant construction (approximately 3400 employees). Therefore no adverse traffic noise impact is expected.

4.3.4.4.2 Radiological Considerations

Liquid and gaseous effluents from WBN are not expected to affect the products from the waste heat park. Product sampling will be conducted to confirm this expectation. Should this program reveal significant impacts from WBN to these products, measures will be implemented to restrict the production and use of the products as necessary.

4.3.4.4.3 Safety

As each potential user applies for park occupancy, TVA will evaluate process details and corresponding health and safety hazards.

4.3.4.5 Terrestrial Ecology

The development of the proposed waste heat utilization facility could eventually result in clearing or alteration of approximately 400 acres of terrestrial habitat, much of which was previously disturbed by nuclear plant construction. Depending upon the nature and type of waste heat development on the western portion of the site, construction and operation of facilities could have an adverse impact on the adjacent Tennessee Wildlife Resources Agency, Yellow Creek Wildlife Management Area.

A condition of the agreement between TVA and park management will provide for the establishment of a buffer zone of riparian vegetation between the waste heat park and Yellow Creek to preserve existing habitats and isolate the Yellow Creek Wildlife Management Area from the waste heat park.

4.3.4.6 Aquatic Ecology

Construction of the proposed waste heat park will result in some site runoff and limited instream construction activities. Primary concerns would be the introduction of large quantities of suspended solids and physical habitat disruption which could cause some mortality to immobile benthic forms including endangered mussel species. Stormwater will be controlled using best management practices, discharges will be in compliance with applicable guidelines, and the location and scheduling of instream activities will be controlled to minimize biological impacts. For a more detailed discussion, refer to Sections B.6 and B.7.

Operation of the WBWHP will result in an additional raw water intake. This could result in a potential cumulative entrainment of 3 percent of the total transported larval fish population. Analysis of the most recent samples collected at Watts Bar Nuclear Plant indicated that 75 percent of the total transported population consisted of Clupeids and 4.5 percent game species (Percichthyids, Centrarchids, and Percids).

Discussion of additional operational impacts from aquacultural, agricultural, and industrial applications at WBWHP is presented in Section B.6.2 of Appendix B. Each application for operation within the waste heat park will be reviewed by TVA to ensure that significant negative impacts to aquatic organisms will not occur. Following its independent review, TVA will cooperate with the State of Tennessee, the U.S. Army Corps of Engineers, and the U.S. Environmental Protection Agency in an attempt to further ensure that park occupants are compatible with the maintenance or enhancement of a balanced indigenous aquatic community and with the fish and wildlife management goals of the citizenry of the Tennessee Valley. TVA will not approve any use which could aggravate existing water quality conditions.

4.3.4.7 Endangered or Threatened Species

Based on the information presented in Section A.7 and Appendix E, and mitigation measures proposed in Sections B.6, B.7.3.1 and B.7.3.2, the development of the proposed Watts Bar Waste Heat Park should not jeopardize the continued existence of any Federally proposed or listed endangered or threatened species nor inhibit opportunities for the recovery of such forms at the regional or national level.

4.3.4.8 Agriculture and Soils

Site development would require approximately 162 hectares (400 acres), 76 percent of which can be classified as prime farmland. Principle crops grown in the area and annual yields as derived from 1979 Tennessee Agricultural Statistics are as follows:

Corn	4.9 m^3/ha (55 bu/ac)
Soybeans	1.9 m^3/ha (22 bu/ac)
Tobacco	2668 kg/ha (2380 lb/ac)
Wheat	2.7 m^3/ha (30 bu/ac)

The proposed site was originally purchased by TVA as part of the Watts Bar Nuclear Plant site. Much of the area has been disturbed during construction of the nuclear plant and none of the land is currently devoted to agricultural uses.

4.3.4.9 Land Use

The land use changes proposed are consistent with the Rhea County land use plan and will allow TVA to maximize the land use potential of this property. There are no existing or proposed recreational facilities located within the confines of the proposed waste heat industrial park.

4.3.4.10 Socioeconomics

Most of the jobs needed to construct and operate the park are expected to be filled by local residents or commuters; no stress on community support facilities are anticipated.

4.3.4.11 Aesthetics

The overall plant layout is located on a river terrace overlooking Chickamauga Lake and surrounded by steep, wooded slopes which already offer some degree of visual screening. Proper landscaping and facility design should combine to provide adequate mitigative measures with respect to visual aesthetic concerns.

4.3.4.12 Cultural Resources

One cultural resource, archaeological site 40RH64, has been determined by TVA to be eligible for the National Register of Historic Places (Appendix F). No site alteration activities are currently planned which would impact this resource.

4.3.4.13 Floodplains and Wetlands

Floodplains

With the exception of facilities such as those listed below, no construction of permanent structures will be permitted below the 1-percent-chance flood elevation (697'), and none where flood damage would be significant or impact TVA reservoir operations below the TVA structure profile elevation. The only facilities to be placed within the 1-percent-chance floodplain (base floodplain) are the open-field soil warming area, aquaculture retention ponds, and necessary support facilities such as roads, parking areas, water intakes and discharges, and utilities (see Sections 4.1 and 4.2), none of which are critical actions for which flood risks must be kept to a minimum nor are incompatible with TVA policies on floodplain development or restrictions for reservoir shoreline development as required for effective operation of the reservoir system.

Alternatives to Floodplain Development

No Action--Restricting all development to elevations above the base floodplain or the TVA structure profile would preclude much of the park site from being developed. For an adequate demonstration of a large-scale, multiple-use complex, additional land outside the reservation boundary would have to be acquired. The no-action alternative would essentially remove all the benefits of the demonstration of waste heat utilization at this site and is not deemed practical.

Alternative Sites--Because a waste heat park must be near the source of waste heat, alternative sites are limited to areas adjacent to generating plants, all of which would have floodplain impacts similar to those at Watts Bar. Because of other conditions identified in Section 2.2, these alternatives were eliminated from consideration as impractical for the initial large-scale waste heat park demonstration.

Because no other practicable alternatives exist and because impacts to the floodplain and to facilities from this type of development will be minimal, the construction of the proposed soil warming area and aquaculture retention facilities within the base floodplain is acceptable.

Mitigation measures, which will be employed to minimize any floodplain impacts, are presented in Section B.12 of Appendix B.

Wetlands

Siting and construction of specific facilities will be evaluated when proposed to assure they are consistent with TVA policy on protection of wetlands. Wetlands identified on the site, as shown in Figure A-12.1, will be avoided in the location of structures and facilities, fill, or drainage systems. Site locations away from all wetlands are deemed impractical based on the considerations outlined above for floodplain siting.

4.3 REFERENCES

1. U.S. Atomic Energy Commission, "Draft Environmental Statement Concerning Proposed Rulemaking Action: Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low as Practicable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents," January 1973.

Table 4.3-1.

SUMMARY OF POTENTIAL IMPACTS

	Bellefonte	Hartsville	Phipps Bend	Watts Bar	Yellow Creek
Land Use	No impacts on agricultural resources would occur because land has already been removed from production. Park development could limit plant expansion	See Bellefonte	See Bellefonte	See Bellefonte	See Bellefonte
Geology	No impacts to geologic features or mineral resources would be expected	See Bellefonte	See Bellefonte	See Bellefonte	See Bellefonte
Soils	Some mixing and loss of soils would result from site development, but no significant impacts to soil resources would be expected	See Bellefonte	See Bellefonte	See Bellefonte	See Bellefonte
Hydrology					
Water Availability	Sufficient water supplies for park operation should be available without affecting water availability to other users	Need for use of surface water supplies may affect availability during periods of low flows	See Hartsville	Decreased flow from springs feeding Yellow Creek impoundment could result from pumping wells used for park water supply; surface supplies should not be affected	See Bellefonte

Table 4.3-1. (Continued)

	Bellefonte	Hartsville	Phipps Bend	Watts Bar	Yellow Creek
Floodplain Considerations	Some park facilities may be developed within the floodplain; however, these will be limited to uses which will not increase risk of flooding upstream and would be consistent with TVA floodplain management policies	See Bellefonte	See Bellefonte	See Bellefonte	See Bellefonte
Water Quality	No significant impacts would be expected	Open-system use of CCW could further concentrate chemicals present in Cumberland River, requiring additional treatment or hold up of any discharges	Insufficient flow for the dispersion of chemical discharges could necessitate additional treatment of such discharges	Low dissolved oxygen levels may necessitate additional treatment of discharges	See Bellefonte
Ecology					
Terrestrial	No impacts to sensitive terrestrial wildlife or plant species would be expected	The presence of several species of wildlife listed as sensitive may necessitate mitigative measures during park development and operation	See Hartsville	See Bellefonte	See Bellefonte
Aquatic (Fisheries)	Cumulative entrainment could be problem to fisheries	See Bellefonte	Cumulative entrainment would be a primary concern to fisheries	Constraints on oxygen-demanding wastewaters would be needed	See Phipps Bend
(Waterfowl)	Waterfowl resources should not be adversely impacted	See Bellefonte	Waterfowl would not be subject to significant impacts	Mitigative measures for impacts to springs would be needed	See Phipps Bend

Table 4.3-1. (Continued)

	Bellefonte	Hartsville	Phipps Bend	Watts Bar	Yellow Creek
Aquatic (Nonfisheries)	No significant impacts would be expected	There may be discharge constraints	Discharge constraints are probable	Constraints on oxygen-demanding wastewaters and instream activities would be needed	See Bellefonte
Wetlands	Measures to minimize impacts to affected wetlands would be consistent with TVA policy on protection of wetlands	See Bellefonte	See Bellefonte	See Bellefonte	No impacts
Air Quality	PSD and BACT regulations should prevent air pollutant emissions from having significant impacts; nuisance odors should be controllable	See Bellefonte	See Bellefonte	See Bellefonte	See Bellefonte
Radiological Considerations	No significant impacts would be expected as a result of park development	See Bellefonte	See Bellefonte	See Bellefonte	See Bellefonte
Cultural Resources	Additional evaluation of reservation would be required to determine extent of existing cultural resources and potential impacts	See Bellefonte	Additional involvement of SHPO and ACHP would be required to evaluate impacts to sites nominated to National Register	See Phipps Bend	No significant impacts to cultural resources would be expected
Socioeconomics	No significant adverse impacts would be expected	See Bellefonte	See Bellefonte	See Bellefonte	See Bellefonte
Recreation and Scenic	No significant adverse impacts that could not be fully mitigated are expected	See Bellefonte	See Bellefonte	See Bellefonte	See Bellefonte

Table 4.3-2

ANNUAL CHILD THYROID DOSES FROM GASEOUS EFFLUENT (MREM/YR)
(Gas Case No. 4)

Reactor Type	Release Rate (Ci/yr) Noble Gases	I-131	Location	Doses (mrem/yr) Distance from station (m) 200	500		800		1000	
PWR	6.7(3)	7.4(-2)	Lakeshore[a]	88[b]	26[b]	(0.27)[c]	14[b]	(0.54)[c]	10[b]	(0.49)[c]
BWR	4.8(3)	1.1(-1)		180[d]	52[d]	(0.62)[e]	28[d]	(1.1)[e]	20[d]	(1.0)[e]
PWR	6.7(3)	7.4(-2)	River[f]	150[b]	46[b]	(0.36)[c]	23[b]	(0.44)[c]	17[b]	(0.41)[c]
BWR	4.8(3)	1.1(-1)		300[d]	91[d]	(0.87)[e]	44[d]	(0.97)[e]	31[d]	(0.89)[e]

a. Doses for lakeshore site from external radiation, ingestion of vegetables and milk, and inhalation.
b. Gaseous effluent release from 50-m roof vent.
c. Gaseous effluent release from 100-m stack.
d. Steam jet air ejector and gland seal effluent released through 100-m stack.
e. All gaseous effluents released from 100-m stack.
f. Similar doses for riverside site.

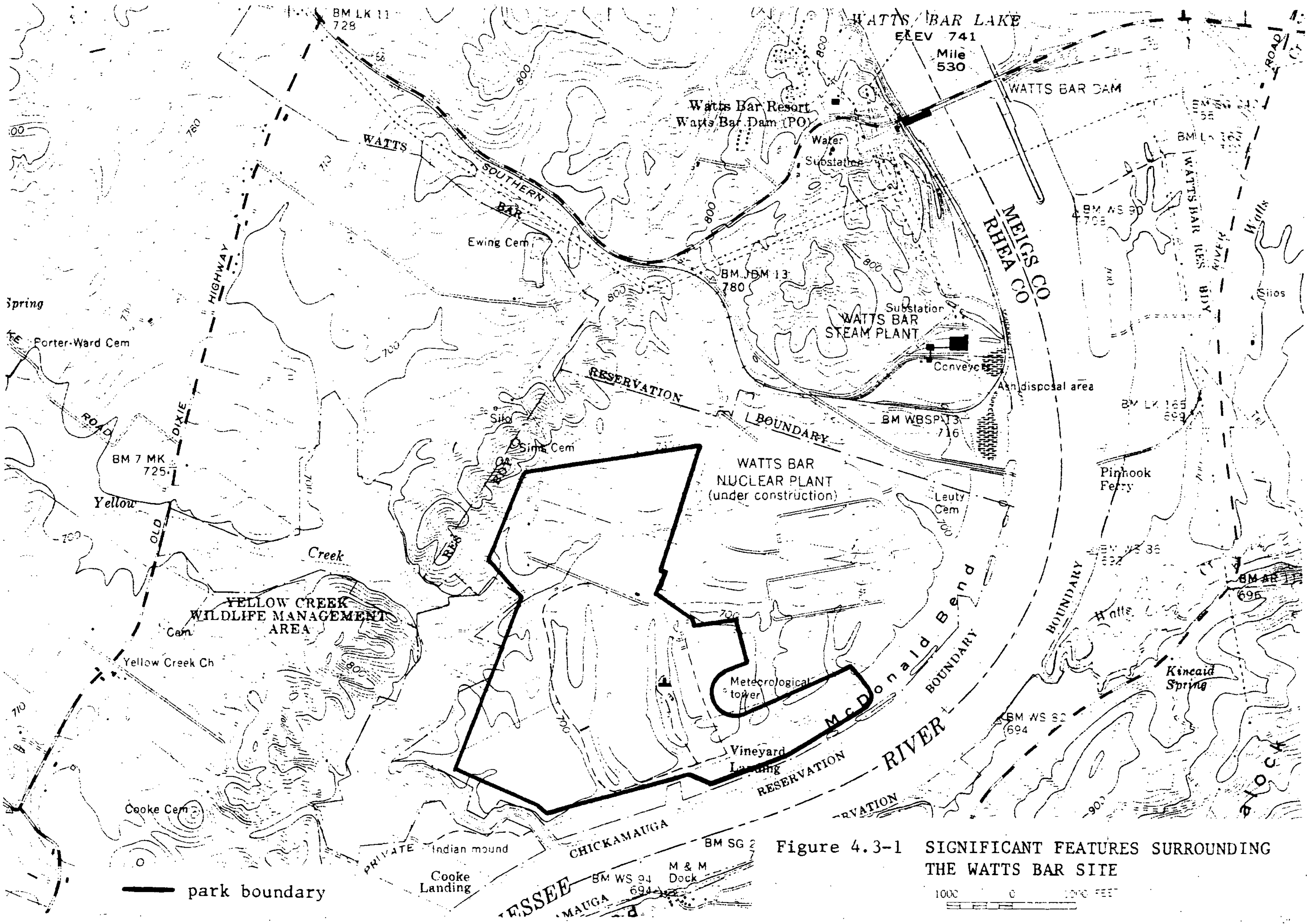

Figure 4.3-1 SIGNIFICANT FEATURES SURROUNDING THE WATTS BAR SITE

4.4 UNAVOIDABLE ADVERSE ENVIRONMENTAL EFFECTS ASSOCIATED WITH DEVELOPMENT OF A WASTE HEAT PARK

Population radiological dose commitments, due to the increase in the number of people working in proximity to the nuclear plant, would be expected to rise but not to a significant degree. Site development would result in the loss of wildlife habitat, open space, soil productivity, and vegetative species diversity for the life of the facility to a limited extent. Consumptive water use would increase. Effluents released to the air, water, and land would be increased; however, the rate of emission from each source would be in compliance with applicable regulatory requirements. It must be emphasized that these impacts are less than would be expected from similar development at Watts Bar or another location utilizing a conventional heat source.

Development of the waste heat park at Watts Bar would reduce the total thermal discharge from the nuclear plant by using the heat rather than discharging it. The use of waste heat for the planned facilties would save conventional fuels for other uses. The adverse environmental impacts resulting from the production, conversion, and use of conventional energy sources would be averted for the facilities that use the waste heat.

4.5 RELATIONSHIP BETWEEN SHORT-TERM USES AND LONG-TERM PRODUCTIVITY OF THE ENVIRONMENT

Development of any waste heat park will be adjacent to an established waste heat source. Successfully utilizing this source would contribute to the immediate goal of demonstrating the feasibility of waste heat utilization and to the long-term consequences of conserving fuel supplies, developing otherwise wasted resources, and advancing related production and process technologies.

One long-term benefit would be the expansion of employment opportunities by providing additional jobs. Most of the jobs would be permanent, which would contribute long-term employment stability to the area. Another gain would be the increased economic activity resulting from the increase in local incomes.

The area could be restored to other uses at the termination of the waste heat park project, which represents a short-term commitment of land use. The preclusion of other site uses could be a long-term effect. Land occupied by expanded urban areas or by transportation facilities would be considered a long-term use. Productivity in relation to soils, vegetation, and wildlife habitat would be altered but would be expected to be restored over the long term.

The operation of the waste heat park should not result in a significant long-term environmental degradation. All effluents discharged to the air, water, and land will be within levels which are considered acceptable for the short-term uses of the environment.

4.6 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

Building materials would be committed for the construction of park facilities, as well as for roads and buildings to accommodate the expected trade growth. Energy, in the form of petroleum products and electricity, would be consumed for development activities, and for park operations. Manpower would be committed to this project in lieu of utilizing the work force elsewhere. From undisturbed areas, wildlife habitat, open space, and some soil quantity would be lost for the life of the project.

5. CONCLUSION

The successful demonstration of commercial waste heat utilization will benefit the Tennessee Valley region and the Nation. The preferred alternative, granting an easement for a waste heat park at Watts Bar, is the best available means of demonstrating large-scale waste heat concepts. Implementing this action at the Watts Bar site should facilitate the demonstration of waste heat technology and should provide sufficient assurance that the park does not adversely affect nuclear plant operation. Impacts created by this project will be mitigated to the extent necessary to protect the health and safety of the public, the environment, and other interests of the United States including those identified by NEPA and TVA's implementing procedures.

It is concluded that granting an easement for the development of a waste heat park at Watts Bar is an environmentally sound action, with fewer adverse impacts than would be expected from similar development elsewhere utilizing conventional heat sources. Development of the waste heat park at Watts Bar is the most reasonable alternative and should be implemented.

6. AGENCY AND PUBLIC REVIEW

6.1 LETTER AND TELEPHONE COMMENTS

This section contains copies of all letters and transcripts of all telephone calls received concerning the Draft EIS in the order that they were received. The text of the EIS was changed in response to some comments; other comments were answered directly in Section 6.2. The numbers noted in the margins of the comment letters indicate the sections in which the questions are answered.

OFFICE OF THE SECRETARY OF THE TREASURY
WASHINGTON, D.C. 20220

November 4, 1980

Dear Dr. El-Ashry:

Thank you for forwarding a copy of the TVA Draft Environmental Impact Statement - Proposed Watts Bar Waste Heat Park. This Department has no comments on the Statement.

Sincerely,

Anthony V. DiSilvestre
Assistant Director (Environmental Programs)
Office of Administrative Programs

Mohamed T. El-Ashry, Ph.D
Director of Environmental Quality
Tennessee Valley Authority
Norris, Tennessee 37828

EQS
NOV 10 '80
ACTION
TO
El-Ashry
Brych
Calhoun
Fitz
Johnson
Kinsel
Montgomery
Smith-Sanclare
Thurman
Energy Group
Crowder MS
Chatta. ER&D
Chatta. NEPA
Files

US Department of Transportation
Federal Aviation Administration

EQS
NOV 12

November 5, 1980

Dr. Mohamed T. El-Ashry
Director of Environmental Quality
Tennessee Valley Authority
Natural Resources Building
Norris, Tennessee 37828

Dear Sir:

Thank you for the opportunity to review your Draft Environmental Impact Statement (DEIS) on the Proposed Watts Bar Waste Heat Park. The Federal Aviation Administration finds no problem with the proposed action. The remoteness of the location should present no problem with commercial aviation from Nashville, Knoxville, or Chattanooga. While general aviation activities can be expected to increase as a result of increased projected business activity, these aircraft in this timeframe will all have been certificated to FAR Part 36 and have minimum noise levels.

We congratulate you on a very well done Draft EIS and please feel free to call on us if any conflict with aviation matters occurs.

Sincerely,

RICHARD N. TEDRICK
Chief, Noise Policy and Regulatory Br.
Office of Environment and Energy

OUR MAILING ADDRESS
DEPARTMENT OF CONSERVATION
[illegible]
NASHVILLE, TENNESSEE 37219

TENNESSEE DEPARTMENT OF CONSERVATION
TENNESSEE HISTORICAL COMMISSION
4721 TROUSDALE DRIVE, NASHVILLE 37220
615/741-2371

November 10, 1980

Dr. Mohamed T. El-Ashry, Director
Environmental Quality Staff
Tennessee Valley Authority
Natural Resources Building
Norris, Tennessee 37828

Re: Draft EIS Watts Bar Waste Heat Park, Rhea County, Tennessee

Dear Dr. El-Ashry:

The State Historic Preservation Officer and his staff have reviewed the above document regarding TVA's compliance with Section 106 of the National Historic Preservation Act as codified at 36 CFR 800 (44 FR 6068-6081, Jan. 30, 1979).

As stated on page 59 of the Draft EIS, a cultural resource survey located one site, 40 RH 64, which meets the criteria of eligibility for the National Register of Historic Places. However, the project as presently planned will have no effect on the site. The Final EIS should include a copy of our July 7, 1980 letter to Maxwell D. Ramsey concurring with TVA's opinion that the project as planned will not affect properties on or eligible for the National Register.

Unless project plans are changed or archaeological remains are discovered during construction no further action is necessary to comply with Section 106.

Your cooperation will be appreciated.

Sincerely,

Herbert L. Harper

Herbert L. Harper
Executive Director and
State Historic Preservation Officer

HLH:sh

xc: Saralee Terry, State Clearinghouse
11-19-80
mc: L. B. Goss, 1110 CST2-C
W. W. LaRoche, E10B 8 C-K

EQS
NOV 12 '80

TO
El-Ashry
Bruch
Calhoun
Fitz
Johnson
Kinsel
Montgomery
Smith-Sanclair
Thurman
Energy Conser.
Crowder-M
Chatta. ERSO
Chatta. NEPA
Files

Appendix F

DEPARTMENT OF AGRICULTURE
Ellington Agricultural Center
Nashville, Tennessee 37204
Telephone (615)741-1531

STATE CLEARINGHOUSE
RECEIVED
NOV 14 1980
TENNESSEE ST.
PLANNING OFFICE

12/5/80

MEMORANDUM

TO: Saralee W. Terry
Tennessee State Planning Office

FROM: Paul M. Koger, Assistant Commissioner PK

DATE: November 10, 1980

SUBJECT: Agency Review A-95

This is to advise that we have reviewed the following projects and have no negative comments:

1. CH#81-3141 U. S. Forest Service Land Acquisition Appalachian Trail
2. CH#81-3154 Nashville Corps of Engineers - 404 Permit
3. CH#81-3151 Old Dominion Power Company - 404 Permit
4. CH#81-3150 404 Permits Issued in September 1980 by Nashville District Corps of Engineers
5. CH#81-3152 City of Norris, Notice of No Significant Effect Comprehensive Neighborhood Center
6. CH#81-3153 General Services Administration-Region 4, Feasibility of Consolidating Federal Activities in Knoxville
7. CH#81-3155 City of Lewisburg, Notice of No Significant Effect
8. CH#81-3156 Boone Lake - 404 Permit
9. CH#81-3158 Fort Loudoun Lake - 404 Permit
10. CH#81-3157 Tennessee River - 404 Permit
11. CH#81-3149 Nashville District Corps of Engineers, FEIS: Disposal of Lands for Public Port and Industrial Use, Cordell Hull Dam
12. CH#81-3148 TVA: Draft Environmental Impact Statement, Watts Bar Waste Heat Park Rhea County, Tennessee

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION
NASHVILLE, TENNESSEE 37219

November 21, 1980

12/5/80

Mr. Mike Jones
A-95 Program Analyst
Tennessee State Clearinghouse
660 Capitol Hill Building
Nashville, Tennessee 37219

SUBJECT: A-95 Notification CH #81-03138 City of Lexington, Notice of No Significant Effect on the Environment; #81-3141 U.S. Forest Service - Land Acquisition Appalachian Trail; #81-3148 TVA: Draft Environmental Impact Statement, Watts Bar Waste Heat Park-Rhea County; #81-3149 Nashville District Corps of Engineers, FEIS: Disposal of Lands for Public Port and Industrial Use, Cordell Hull Dam; #81-3151 Corps of Engineers Public Notice 80-229 (46,595): #81-3152 City of Norris, Notice of No Significant Effect Comprehensive Neighborhood Center; #81-3153 General Services Administration Region 4, Feasibility of Consolidating Federal Activities in Knoxville; #81-3154 Corps of Engineers Public Notice 80-213.

Dear Mr. Jones:

We have reviewed the above notices for the subject improvements and find no apparent conflict with any present or proposed plans of the Department of Transportation at this time.

If I may be of further assistance, please do not hesitate to call me.

Sincerely,

(for) E. R. Terrell
Director
Bureau of Transportation
Planning and Programming

RSC:nes

73

CARCOG SETDD

CHATTANOOGA AREA REGIONAL COUNCIL OF GOVERNMENTS
HARRY L. DETHERO
Chairman

SOUTHEAST TENNESSEE DEVELOPMENT DISTRICT
C. L. THRAILKILL
Executive Director

November 24, 1980

Dr. Mohamed T. El-Ashry
Director of Environmental Quality
Tennessee Valley Authority
Forestry Building
Norris, Tennessee 37828

SUBJECT: TVA's Draft Environmental Impact Statement, Watts Bar Waste Heat Park, Rhea County, Tennessee

Dear Dr. El-Ashry:

In accordance with the Office of Management and Budget Circular A-95 this office, as the areawide clearinghouse, has reviewed the subject statement.

B.9.2 The information and analysis presented in the draft Environmental Impact Statement are generally consistent with local planning data and development objectives. However, the industrial employment figures (page B-33), while hypothetical, may be somewhat low based on recent interest by industrial concerns in participating in the park.

On the basis of the information now available to this office, our findings reveal no conflicts with existing or planned activities in the area. Therefore, this office recommends approval of the draft impact statement.

In accordance with the provisions of the Office of Management and Budget Circular A-95, a copy of this letter of review and comment must be attached to your formal application.

Should there be any question, or if we may be of further assistance, please contact this office.

Sincerely,

Charles L. Thrailkill
Executive Director

CLT:HCB:cm

cc: Mike Jones
John Moeller

11-26-80--MKE
cc: L. B. Goss, 1110 CST2-C
W. W. LaRoche, E1-C55 C-K
L. H. Woosley, 375B 401B-C

REC'D
DEC 2 1980

413 JAMES BUILDING ☐ 735 BROAD ST. ☐ CHATTANOOGA, TN. 37402 ☐ PHONE 615/266-5781

CITIZEN ACTION LINE CALL   BY: JD   80/12/08 11:23   C01514.JD

SUBJECT CODE: N   TYPE CALL: PC   STATUS: C

SUBJECT: NUCLEAR- WB WASTE HEAT PARK-SUPPORT

GAIL HITCHCOX   HOME PHONE:
RT. 2, BOX 1
DAYTON, TN 37321   BUSINESS PHONE:

MAJOR POINTS: WANTED TO VOICE HER SUPPORT OF THE WATTS BAR WASTE HEAT PARK.

ACTION: TOLD HER THAT HER COMMENTS WOULD BE INCLUDED IN THE RECORD.

DISTRIBUTION: CAL FILES (1)

CITIZEN ACTION LINE CALL   BY: JD   80/12/08 11:47   C01516.JD

SUBJECT CODE: N   TYPE CALL: PC   STATUS: C

SUBJECT: NUCLEAR- WB WASTE HEAT PARK-SUPPORT

BARBARA BRADY   HOME PHONE:
RT. 1, BOX 41
DAYTON, TN 37321   BUSINESS PHONE:

MAJOR POINTS: WANTED TO VOICE HER SUPPORT OF THE WATTS BAR WASTE HEAT PARK.

ACTION: TOLD HER THAT HER COMMENTS WOULD BE ADDED TO THE RECORD.

DISTRIBUTION: CAL FILES (1)

CITIZEN ACTION LINE CALL   BY: PH   80/12/08 12:11   C01527.PH

SUBJECT CODE: N   TYPE CALL: TN   STATUS: C

SUBJECT: NUCLEAR- WB WASTE HEAT PARK-SUPPORTS

JOE ROBERTS   HOME PHONE:
DAYTON, TN   BUSINESS PHONE:

MAJOR POINTS: VERY MUCH IN FAVOR OF PROJECT.

DISTRIBUTION: CAL FILES (1)

CITIZEN ACTION LINE CALL   BY: CA   80/12/08 14:45   C01854.CA

SUBJECT CODE: N   TYPE CALL: P   STATUS: C

SUBJECT: NUCLEAR- WB WASTE HEAT PARK

MARK TRAVIS   HOME PHONE:
ROUTE 1, BOX 447
DAYTON, TN 37321   BUSINESS PHONE:

MAJOR POINTS: WANTS TO GO ON RECORD IN FAVOR OF THE WATTS BAR WASTE HEAT PARK; SAYS HE THINKS IT SHOULD BE STARTED IMMEDIATELY.

ACTION: TOLD MR. TRAVIS HIS COMMENTS WOULD BE NOTED.

DISTRIBUTION: CAO FILES (1)
CAO NEWSLETTER (1)

CITIZEN ACTION LINE CALL   BY: MT   80/12/08 16:09   C01867.MT

SUBJECT CODE: N   TYPE CALL: TN   STATUS: C

SUBJECT: NUCLEAR- WB WASTE HEAT PARK

DAVID HAUGHT   HOME PHONE:
P.O. BOX 143
DAYTON, TN 37321   BUSINESS PHONE:

MAJOR POINTS: IS A CONCERNED CITIZEN OF RHEA COUNTY WHO HAS READ ABOUT THE PROPOSED WASTE WATER TREATMENT PLANT--WANTS TO VOICE AN OPINION. IS VERY EXCITED ABOUT THE POSSIBILITY AND THINKS IT WILL BE GOOD FOR THE COUNTY.

ACTION: TOLD CALLER WE WOULD FORWARD HIS COMMENTS TO THE APPROPRIATE STAFF.

DISTRIBUTION: CAL FILES (1)
CAO NEWSLETTER (1)

CITIZEN ACTION LINE CALL   BY: RM   80/12/08 16:18   C01869.RM

SUBJECT CODE: N   TYPE CALL: TN   STATUS: C

SUBJECT: NUCLEAR- WB WASTE HEAT PARK-SUPPORTS

JEANETTE BOOTH   HOME PHONE:
DAYTON, TN   BUSINESS PHONE:

MAJOR POINTS: READ ABOUT PROPOSED NUCLEAR WASTE HEAT INDUSTRIAL PARK AND IS FOR IT 100 PERCENT.

DISTRIBUTION: CAL FILES (1)

CITIZEN ACTION LINE CALL   BY: RM   80/12/08 16:19   C01870.RM

SUBJECT CODE: N   TYPE CALL: TN   STATUS: C

SUBJECT: NUCLEAR- WB WASTE HEAT PARK

ROBERT SWEATT   HOME PHONE:
DAYTON, TN   BUSINESS PHONE:

MAJOR POINTS: READ ABOUT PROPOSED NUCLEAR WASTE HEAT PARK IN LOCAL NEWSPAPER AND SUPPORTS IDEA WHOLEHEARTEDLY.

DISTRIBUTION: CAL FILES (1)

CITIZEN ACTION LINE CALL   BY: RM   80/12/08 16:21   C01871.RM

SUBJECT CODE: N   TYPE CALL: TN   STATUS: C

SUBJECT: NUCLEAR- WB WASTE HEAT PARK

MARK MORGAN   HOME PHONE:
TENNESSEE WAREHOUSE
DAYTON, TN   BUSINESS PHONE:

MAJOR POINTS: READ ABOUT PROPOSED NUCLEAR WASTE HEAT PARK NEAR WATTS BAR. IS READY TO GO WITH IT. THINKS IT IS A GOOD THING AND STATED IT IS MORE THAN WELCOME BY THE PEOPLE HE HAS TALKED WITH.

DISTRIBUTION: CAL FILES (1)

CITIZEN ACTION LINE CALL. BY: [illegible] 80/12/04 16:23 C01872.[illegible]

SUBJECT CODE: N TYPE CALL: [illegible] STATUS: C

SUBJECT: NUCLEAR- WB WASTE HEAT PARK

GARY LOUALLEN
DAYTON, TN

HOME PHONE:
BUSINESS PHONE:

MAJOR POINTS: READ ABOUT PROPOSED NUCLEAR WASTE HEAT INDUSTRIAL PARK NEAR WATTS BAR. IS ALL FOR IT AND FEELS IT IS A GOOD THING.

DISTRIBUTION: CAL FILES (1)
CAL FILES (1)

CITIZEN ACTION LINE CALL BY: JC 80/12/04 17:15 C01891.JC

SUBJECT CODE: N TYPE CALL: PC STATUS: C

SUBJECT: NUCLEAR- WB WASTE HEAT PARK-SUPPORT

GENA HOUSLEY
DAYTON, TN

HOME PHONE:
BUSINESS PHONE:

MAJOR POINTS: CALLED TO VOICE SUPPORT FOR THE WATTS BAR WASTE HEAT PARK.

ACTION: INFORMED CALLER I WOULD MAKE CALL A PART OF MY RECORD.

DISTRIBUTION: CAL FILES (1)

CITIZEN ACTION LINE CALL. BY: JC 80/12/04 17:10 C01886.JC

SUBJECT CODE: N TYPE CALL: PC STATUS: C

SUBJECT: NUCLEAR- WB WASTE HEAT PARK-SUPPORT

JERRY CHEEKS
DAYTON, TN

HOME PHONE:
BUSINESS PHONE:

MAJOR POINTS: CALLED TO VOICE HIS SUPPORT FOR THE WATTS BAR WASTE HEAT PARK.

ACTION: THANKED CALLER FOR COMMENT. INFORMED HIM I WOULD MAKE HIS CALL A PART OF MY OFFICIAL RECORD.

DISTRIBUTION: CAL FILES (1)

CITIZEN ACTION LINE CALL. BY: JC 80/12/04 17:17 C01[illegible].JC

SUBJECT CODE: N TYPE CALL: PC STATUS: C

SUBJECT: NUCLEAR- WB WASTE HEAT PARK-SUPPORT

MIKE LOUALLEN
DAYTON, TN

HOME PHONE:
BUSINESS PHONE:

MAJOR POINTS: CALLED TO VOICE HIS SUPPORT FOR THE WATTS BAR WASTE HEAT PARK.

ACTION: INFORMED CALLER I WOULD MAKE A PART OF MY RECORDS.

DISTRIBUTION: CAL FILES (1)

CITIZEN ACTION LINE CALL BY: HT 80/12/05 07:56 801515.HT

SUBJECT CODE: N TYPE CALL: IN STATUS: C

SUBJECT: NUCLEAR- WB WASTE HEAT PARK

RONNIE CLABAUGH HOME PHONE:
ROUTE 2
BOX 91D
DAYTON, TN 37321 BUSINESS PHONE:

MAJOR POINTS: IS IN FAVOR OF THE PROPOSED WATTS BAR WASTE HEAT PARK. SAYS MANY PEOPLE IN THE AREA ARE OUT OF WORK, AND MAYBE THIS WILL GET SOME OF THEM OFF OF WELFARE AND BACK TO WORK.

DISTRIBUTION: CAL FILES (1)

EQS

DEC 11 '80

(4)

Files

TENNESSEE STATE PLANNING OFFICE
660 CAPITOL HILL BUILDING
301 SEVENTH AVENUE, NORTH
NASHVILLE, TENNESSEE 37219
615-741-1676

December 5, 1980

Mr. Richard L. Morgan, Jr.
Manager
Office of Community Development
Tennessee Valley Authority
201 Summer Place Boulevard
Knoxville, Tennessee 37902

A-95 No. 121

RE: CH#81-3148 DEIS Watts Bar Waste Heat Park, Rhea County, TN

Dear Mr. Morgan:

In accordance with OMB Circular A-95 and as the designated State Clearinghouse for federal grant programs, we have reviewed your proposal and have assigned this project the State Clearinghouse number indicated.

Our evaluation of submitted materials identified no conflicts with existing or planned state activities. We hereby are notifying you that your proposal is deemed acceptable on the basis of the descriptive information you have made available to this office. We, or other reviewing authorities, may wish to comment further at a later time.

If our office, as the State Clearinghouse, can be of further assistance, please do not hesitate to contact me.

Sincerely,

Thomas M. Webb

Thomas M. Webb
Manager, Environmental Services

TMW:pbw

Orig: WM:GW
cc: JVC

DEC 19 1980

M. T. Elskey, Inc.
C. E. Gray, 1000 CST 2-C
Jim Jenkins, Cleveland
Jim Loney, For B-71
H. S. Sangster, E11B33, C-K

OFFICE OF COMMUNITY DEVELOPMENT

DEC 12 '80

MANAGER
DEPUTY MANAGER
DIR. COMMUNITY
DIR. COMM. SERV.
POLICY P... PLANNING

OFFICE OF THE

Rhea County Executive

DAN WADE

RHEA COUNTY COURT HOUSE

DAYTON, TENNESSEE 37321

(615) 775-0187

December 5, 1980

Dr. Mohamed T. El-Ashry
Director Environmental Quality Staff
Office of Natural Resources
Tennessee Valley Authority
Forestry Building
Norris, Tennessee 37828

Dear Sir:

As the Chief Executive of Rhea County Government, I wish to express my unqualified support for the Watts Bar Waste Heat Park. The park concept is totally in harmony with Rhea County's future growth and planning.

Sincerely,

Dan Wade

are

EQS
DEC 8 '80

El-Ashry
Crowder
Chatta. EPA
Chatta. NEPA
Files

mc: 12-11-80
L. B. Goss, 1110 CST2-C
W. W. LaRoche, E10B 8 C-K

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION IV

345 COURTLAND STREET
ATLANTA, GEORGIA 30365

December 9, 1980

4SA-EIS

Dr. Mohamed T. El-Ashry, Director
Environmental Quality Staff
Natural Resources Building
Norris, Tennessee 37828

Dear Dr. El-Ashry:

We have reviewed the Draft Environmental Impact Statement (DEIS) for the Watts Bar Waste Heat Park in Rhea County, Tennessee. While EPA strongly supports the concept of low grade waste heat recovery, our review of the DEIS raises some fundamental questions about the environment limitations of the Watts Bar site and the adequacy of the DEIS in quantifying the potential environmental consequences of the project. Specifically, we are concerned about the possibility of water quality degradation in the Chickamauga Reservoir after the Park is fully developed. Our attached technical comments develop this and our other concerns in more detail.

As a result, we have rated the DEIS LO-2, i.e., we have no significant objections to the proposal, but request the above issues be addressed in the FEIS.

Sincerely yours,

John E. Hagan III

John E. Hagan III
Chief, EIS Branch

Enclosure

EQS
DEC 11 '80

Calhoun
Johnson
Kinsel
Montgomery
Smith-Sanclair
Thurman
Energy Group
Crowder-MS
Chatta. EPA
Chatta. NEPA
Files

12-16-80
mc: L. B. Goss, 1110 CST2-C
W. W. LaRoche, E10C 55 C-K

TECHNICAL COMMENTS:

Page A-18, last paragraph

Table A.3-3 The FEIS should include the dissolved oxygen concentration both seasonally and at selected depths in the Chickamauga Reservoir (or above Watts Bar Dam). The FEIS should also discuss to what extent the dissolved oxygen concentration will limit full development of the waste heat park
6.2.1 using a specified "mix" of industries.

Page A-18, last paragraph

A.3.3.1 Is the Chickamauga Reservoir adjacent to the proposed facility thermally stratified during the summer months?

General Comment

1.2 What percent of the waste heat produced by the Watts Bar Nuclear Facility will be used by the waste heat park when full developed?

Page B-4, last paragraph

4.3.4.2 The DEIS does not adequately address the air quality impacts of the coal-fired backup and heat augmentation system. The FEIS should include
B.2.2.2 a microscale analysis of the air quality impacts of a backup heat generation system of the type described in the DEIS.

Page 22 (Section 4.2), General Comment

The DEIS does not adequately evaluate the BOD and nutrient discharge characteristics of the industries that are likely to be located in the waste heat park. Specifically, the FEIS should, for each industry included in Section 4.2, list the amount of Total-Nitrogen, NO_3-Nitrogen,
6.2.1 Phosphorous, potassium, and BOD (in lbs/day) to be discharged after application of best available control technology (BACT) or its equivalent. For industries where BACT has not been promulgated, the discharge amounts should be based on "best engineering judgment" with the pollution control technology proposed identified. If the control technology is a completely closed system (no NPDES permit), the FEIS should state such.

First United Methodist Church

P. O. Box 1?
DAYTON TENNESSEE 37321

CHURCH (615) 775-0262
PARSONAGE (615) 775-0101

December 10, 1980

Dr. Mohamed T. El-Ashry
Director of Environmental Quality Staff
Office of Natural Resources
Forestry Building
Norris, TN 37828

Dear Dr. El-Ashry:

I want to express my support for the effort of TVA in developing the industrial park at Watts Bar Nuclear Plant. I believe that the Park is environmentally sound, economically sound and commercially feasible.

As the Pastor of a 500-member church, I realize that if our community is to grow, we must continue to see growth in industry. We need new jobs for our community, plus, we must continue to search for new sources of taxes that will improve our schools, highways and many other programs.

I speak not only for myself in regard to this matter, but for the majority of our membership.

Sincerely yours,

Jack Edwards
Pastor

bam

12-15-80--MEE
cc: L. B. Goss, 1110 CST2-C
W. W. LaRoche, E10C55 C-K
L. H. Woosley, 375B 401B-K

EQS
DEC 15 80
Quila EDSD
Quila NEPA

DEPARTMENT OF THE ARMY
NASHVILLE DISTRICT, CORPS OF ENGINEERS
P. O. BOX 1070
NASHVILLE, TENNESSEE 37202

12-16-80--HKE
cc: L. B. Goss, 1110 CST
W. W. LaRoche, E10C5
L. H. Woosley, 375B

IN REPLY REFER TO
ORNED-P

11 DEC 1980

Dr. M. T. El-Ashry
Director of Environmental Quality
Tennessee Valley Authority
Knoxville, TN 37902

Files
Chatta NEPA
Chatta ERs
Crowder
EOS

Dear Dr. El-Ashry:

I have received the Draft Environmental Impact Statement - Proposed Watts Bar Waste Heat Park for review and comments. I find the following comments applicable:

Vol. I, page 5, para 2. Alternatives.

2.2 Under this section, three alternatives are presented, i.e., a waste heat park at Watts Bar Nuclear Power Plant, waste heat parks at other TVA power plants, and no action. Are non-Federally owned sources of waste heat available in the Tennessee Valley which could be additional alternatives to the Watts Bar site?

Vol. I, p.7, para 2.3 Alternative Management Schemes, para 3.

6.2.2 Will the selection of occupants for the park be subject to interagency review? If so, what kind of document will facilitate the review--EIS supplement, EA? What restrictions concerning the maintenance of environmental quality will be used in instruments to convey the land?

Vol. II, p. A-39, para A.7 Endangered or Threatened Species; A.7.2 Aquatic Invertebrates and Fish, para 3.

A.7.2 The reference to the identification of two specimens of the snail darter, *Percina tanasi*, by sight, in the Tennessee River near TRM 515.4 has doubtful scientific value for the purposes of this assessment unless further substantiation is provided by reference to the observer, his or her scientific qualifications, and the time, date, and circumstances of the observation.

Vol. II, p. A-45, Fig. A.8-2 Generalized Land Use in the Vicinity of the Watts Bar Waste Heat Park.

Fig.A.8-2 This figure does not depict Yellow Creek Wildlife Management Area, adjacent to the park, either as an existing or future land use.

Vol. II, p. B-36, B-37, B.12 Floodplains and Wetlands.

B.12.4 In keeping with Executive Orders 11990 and 11988, Federal agencies are encouraged to provide leadership to protect wetlands and floodplains and to avoid indirect support of new development in floodplains and wetlands whenever there is a practicable alternative. The Corps concurs with TVA's statement, B.12.a, para 1, that only open-field soil warming areas, aquaculture retention ponds, and necessary support facilities, i.e., roads, parking areas, and utilities, will be located in the one-percent chance floodplain. Avoiding impacts on the identified wetlands is also encouraged.

Appendix E

Appendix F The final EIS should show SHPO concurrence with TVA's request for determination of eligibility for archeological site 40RH64.

Appendix D If the possibility exists that a Department of the Army Permit will be required during the development of the waste heat park, TVA should request that the Corps become a cooperating agency. This coordination will insure that the EIS produced will satisfy the procedural and statutory requirement of the Corps and could possibly be adopted as a Corps EIS in accordance with 40 CFR 1506.3.

Thank you for the opportunity to comment on this document. If I can be of further assistance to you in this matter, please contact me.

Sincerely,

W. G. Eastland
FOR
E. C. MOORE
Chief, Engineering Division

CITIZEN ACTION LINE CALL. BY: JD 80/12/11 1[illegible]:17 001858.JD

SUBJECT CODE: [illegible] TYPE CALL: PC STATUS: [illegible]

SUBJECT: NUCLEAR-WB WASTE HEAT PARK-SUPPORT

TOM DAVIS
RT. 5, BOX 417
DAYTON, TN 37321

HOME PHONE:

BUSINESS PHONE:

MAJOR POINTS: WANTED TO STATE THAT HE IS IN FAVOR OF THE WASTE HEAT PARK AT WATTS BAR. STATED THAT THE AREA REALLY NEEDS THIS.

ACTION: TOLD HIM THAT THIS COMMENTS TO BE ADDED TO MY RECORD.

DISTRIBUTION: CAL FILES (1)

104 Davey Laboratory
The Penn. State University
University Park
Pa., 16802

14 December 1980

Dr. Mohamed T. El-Ashry, Director
Environmental Quality Staff
Natural Resources Building
Norris, Tennessee, 37828

Gentlemen:

Enclosed are my comments on the Draft Environmental Impact Statement on the Watts Bar Waste Heat Park. Please note that the opinions and calculations are m not necessarily those of The Pennsylvania State University, which is well known for its encouragement of free thought. The affiliation is used here for identification purposes only.

Your use of an index in the main report is useful and appreciate

Sincerely,

William A. Lochstet

Wm. A. Lochstet, Ph.D.

bc: L.B. Goss, 1110 CST2-C
W.W. Laroche, E10B 8 C-K
M.E. Martin, 226 NRB-N

EQS
DEC 22 '80
13
TO
ACTION
El-Ashry
Bruch
Calhoun
Fitz
Johnson
Kinsel
Montgomery
Smith-Sinclair
Thurman
Energy Group
Crowder-MS
Chatta. ER&D
CC Chatta. NEPA
Files

Woosley

Environmental Impact of the
Watts Bar Waste Heat Park
by

William A. Lochstet, Ph.D.
The Pennsylvania State University *

December 1980

The Tennessee Valley Authority has attempted to evaluate
the environmental impact of its proposed Waste Heat Park
at the Watts Bar site in its October 1980 Draft Enfironmenal
Impact Statement (DEIS).
The expected radiological consequences are calculated in~~x~~
terms of individual exposures ~~ix~~ as shown in Tables 4.3-2, A.4-3,
and A.4-4. The total population doses should, and must be
evaluated. In particular, this represents a change in the
population in close proximity to the Watts Bar plant(the
Waste Heat Park employees). Because of this added population,
there will be an increased population dose to this population.
The requirement of 10 CFR 50 Appendix I is ~~x~~ that all reasonable
additions be made to reduce emissions until a balance is reached
6.2.3 at $1000 per total body person-rem, or per thyroid person-rem.
In addition, the products of the "Park" will contain <u>some</u>
radioactive material, regardless of how small. The effects of
this on the general public should be evaluated (customers) in
terms of person-rem population dose. If food is to be grown
in this "Park" it is particularly critical that this be done
in good faith as required by NEPA. The marketability and public
6.2.4 acceptance of such material may not be positive.
The optemistic assurance that water supplied to the "Park"
6.2.5 is unlikely to contain radioactivity (DEIS, Page A-26) needs

* The opinions and calculations contained herein are my own,
and not necessarily those of the Pennsylvania State University,
which affiliation is for identification purposes only.

to be considered very carefully. Since steam generators are
known to develop leaks, as well as condensers, and ~~fxix~~ fuel
rods, it may not be so unlikely for radioactivity to be present
in condenser cooling water. This must br evaluated numerically.
The ideal site for such a "Park" would be at a multi-unit
coal fired location. The use of coal would greatly reduce the
problems of radioactivity in the products and worker exposures.
~~Thxt~~ This alternative is rejected on the basis of a very cursory
6.2.6 and inadequate evaluation in the DEIS.
A second alternative that must be considered is to ~~x~~ locate
the "Park" several miles from the power stations. In the case of
6.2.7 nuclear, this would provide additional protection for both
accident and normal operation. Consideration should also be given
to the use of an additional heat exchanger at the "Park" end of
6.2.8 the connecting pipeline. If the pipeline were operated ~~xx~~ at
lower pressure than the "Park" ~~xxx~~ service water, this would lower
the quantities of radioactivity reaching the park.
Consideration should be given to the restricting of activities
so as to eliminate all food or agriculture industries. This
6.2.9 would hopefully lower the normal population dose expected.
The use of floodplain areas for the "Park" seems particularly
inappropriate. If this is such a useful idea other lands should
6.2.10 be found that are more appropriate.

MEMORANDUM

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
FOOD AND DRUG ADMINISTRATION

TO : Dr. Mohamed T. El-Ashry, Director of Environmental Quality, Tennessee Valley Authority, Knoxville, Tennessee 37902

DATE: December 15, 1980

FROM : Buzz L. Hoffmann, Ph.D. Chief, Environmental and Economic Analysis and Research Section

SUBJECT: DRAFT ENVIRONMENTAL IMPACT STATEMENT-PROPOSED WATTS BAR WASTE HEAT PARK

I have attached, as FDA's response to the Draft Environmental Impact Statement covering the proposed Watts Bar Waste Heat Park, comments prepared by Dr. William Stroube, of the Bureau of Foods.

Any Questions you may have regarding his comments should be directed to him. He may be reached at 301-921-3216.

Jerry C. [signature], Ph.D.
for Buzz L. Hoffmann Ph.D. Chief,
Environmental and Economic
Analysis and Research Section

12-24-80--MKE
cc: L. B. Goss, 1110 CST2-C
W. W. LaRoche, E10C55 C-K
L. H. Woosley, 375B 401B-CEQS

DEC 23 '80
ACTION
El-Ashry
Smith-Sinclair
Crowder, MS
NEPA

83

MEMORANDUM

DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
FOOD AND DRUG ADMINISTRATION

TO : Buzz Hoffman, HFF-26

DATE: December 3, 1980

FROM : Research Chemist, Analytical Chemistry & Physics Branch, HFF-456

SUBJECT: Review of Draft Environmental Impact Statement - Proposed Watts Bar Waste Heat Park

As requested, this draft environmental impact statement (DEIS) has been reviewed to determine any impact of radioactive emissions upon food production in this project. With a closed-loop cooling tower operation, such as the Watts Bar Plant, no contact is made between systems containing radionuclides and the user of the waste heat. Under normal operating conditions, the radionuclide emissions from this plant will be negligible.

Sampling of items produced at the Waste Heat Park will be performed by the Tennessee Valley Authority, as described in Section 4.3.4.4.2 of the DEIS. FDA would probably also sample foods produced in such a situation as part of routine surveillance in the Radionuclides in Foods Program. Based upon our past experience of monitoring foods grown near nuclear power plants, the Watts Bar Waste Heat Park will not be affected by emission from the adjacent nuclear power plant.

William Stroube
William B. Stroube, Ph.D.

Attachments

J03 810106 552

Energy People

120 31st Avenue North • Nashville, Tennessee 37203 • (615) 269-6786

December 15, 1980

Gentlemen,

Although we learned only today of your invitation to comment on your proposed Watts Bar Heat Park, we'd like to contribute briefly our thoughts.

6.2.11 1. Such a proposal would increase working, and perhaps residential, population adjacent to an operating reactor, complicating evacuation.

6.2.12 2. Products manufactured, as well as employees hired, would suffer from possible radiation contamination and/or accumulation, daily.

6.2.13 3. Manufacturers located in such proximity for the purpose of utilizing waste heat would suffer from shutdowns of reactors and their eventual decommissioning — the removal of their heat source.

Therefore, we would oppose such a project and urge that under no circumstances it be promoted.

Sincerely yours,

Faith Young

for Energy People, Inc.

P.S. We request by this letter a copy of the E.I.S. as well as correspondence from all those who comment.

F.Y.

J01 810112 254

DAYTON, TENNESSEE 373

December 16, 1980

Dr. Mohamed T. El-Ashry, Director
Environmental Quality Staff
Office of Natural Resources
Forestry Building
Norris, Tenn 37828

Dear Dr. El-Ashry,

As President and on behalf of the Greater Dayton Area Chamber of Commerce, I want to strongly voice our feelings on the importance of the development of the Waste Heat Industry Park at the Watts Bar Nuclear Plant.

We want to encourage you in all ways possible in helping to secure the funds needed to develop the park. Applications already received from companies that want to locate in the park are an excellent indication of the interest shown. This would also give a sorely needed boost to the economy here in Rhea County.

We look forward to hearing from you and we would like to offer any assistance possible on this matter.

Sincerely,

Jack L Smith, President
Greater Dayton Area
Chamber of Commerce

JLS/sh

12-19-80--MKE
cc: L. B. Goss, 1110 CST2-C
W. W. LaRoche, E10C53 C-K
L. H. Woosley, 375B 401B-C

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

ER 80/1269

DEC 16 1980

Mohamed T. El-Ashry, Ph.D.
Director of Environmental
Quality
Tennessee Valley Authority
Knoxville, Tennessee 37902

Dear Dr. El-Ashry:

We have reviewed the draft environmental impact statement for the Watts Bar Waste Heat Park, Rhea County, Tennessee. Our comments are presented according to the format of the statement or by subject.

<u>Nuclear Safety Systems</u>

2.4 The draft statement indicates that "There is little conflict with nuclear safety-related systems" on page 9, item E. We believe that <u>any</u> such conflict should be fully identified and evaluated in the main body of the environmental statement, as the present references to safety on pages 6, 7, 9, 11, 53, 57, B-1 and B-2 do not clearly encompass nuclear safety-related systems.

<u>Groundwater</u>

B.3.2.2 We suggest that because of the proximity of the water-well field of the Watts Bar Nuclear Plant, at least a typical long-term radius of influence should be included for the wells which are expected to yield 1,000 to 1,500 gpm to supply the proposed facilities.

<u>Wetlands</u>

B.12.4 We are concerned about potential impacts on wetland values from development adjacent to wetland areas. The State controlled Yellow Springs Wildlife Management Area on the west side of the proposed waste heat park is intensively managed for wintering waterfowl, and utilized throughout the winter. During peak concentrations in late January 15,000 to 20,000 waterfowl, mainly mallards and black ducks, use the Chickamauga Lake area. During the hunting season a portion of the wildlife management area adjacent to the proposed park provides substantial recreational

B.5.3 hunting opportunity. It would be advisable to incorporate provisions for the establishment of a wooded buffer strip adjacent to the wildlife management area. In addition, to assure that the 40 to 50 acres of wetlands within the park
B.12.4 site are not adversely impacted, a buffer strip should also be established around them.

We hope these comments will be helpful to you in the preparation of a final statement.

Sincerely,

James H. Rathlesberger
Special Assistant to
Assistant SECRETARY

bc: L. Barry Goss, 1110 CST2-C
W. Walter Laroche, E10B 8 C-K

CITIZEN ACTION LINE CALL BY: CA 80/12/16 09:34 C02095.CA

SUBJECT CODE: N TYPE CALL: PC STATUS: C

SUBJECT: NUCLEAR- WB WASTE HEAT PARK

ANN DILLARD HOME PHONE: 615/775-9571
P.O. BOX 474
DAYTON, TN 37321 BUSINESS PHONE:

MAJOR POINTS: IS IN FAVOR OF THE WASTE HEAT PARK PROPOSED FOR WATTS BAR NUCLEAR PLANT. SAID SHE HOPES TVA WILL GO AHEAD WITH PLANS BECAUSE PROJECT WILL MEAN A GREAT DEAL TO THE LOCAL COMMUNITY.

ACTION: ASSURED MS. DILLARD THAT HER COMMENT WOULD BE RECORDED.

DISTRIBUTION: CAL FILES (1)

CITIZEN ACTION LINE CALL BY: KG 80/12/16 17:46 C02185.KG

SUBJECT CODE: L TYPE CALL: PC STATUS: C

SUBJECT: LAND-USE

CLAUDE REAL HOME PHONE:
DAYTON, TN BUSINESS PHONE:

MAJOR POINTS:
VISITOR: PHIL HYATT

MR. REAL CALLED TO SAY HE IS IN FAVOR OF THE THE RHEA COUNTY WASTE HEAT INDUSTRIAL PARK.

SAID HE READ IN THE LOCAL PAPER THAT HE COULD REGISTER HIS OPINION WITH THE CITIZEN ACTION LINE.

DISTRIBUTION;CAL STAFF

DISTRIBUTION: CAL STAFF (1)

CITIZEN ACTION LINE CALL BY: JD 80/12/17 10:50 C02198.JD

SUBJECT CODE: N TYPE CALL: PC STATUS: C

SUBJECT: NUCLEAR- WB WASTE HEAT PARK-SUPPORT

PAM CORBIN HOME PHONE:
RT. 4, BOX 240A
APT. 1C
DAYTON, TN 37321 BUSINESS PHONE:

MAJOR POINTS: WANTED TO SAY THAT SHE WAS IN FAVOR OF THE WASTE HEAT PARK AT WATTS BAR.

ACTION: EXPLAINED THAT HER COMMENTS WOULD BE MADE PART OF THE RECORD.

DISTRIBUTION: CAL FILES (1)

CITIZEN ACTION LINE CALL BY: JD 80/12/17 13:02 C02211.JD

SUBJECT CODE: N TYPE CALL: PC STATUS: C

SUBJECT: NUCLEAR- WB WASTE HEAT PARK-SUPPORT

BILL EDGEMAN HOME PHONE:
RT. 5, BOX 233
DAYTON, TN 37321 BUSINESS PHONE:

MAJOR POINTS: WANTED TO STATE THAT HE IS IN FAVOR OF THE WATTS BAR WASTE HEAT PARK.

ACTION: EXPLAINED THAT HIS COMMENTS WOULD BE INCLUDED WITH THE RECORD.

DISTRIBUTION: CAL FILES (1)

CITIZEN ACTION LINE CALL BY: JD 80/12/17 13:47 C02212.JD

SUBJECT CODE: N TYPE CALL: PC STATUS: C

SUBJECT: NUCLEAR- WB WASTE HEAT PARK-SUPPORT

PHIL LOEFFLER HOME PHONE:
P.O. BOX 381
DAYTON, TN 37321 BUSINESS PHONE:

MAJOR POINTS: WANTED TO VOICE HIS SUPPORT FOR THE WASTE HEAT PARK AT WATTS BAR. FELT THAT IT WOULD BE A GOOD THING FOR RHEA COUNTY.

ACTION: EXPLAINED THAT HIS COMMENTS WOULD BE MADE A PART OF THE RECORD.

DISTRIBUTION: CAL FILES (1)

CITIZEN ACTION LINE CALL BY: JD 80/12/17 13:54 C02213.JD

SUBJECT CODE: N TYPE CALL: PC STATUS: C

SUBJECT: NUCLEAR- WB WASTE HEAT PARK-SUPPORT

KENT GREEN HOME PHONE:
P.O. BOX 456
DAYTON, TN 37321 BUSINESS PHONE:

MAJOR POINTS: WANTED TO SAY THAT HE WAS IN FAVOR OF THE WASTE HEAT PARK AT WATTS BAR.

ACTION: EXPLAINED THAT HIS COMMENTS WOULD BE MADE A PART OF THE RECORD.

DISTRIBUTION: CAL FILES (1)

CITIZEN ACTION LINE CALL BY: GC 80/12/17 14:45 C02217.GC

SUBJECT CODE: N TYPE CALL: P STATUS: C

SUBJECT: NUCLEAR- WB WASTE HEAT PARK

STEVE DILLARD HOME PHONE:
DAYTON, TN BUSINESS PHONE:

MAJOR POINTS: WANTS HIS COMMENTS TO BE KNOWN ON THE WATTS BAR WASTE HEAT PRAK. IS DEFINITELY IN FAVOR OF IT; FEELS IT WOULD BE AN ASSET TO RHEA COUNTY DUE TO THE HIGH UNEMLOYMENT RATE THERE; FEELS THE GENERAL CONSENSUS OF THE COMMUNITY IS TO SUPPORT THE PROGRAM.

DISTRIBUTION: CAL FILES (1)

CITIZEN ACTION LINE CALL BY: BM 80/12/17 17:28 C02242.BM

SUBJECT CODE: N TYPE CALL: PC STATUS: C

SUBJECT: NUCLEAR- WB WASTE HEAT PARK SUPPORT

GRACE SAWYER HOME PHONE:
, TN BUSINESS PHONE:

MAJOR POINTS: W. O. BROWN'S CALL.

CALLER ENDORSES HEAT PARK AT WATTS BAR.

ACTION: EXPLAINED THAT CALL WOULD BE DOCUMENTED.

DISTRIBUTION: CAL FILES (1)

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
ATLANTA REGIONAL OFFICE
RICHARD B. RUSSELL FEDERAL BUILDING
75 SPRING STREET, S.W.
ATLANTA, GEORGIA 30303

REGION IV

December 18, 1980

IN REPLY REFER TO
4C

Dr. Mohamed T. El-Ashri
Director
Environmental Quality Staff
Tennessee Valley Authority
Natural Resources Building
Norris, Tennessee 37828

Dear Dr. El-Ashri:

We appreciate the opportunity to review the Draft EIS for the proposed Watts Bar Waste Heat Park, Rhea County, Tennessee. Our comments are as follows:

B.12.1 and B.12.2.2 — 1. In the Executive Summary it is indicated the irreversible and irretrievable resources will primarily be building materials, wildlife, open space and soil quality and quantity. However, it seems from the report there may be a loss of floodplain areas which are a significant resource. Further, it is not indicated
4.3.4.8 — whether this land is classified as prime farmland by the U.S. Department of Agriculture.

2. There is not a clear estimate of the potential employment. On page 22, it indicates the operating labor force would be 6 to 10 full-time employees and 3 to 5 part-time employees per acre. With 100 acres of greenhouses this represents approximately 1,500 employees at the maximum expected employment rate. This is a significant number of workers. At the minimum expected employment rate there will be 900 employees. In addition to this employment they are estimating 100 - 300 employees for full industrial development. This could represent an employment of
B.9.2 — 1,800 employees at full development.

3. With the potential employment of 1,800 there could be a significant traffic problem from this employment generator. This employment generator will have a high volume of trucks to transport the
A.9.3 — finished food products. There is no discussion of these issues.

4. There is little discussion of the noise impacts this traffic will have on residential areas along the major transportation system.
4.3.4.4.1 — On page 57, it is indicated there are no local or Federal noise regulations applicable to the park at this time. There may not be any standard directly related to the park but HUD has established noise standards for residential areas which would be impacted by the increased traffic on the highways and railroads.

B.9.3 — 5. Without knowing the existing unemployment in the area it is difficult to determine whether all of the employment would come from the immediate area. If the employment will be an influx, there will be changes in the infrastructure and services. This has not been sufficiently discussed in the EIS.

B.12.1 / B.12.2.2 — 6. The EIS does not indicate whether there will be fill material placed in the floodplain. There should be discussion of how this development will change the floodplain.

4.2.3.9 — 7. There is concern with the food processing industries causing substantial odors on residential and recreational areas. An evaluation of the appropriate landfill for the food processing disposal is needed to determine indirect impacts.

If we can be of further assistance please contact Ivar O. Iverson, Regional Environmental Officer, at 404/221-4096.

Sincerely,

Geraldine G. Thompson
Regional Administrator

RECEIVED
OFFICE OF POWER
JAN 14 1981
5a
DIVISION OF ENERGY DEMONSTRATIONS & TECHNOLOGY

A02 810112 015

RECEIVED
EDST
JAN 1 6 1981
WASTE HEAT UTILIZATION BRANCH

ARMS, MDH
KC: further handling as appropriate
EJT
CLM
LMM
MBH
Alw

Energy People

120 31st Avenue North • Nashville, Tennessee 37203 • (615) 269-6786

RECEIVED
CHATTANOOGA, TENN.
JAN 12 1981
OFFICE OF THE MANAGER OF POWER

JANUARY 9, 1981

OFFICE OF POWER
TVA
500-A CHESTNUT STREET
CHATTANOOGA, TN. 37402

RE: PROPOSED WATTS BAR HEAT PARK

GENTLEMEN:

WE ARE IN RECEIPT OF YOUR ENVIRONMENTAL IMPACT STATEMENT DRAFT ON THE ABOVE PROPOSAL AND WOULD LIKE TO COMMENT AS FOLLOWS: IN OBJECTION TO SUCH A PROJECT;

6.2.12 SINCE PWR'S, SUCH AS THOSE IN CONSTRUCTION AT WATTS BAR, LEAK OR DISCHARGE RADIONUCLIDES (IN VENTING OR IN PURGING THE CONTAINMENT) INTO THE ATMOSPHERE, AND SINCE THE AUXILIARY BUILDINGS AND REACTOR BUILDINGS ALSO RELEASE RADIOACTIVE GASES INTO THE ATMOSPHERE, AND SINCE MANY TENS OF THOUSANDS OF POUNDS OF STEAM COULD BE DUMPED, VIA STEAM DUMP VALVES, (WHEN REACTOR POWER IS REDUCED) INCLUDING RADIOACTIVITY, IN A MINUTE, THE POTENTIAL OF RADIOACTIVE CONTAMINATION OF HEAT PARK INDUSTRIAL WORKERS AND THEIR PRODUCTS IS OF CONSEQUENCE. THIS UNCERTAINTY OF SAFE OPERATION OF ADJACENT INDUSTRY SHOULD RENDER ANY EXTRANEOUS INDUSTRIAL OPERATION IN THE VICINITY ~~UNWISE~~ UNWISE

6.2.11 THE ADDITION OF UP TO 2,000 WORKERS WITHIN THE NUCLEAR VICINITY SHOULD EFFECTIVELY COMPLICATE EVACUATION OF THE LOCAL PERMANENT POPULATION IN TIME OF ACCIDENT AND COUNTER THE E.I.S. FOR THE NUCLEAR PLANT WHICH BASES ITS ESTIMATE OF POPULATION AT 160 PERSONS, LESS THAN A TENTH OF ANTICIPATED HEAT PARK POPULATION.

6.2.14 ECONOMIC HARDSHIP TO PARTICIPATING INDUSTRY WITHIN THE PROPOSED HEAT PARK SHOULD ELIMINATE ALL BUT THE TOTALLY INVULNERABLE. NOT ONLY MAY PRODUCTS BE WITHDRAWN FROM THE PUBLIC MARKET IF RADIOACTIVELY CONTAMINATED, BUT THE GOVERNMENT EXEMPTS THOSE INDUSTRIES (AS WELL AS THE PUBLIC) FROM ALL BUT TOKEN INSURANCE COVERAGE IN TIME OF NUCLEAR ACCIDENT.

YOURS TRULY,
FAITH YOUNG
FOR ENERGY PEOPLE, INC.

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6.2 RESPONSES TO COMMENTS NOT INCORPORATED INTO TEXT

6.2.1 Response to EPA Comments 1 and 5

Near the Watts Bar site, the Tennessee River is classified as a "water quality limited segment" for dissolved oxygen (segment of waters or segments of waters which due to background quality, flow characteristics, or waste discharges, require a level of effluent control more restrictive than the control produced by utilization of practical conventional unit treatment processes, BPTCA, BATEA, or NSPS). According to Tennessee Department of Public Health Rules on Effluent Limitations and Standards (1200-4-5-.04):

> Permits for all existing or proposed discharges to water quality limited or proposed water quality limited segments of the State's waters may include, when necessary to maintain assigned classifications, individually calculated effluent limitations on any parameter more stringent than BPTCA, BATEA, or results of treatment by practical conventional unit treatment processes.

At this point several industries (greenhouses, leather tanning, ethanol) have expressed interest in the park as a potential location, but no information has been developed by the industries on specific plant designs, processes capabilities, effluents, or treatment methods. Therefore, it is not possible at this stage to determine the specific amounts of pollutants each industry would discharge in lbs/day beyond the information presented in Section 4.2. When industries do propose to locate at the park and develop proposed designs and discharges, the State of Tennessee will require by permit that the industry meet individually calculated effluent limitations for oxygen-demanding wastes. In addition, TVA will review each potential applicant under NEPA and TVA's implementing procedures, and if necessary, conditions will be placed on contracts or easement agreements to protect the health and safety of the public, the environment, and other interests of the United States. TVA will work with EPA and the State of Tennessee to assure that State standards for protection of the water resources (in particular, dissolved oxygen) are met. As appropriate, studies may be required to evaluate treatment effectiveness and substantiate maintenance of instream oxygen resources.

The dissolved oxygen concentrations of the Tennessee River should not directly limit development of the waste heat park. The cost of meeting individually calculated effluent limitations may, however, prohibit some industries from locating at the park.

6.2.2 Response to Department of the Army Comment 2

TVA will transfer the land to be utilized as a waste heat park by the issuance of an easement to the park management organization. TVA will specify in this easement that all potential park occupants submit an application with appropriate environmental evaluations for review and approval by TVA as well as the park management organization. TVA will subject the application with environmental evaluations to an interdisciplinary review in conformance with NEPA and TVA's implementing procedures. In some cases it may be necessary for TVA to prepare an environmental assessment or supplemental environmental impact statement. At that time the necessary level of public and interagency review would be solicited as part of the NEPA process. After this review, utilizing the information provided in the application and the results of the NEPA review, TVA would make a decision whether to approve or disapprove the application. If approved, TVA will require as a condition in the park occupants' contract with the park management organization, that the facility comply with all applicable Federal, State, and local environmental laws, rules, and regulations, and if necessary, any other conditions which TVA determines are in the best interest of the United States.

6.2.3 Response to W. A. Lochstet Comments 1 and 2

Although a population dose for WBWHP workers is not explicitly presented in Section A.4.2, one can be calculated using the information in Table A.4-3. From this table the maximum dose from plant effluents to an individual at the WBWHP is listed as 1.3 mrem/yr per unit, assuming continuous occupancy. Hence, the population dose to 350 personnel for a 2-unit plant is about 0.9 man-rem/yr. For a 40-hour per week occupancy, the population dose to these personnel would be about 0.2 person-rem/yr. This represents less than one-half of one percent of the dose to this same population from natural background radiation. It is highly unlikely that such a small population dose could be further reduced through alteration of plant design and/or operation at a cost of $1,000 per person-rem. However, administrative controls and operational procedures at WBN will be implemented to ensure that all exposures are "as low as reasonably achievable."

6.2.4 Response to W. A. Lochstet Comment 3

A precise estimation of the population dose to potential customers of WBWHP products would require more detail regarding productivities and product distribution than is now available. However, using the maximum individual doses from Table A.4-3 for ingestion, the maximum dose to a population of product consumers would be no greater than 4 to 8 percent of the dose to the same population from natural background radiation. It should be noted that this estimate assumed no decay time for transport in the food distribution system and is therefore very conservative. Further, product sampling will be conducted to confirm these estimates. Should this program reveal significant impacts from WBN to these products, measures will be implemented to restrict the production and use of the products as necessary.

6.2.5 Response to W. A. Lochstet Comment 4

Evaluations have been performed as part of the plant design on the probability of the condenser circulating water (CCW) becoming contaminated. Since the CCW is a tertiary system to the reactor coolant loop, it is very unlikely that it would become contaminated. An intermediate heat exchanger (secondary) loop serves to isolate the CCW from any radioactivity, thereby preventing any direct interaction between the reactor and CCW, should a leak occur. If by chance there was a simultaneous leak in the tertiary and secondary loops, subatmospheric pressures in the condensers serve to prevent a leak into the CCW system from the secondary system. As further safeguard, routine samples will be taken from the waste heat park products to ensure there is no radioactive contamination beyond that of normal background levels.

6.2.6 Response to W. A. Lochstet Comment 5

The primary reason for locating waste heat parks at TVA future nuclear plants rather than fossil-fired plants is the higher waste heat water temperatures. TVA's fossil-fired plants have less than a 20°F temperature rise across their condensors with an open-cycle cooling system operation, whereas all of TVA's future nuclear plants (Watts Bar and beyond) have more than a 30°F temperature rise and have a closed-cycle cooling system operation. This means that the average waste heat water temperature at each fossil-fired plant is below 80°F, while the average waste heat water temperature at Watts Bar is 112°F and is over 100°F at the other future nuclear plants. TVA's Paradise Power Plant unit 3 is the only exception to these general characteristics for the fossil-fired plants, but had to be excluded for the reasons as stated in Section 3.1 of the EIS.

6.2.7 Response to W. A. Lochstet Comment 6

Locating the park several miles from the power plant would decrease the feasibility of waste heat use. The major disadvantage would be the temperature drop in the waste heat water associated with greater distances. The present temperature drop for the waste heat park is approximately 3°F at a distance less than a mile. Greater distances would increase this temperature drop significantly. Other disadvantages include: additional capital investment, increased operating and maintenance costs, and higher pumping costs associated with the greater distance.

6.2.8 Response to W. A. Lochstet Comment 7

The use of an additional heat exchanger between the waste heat park and the power plant would decrease the available temperature to the waste heat park occupants due to the low efficiency of low temperature heat exchangers. Also there would be a substantial cost associated with the additional equipment.

6.2.9 Response to W. A. Lochstet Comment 8

As assessed in Section B.4.2.3, effluents from Watts Bar Nuclear Plant are not expected to affect products from the waste heat park. The

Food and Drug Administration has reviewed the Draft EIS and concurs with TVA's assessment. The Food and Drug Administration's comments appear in Section 6.1 of the EIS.

6.2.10 Response to W. A. Lochstet Comment 9

As assessed in Section B.12.2.1, it would be impractical to locate the waste heat park entirely above the floodplain, and development as planned will be consistent with TVA's policy on floodplain management. The U.S. Army Corps of Engineers has reviewed the Draft EIS and concurs with TVA's assessment. The Corps of Engineers' comments appear in Section 6.1 of the EIS.

6.2.11 Response to Energy People Comment 1 of December 15, 1980 Letter and Comment 2 of January 9, 1981 Letter

Although we agree that the working and perhaps the residential populations would increase with the development of the park, we question the estimate "of up to 2000" workers quoted in coment 2 for this demonstration waste heat park. It is estimated that the park would employ around 1100 people when fully developed.

Second, we question the contention that the increase in the workforce at the site and the slight, if any, increase in the residential population would complicate the radiological emergency evacuation plans for the Watts Bar Nuclear Plant (WBN).

Regardless of which of these figures is used, the impact on the emergency evacuation plans would be minor. The reservation is located in a sparsely populated area, as is evident with reference to the projected 1980 census figures provided in the WBN "Final Safety Analysis Report." Approximately 12,400 persons reside within the 10-mile emergency planning zone and over 80 percent of these people live between 5 and 10 miles from the site. Furthermore, the addition of the 1100 WBWHP employees to the WBN "Final Environmental Statement" manpower estimate of 170 persons is not expected to cause more than a minor impact on the evacuation time for the local population from the emergency planning zone.

It is our intention to include the WBWHP workforce in the evacuation time studies, which will be contained in the WBN radiological emergency plan. This document is to be submitted in its entirety to the Nuclear Regulatory Commission early in 1982.

6.2.12 Response to Energy People Comment 2 of December 15, 1980 Letter and Comment 1 of January 9, 1981 Letter

Radiological impacts to individuals employed at the WBWHP were estimated in Section A.4.2. These impacts were evaluated for effluents from plant operation and for potential exposures from a volume reduction system and onsite storage facility for low-level waste management. All major radiological pathways to man were evaluated in this section, including the ingestion of foodstuffs produced at the park. As indicated in the section, all impacts were found to be within the objectives of 10 CFR 50 Appendix I and 40 CFR 190, where applicable. Sampling of products will be performed to confirm these estimates. Should this program reveal significant impacts from WBN to these products, measures will be implemented to restrict the production and use of the products as necessary.

6.2.13 Response to Energy People Comment 3 of December 15, 1980 Letter

Either a central heat backup system will be provided by park management or each occupant of the waste heat park will have his own backup heating system due to a small fraction of time (approximately 8 percent) that both units are projected not to be operating and waste heat water will not be available. This backup system will allow the occupant to continue his operations.

6.2.14 Response to Energy People Comment 3 of January 9, 1981 Letter

In case of a nuclear incident, the Price-Anderson Act provides a minimum level of $560 million protection for the public. With this level of protection available, we do not believe this places any economic hardship on the participating industries.

7. CONSULTATION AND COORDINATION

Copies of the Draft Environmental Impact Statement were sent to the following:

Federal Agencies

Advisory Council on Historic Preservation
Appalachian Regional Commission
Community Action Office
Community Services Administration
Council on Environmental Quality
Department of Agriculture
Department of the Army, Corps of Engineers
Department of Commerce
Department of Defense
Department of Energy
Department of Health, Education, and Welfare
Department of Housing and Urban Development
Department of the Interior
Department of Labor
Department of State
Department of Transportation
Department of Treasury
Environmental Protection Agency
Federal Energy Regulatory Commission
General Services Administration
Interstate Commerce Commission
National Aeronautics and Space Administration
Nuclear Regulatory Commission
Water Resources Council

State and Regional Interest

Chattanooga-Hamilton County Regional Planning Commission
Southeast Tennessee Development District
Tennessee Department of Conservation
Tennessee Historic Commission
Tennessee State Planning Office
Tennessee Wildlife Resources Agency

Local Officials

D. T. Wade, County Executive
Rhea County Courthouse
Dayton, Tennessee 37321

J. E. Powell, County Executive
Meigs County Courthouse
Decatur, Tennessee 37322

Jimmy Cunnyngham
Mayor of Dayton
Municipal Building
Dayton, Tennessee 37321

M. L. Knox
Mayor of Graysville
City Hall
Graysville, Tennessee 37338

P. H. Hale
Mayor of Spring City
City Hall
Spring City, Tennessee 37381

John Marchi, Chairman
Meigs County Planning Commission
Route 2, Box 34
Ten Mile, Tennessee 37880

Robert Forsten, Chairman
Rhea County Planning Commission
Blythe Ferry Road
Dayton, Tennessee 37321

J. R. Moeller, Regional Director
Southeast Tennessee Region
Tennessee State Planning Office
Suite 212, 409 Chestnut Street
Chattanooga, Tennessee 37402

Hon. Marilyn Lloyd Bouquard
230 Post Office Building
Chattanooga, Tennessee 37402

Libraries

Mercer-Pfeiffer Library
Tennessee Wesleyan College
Athens, TN 37303

Cleveland State Community
College Library
Cleveland, TN 37311

John Stores Fletcher Library
University of Tennessee at
Chattanooga
McCallie Avenue
Chattanooga, TN 37203

Fort Loudoun Regional Library
Center (5)
718 George Street, NW.
Athens, TN 37303

Oak Ridge Public Library
Turnpike and Tulane Avenue
Oak Ridge, TN 37830

Ironside Memorial Library
William Jennings Bryan College
Dayton, TN 37321

Hoskins Library
University of Tennessee
Knoxville, TN 37916

Knoxville-Knox County Public Library
500 West Church Street
Knoxville, TN 37902

Murray State University Library
Special Collections
Box 1126
Murray, KY 42071

Tennessee State Library and
Archives
Seventh Avenue North
Nashville, TN 37219

Memphis-Shelby County Public
Library & Information Center
1850 Peabody Street
Memphis, TN 38104

Fayette County Public Library
Somerville, TN 38068

Tipton County Public Library
300 West Church Street
Covington, TN 38019

The Chattanooga Hamilton County
Bicenntenial Library
1001 Broad Street
Chattanooga, TN 37402

TVA Library
100 401B-C

TVA Technical Library (6)
E2B7 C-K

Ben West Library
Eighth Avenue North & Union
Nashville, TN 37203

TVA Technical Library
NFDC-M

Jacqueline Dasch, Librarian
Energy Impact Associates
P.O. Box 1899
Pittsburgh, PA 15230

Rhoda Granat, Librarian
Wapora, Inc.
6900 Wisconsin Avenue, NW.
Washington, DC 20015

Peggy B. Lambert, Librarian
Duke Power Company, Electric Center
David Nabow Library, Box 33189
Charlotte, NC 28242

Individuals

Donald B. Ball
Louisville, Kentucky 40219

Erbin Baumgardner
Decatur, Tennessee 37322

Clarence A. Bina
Bismarck, North Dakota 58501

William Blake
Spruce Head, Maine 04859

E. J. Farkas
Waterloo, Ontario, Canada
N2L 3G1

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Evanston, Illinois 60201

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Crossville, Tennessee 38555

Woodrow Long, Jr.
Lookout Mountain, Tennessee 37350

Walter A. Ludeman
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Washington, DC 20036

Irwin Schisler
East Lansing, Michigan 48824

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Chattanooga, Tennessee 37416

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Houston, Texas 77004

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Idabel, Oklahoma 74745

Fred Taylor
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Cynthia Westerfield
Hartsville, Tennessee 37074

Faith Young
Nashville, Tennessee 37203

TVA/ONR/PCS-81/2

Tennessee Valley Authority

FINAL

ENVIRONMENTAL IMPACT STATEMENT

WATTS BAR
WASTE HEAT PARK
RHEA COUNTY, TENNESSEE

VOLUME II
APPENDICES

Index No: 87

APPENDIX A

AFFECTED ENVIRONMENT - WATTS BAR SITE

A. AFFECTED ENVIRONMENT - WATTS BAR SITE

This appendix describes the environmental features of the Watts Bar site, emphasizing those factors most likely to be affected by the proposed action. Additional detail is provided on this site to assist regulatory agencies and potential park users in permitting procedures.

A.1 SITE DESCRIPTION

The Watts Bar Waste Heat Park would be located in Rhea County, in the eastern Tennessee portion of the Southern Appalachian Region. The site is approximately 100 km (60 mi) southwest of the Knoxville metropolitan area, which has a population of almost 455,000 and 100 km (60 mi) northeast of the Chattanooga metropolitan area, which has a population of approximately 400,000. Figure A.1-1 shows the location of the site in relation to these metropolitan areas and other cities in the region.

As shown in Figure A.1-2, the site is about 13 km (8 mi) southeast of Spring City, Tennessee, (population 1900). Other nearby towns are Dayton (population, 4,300), and Decatur (population 800). The site is accessible to major highway and rail services. Interstate Highways 40 and 75 pass to the north and east of the site and can be reached via Tennessee State Highway 68 and U.S. Highway 27 (Tennessee Highway 29). The Southern Railroad serves the area. Commercial air carrier airports are located at Knoxville and Chattanooga and the nearest public general aviation airport is located at Dayton, about 32 km (20 mi) from the site. A 3-m (9-ft) commercially navigable waterway is adjacent to the site and connects it with the Interconnected Inland Waterway System. The Watts Bar Dam on the Tennessee River and the Watts Bar Steam Plant are located within two miles north of the site.

The approximately 162-ha (400-acre) site (Figure A.1-3) is adjacent to TVA's Watts Bar Nuclear Plant, which is presently under construction at Tennessee River mile 528 on the west shore of Chickamauga Lake. The Yellow Creek Wildlife Management area is located just west of the site.

A.1.1 Physiography and Geology

The Watts Bar Reservation is a moderately wooded area with rolling hills, located in a valley approximately 16 km (10 mi) wide, flanked on the west by Walden Ridge (275-550 m [900 to 1,800 ft]) and by a series of lower ridges (240 to 300 m [800 to 1,000 ft]) on the east, on the west bank of a bend in the Tennessee River. The waste heat park would be located in the southwestern portion of the reservation. In the vicinity of the park, the land rises from the water surface (normal maximum level elevation 208 m [682.5 ft] above mean sea level) to approximately 222 m (730 ft) above mean sea level along the northwestern edge of the site.

Geological studies of the bedrock at the site show that it is overlain by approximately 12 m (40 ft) of unconsolidated terrace deposits laid down by the Tennessee River when flowing at a higher level. The upper half of the terrace deposits consist of sandy, silty clay. The lower half is much coarser, consisting of pebbles, cobbles, and small boulders of quartz or quartzitic sandstone embedded in a sandy clay matrix. Beneath the terrace cover at the southeast corner of the site are the interbedded limestone and shales of the Conasauga Formation of Middle Cambrian Age. The Rome Foundation, predominately variegated shale and siltstone with some fine-grained sandstone, underlies the terrace deposits on the remainder of the site and extends under the Conasauga to the southeast. Most park structures will be soil-supported; for any requiring rock foundations, physical testing has shown that the Conasauga is capable of supporting loads in excess of those imposed by the nuclear plant structures, so it will provide a satisfactory foundation for such park structures. The Rome is a much more competent formation than the Conasauga and will also be satisfactory for foundations. Both formations at the site are relatively unfossiliferous and have no known areas of unique paleontologic significance. Details on seismic considerations and mineral resources at the site, neither of which present significant limiting conditions to park development, have been addressed in the Environmental Statement on the Watts Bar Nuclear Plant.[1]

Soils investigations conducted for the Watts Bar Nuclear Plant indicate that the predominant soil type in the park area is alluvial sandy lean clay. Secondary soils are silty sand and sandy silt. These fine-textured, essentially impervious soils have natural moisture contents ranging from 2 to 5 percent above optimum. Most of the soils are well drained, with the exception of those along Yellow Creek, which typically are poor to moderately drained.

A.1.2 Existing Facilities

The Watts Bar Nuclear Plant has its own ground water supply to provide potable water. The capacity of this system is 2.7 million l (720,000 gal) per day. The maximum daily consumption is expected to be 2.2 million l (580,000 gal). The nearest central water distribution system is the city water supply for Spring City, with intake from the Tennessee River. The Spring City system, with 15 and 20 cm (6" and 8") lines, has a capacity of 1.1 million l (300,000 gal) per day, with a current daily consumption of 833,000 l (220,000 gal). Other nearby utility services which conceivably could be extended to the site include natural gas distributed by Middle Tennessee Gas Utility, telephones through South Central Bell, solid waste collection by a private firm, electricity distributed by the Volunteer Electric Cooperative, and sewage treatment at the Spring City municipal system, which has a daily capacity of 1.5 million l (400,000 gal) of which 800,000 l (210,000 gal)/day is being utilized. There is countywide police protection and ambulance service. There is no county fire protection. Rhea County leases a State-approved sanitary landfill about 16 km (10 mi) southwest of the proposed park site. Assuming a continuation at the present rate of disposal, the landfill has less than six years' capacity remaining.

A.1.3 Relation to Watts Bar Nuclear Plant

The proposed waste heat tie-in facility does not require a specific Nuclear Regulatory Commission (NRC) license. It is possible, however, that the NRC might seek to impose restrictions on the facility to assure that no adverse impact resulted to the public health and safety in relation to the operation of the Watts Bar Nuclear Plant. Description of the waste heat facility and potential health and safety impacts will be included in the Final Safety Analysis Report accompanying TVA's application for the operating license; or, if the waste heat facility is approved subsequent to the issuance of the operating license, in a later document.

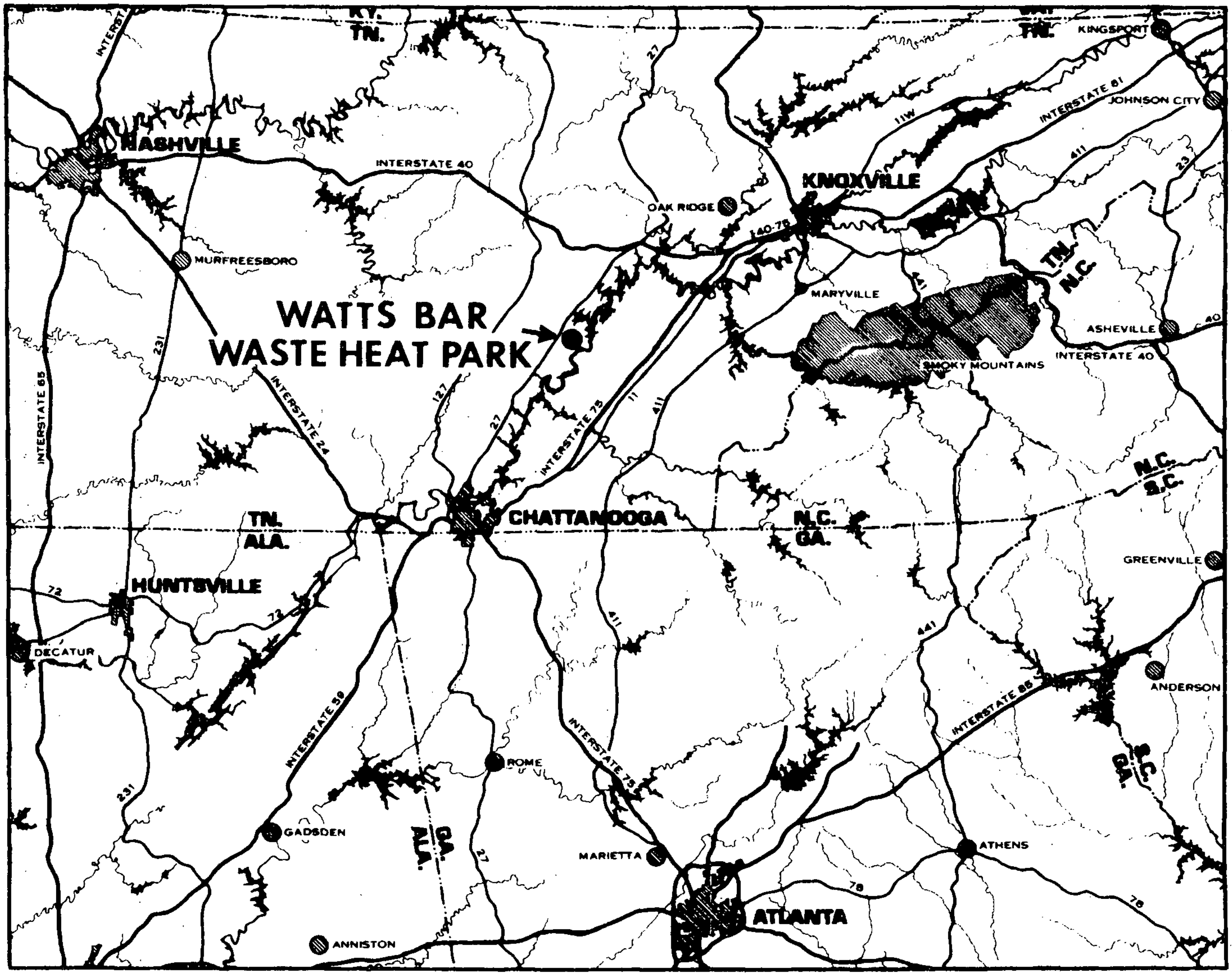
The exclusion area is the area surrounding the reactor over which TVA must retain authority for total control. This control authority includes the ability to evacuate personnel and remove property from the area and control of all traffic on highways, railroads, and waterways within the area. Consequently, activities unrelated to the operation of the reactor are subject to these controls. The waste heat park (WHP) is presently located within the exclusion area for Watts Bar Nuclear Plant (1200-meter radius from the intersection of the plant centerlines). However, preliminary analysis indicates that the radiological consequences of the maximum hypothetical accident (loss-of-coolant accident) results in doses well within the guidelines stated in 10 CFR Part 100 at the boundary of the WHP, 400 m from plant centerlines. It may then be possible to reduce the exclusion radius so that the WHP is outside the exclusion boundary. By ensuring that activities not related to plant operations are kept beyond this 400-m distance, compliance with 10 CFR Part 100 specifications can be met. On the other hand, sufficient TVA controls could be imposed on the operation of the WHP (evacuation, etc.) so that the WHP could be located within the 1200-m exclusion area if necessary.

The low population zone is the area immediately surrounding the exclusion area to a distance of about 4.8 km (3 mi) (for the Watts Bar plant) and may contain residents. While total control of the low population zone by TVA is not necessary, the Watts Bar Radiological Emergency Plan must address evacuation procedures for this area in the event of a radiological emergency. Any increases in transient population due to the waste heat facilities would have to be addressed in the Radiological Emergency Plan.

Information will be made available to the NRC to ensure that it has the data necessary to evaluate the impacts on the nuclear plant.

A.1 REFERENCES

1. Tennessee Valley Authority. Final Environmental Statement - Watts Bar Nuclear Plant Units 1 and 2. November 9, 1972.



REGIONAL LOCATION

MAJOR CITIES (POPULATION OF 100,000 AND UP)

MINOR CITIES (POPULATION OF 25,000 TO 100,000)

STATE BOUNDARY LINES

MAJOR HIGHWAYS

0 25 miles

Figure A.1-1

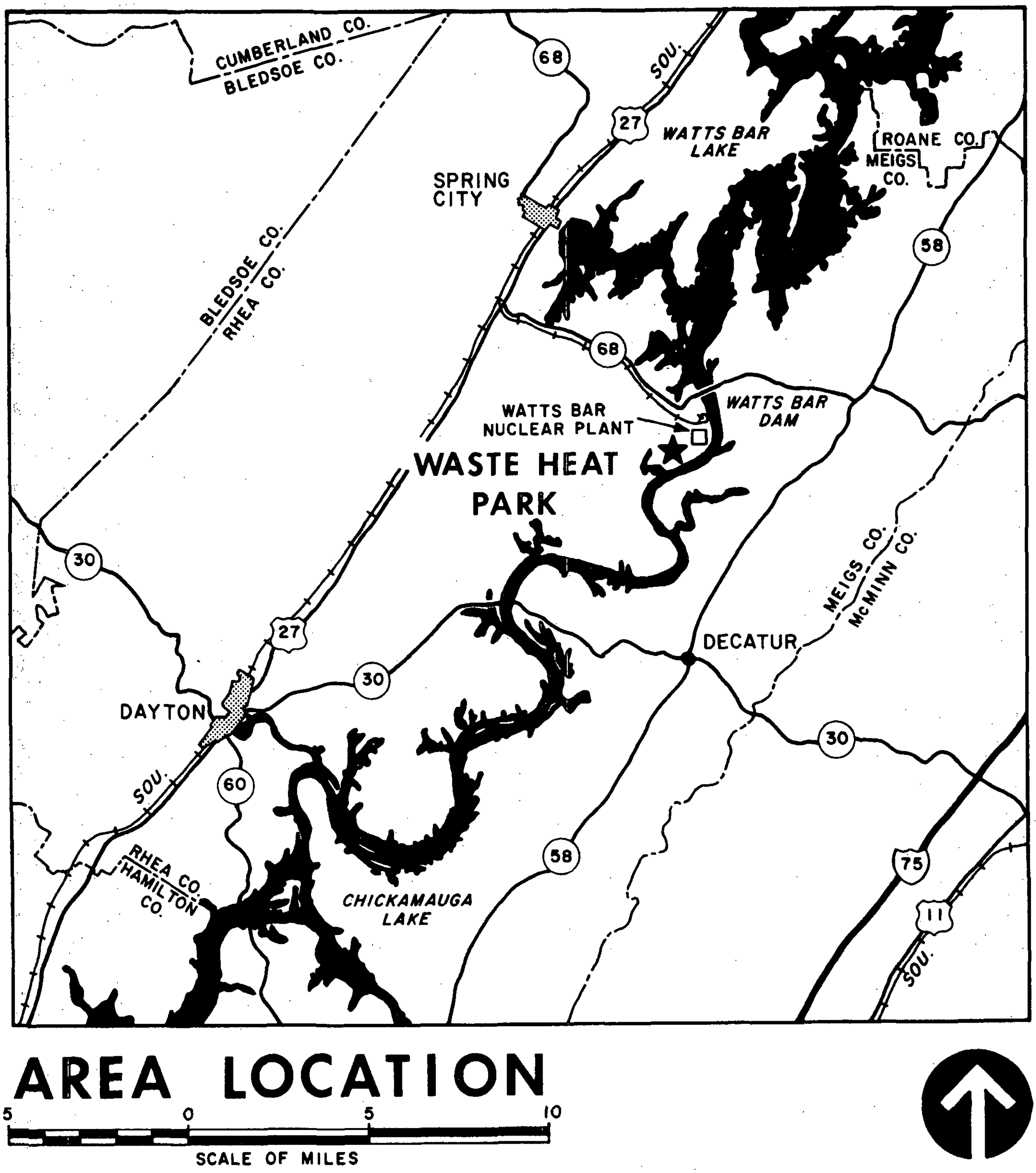

CUMBERLAND CO.
BLEDSOE CO.
68
SOU.
27
WATTS BAR
LAKE
ROANE CO.
MEIGS
CO.
SPRING
CITY
58
BLEDSOE CO.
RHEA CO.
68
WATTS BAR
NUCLEAR PLANT
WATTS BAR
DAM
WASTE HEAT
PARK
30
MEIGS CO.
McMINN CO.
27
DECATUR
30
DAYTON
30
60
SOU.
58
75
RHEA CO.
HAMILTON
CO.
CHICKAMAUGA
LAKE
11
SOU.
AREA LOCATION
5
0
5
10
SCALE OF MILES

Figure A.1-2

SITE LOCATION

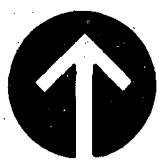


Figure A.1-3

A.2 AIR QUALITY

A.2.1 Present Air Quality Status

With one exception, all of the area within 50 km (31 mi) of the proposed site is a designated Class II area under the prevention of significant deterioration (PSD) regulations for SO_2 and TSP. The exception is that portion of the city of Rockwood in Roane County, Tennessee (about 30 kilometers north-northeast of Watts Bar), which is classified as nonattainment for TSP. However, the ambient air quality impacts of any particulate sources located at the proposed site are not expected to exceed the significance increments for TSP within this nonattainment area. Therefore, the air quality status of this area is not expected to affect siting opportunities at Watts Bar. There are no SO_2 nonattainment areas within 50 kilometers; however, the area surrounding the Kingston Steam Plant (about 40 kilometers northeast of Watts Bar) is unclassified with respect to SO_2, and thus PSD provisions are applicable.

There are several nonattainment areas for photochemical oxidants in the region, including Roane County (northeast of Watts Bar) and Bradley and Hamilton Counties (south of Watts Bar). The nonattainment status of these counties is not expected to affect the Watts Bar area.

The nearest Class I PSD areas are the Cohutta National Wilderness area and the Smoky Mountains National Park, about 70 kilometers south-southeast and 70 kilometers east of Watts Bar, respectively. The ambient air quality impacts of any particulate or SO_2 sources located at the proposed site are not expected to exceed the significance increments for TSP or SO_2 within the Class I areas. Therefore, the Class I status of these two areas is not expected to affect siting opportunities for waste heat park facilities at Watts Bar.

A.2.2 Baseline and Increment Availability

Preliminary* estimates of baseline SO_2 and TSP concentrations in the vicinity of Watts Bar were based on 1977 and 1978 air quality monitoring data for Watts Bar Steam Plant. The baseline estimates and corresponding estimates of Class II increment availability are presented in tables A.2-1 (SO_2) and A.2-2 (TSP). The more recent (1978) monitoring data indicate that full Class II PSD increments are currently available for both SO_2 and TSP. It should be noted, however, that a potential exists for more limited increment availability than that indicated. The monitoring data represent the real baseline in the area only to the extent that the Watts Bar steam plant, which is part of the baseline, was operating at full capacity. This is not always the case. For example, during the period when the second highest 3-hour SO_2 concentration was measured in 1978, the steam plant was operating at only 25 percent of capacity. Had the steam plant been operating at full load during this period it is probable that a much higher SO_2 concentration would have been measured.

---

*Under applicable regulations, baseline is established as of the date of the first completed application for a PSD permit in an area.

A.2.3 Meteorology

Onsite meteorological monitoring data for the Watts Bar Nuclear Plant are available for assessing atmospheric dispersion conditions in the vicinity of the proposed site for the waste heat park. Joint percentage frequency distributions of wind speed and direction (wind roses) based on these data are provided in figures A.2-1 (for the 10-meter height) and A.2-2 (for the 92-meter height).

A.2.4. Existing Sources

Existing sources of SO_2 and TSP emissions of 10 tons or more per year in the Watts Bar area are given in tables A.2-3 for Rhea County and in A.2-4 for Meigs County. Of the two counties, Rhea County, in which the proposed site for the waste heat park is located, has the larger number of major industrial sources. Most of the area for the proposed heat park lies between 1.5 and 2 kilometers southwest of the largest source in Rhea County, the Watts Bar Steam Plant.

Table A.2-1

AMBIENT SO_2 CONCENTRATIONS AND ESTIMATED INCREMENT AVAILABILITY FOR THE WATTS BAR STEAM PLANT[a]

Year	Averaging Period	Limiting Concentration[b] ($\mu g/m^3$)	NAAQS ($\mu g/m^3$)	Increment remaining to NAAQS ($\mu g/m^3$)	Class II Increment ($\mu g/m^3$)	Available increment ($\mu g/m^3$)	Percent of Class II increment
1977	Annual	36	80	44	20	20	100
	24-hour	286	365	79	91	79	87
	3-hour	1118	1300	182	512	182	36
1978	Annual	24	80	56	20	20	100
	24-hour	156	365	209	91	91	100
	3-hour	728[c]	1300	572	512	512	100

[a]Based on data from three SO_2 monitors.

[b]Highest annual and highest of the three second highest 24-hour and 3-hour concentrations measured at the three monitors.

[c]During the period when this measurement was made, the Watts Bar Steam Plant was operating at only 25-percent load. Had the plant been operating at full load, it is probable that a much higher SO_2 concentration would have been measured.

Table A.2-2

AMBIENT TSP CONCENTRATIONS AND ESTIMATED
INCREMENT AVAILABILITY FOR THE WATTS BAR STEAM PLANT

Year	Averaging Period	*Limiting* Concentration[a] (μg/m³)	NAAQS (μg/m³)	Balance *remaining to* NAAQS (μg/m³)	*Class II* Increment (μg/m³)	*Available* increment (μg/m³)	*Percent* of Class II increment
1977	Annual	31	75	29	19	19	100
	24-hour	86	150	64	37	37	100
1978	Annual	36	75	24	19	19	100
	24-hour	87	150	63	37	37	100

[a]Annual average and second highest 24-hour concentration measured by the one TSP monitor.

Table A.2-3

SIGNIFICANT* SO_2 AND TSP SOURCES IN RHEA COUNTY, TENNESSEE

Company	Allowable Emissions (TPY) TSP	SO_2
South Silk Mills	66	609
Charles Knitting Mills	25	165
Rhea County Limestone	286	0
TVA Watts Bar Steam Plant	1693	48306
TVA Watts Bar Nuclear Plant**	822	291
Zenith Hosiery Mill	18	122
Kayser-Roth Hosiery Mill	59	0
Robinson MFG	10	50
Suburban MFG	11	52
La-z-boy	95	425
Welch Concrete Prod., Inc.	58	0
Dayton Material, Inc.	21	285

*Allowable SO_2 or TSP emissions of 10 tons or more per year. These data have been abstracted from unvalidated State of Tennessee emission inventories (base year 1976).

**Includes both construction and operational sources.

Table A.2-4

SIGNIFICANT* SO_2 AND TSP SOURCES IN MEIGS COUNTY, TENNESSEE

Company	Allowable Emissions (TPY) TSP	SO_2
Ten Mile Stone	232	0

*Allowable SO_2 or TSP emissions of 10 tons or more per year. These data have been abstracted from unvalidated State of Tennessee emission inventories (base year 1976).

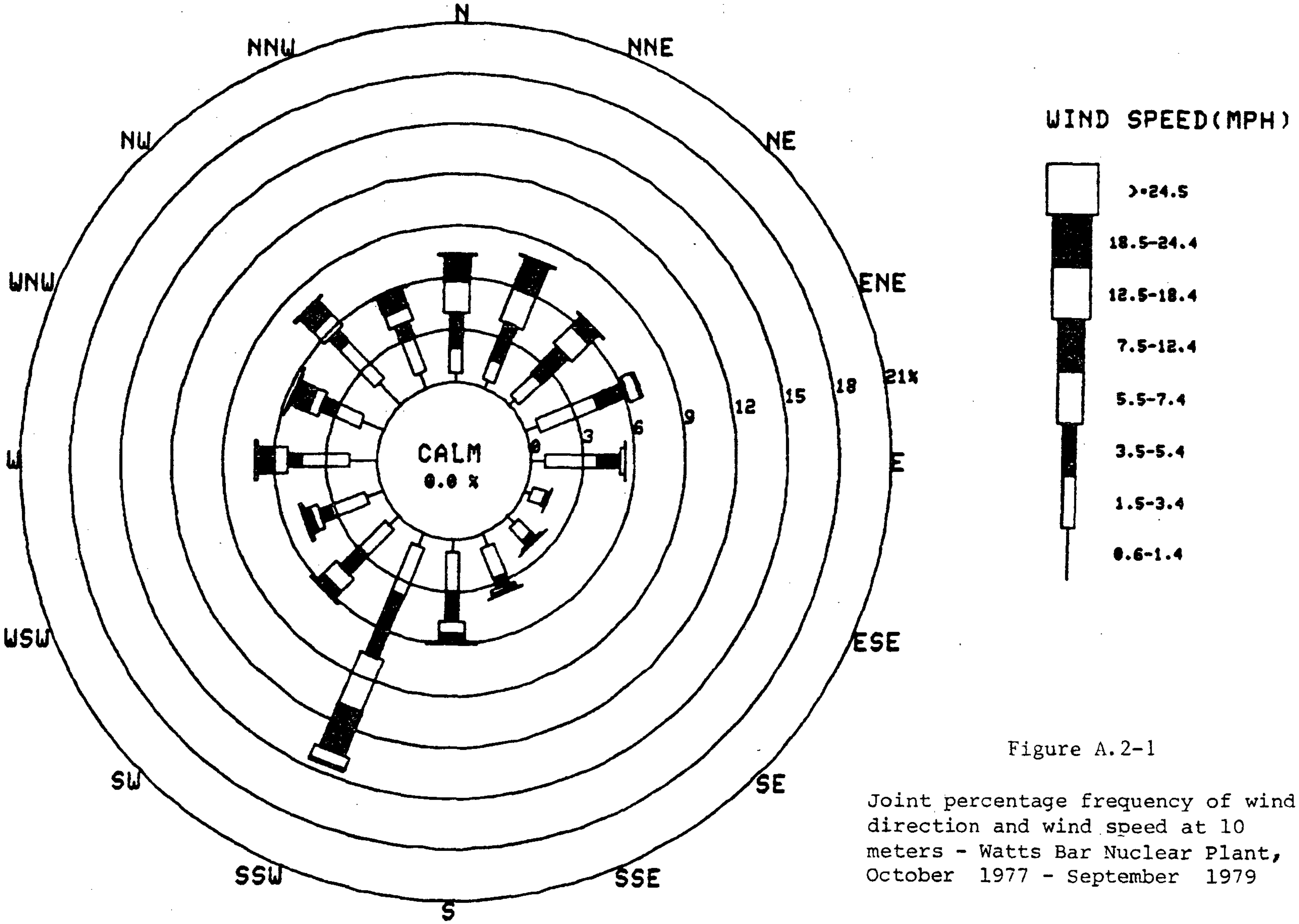


Figure A.2-1

Joint percentage frequency of wind direction and wind speed at 10 meters - Watts Bar Nuclear Plant, October 1977 - September 1979

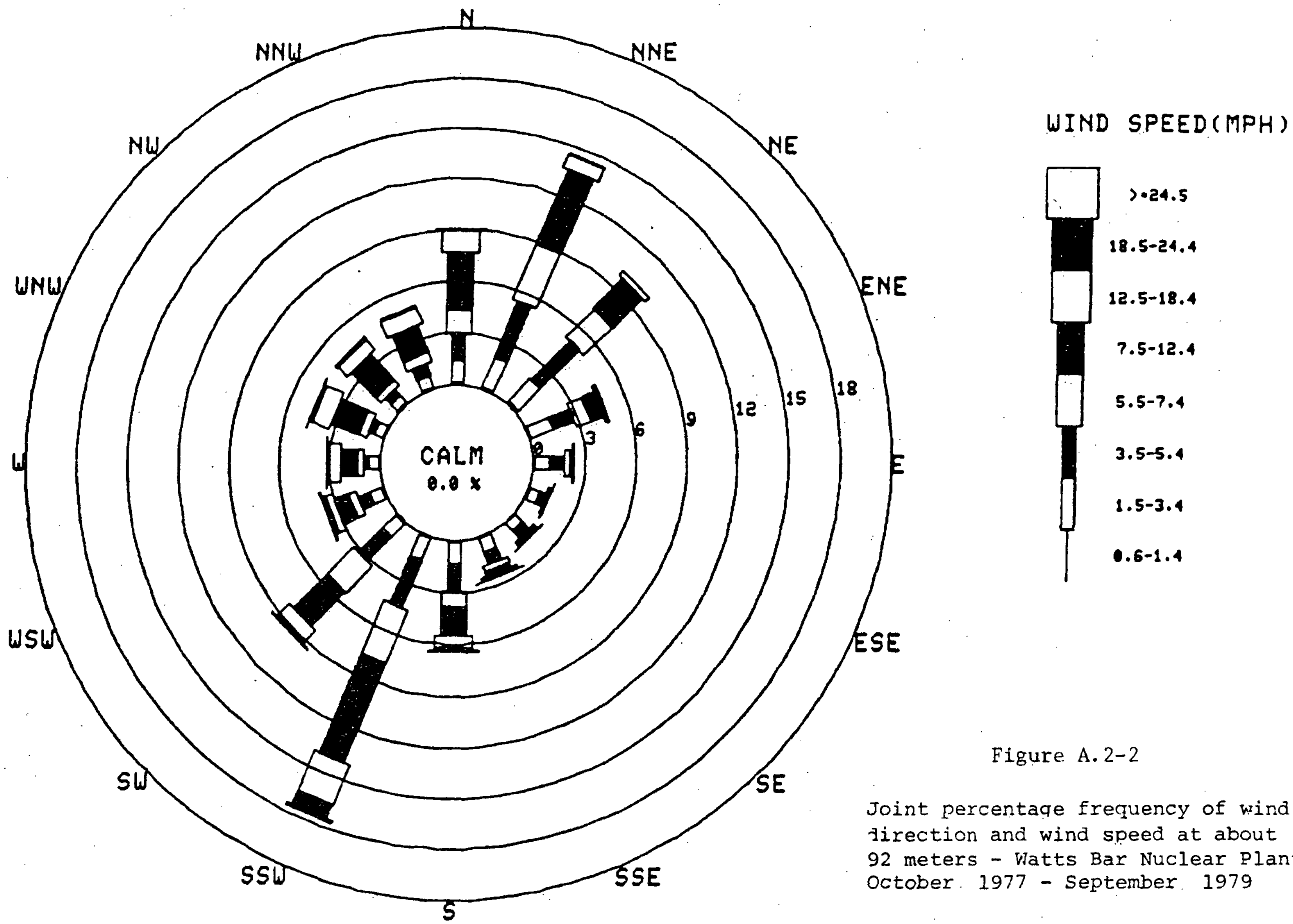


Figure A.2-2

Joint percentage frequency of wind direction and wind speed at about 92 meters - Watts Bar Nuclear Plant, October 1977 - September 1979

A.3 HYDROLOGY AND WATER QUALITY

A.3.1 Surface Water

A.3.1.1 Description

Surface water features which bound the 400-acre site are Chickamauga Lake and Yellow Creek. The drainage area of the Tennessee River at the site is 17,320 square miles. Chickamauga Reservoir at this location is about 1,100 feet wide with depths ranging up to 25 feet at normal pool, elevation 682.5.

The Tennessee River above the site is formed by two major tributaries, the Holston and French Broad Rivers, having respective drainage areas of 3,776 and 5,124 square miles which unite above Knoxville at river mile 652.2. The Holston River rises in terrain varying from the rolling uplands of the valley and ridge physiographic province in the forks of the Holston in Virginia to the rugged Appalachian Mountains drained by the Watauga River in eastern Tennessee and western North Carolina. Elevations range up to 5,720 feet on the rim of the South Fork Holston River basin and up to 6,285 feet on the southern rim of the Watauga basin. The French Broad River, including its principal tributary, the Nolichucky River, drains more than half of the mountainous North Carolina portion of the Tennessee Valley between the Blue Ridge and the chain of mountains forming the North Carolina-Tennessee State line. Elevations in this region range up to 6,684 feet at Mt. Mitchell. The Tennessee side of the mountains is drained by the Pigeon, Little Pigeon, and lower Nolichucky Rivers, which flow through the valley and ridge type of terrain as they approach the French Broad River.

Downstream at mile 601.1, the Little Tennessee River, with a drainage area of 2,627 square miles, flows into the Tennessee River from the southeast. The Blue Ridge forms the eastern rim of the basin with elevations generally between 3,000 and 4,000 feet. Within the basin a number of peaks in the rugged Appalachian Mountain region rise above 6,000 feet.

The Clinch River, with a drainage area of 4,413 square miles, flows southwestward into the Tennessee River at mile 567.8. Except for its northwestern edge, the river basin is in the Appalachian valley physiograpic subregion characterized by comparatively narrow parallel ridges and somewhat broader intervening valleys of northeast-southwest trend. The northwestern boundary of the Clinch River basin, also the boundary of the Tennessee Valley, is formed by the Cumberland Mountains which range up to 4,200 feet above sea level. The southeastern boundary follows Clinch Mountain and Black Oak Ridge, with elevations ranging up to 4,700 feet. Forest covers 48 percent of the basin.

In the immediate vicinity of the site, Yellow Creek flows in a southerly direction just to the west of the site and empties into the Tennessee River at mile 526.8. This stream drains an area of 12.6 square miles at its mouth. Chickamauga Reservoir backs up Yellow Creek for about 1.7 miles to a small dam on the wildlife management area. About half the site area drains into Yellow Creek embayment below the dam. The remainder of the site drains into two small tributaries which empty into the Tennessee River just upstream from the mouth of Yellow Creek.

A.3.1.2 Streamflow

Tennessee River streamflow past the site has been completely regulated since January 1940 with the closure of Chickamauga Dam located at Tennessee River mile 471.0. Flows at the site are also affected by operation of Watts Bar Dam, 1.9 miles upstream from the site at Tennessee river mile 529.9. Both reservoirs are operated for flood control, navigation, and power production.

Flows at the site are mainly dependent upon the operation of Chickamauga and Watts Bar Reservoirs. The average discharge (release) at Watts Bar Dam for the period of 1945-1978 (calendar years) was 27,370 cubic feet per second. Flow data for water years 1951-1965 indicate an average flow of about 21,100 cfs during the summer months and about 34,400 cfs during the winter months. Watts Bar Dam is operated to provide peaking power, with no discharge from the dam 10.5 percent of the hours during the year. The maximum duration of no discharge is 12 hours, except for planned special operations. The normal discharge through each of the five turbines at the dam ranges from 7,500 to 10,000 cfs. The minimum flow at which the turbines can operate is 3,500 cfs, although discharges seldom fall below about 5,000 cfs per unit. At Watts Bar Dam, the minimum 7-day flow with a 10-year recurrence interval is estimated to be 5,200 cubic feet per second; and the minimum 3-day flow with a 20-year recurrence interval is estimated to be 2,650 cubic feet per second.

The average discharge (release) at Chickamauga Dam for the period of 1945 through 1978 was 35,040 cubic feet per second. The minimum daily average flow has been zero and occurred on March 30 and 31, 1968, when discharge was cut off during special operations to aid in the chemical treatment of Eurasian watermilfoil. The minimum daily average discharge under normal operating conditions has been 1,700 cubic feet per second and occurred on May 7, 1967. Since June 1975, Chickamauga Dam has been operated to attempt to provide a minimum 24-hour average flow of not less than 6,000 cubic feet per second in order to maintain desirable water quality levels at Chattanooga.

Monthly average discharges at Watts Bar and Chickamauga Dams for the period 1945-1978 are shown in Tables C-1 and C-2, Appendix C. Maximum, minimum, and mean daily discharges for the same period are shown for Watts Bar in Table C-3 and for Chickamauga in Table C-4.

The maximum known flood discharge at the site occurred on February 14, 1948, and is estimated to be 194,600 cubic feet per second; however, the March 1973 water level was the highest since Watts Bar Dam was closed in 1942. The March 17, 1973, flood elevation at the site was 694 feet.

A.3.1.3 Water Levels

Water surface elevations downstream of Watts Bar Dam in the vicinity of the plant sites are determined by the headwater elevation at Chickamauga Dam and the discharge from Watts Bar Dam. Chickamauga Lake elevations vary from a normal maximum elevation of 682.5 feet in the summer months to a normal minimum elevation of 675.0 feet in the winter months. However, Watts Bar Dam discharges may raise the water surface elevation if the lake elevation is less than 682.5 feet. Table C-5 shows the approximate stage-discharge relationship below Watts Bar Dam at minimum pool conditions in the winter. Elevations at the bottom of the river channel at the site are about 655 to 660 feet. Tables C-6 and C-7 show the maximum and minimum range of daily variations in Chickamauga headwater and Watts Bar tailwater elevations for calendar year 1976, a typical year based on present operations. Table C-8 shows midnight elevations at Chickamauga Dam for 1976.

A.3.1.4 Temperatures

A summary of tailrace temperatures at Watts Bar Dam is given in Table A.3-1. Monthly average river temperatures vary from 43.5°F in January to 76.5°F in August. The maximum weekly observed tailrace temperature was 86.0°F in July and August, and the minimum weekly tailrace temperature was 32.0°F in January. A summary of the probability of high tailrace temperatures is given in Table A.3-2, showing river temperatures approaching the State of Tennessee maximum water temperature standard of 86.9°F (30.5°C).

Water temperature verticals were taken at Washington Ferry, river mile 518.0, during the periods April 1943 to September 1948 and October 1974 to January 1977. The minimum observed during this period was 35°F and the maximum was 75°F. Figure A.3-1 is a plotting of these temperatures for the period 1943-1948.

A.3.2 Ground Water

Ground water occurs at the site in the alluvial material overlying bedrock and in small openings along fractures and bedding planes in the Conasauga and the Rome Formations. However, all have poor yields and could not supply the park's potable water requirements. The most significant water-bearing formation in the area is the Knox Dolomite, in which water occurs in solution cavities formed along bedding planes and fractures. Discharge from the Knox is a major source of base flow in streams. Large springs are fairly common in outcrop belts of the Knox.

If a 500 gal/min ground water supply is considered for the Watts Bar Waste Heat Park, a well or wells would be located in the belt of Knox Dolomite to the northwest. A likely reasonable upper limit to be expected from ground water in the Watts Bar area is about 3800-5700 l/min (1000 to 1500 gal/min), from three to six wells.

A.3.3.2 Ground Water

Water Use

The ground water yield from the alluvial material overlying bedrock at the site is extremely low, usually less than 20 gpm.[4] The Knox Dolomite, outcropping to the northwest of the site is the only formation regionally significant as an aquifer. Total public and industrial ground water use in a 32 km (20 mi) radius of the nuclear plant is 0.16 m^3/s (3.6 mgd) and 0.2 m^3/s (0.48 mgd), respectively. The nearest significant ground water supply system, located 4 km (2.5 mi) to the northwest and withdrawing from the Knox, are the wells utilized by the Watts Bar Nuclear, Steam, and Hydro Plants, and the nearby resort.

Data Summary and Evaluation

Evaluation of limited analyses of water obtained by TVA in 1978 from the alluvial material reveals that its quality varies significantly with location. The water quality ranges from good to very poor with concentrations of dissolved solids reported between 160 and 2300 mg/l. The ground water is neutral to alkaline (pH 7.7 to 9.0), and high levels of sodium were observed (up to 800 mg/l).

Regionally, the quality of water from wells and springs in the Knox Dolomite is similar to that from other carbonate aquifers. The hardness ranges from about 50 to 250 mg/l. Ward Spring, a large spring 4.4 km (2.7 mi) west of the site, was sampled by TVA in 1971. The ground water quality was good and reported to be soft and neutral. Low concentrations of nitrate, sulfate, iron, and sodium were measured.

TVA also periodically samples its Watts Bar Reservation well field; the quality of the water is routinely in compliance with nitrate, turbidity, and bacteriological standards for noncommunity public water supplies. The quality of ground water is good, with dissolved solids concentrations averaging 130 mg/l. The ground water is soft to moderately hard and is neutral. Concentrations of minerals, metals, and nutrients in the ground water were normally well below EPA primary and secondary standards for finished drinking water.

A.3.3.3 Projected Water Quality During the Development of the Waste Heat Park

The above description evaluates the water quality during the period 1973-1977 without the nuclear plant in operation. However, the nuclear plant will not be discharging significant volumes of oxygen-demanding wastes which would significantly impact DO levels in the reservoir, since sanitary wastes (about 36,000 gpd (136 m^3/day) based on a projected total employment of 1450) will be the only oxygen-demanding waste discharge from the nuclear plant. This wastewater will receive secondary treatment to meet existing NPDES permit limitations. The operation of the nuclear plant will not thermally impact the water quality in the site vicinity, and changes in water quality due to the Watts Bar Nuclear Plant will not preclude any of the current or projected uses of the Tennessee River.[3] An operational NPDES permit was issued by EPA and the plant is meeting its requirements as applicable at the present time.

A.3 REFERENCES

1. Division of Water Quality Control, Tennessee Department of Public Health. Upper Tennessee River Basin Plan. November 1978.

2. Mulkey, C. E., E. B. Robertson, W. J. Pardue, and R. D. Harned. Status of the Nonradiological Water Quality and Nonfisheries Biological Communities in the Vicinity of Watts Bar Nuclear Plant, 1973-1977, June 1980, TVA, Division of Water Resources.

3. Nuclear Regulatory Commission, Final Environmental Statement Related to the Operation of Watts Bar Nuclear Plant, Units 1 and 2, December 1978.

4. Tennessee Valley Authority, Final Safety Analysis Report, Watts Bar Nuclear Plant, Units 1 and 2, October 4, 1976.

Table A.3-1

SUMMARY OF TAILRACE TEMPERATURES

WATTS BAR DAM

FEBRUARY 1950 - SEPTEMBER 1977

Month	Minimum		Average		Maximum	
	°C	(°F)	°C	(°F)	°C	(°F)
January	0	(32.0)	6.4	(43.5)	11.0	(51.8)
February	2.5	(36.5)	6.6	(43.9)	17.0	(62.6)
March	3.0	(37.4)	9.4	(48.9)	17.0	(62.6)
April	8.8	(47.8)	13.8	(56.8)	18.5	(65.3)
May	9.0	(48.2)	18.9	(66.0)	24.5	(76.1)
June	18.0	(64.4)	22.6	(72.7)	29.0	(84.2)
July	19.5	(67.1)	24.5	(76.1)	30.0	(86.0)
August	21.0	(69.8)	24.7	(76.5)	30.5	(86.9)
September	18.0	(64.4)	24.2	(75.6)	27.5	(81.5)
October	9.0	(48.2)	20.2	(68.5)	25.0	(77.0)
November	5.5	(41.9)	14.4	(57.9)	22.0	(71.6)
December	3.0	(37.4)	9.2	(48.7)	15.0	(59.0)
AVERAGE			15.8	(60.5)		

n.b. Based upon 1320 weekly observations, varying in number from 40 to 67 in any full year of record. Data missing for 1956, January-June 1957, and February 1969.

Table A.3-2

PROBABILITY OF HIGH TAILRACE TEMPERATURES

WATTS BAR DAM

FEBRUARY 1950 - SEPTEMBER 1977

Ti (°C)	Ti (°F)	Percentage of Weekly Observatons Exceeding Ti (percent/year)	Average No. of Weekly Observations Exceeding Ti (No./year)
23.5	74.3	23.1	12.0
24.5	76.1	15.8	8.2
25.5	77.9	7.3	3.8
26.5	79.7	3.1	1.6
27.5	81.5	0.7	0.4
28.5	83.3	0.5	0.2
29.5	85.1	0.3	0.2
30.5	86.9	0.0	0.0

n.b. Based upon 1320 weekly observations, varying in number from 40 to 67 in any full year of record. Data missing for 1956, January-June 1957, and February 1969.

Table A.3-3

SEASONAL DISSOLVED OXYGEN CONCENTRATIONS AND TEMPERATURES IN THE TENNESSEE RIVER AT SELECTED DEPTHS AND LOCATIONS

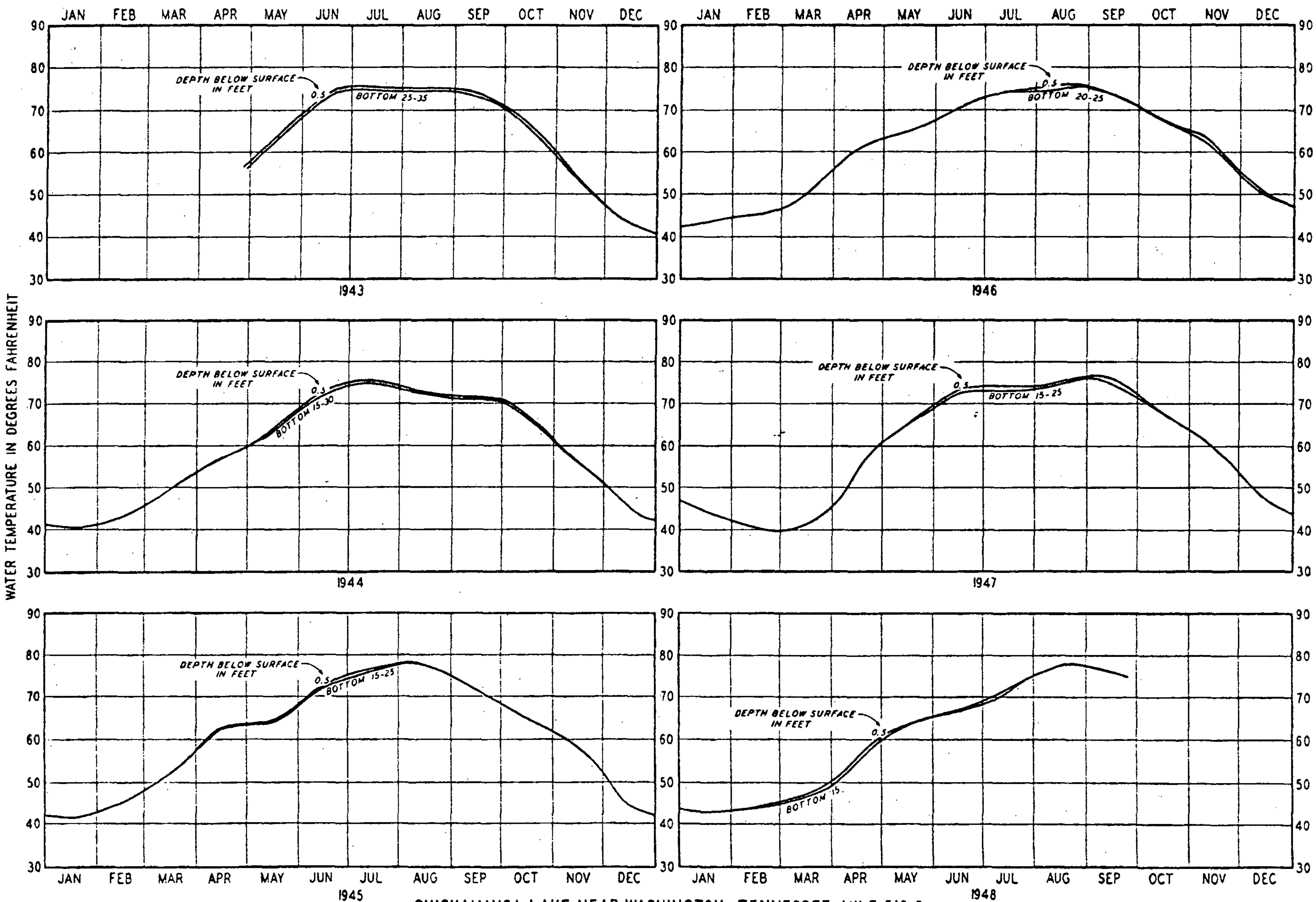
Sampling Location	Date	Disolved Oxygen (mg/l) Depth (feet)								Temperature (Cent.) Depth (feet)							
		1	3	5	10	16	23	36	56	1	3	5	10	16	23	36	56
TRM 532	Feb 77	13.0	13.0	13.1	13.1	13.1	13.1	13.1	13.1	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	May 77	10.3	10.2	10.1	9.7	8.4	8.2	8.0	8.0	18.0	18.0	18.0	17.8	16.7	16.3	16.0	15.8
	Aug 77	5.0	4.5	4.1	2.3	1.4	1.0	1.0	1.1	27.0	27.0	26.8	26.2	26.1	25.5	25.5	24.6
	Nov 77	7.6	7.3	7.1	7.0	6.8	6.7	6.4	6.4	18.0	17.4	17.2	17.2	17.0	17.0	17.0	16.9
TRM 528	Feb 77	13.5	13.2	13.2	13.2	13.2	13.2			2.5	2.5	2.5	2.5	2.5	2.5		
	May 77	8.8	8.7	8.7	8.6	8.6	8.6			16.8	16.8	16.8	16.8	16.8	16.8		
	Aug 77	4.3	3.9	3.8	3.3	2.0	1.7			26.4	26.0	26.0	26.0	26.0	26.0		
	Nov 77	6.9	6.7	6.6	6.6	6.6	6.6			17.0	17.0	17.0	17.0	17.0	17.0		
TRM 527	Feb 77	13.4	13.4	13.3	13.3	13.3				2.5	2.5	2.5	2.5	2.5			
	May 77	7.7	7.6	7.5	7.5	7.5	7.5			16.5	16.6	16.6	16.5	16.5	16.5		
	Aug 77	3.7	3.4	3.3	3.2	2.6	1.7			26.5	26.0	26.0	26.0	26.0	26.0		
	Nov 77	6.8	6.7	6.6	6.6	6.6	6.6			17.0	17.0	17.0	17.0	17.0	17.0		
TRM 518	Feb 77	13.1	13.2	13.2	13.2	13.2				2.5	2.5	2.5	2.5	2.5			
	May 77	8.6	8.5	8.5	8.4	8.4	8.4			16.8	16.8	16.8	16.8	16.8	16.8		
	Aug 77	4.5	4.3	4.3	4.3	4.3				26.0	26.0	26.0	26.0	25.9			
	Nov 77	6.8	6.7	6.6	6.6	6.6	6.6			17.0	17.0	17.0	17.0	17.0	16.9		

Table A.3-4

SUMMARY OF WEEKLY OBSERVED DISSOLVED OXYGEN CONCENTRATIONS IN THE TAILRACE OF WATTS BAR DAM, 1960-1979

Year	Minimum DO concentrations mg/l	Maximum DO concentrations mg/l	Number of weeks below 3.0	Number of weeks below 5.0
1960	3.3	10.5	0	7
1961	4.7	11.8	0	1
1962	3.0	11.6	0	11
1963	2.4	11.5	2	13
1964	3.2	11.4	0	5
1965	2.8	10.7	1	13
1966	2.2	12.6	4	11
1967	3.9	13.5	0	3
1968	3.3	12.4	0	8
1969	2.2	11.0	2	12
1970	2.9	11.6	1	15
1971	3.0	10.8	0	14
1972	4.1	11.3	0	5
1973	4.2	11.5	0	3
1974	5.2	10.7	0	0
1975	3.9	13.3	0	3
1976	3.9	12.0	0	1
1977	2.4	13.0	1	17
1978	3.1	12.6	0	13
1979	5.2	12.2	0	0
1960-1979, Mean	3.4	11.8	0.6	7.8
1960-1969, Mean	3.1	11.7	1.0	8.5
1970-1979, Mean	3.8	11.9	0.2	7.1

TENNESSEE RIVER



CHICKAMAUGA LAKE NEAR WASHINGTON, TENNESSEE, MILE 518.0

FIGURE A.3-1, WATER TEMPERATURES

A.4 HEALTH AND SAFETY

A.4.1 Noise

Preoperational (or baseline) sound surveys were conducted by TVA in the vicinity of the proposed heat park site in September 1979 and March 1980. Work at the Watts Bar Nuclear Plant construction site had ceased for the weekend. The survey data, therefore, represented community baseline sound conditions in the absence of TVA construction activities. The three locations surveyed are shown on the map, Figure A.4-1.

At each survey location, analog tape recordings were made of the existing sound during the daytime period (7 a.m. - 10 p.m.) and again during the nighttime period (10 p.m. - 7 a.m.). Each recording was approximately 15 minutes in length. Equivalent sound levels were computed for daytime values (Ld), for nighttime values (Ln), and for a day-night composite value (Ldn).

Summertime survey data are presented in Table A.4-1, wintertime in A.4-2. The difference in levels is caused by insect and bird noise present in the summertime data. Because of the short sampling period (15 minutes), intermittent noises caused by road traffic and aircraft flyovers are missing and the noise levels given are more representative of minimal levels than average levels. Data taken at similar locations for other TVA sites show an average baseline Ldn between 50-60 dB.

A.4.2 Radiological Conditions

A.4.2.1 Exposure Pathways to Man

Liquid Effluents--Water supplied to the waste heat park will be condenser cooling water which represents a tertiary heat exchange from the operating reactor. This provides multiple barriers against movement of radioactivity from the plant and it is therefore unlikely that any significant amounts of radioactivity would exist in the supply water to the heat park. Furthermore, water in the reactor systems is monitored for the presence of radionuclides. Water in closest contact with that supplying the waste heat park will be removed from contact with the supply water when necessary to avoid significant radiological releases to the environment.

Gaseous Effluents--Both construction and operations personnel for the waste heat park may be exposed to gaseous effluents during operation of WBN via the following pathways: (1) direct radiation (like that received from medical X-rays) from radioactivity in the air and on the ground; (2) inhalation; and (3) ingestion of beef and vegetables. An assessment was conducted to evaluate the potential impacts to the whole body and important organs of individuals. The modeling used in this assessment was consistent with that used by the regulatory agencies. Resultant impact estimates based on continuous occupancy by personnel at the waste heat park are presented in Table A.4-3. Calculating for an adult and excluding ingestion, the doses per reactor unit are approximately one-tenth of the applicable guidelines (Appendix I to 10 CFR Part 50) specified by the regulatory agency. Including ingestion, the calculated dose rates are still well within the regulatory guidelines. The total body dose to an individual at the location cited in Table A.4-3 is approximately 1 mrem/yr per unit from gaseous effluents from the operation of WBN.

Direct Radiation--In addition to exposures from radioactivity released in gaseous effluents, external exposures to individuals resulting from direct radiation from storage tanks at the nuclear plant have also been assessed (Table A.4-4).

Shipments of radioactive materials to and from WBN also present a potential for exposure. A buffer zone of one hundred feet has been provided between the access road to the plant and the property for the waste heat park. Assuming 200 shipments per year and that the exposure rate from any radioactive materials shipment is the maximum permissible, the resulting exposure rate to a person standing at the boundary of the buffer zone should not exceed about 0.03 mrem.

An assessment of the potential radiological impacts of operating a volume reduction system (VRS) and an onsite storage facility (OSF) for low-level radioactive waste (e.g., gloves and mops) and an away from reactor onsite spent fuel storage facility (AFR) has been performed. For the storage of about 54,500 Ci/yr of low-level waste, annual doses to waste heat park personnel due to direct radiation are less than about 7 mrem/yr assuming a 2000 hr/yr occupancy factor and a non-day shift module loading operation. The annual dose to an individual working at the waste heat park site due to the operation of an AFR has been estimated to be about 0.34 mrem/yr. The highest estimated annual dose due to the operation of the VRS is about 2.1 mrem/yr (assuming incineration of all low-level waste including resins, and a 2000 hr/yr occupancy factor). These doses are well within the Federal guidelines. Dose rates to heat park personnel from normal operational releases will be less than those specified in the Federal guidelines, considering the operations of WBN, the VRS, the OSF, and the AFR. Appropriate measures will be taken to maintain exposures to personnel at levels which are as low as reasonably achievable (ALARA).

Direct radiation levels measured in the vicinity of WBN for the period 1977 through 1978 were found to be approximately 80 mrem/yr. By comparison, the dose from gaseous effluents, storage tanks, VRS, OSF, and AFR would result in about 10 mrem/yr assuming the operation of two units at WBN and a 2000 hr/yr occupancy factor for waste heat park personnel. Again, operational procedures for the plant will continually be reviewed to make sure that exposures are maintained at levels that are as low as reasonably achievable.

A.4 REFERENCES

1. Code of Federal Regulations, Title 10 Part 50 Appendix I, "Numerical Guidelines for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low As Practicable' for Radioactive Material In Light-Water-Cooled Nuclear Power Reactor Effluents."

2. Tennessee Valley Authority, Environmental Statement on the Watts Bar Nuclear Plant Units 1 and 2, November 1972; Section 2.1 and Appendix A.

Table A.4-1

BASELINE SOUND SURVEY DATA, WATTS BAR WASTE HEAT PARK

September 1, 1979

Measurement Location	Average Sound Level, dBA Day	Night	Day-Night
No. 1 on map. West of site near Sims Cemetery. Approximately 5600 feet from plant cooling towers.	43	52	58
No. 2 on map. Southeast of site near shoreline. Approximately 5300 feet from cooling towers.	49	50	56
No. 3 on map. Across river southeast of site. Approximately 3500 feet from cooling towers.	48	50	56

Table A.4-2

BASELINE SOUND SURVEY DATA, WATTS BAR WASTE HEAT PARK

March 15, 1980

Measurement Location	Average Sound Level, dBA		
	Day	Night	Day-Night
No. 1 on map. West of site near Sims Cemetery. Approximately 5600 feet from plant cooling towers.	25	26	32
No. 2 on map. Southeast of site near shoreline. Approximately 5300 feet from cooling towers.	33	36	42
No. 3 on map. Across river southeast of site. Approximately 3500 feet from cooling towers.	38	38	44

Table A.4-3

ESTIMATED MAXIMUM[1] INDIVIDUAL DOSE RATES FROM GASEOUS EFFLUENTS, PER UNIT

External Exposures

Pathway	Guideline[2]	Dose
γ air dose	10	0.65 mrad/yr
β air dose	20	3.77 mrad/yr
Total body	5	0.57 mrem/yr
Skin	15	1.34 mrem/yr

Internal Exposures (critical organ is the thyroid)

Pathway	Guideline	Dose to Adult (excluding ingestion)
Radioiodines and Particulates	15	1.3 mrem/yr

Breakdown of Internal Exposures (mrem/yr)

	Child[3]	Adult
Inhalation	1.21	0.75
External	0.58	0.58
Total	1.79	1.33
Ingestion		
Vegetables	4.59	2.38
Beef	0.48	0.29
TOTAL, assuming existence of ingestion pathway	6.9	4.0

---

1. Maximum exposure point is 625 m in the SSE sector.
2. Guidelines as defined by Section II of Appendix I to 10 CFR 50 (see reference 3).
3. The listed inhalation and external dose rates are calculated assuming a child were continuously present in the WBWHP. For other than employees the presence of either a child or an adult at the site for extended periods of time is unlikely.

Table A.4-4

ANNUAL DOSE FROM DIRECT RADIATION

Compass Sector	Distance,[1] m	Direct Radiation Exposure (mrem/yr/unit) Refueling Water Tank	Primary Makeup Water Tank
SSE	625	4.0(-3)	7.0(-5)
S	640	2.5(-3)	4.0(-5)
SSW	610	7.0(-3)	1.5(-4)
SW	580	1.3(-2)	2.3(-4)
WSW	670	4.5(-3)	8.0(-5)
W	580	1.8(-2)	4.5(-4)
WNW	580	2.5(-2)	7.0(-4)

1. Distances listed are those used for atmospheric pathway assessment and are measured from the center of the facility. Values used for direct radiation expsoure assessment may differ slightly.

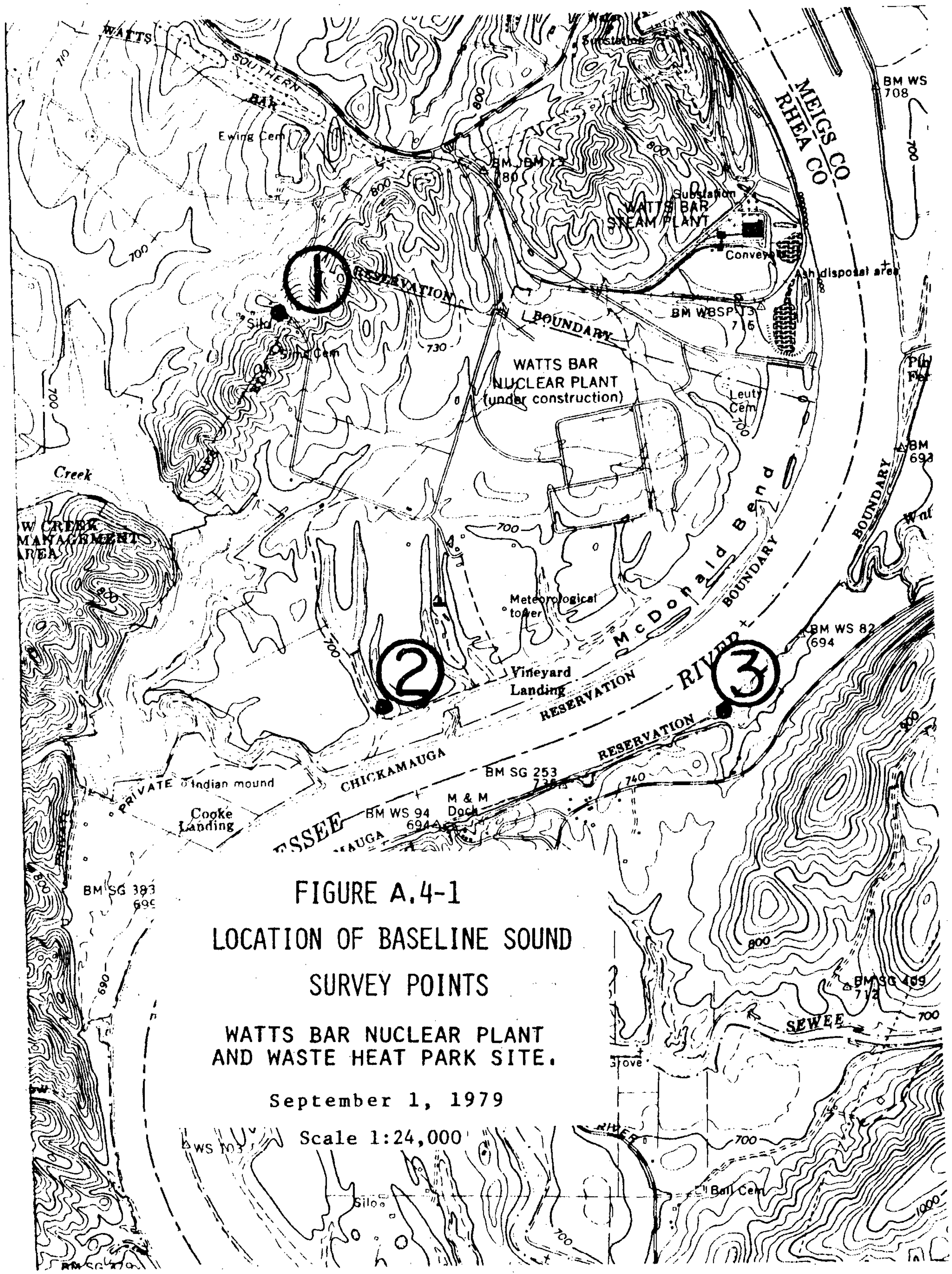


FIGURE A.4-1
LOCATION OF BASELINE SOUND SURVEY POINTS

WATTS BAR NUCLEAR PLANT AND WASTE HEAT PARK SITE.

September 1, 1979

Scale 1:24,000

A.5 TERRESTRIAL ECOLOGY

A.5.1 Vegetation

The proposed park lies within the Ridge and Valley Physiographic Province in east Tennessee. Major habitats present include fields in various stages of succession, marshlands, bottomland hardwood forests, upland hardwood forests, ponds, and riparian habitats along Yellow Creek. A significant portion of the site has been disturbed as a consequence of construction of Watts Bar Nuclear Plant. Disturbed areas include active and reclaimed borrow areas, numerous unimproved roads, construction buildings, and storage areas.

Areas of the proposed Waste Heat Park that are not disturbed by construction activities are either in open fields or wooded. None of the habitats seen are unusual for the region.

Onsite wooded areas are chiefly bottomland hardwood forests with upland species restricted to slopes and ridges. Bottomland species in the overstory include sweetgum, tulip tree, red maple, black gum, white oak, willow and sycamore. The shrub layer is mainly dogwood, viburnum, muscadine, cane, and paw paw. Understory includes Japanese honeysuckle, touch-me-not, partridge berry, lizard tail, skull cap, crossvine, and cinnamon fern. The more upland slopes have white oak, southern red oak, hickory, and scattered cedars.

Open fields on the site are either in pasture or early succession. Pastures are predominantly fescue with mixtures of other grasses, white clover, and scattered morning glory. Fields in early succession have a mixture of grasses as well as blackberry, sumac, cedars, sassafras, asters, sunflowers, and beggar ticks.

A.5.2 Wildlife

There are approximately 357 species of terrestrial vertebrates whose ranges include the area to be impacted by park development. I-5
The terrestrial vertebrate fauna is typical of similar areas in the Ridge and Valley of east Tennessee, and no unique faunal assemblages are known from the site.

However, due to the juxtaposition of the various habitats on the site, a large diversity of upland game could inhabit the site. Species typically inhabiting the open field and early successional habitat include cottontail rabbit, bobwhite quail, and groundhog. Game species inhabiting upland and bottomland wooded areas include gray squirrel, raccoon, and opossum. Species utilizing both wooded and open land to fulfill habitat requirements include white-tailed deer, gray fox, and red fox. Riparian zones serve as a habitat component for a number of the above-listed species and as primary habitat for mink and muskrat.

Nongame species typical of early successional fields and reclaimed borrow areas include the eastern harvest mouse, deer mouse, eastern meadowlark, red-winged blackbird, blue grosbeak, black racer, black rat snake, and black kingsnake. In addition to these species, brushy fields on the site provide habitats for the short-tail shrew, cotton rat, eastern kingbird, gray catbird, white-eyed vireo, summer tanager, indigo bunting, and fence lizard.

Common nongame species of woodlands on the site include the wood thrush, red-eyed vireo, hooded warbler, Kentucky warbler, eastern box turtle, ringneck snake, and brown snake. Typical species of marshlands, wooded swamps, and ponds include the green heron, common yellowthroat, pied-billed grebe, common snapping turtle, northern water snake, marbled salamander, red-spotted newt, Fowler's toad, upland chorus frog, spring peeper, green frog, and bullfrog. Several species such as the dusky salamander, two-lined salamander, and red salamander occur along rocky clear streams on the site.

The proposed Watts Bar Waste Heat Park is located adjacent to the Yellow Creek Wildlife Management Area which is managed by the State of Tennessee. The Yellow Creek Management Area supports large numbers of migrant-wintering waterfowl populations and is managed as a waterfowl hunting area. Shallow water areas provide habitat for shore and wading birds, including great blue and green herons.

A.5 REFERENCES

1. Conant, R. 1975. A Field Guide to Reptiles and Amphibians of Eastern and Central North America. Houghton Mifflin Company, Boston. XVIII T 429 pp.

2. Burt, W. H. and R. P. Grossenheider, 1964. A Field Guide to the Mammals. Houghton Mifflin Company, Boston. XVII T 284 pp.

3. Mengel, R. M. 1965. The Birds of Kentucky. American Ornithologist Union, Ornithological Monographs No. 3. Allen Press, Lawrence, Kansas. 581 pp.

4. Robbins, C. S., B. Bruun, and H. S. Zim. 1966. A Guide to Field Identification of Birds of North America. Golden Press, New York. 340 pp.

5. Hall, E. R. and K. R. Kelson. 1959. The Mammals of North America Ronald Press, New York. 2 Volumes, 1083 pp.

A.6 AQUATIC ECOLOGY

A.6.1 Nonfisheries

TVA biologists, as a part of the preoperational monitoring program for the Watts Bar Nuclear Plant, monitored and inventoried the biological elements of the upper reaches of Chickamauga Reservoir from February 1973 through December 1977. Four of the eight biological monitoring stations included in that preoperational program were in the tailwaters of Watts Bar Dam in the vicinity of the proposed waste heat park. Quarterly samples of phytoplankton, zooplankton, and benthos were taken during this period. From 1975 through 1977, mussel surveys were conducted in addition to the normal benthic monitoring.

During 1978, more extensive sampling for mollusks was conducted in the Watts Bar tailwater as part of TVA siting investigations. These data were collected similarly to the preoperational qualitative surveys except that individual scuba searches were not limited to 20 minutes and specimens were not measured. From this survey work, data were available to update mussel distributions from Watts Bar Dam to about TRM 514.

A.6.1.1 Phytoplankton (microscopic plants - primarily, whose locomotion is almost entirely controlled by water currents)

As primary producers, phytoplankton play an important role in the food chain of reservoirs, serving as a food source for both secondary producers (e.g., zooplankton) and herbivorous fishes. The phytoplankton communities of Watts Bar and Chickamauga Reservoirs in the site vicinity were abundant and diverse on most occasions with many species of diatoms and green algae. However, during the summers of 1976 and 1977, the blue-green algae exhibited a marked increase in numbers and hence composed a greater percentage of the community at all sampling stations. This marked increase in blue-greens cannot be related to any point source discharge, but permanent or significant increases in blue-green algal composition are considered both detrimental, and indicative of poorer water quality. When present, increases in blue-green populations most frequently will occur in the late summer and fall. Warmer temperatures, lower flows, and organic enrichment are environmental factors which most frequently enhance the growth of blue-green populations.

A.6.1.2 Zooplankton (microscopic animals - primarily, whose locomotion is greatly influenced by water currents)

Zooplankton play an important role in the aquatic food chain of a reservoir as secondary producers (primary consumers) and provide an excellent food source for larval and juvenile fish. The zooplankton populations in the tailwater of Watts Bar Dam exhibit considerable yearly and seasonable variability. Standing crop estimates during the period from 1973 through 1977 were lowest in the winter and fall and were highest in the spring and summer. Total zooplankton numbers at the four stations in the vicinity of the proposed waste heat park ranged from a low of 2,790 organisms per cubic meter in the fall of 1973 to a high of 316,003 organisms per cubic meter in the summer of 1976.

The standing crop estimates obtained from the Watts Bar Nuclear Plant preoperational monitoring program show that there is a trend for total zooplankton numbers to decrease with increasing distance downstream from the Watts Bar Dam. This would seem to indicate that the Watts Bar Reservoir is the only significant source of zooplankton in this tailwater area.

A.6.1.3 Benthos (organisms associated with bottom of river or reservoir)

The prevalent benthic macroinvertebrate fauna of the Watts Bar Dam tailwater is comprised of clams, mussels, insect larvae and nymphs, and aquatic worms. Results of these studies indicate that taxa which are characteristic of flowing water conditions tend to occur with regular frequency in the most upstream (more riverine) reaches of the tailwater. Toward the lower end of the study area (more affected by impoundment) taxa characteristic of reservoir habitats occur most frequently. This faunal shift occurs gradually within the study area and is considered to be characteristic of faunal shifts which occur downstream from mainstream impoundments. There are no obvious distributional patterns which would typify significant point source pollution problems; however, the data are inadequate for any definitive conclusions in this regard.

The Tennessee River has long been noted for its indigenous mussel fauna. This group of organisms once provided a substantial commercial fishery in the section of the Tennessee River downstream from Watts Bar Dam. A combination of overharvesting and impoundment of the river have functioned to greatly reduce and modify the mussel fauna. Despite these factors and periodic occurrences of dissolved oxygen below 2.0 mg/l, a relatively diverse mussel fauna still exists in the Watts Bar Dam tailwater, especially in a reach 5-10 miles downstream from the dam.

There are three areas within the Watts Bar Dam tailwater where the mussel fauna is most diverse (mussel beds). These are TRM 528.1-526.1, TRM 525.0-524.0, and TRM 521.3-520.2. All but 0.3 mile of these areas fall within a State designated mussel sanctuary (TRM 522.5 to Watts Bar Dam) where commercial harvesting is prohibited. Most of the habitat downstream from the sanctuary is only marginally suitable for mussels, and is not productive enough to support a commercial mussel fishery.

For additional detail regarding the aquatic macroinvertebrate fauna of the Watts Bar Dam tailwater, see references 1 and 3.

A.6.2 Fish and Fishery Resources

As a result of approximately four years' preoperational monitoring for Watts Bar Nuclear Plant, 54 species of fish representing 15 families were identified from the site vicinity. These fish were taken by gill nets, hoop nets, electrofishing, seining, and rotenone (cove). Clupeids (i.e., skipjack herring, gizzard shad, and threadfin shad) were the most abundant species taken with gill nets, electrofishing, and rotenone.

White crappie, bluegill, and white bass were taken most often in hoop nets; and brook silverside, emerald shiner, and bluegill were most numerous in shoreline seining samples.

The Watts Bar tailwater area supports an intensive sport fishery, including migratory spawning species as well as more resident species. Creel survey data indicate white crappie to be the numerically dominant species. Bluegill, sauger, white bass, channel catfish, and largemouth bass are also important to angler harvest.

Ichthyoplankton samples collected near the Watts Bar Nuclear Plant over the period 1976-1979 showed clupeid larvae the dominant family collected, exceeding 50 percent of the total catch in each of the four years. Larvae of migratory taxa purported to spawn in the tailwaters were collected infrequently, indicating that the Watts Bar tailwater in the site vicinity is probably not used extensively by these species for spawning.

A.6 REFERENCES

1. Gooch, C. H., W. Jeffrey Pardue, and Donald C. Wade. "Recent Mollusk Investigations on the Tennessee River--1978." Draft report, January 1979, Water Quality and Ecology Branch, TVA, Division of Environmental Planning.

2. Watts Bar Nuclear Plant Preoperational Fisheries Monitoring Report, 1977-79. Prepared by J. P. Buchanan, M. S. Kirby, G. E. Peck, J. M. Roberts, A. O. Smith, C. T. Swor, and R. Wallus. TVA, 1980.

3. Watts Bar Nuclear Plant Preoperational Aquatic Monitoring Report, 1973-77. Prepared by R. D. Harned, C. E. Mulkey, W. J. Pardue, and E. B. Robertson. TVA, Division of Water Resources, April 1980.

A.7 ENDANGERED OR THREATENED SPECIES

A.7.1 Coordination with U.S. Fish and Wildlife Service

On October 4, 1979, a request was submitted (see Appendix E) to the Regional Office of the U.S. Fish and Wildlife Service for the names of those species either listed or proposed for listing as endangered or threatened and which might occur in the vicinity of the proposed project. In a response, dated November 16, 1979, the acting regional director of that agency indicated that three species of endangered freshwater mussels may occur in the vicinity of the site. This letter did not indicate the possible presence of fish, terrestrial wildlife, or plant species; however, for the purposes of this environmental statement we have elected to include some discussion of State or Federally listed terrestrial and fish species which have been reported to inhabit the general area of Watts Bar and Chickamauga Reservoirs. The following information is considered TVA's "biological assessment" pursuant to Section 7(C) of the Endangered Species Act of 1973 as amended.

A.7.2 Aquatic Invertebrates and Fish

Two endangered mussel species are known to occur in the vicinity of the proposed waste heat park site. *Lampsilis orbiculata* (Hildreth, 1828), the pink mucket pearly mussel, occurs at many sites from Tennessee River Mile (TRM) 528.3 downstream to at least TRM 517.4. Although it is protected as an endangered species, this mussel is widespread in the Tennessee River. *Dromus dromas* (Lea, 1834), the dromedary pearly mussel, is known from only three sites within the area from TRM 520.8-520.2. Though once a common component of the Tennessee River fauna, this species is now extremely rare in the Tennessee River.

In their listing of endangered species likely to be affected by this project, the U.S. Fish and Wildlife Service included *Plethobasus cooperianus* (Lea, 1834), the orange-footed pearly mussel, along with the two mussel species discussed above. *P. cooperianus* originally occurred in much of the mainstream Tennessee River; however, the 1978 TVA survey found this species only below Pickwick Landing Dam (TRM 206), Guntersville Dam (TRM 349), and Fort Loudoun Dam (TRM 602).[1] In all of these areas, this species made up less than 0.2 percent of the mussel specimens examined. No specimens of *P. cooperianus* were found below Watts Bar Dam during TVA surveys in 1978 or 1980; however, a specimen was collected at TRM 515 in 1957.[2] If *P. cooperianus* continues to exist in this reach of the river, it is apparently present in extremely low numbers.

No specimens of any aquatic threatened or endangered fish species have been collected in the immediate site area. Two specimens, identified as *Percina tanasi*, the snail darter, were seen (but not captured) just off Lick Light (TRM 515.4) on April 19, 1976. A TVA fisheries biologist made the sitings while scuba diving on Hazel Ridge Shoals as part of a survey to establish snail darter distribution in the Tennessee Valley. The siting of these specimens suggested that snail darters might occur in areas with sand and gravel substrates from Lick Light to Watts

Bar Dam. Until 1981 searches of this river reach had failed to locate such a population or to repeat this siting. However, in April 1981, immature snail darters were found in Sewee Creek (TRM 524.9) which again supports the hypothesis of a viable population in the Watts Bar Dam tailwaters.

A.7.3 Terrestrial Wildlife

No resident populations of federally listed or proposed endangered or threatened species are known from the project area. However, bald eagles (Haliaeetus leucocephalus), considered endangered by the U.S. Fish and Wildlife Service, have been observed year-round along the mainstream of Chickamauga and Watts Bar Reservoirs near the proposed waste heat park. Most of their activities are confined to the mainstream and large trees along the reservoir bank. The gray bat (Myotis grisescens), also considered federally endangered, is known from two caves in Rhea County and three caves in Meigs County. Information on these caves is presented in the following table:

Cave Name	Use	Location from Project Site
Bat Cave No. 1	Maternity Colony	Rhea County, approximately 10 miles downstream of site.
Bat Cave No. 2	Maternity Colony	Rhea County, approximately 10 miles downstream of site.
Bat Cave No. 3	Bachelor/transient	Meigs County, approximately 13 miles upstream of site.
Bat Cave No. 4	Bachelor/transient	Meigs County, approximately 3.5 miles downstream of site.
Bat Cave No. 5	Bachelor/transient	Meigs County, approximately 27 miles downstream of site.

A pair of ospreys (Pandion haliaetus), listed as endangered by the State of Tennessee, nested at the southern edge of the proposed site as late as 1974. The tree was storm damaged in 1975 and no recent nesting attempts have been made. However, ospreys are common in the area during spring and fall migrations.

Hayfields and vegetated borrow areas appear to provide suitable habitat for grasshopper sparrows (Ammodramus savannarum), listed as threatened by the State of Tennessee. However, there are no nesting records for this species from the proposed site. Marsh hawks (Circus cyaneus), listed as threatened in Tennessee, are a common winter resident and utilize low-lying hayfields and marshlands on the site.

The Tennessee cave salamander (Gyrinophilus palleucus), listed as threatened by the State of Tennessee, is known from Blythe Ferry Cave in Meigs County. However, no cave systems are known within or near the project boundaries.

Species listed as being "in need of management" by the State of Tennessee which occur in the vicinity of the project include the great blue heron (Ardea herodias), red-shouldered hawk (Buteo lineatus), sandhill crane (Grus canadensis), small-footed myotis (Myotis leibii), green anole (Anolis carolinensis), six-lined racerunner (Cnemidophorus sexlineatus), northern pine snake (Pituophis melanoleucus), Cumberland turtle (Pseudemys scripta troosti), and hellbender (Cryptobranchus alleganiensis).

Two colonies of nesting great blue herons have been identified in the vicinity of the proposed site. These birds travel great distances to feed and occasionally occur on the project site. The red-shouldered hawk utilizes bottomlands and swamplands both on and adjacent to the project site. This hawk is not known to nest on the project site. The sandhill crane, a migratory species, has been observed during waterfowl surveys near the Yellow Creek Wildlife Management Area.

The small-footed myotis is known from Rhea County approximately 10.0 miles west of Dayton. No resident populations are known to occur on the site. The green anole, six-lined racerunner, and northern pine snake are also known from Rhea and Meigs Counties. Although suitable habitats for these species are present, there are no known records on the proposed site. Hellbenders have been recorded in Rhea County; however, this large aquatic salamander inhabits medium to large, free-flowing, rocky streams and does not occur on or near the project site.

A.7 REFERENCES

1. Gooch, C. H., W. Jeffrey Pardue, and Donald C. Wade. "Recent Mollusk Investigations on the Tennessee River-1978." Draft Report, January 1979, Water Quality and Ecology Branch, TVA, Division of Environmental Planning.

2. Scruggs, George D., Jr. "Status of Fresh-Water Mussel Stocks in the Tennessee River." U.S. Fish and Wildlife Service Special Report, Fisheries No. 370:1-41, 1960.

A.8 LAND USE

A.8.1 Site Area

The park site is located on a mostly cleared, gently sloping portion of the Watts Bar Reservation. The park is bounded by the Yellow Creek Wildlife Management area on the west, Chickamauga Lake on the south, Watts Bar Nuclear Plant on the east, and a ridge on the north. Figure A.8-1 is a map of the site area. State Highway 68 provides direct road access and a Southern railway spur provides direct rail access to the site. Portions of the site are presently used as the location for construction buildings, storage areas, and earth borrow for the construction of Watts Bar Nuclear Plant. The major portion of the waste heat park site will be located on a large tract of land that had been designated by local communities and by State industrial development groups as a potential industrial area.

A.8.2 Generalized Vicinity Land Use

The proposed site of the waste heat park is located adjacent to TVA's Watts Bar Nuclear Plant. This is the most significant industrialized land use within a 5-mile radius of the site. It is also the location of TVA's hydro and steam generating plants. Generalized land use in the vicinity of the Watts Bar Waste Heat Park site is characterized on Figure A.8-2.[1,2,3]

Existing land use in the vicinity of this site is predominately agricultural and forestry. The major concentration of urban population is located in Spring City and Decatur. These communities had a resident population of 1,840 and 865, respectively, in 1977.[4] 1978 population estimates for Rhea and Meigs Counties are 22,700 and 7,000.[4] The largest community in the Watts Bar area is Dayton, which had an 1977 estimated population of 4,240.[4]

The existing character of the lower portion of Watts Bar Reservoir is predominately recreational. The major focal points of recreation use include the numerous city and county parks, commercial recreation resorts, and TVA recreation areas. Other TVA-managed property on Watts Bar and Chickamauga Reservoirs, notably the Fooshee Peninsula and Smith Bend areas are utilized for passive recreation and wildlife management purposes. The lower portion of Watts Bar Reservoir has experienced notable reservoir-oriented residential development.

Projected development in the vicinity of the proposed waste heat park is shown on Figure A.8-2. Locally adopted land use plans indicate the major land use changes expected during the next 10-20 years will reinforce past trends. Continuation of these trends will result in urban expansion around the existing communities, intensification of the residential/recreational uses on Watts Bar Reservoir, and the development of industrial uses on waterfront sites in the upper reaches of Chickamauga Reservoir.

A.8.3 Recreation

Watts Bar and Chickamauga Reservoirs are attractive lakes for recreation users. Recreational activities in the vicinity of the proposed waste heat park are concentrated during April 15 through October 15. A privately operated resort and restaurant are located on Watts Bar Dam Reservation, and a small, commercial dock is located at River Mile 527.01 opposite the proposed waste heat park. Meigs County Park is located on the left bank of the reservoir just upstream from the dam. A short distance upstream from this park is Fooshee Bend, an 890-acre peninsula, a small part of which has been developed as a recreation area by TVA. The entire peninsula is under consideration as a potential State park site. Several other resorts are located within a 25-mile radius.

TVA has provided a boat-launching ramp and parking area on the left bank of the river below Watts Bar Dam. A recreation area upstream on the left bank of Watts Bar Dam Reservation provides an improved swimming beach, picnic facilities, toilet facilities, boat-launching ramp, and parking area. The Yellow Creek Wildlife Management Area, located adjacent to the proposed site, is a managed waterfowl hunting area.

The two dominant features in the vicinity of the Watts Bar Waste Heat Park are the Watts Bar Nuclear Plant and the Watts Bar Steam Plant. Due to the operational nature of these two facilities and because of a wide choice and variety of public and commercial recreational opportunities currently located in the vicinity, the overall potential for additional public recreational use and for development at the proposed industrial park site is considered very low. There are no existing recreational facilities on the site of the waste heat park.

A.8 REFERENCES

1. Tennessee State Planning Office, "Rhea County, Tennessee: Population Study, Economic Study, Existing Land Use Analysis, Land Use Plan." April 1973.

2. Tennessee State Planning Office, "Meigs County, Tennessee Land Use Plan." June 1977.

3. Chattanooga Area Council of Governments/Southeast Tennessee Development District, "Regional Development Plan - 2000." 1977.

4. U.S. Bureau of Census, Current Population Reports, Series p. 25 and p. 26, "Population Estimates."

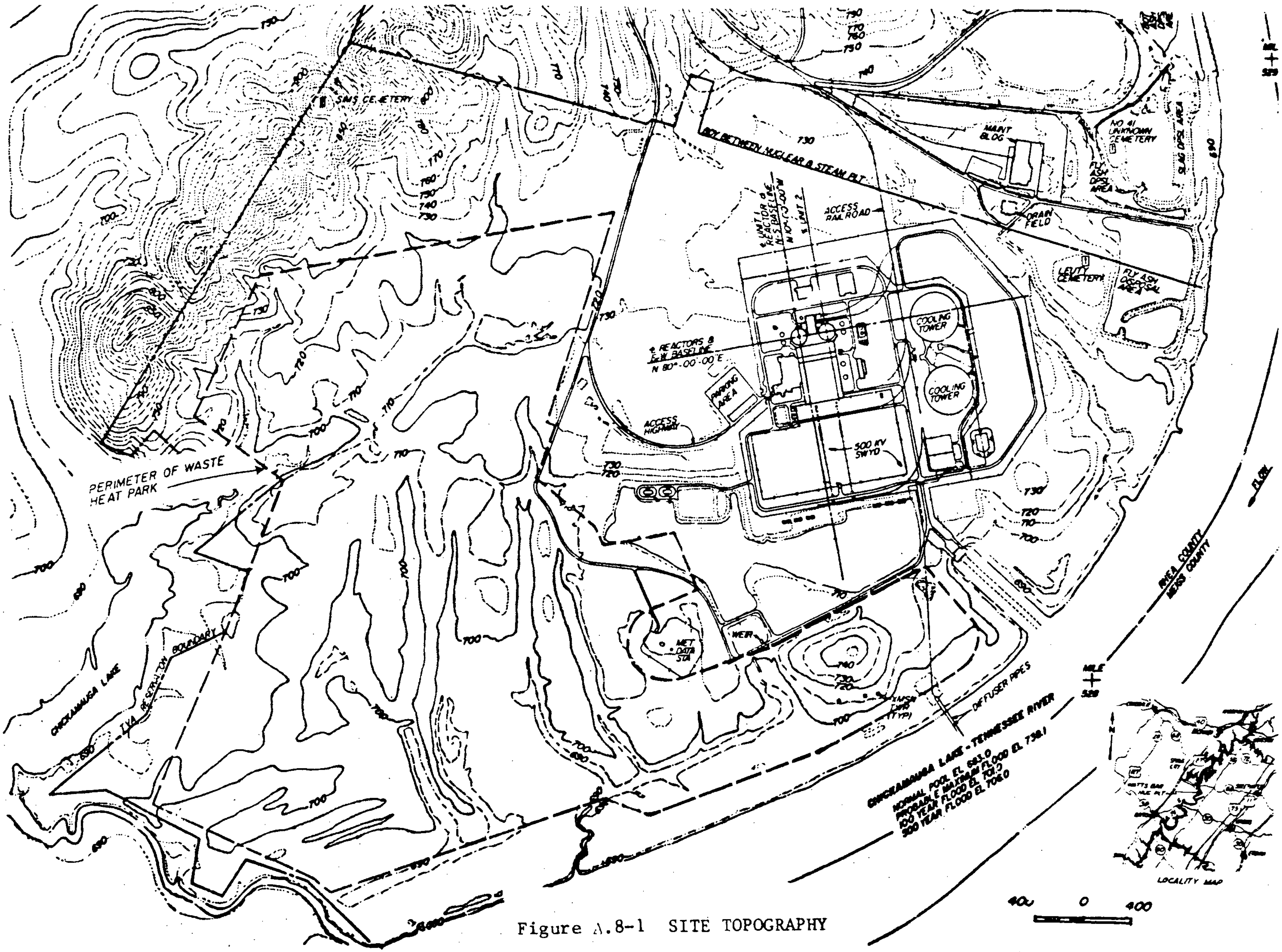
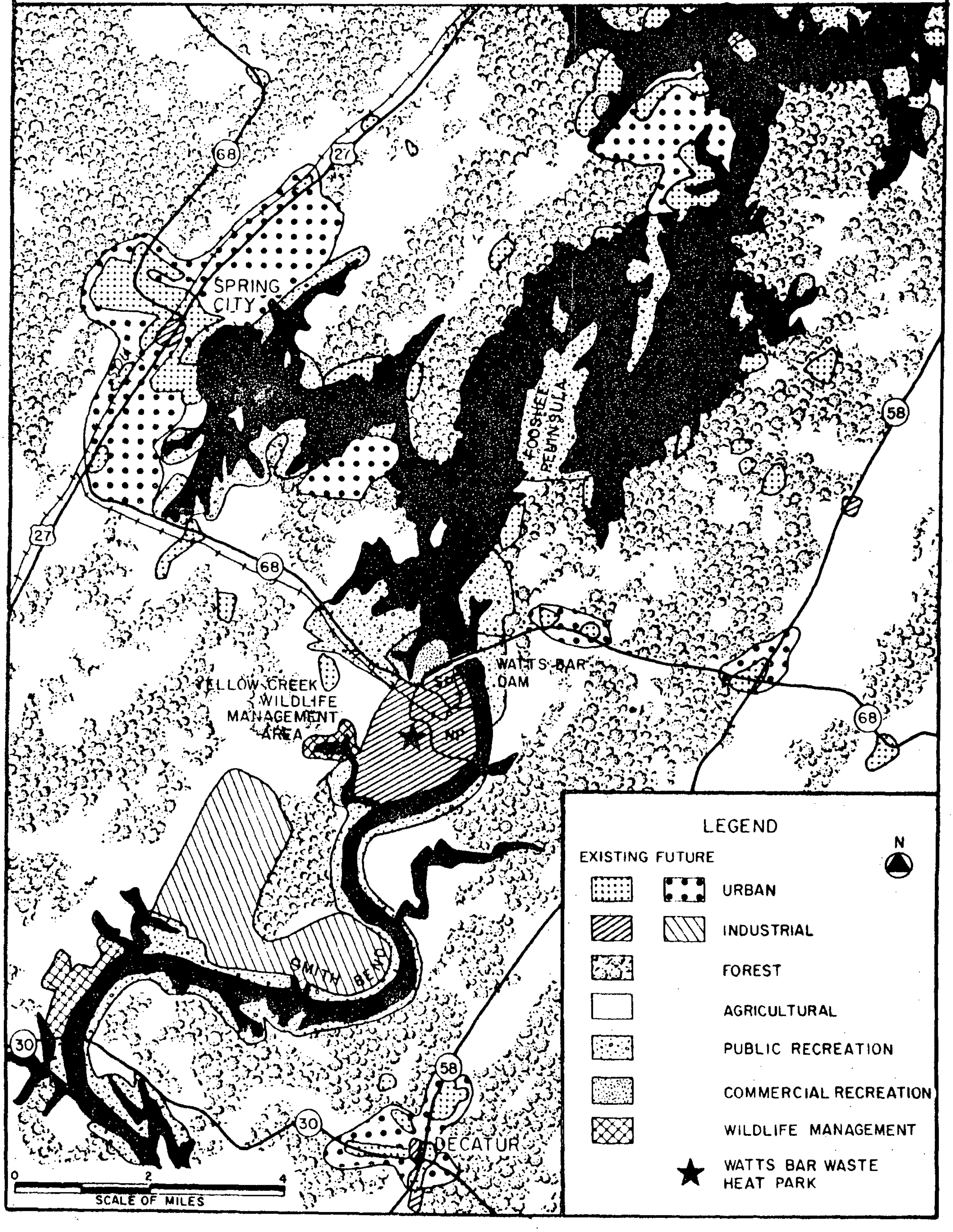


Figure A.8-1 SITE TOPOGRAPHY

GENERALIZED LAND USE IN THE VICINITY OF THE WATTS BAR WASTE HEAT PARK



A.9 SOCIOECONOMICS

A.9.1 Population and Employment

Rhea and Meigs Counties are sparsely settled. The 2-county area had a population of about 29,700 in 1978. The 1978 estimated residential population of Rhea County was 22,700 and of Meigs County, 7,000. From 1960 to 1970, net population growth for these counties was slow, totaling 1400 persons. However, these counties have experienced greater population growth in the past decade with a net increase of about 7300 persons between 1970 and 1978. Dayton, the county seat of Rhea County, is the largest city in the area with a 1977 population of about 4,240. In 1975 about 78 percent of those persons employed within the two counties were employed in manufacturing and government.

Population growth in the area is indicated in Table A.9-1. Present and projected population distribution patterns have been published as part of the operating license application for Watts Bar Nuclear Plant.[1,2]

A.9.2 Community Facilities and Services

As a result of Watts Bar Nuclear Plant construction, the local economy of the region was stimulated by the creation of new jobs and the influx of construction workers associated with the project.[2] Growth in the housing industry, mitigative measures applied to educational facilities, and the expansion of other services has apparently been adequate to accommodate the large work force (up to 3400 employees) associated with the nuclear plant.[2] The work force at the nuclear plant is declining; consequently, there should be sufficient community services and facilities available to accommodate the smaller work force projected for the waste heat park.

A.9.3 Transportation

The transportation facilities for the Watts Bar Nuclear Plant adequately served the logistical traffic for construction of the plant, which included traffic associated with a peak work force of 3400 employees. Traffic incident to the construction of the nuclear plant is diminishing as the plant nears completion. Since logistical traffic for the waste heat park, including traffic for approximately 1100 employees, will be less than and not concurrent with peak nuclear plant construction traffic, the existing transportation facilities should be adequate.

A.9 REFERENCES

1. Tennessee Valley Authority. Supplement 1, Watts Bar Nuclear Plant Environmental Information. 1977.

2. Nuclear Regulatory Commission. Final Environmental Statement related to operation of Watts Bar Nuclear Plant Unit Nos. 1 and 2, Tennessee Valley Authority, Docket Nos. 50-390 and 50-391. December 1978.

Table A.9-1

POPULATION
WATTS BAR WASTE HEAT PARK IMPACT AREA AND SELECTED AREAS

	Population				Percent Change		
	1960	1970	1977	1978	1960-1970	1970-1977	1977-1978
Meigs County, TN	5,160	5,219	6,800	7,000	1.1	23.3	2.9
Decatur	681	698	865	NA	2.5	19.4	NA
Rhea County, TN	15,863	17,202	21,900	22,700	7.8	21.5	3.7
Dayton	3,500	4,361	4,240	NA	19.8	-2.8	NA
Spring City	1,800	1,756	1,840	NA	-2.5	4.7	NA
Total 2-county area	21,023	22,421	28,700	29,700	6.6	21.9	3.5
State of Tennessee	3,567,089	3,924,164	4,292,000	4,357,000	10.0	9.4	1.5

NA - Not available.

Source: U.S. Bureau of the Census, Census of Population, 1970.
U.S. Bureau of the Census, Current Population Reports, Series P-25 and P-26.

Community Economics Projects Group
1/11/80

A.10 AESTHETICS

No unique scenic features are located on the site or in the immediate vicinity. Thus, the ultimate design and layout of buildings or factories that utilize the waste heat, and their proximity and visual line of sight to nearby roads and recreational boaters, are the primary factors affecting aesthetics. Also, potentially affecting aesthetics are the design and location of coal-fired backup units and the size and location of the coal stockpile that would be used to provide heat during times of plant outage. The proposed waste heat park would be in concert with the industrial environment already established.

A.11 CULTURAL RESOURCES

Archaeological investigations in the locality of the Waste Heat Park over the past 70 years resulted in the identification of at least 12 prehistoric mounds and a series of stratified occupation levels ranging in time from 3000 B.C. to A.D. 1200.

During late fall and early winter of 1979, an intensive archaeological survey and testing program was conducted by consultants for TVA on the 400-acre tract of the proposed Waste Heat Park.[1]

Over half of this tract had been previously disturbed by various terrain altering activities. This survey resulted in the identification of a singular significant archaeological site, 40RH64. This stratified site (6000 B.C. to A.D. 300) is on a natural levee of the Tennessee River and is approximately 300 feet in width and 6000 feet in length, extending north from the mouth of Yellow Creek to the Watts Bar Nuclear Plant intake channel.

An internal evaluation of historic structures was made by TVA's Cultural Resource staff and none were found to be on or eligible for the National Register of Historic Places.

A.11 REFERENCES

1. GAI Consultants, Inc. Archaeological Survey and Testing of the Proposed TVA Watts Bar Waste Heat Park - Final Report, May 1980.

A.12 FLOODPLAINS AND WETLANDS

A.12.1 Floodplain Evaluation

The site is subject to flooding from the Tennessee River, Yellow Creek, and an unnamed tributary to Yellow Creek. The 1- and 0.2-percent-chance flood elevations are 697 and 701, respectively, on the Tennessee River and the lower portion of Yellow Creek at the site. The Tennessee River backwater elevations would be the controling elevations on Yellow Creek and up to mile 0.45 on the tributary to Yellow Creek, where they would intersect with headwater flood elevations. In addition to these three flooding sources, there are three small, unnamed drainageways that flow through the site. The TVA structure profile elevation at the site is 706 between Tennessee River Miles (TRM) 526 and 527, 707 from TRM 527 to TRM 528, and 708 between TRM 528 and Watts Bar Dam.

A.12.2 Wetlands

The proposed Watts Bar Waste Heat Park borders extensive wetlands located along Yellow Creek adjacent to the west boundary of the Watts Bar site. Additional wetlands are formed on the area by embayments which are part of the backwaters of the Chickamauga Lake. Other wetlands are formed by portions of the Yellow Creek drainage which transverses Watts Bar Reservation. Some of these wetlands appear to have been formed by alteration of the Watts Bar Reservation during construction of the nuclear plant located at this site. These wetlands located on the site are identified in Figure A.12-1 and are classified as follows (Cowardin et al. 1977):

System - Palustrine
Class - Scrub/Shrub Wetland
Subclass - Broad-leaved deciduous
Modifier - Artificially Flooded
Special Modifier - Impounded

System - Palustrine
Class - Forested Wetland
Subclass - Broad-leaved Deciduous
Modifier - Artificially Flooded
Special Modifier - Impounded

These wetlands will be preserved or other mitigative measures implemented if no practicable alternative exists to their disturbance. All activities will be evaluated to assure that they are consistent with TVA policy on wetland protection.

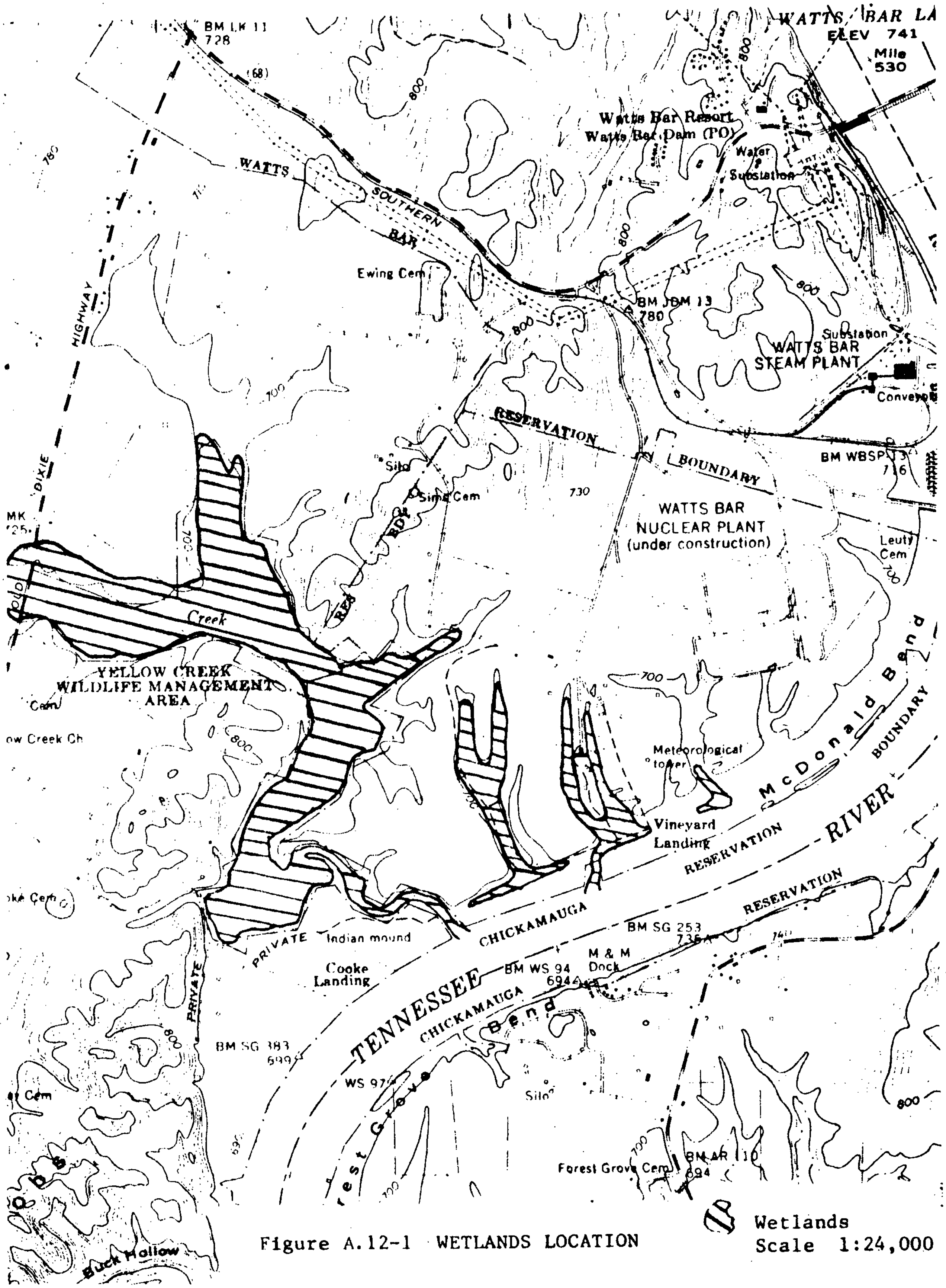


Figure A.12-1 WETLANDS LOCATION

Wetlands
Scale 1:24,000

APPENDIX B

ENVIRONMENTAL CONSEQUENCES - WATTS BAR SITE

B. ENVIRONMENTAL CONSEQUENCES - WATTS BAR SITE

Impacts likely to be created by the proposed action are evaluated in this appendix. Site-specific mitigative measures are also presented.

B.1 SITE DEVELOPMENT

B.1.1 Construction and Operation Impacts

No significant impacts to geologic features or to existing site facilities are expected, especially since a large portion of the site has already been disturbed. Impacts to soils include inhibition of soil-forming processes and soil structure destruction, which are unavoidable consequences of soil removal during site preparation. Lack of structure and destruction of soil microorganisms will result in decreased fertility and compaction of the topsoil. Potential mixing of soil types during stripping can further reduce topsoil quality, while wind and water erosion reduce the quantity of available soil and increase sediment loads in Yellow Creek and Chickamauga Reservoir.

Potential effects on normal operations of the nuclear plant would be related to a minor change in the quality of the CCW and the increased working force in proximity to the plant. The potential for waste heat park-related accidents to impact the safe operation of the nuclear plant will be evaluated by both TVA and the NRC, if appropriate, at such time specific uses are identified. The severity of this impact is a function not only of distance from the reactor but also of the nature of activities at the waste heat facilities.

B.1.2 Mitigative Measures

The park and/or individual site developer will be required to use best management practices during site preparation to minimize soil losses due to erosion. Material useful as plant growth media will be segregated and stockpiled, then redistributed for site landscaping.

Park occupants would be required to provide adequate treatment of the CCW so that the water returned to the cooling system would be of acceptable quality. Regarding thermal conditions, cooled water from open-system users, which would be returned at a temperature less than or equal to that of CCW leaving the cooling towers, would be collected and pumped to the cooling tower basin, bypassing the cooling tower. For those users not consuming significant quantities of heat, the water would be routed back to the cooling tower supply conduit.

The Radiological Emergency Plan for the nuclear plant would have to be revised to include provisions for the employees and activities of the waste heat park.

Mitigation to minimize effects from park-related operations or accidents on plant operation include screening of potential park users and controls on park operations. Generally explosive substances and tall structures would be avoided, and the park is isolated from the cooling system of the plant so as to pose no hazard potential.

B.2 AIR QUALITY

B.2.1 Construction Impacts

The primary construction-related air quality impacts are associated with fugitive dust resulting from grading and clearing operations and from construction traffic. Wet suppression techniques, including periodic application of water on unpaved access roads, will be employed to minimize the fugitive dust associated with these activities. Fugitive emissions may occasionally degrade visibility onsite; however, no significant air quality impacts would be expected offsite. Minor increases in combustion emissions from operation of construction vehicles can be expected during construction. These emissions, however, will be of a temporary nature and are only expected to have a very small impact, if any, offsite.

B.2.2 Operational Impacts

Air quality in the area is protected by state implementation plan (SIP) provisions affecting existing sources and by new source performance standards (NSPS) and PSD provisions which regulate new sources. These provisions and regulations will assure that NAAQS are maintained to protect public health and welfare in the area.

B.2.2.1 Park Users

Most of the atmospheric emissions associated with activities and facilities of potential users, of the size considered for the waste heat park, are expected to be small. In addition, most of the processing activities would be regulated by process permit conditions. Consequently, no significant air quality impacts resulting from these emissions would be expected offsite. Qualitative assessments of the potential air pollutant emissions associated with the various activities are provided below.

Cultivation--Cultivation activities associated with the 25-acre soil warming area will create minor amounts of onsite fugitive dust.

Grain Drying--Loading and unloading activities associated with the drying facility will create minor amounts of fugitive dust. Controls will be required on the grain bins to mitigate potentially significant point source (nonfugitive) particulate emissions.

Soybean Processing--Loading and unloading activities associated with the soybean facility will create minor amounts of onsite fugitive dust. Controls will be required on significant point (nonfugitive) sources of particulate emissions. Supplemental heat, required in the drying process, would be provided by a natural gas or fuel oil-fired heat exchanger. Depending on the type and amount of fuel used and the efficiency of the heat exchanger, minor amounts of the following criteria pollutants could be emitted: CO, NO_x, HC, SO_2.

Livestock Production and Animal Waste Reclamation--The significant atmospheric emissions associated with livestock production and animal waste reclamation are methane gas (CH_4) and odorous organic molecules. Occasionally, odors may be detected due to gaseous evolution from natural biological processes associated with animal wastes. Detection of these nuisance odors would be dependent upon ambient conditions. The potential for detecting odors offsite is expected to be very small.

Vegetable Processing--Minor amounts of steam would be discharged from activities associated with vegetable processing. However, no significant discharges of air pollutants would be expected.

Concrete Block and Brick--Loading and unloading activities associated with concrete block and brick production will create minor amounts of onsite fugitive dust. Controls will be required on brick kilns, if any, and on any significant point sources of particulate emissions.

Greenhouse Facilities--Activities associated with operation of the greenhouse facilities create a potential for atmospheric releases of pesticides. Only pesticides approved by the EPA will be used. Application of pesticides will be subject to certification procedures. Consequently, no significant air quality impacts are expected from the application of pesticides.

Many of the facilities listed in Section 4.2.3 (Industrial Applications) have the potential to emit hydrocarbons in small quantities. If considered as individual nonmajor sources operated independently, BACT may not be a requirement. Odors which would be considered offensive to some people would be produced by most of the industrial activities. Controls on HC emissions and the filtering of air exhausted from these facilities will reduce the potential for odors becoming a nuisance offsite.

B.2.2.2 Central Coal-fired Facilities

Central coal-fired heat backup and heat augmentation systems (Figure B.2-1) constructed and operated by the park management are assumed, as opposed to individual units for each park user. Based on preliminary source data and assumptions, it is expected that the backup and the augmentation facilities would be classified as major new SO_2 sources under existing PSD regulations. Consequently, these facilities would be subject to full PSD review, including (1) a requirement for preconstruction monitoring, and (2) demonstrations of expected ambient impacts for comparison with NAAQS and available Class II increments.

Preliminary engineering designs for the backup and augmentation facilities specified a 90×10^6 Btu/hr augmentation unit, a 190×10^6 Btu/hr industrial backup, and a 560×10^6 Btu/hr rest-of-park backup. Planned stack heights were 140 ft, 170 ft, and 200 ft, respectively. Because of their sizes and types, these facilities would be expected to use best available control technology (BACT) to control particulates, nitrogen oxides (NO_x), and sulfur dioxide (SO_2) emissions. BACT may also be necessary for carbon monoxide (CO) and hydrocarbons (HC), but such a determination will require more specific design information than is currently available.

The potential increase in ambient levels of SO_2 is expected to be the most restrictive air quality related limitation on locating facilities of these sizes at the waste heat park site. Therefore, air quality modeling was performed to determine the extent of the SO_2 impact. Emission rates used for the modeling are provided in Table B.2-1. These emission rates are based on a new source performance standard (NSPS) of 1.2 lb $SO_2/10^6$ Btu. Final sizes of the actual facilities will depend primarily on the number and sizes of park users.

With the design information provided, the CRSTER and VALLEY models were applied, as appropriate, to estimate potential contributions of this configuration to ambient SO_2 concentrations. Conservative assumptions were used for the analyses. The three facilities were treated as separate, but collocated sources, operating simultaneously and continuously. A selected "worst case meteorological year" was used for the CRSTER model and specified "worst case" meteorological conditions were used for the VALLEY model.

Estimated three-hour average SO_2 concentrations from the centralized facilities did not exceed either the NAAQS or the Class II PSD increment. The estimated highest and second-highest 24-hour average SO_2 concentrations were below the 24-hour average NAAQS (365 mg/m^3) for SO_2. However, they exceeded the total allowable Class II PSD increment (91 mg/m^3).

Estimates of the combined impacts of the centralized facilities and the Watts Bar Steam Plant emissions indicated that the 24-hour average NAAQS for SO_2 could be exceeded at critical terrain locations southwest of the heat park. However, it is very unlikely that all three units would be operating simultaneously and continuously at full load as modeled. Therefore, any necessary PSD permit restrictions will be proposed in the PSD permit application to limit either the hours of operation or operating procedures of the facilities. These operating limitations will allow more realistic modeling assumptions to be used. It may be that there will be no exceedances of either the NAAQS or the PSD increment with more realistic assumptions. If PSD permit application modeling still shows a problem, then additional controls or mitigative actions will be needed.

Several measures are available to avoid exceeding the SO_2 NAAQS or the available SO_2 PSD increment. While proposed stack heights for two of the units are already close to "good engineering practice (GEP)" stack heights, the stack on the third unit could be increased to GEP height to help reduce impacts. The units could be physically separated by a greater distance which would help reduce impacts. It is also possible that smaller units could be used.

Preliminary estimates of potential particulate and NO_x impacts are well below their respective NAAQS. Estimated particulate concentrations could be expected to consume about one-fourth of the total allowable 24-hour Class II PSD increment (37 mg/m^3). However, the addition of appropriate controls should reduce this significantly. There is no PSD increment for NO_x. According to preliminary information, impacts from other pollutant emissions are expected to be minor.

Potential air quality impacts associated with individual backup and augmentation facilities would depend primarily upon the types of fuel used (LP or natural gas, fuel oil, coal, or wood). Potential emissions of SO_2 and TSP per unit of heat produced would generally be less for units burning gas or oil than for units burning coal. Fugitive emissions from gas or oil-fired units would not be significant. Individual coal-fired units could cause air quality problems if adequate controls are not installed to reduce SO_2 and TSP emissions. Wood-fired units present a similar potential problem with respect to TSP emissions. Both coal- and wood-fired units would have some fugitive emissions.

Cumulative impacts of SO_2 and TSP emissions from individual units burning gas, fuel oil, coal, or wood may be equal to or even greater than those from central coal-fired facilities, because of the more stringent controls required for the larger coal-fired units. Thus, any net air quality advantage of individual units over central coal-fired units may occur only due to the reduction of fugitive particulate emissions (especially if gas- or oil-fired units are used).

B.2.2.3 Microclimate Changes

Operation of the waste heat park facilities will result in microclimatic modifications in an area which includes the meteorological monitoring facility for the nuclear plant. These modifications may include changes in local wind speed and wind direction near the ground, changes in the local thermodynamic stability of the atmosphere within about 100 m of the ground, and changes in the amount of water vapor in the air near the ground.

B.2.3 Mitigative Measures

B.2.3.1 During Construction

Fugitive dust associated with construction activities will be mitigated by dust suppression techniques. This will include applications of water or chemical suppressants on unpaved access and construction roads, as frequently as necessitated by weather conditions.

B.2.3.2 During Operation

Air pollutants produced during the operation of waste heat park facilities will be regulated by NSPS, PSD permit specifications, and process permit specifications. The various permit requirements will ensure that air quality in the area is maintained at levels necessary to protect public health and welfare. Consequently, additional mitigative measures to protect air quality are not expected to be necessary during operation.

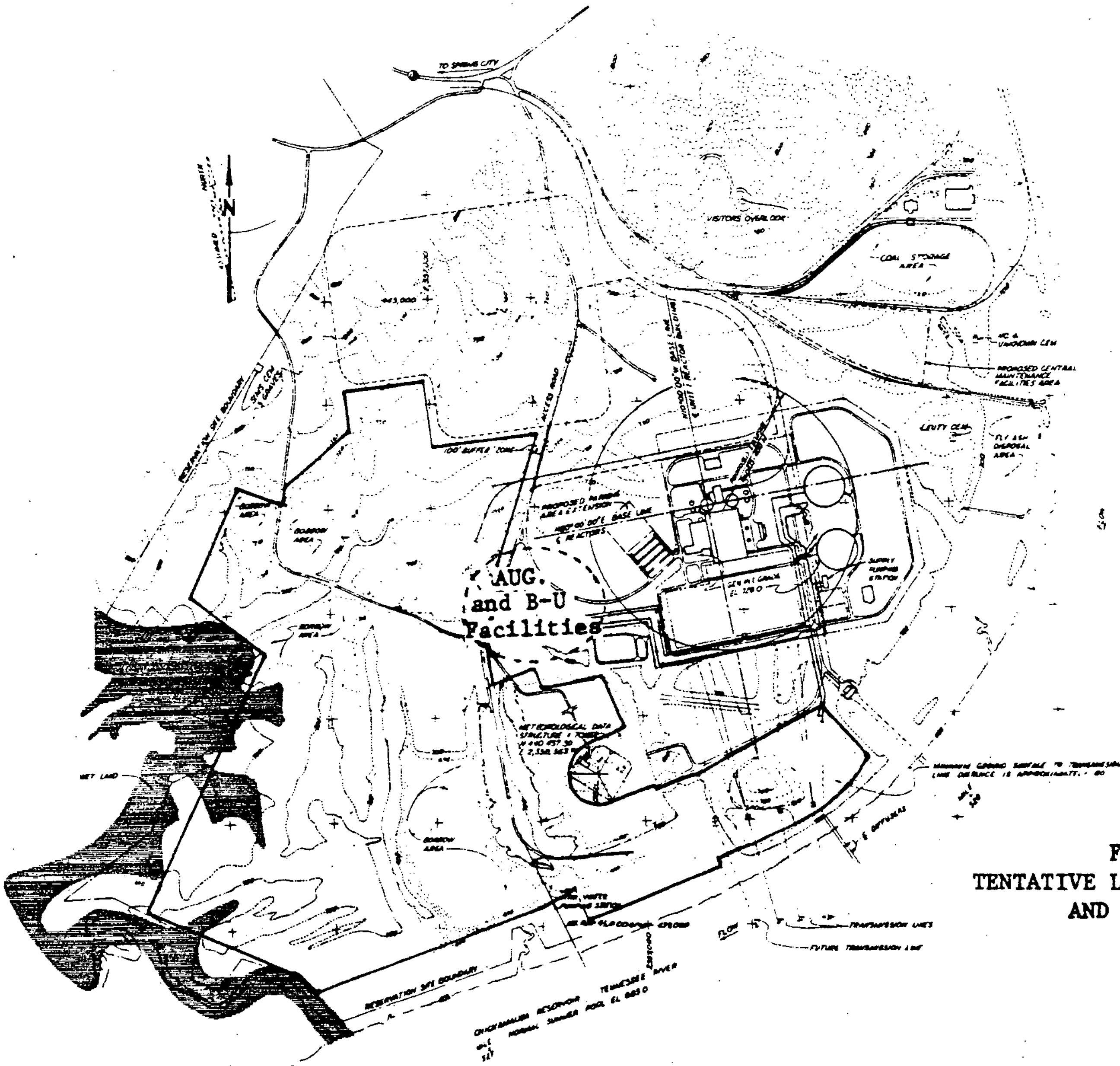
Necessary modifications will be made to the existing meteorological monitoring program to ensure it continues to meet NRC requirements after the park commences operation. Criteria for locating buildings and conducting activities in the park will be established.

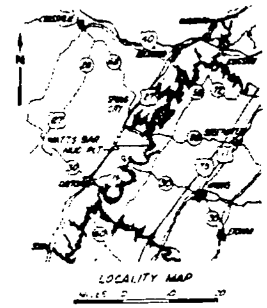
Table B.2-1

ESTIMATED ALLOWABLE SO_2 EMISSIONS[a] USED FOR THE AIR QUALITY MODELING

Unit	Energy Consumption Rate (M Btu/hr)	Allowable SO_2 Emissions (lb/hr)	(TPY)[b]
Augmentation	90[c]	108	473
Industrial Backup	190[c]	228	999
Rest-of-Park Backup	560	672	2943

a. Based on NSPS of 1.2 lb $SO_2/10^6$ Btu.
b. Assumes continuous year-round operation. TPY is tons per year.
c. For units of this size, NSPS would not apply. Actual allowable emissions would be based on a State SO_2 standard of 4.0 lb/10^6 Btu.





Scale: 1"=1600'

FIGURE 8.2-1
TENTATIVE LOCATION OF AUGMENTATION
AND BACK-UP SYSTEMS

B.3 HYDROLOGY AND WATER QUALITY

B.3.1 Construction and Operation Impacts

B.3.1.1 Surface Water

Waste heat park development will alter the present natural drainage system within the site boundaries and could, to a limited degree, increase erosion and sedimentation in the drainage system during construction. The Tennessee River or Yellow Creek downslope from the disturbed area could be affected.

The park's raw water supply will require a total withdrawal of up to 100 cfs (45,000 gpm). This is less than 0.5 percent of mean daily flow past the site. Minimal consumptive use of the water is expected, so that the removal of water will have a negligible effect on the streamflow through or pool elevation of Chickamauga Reservoir. This can be compared to water consumption at Watts Bar Nuclear Plant (28,800 gpm of total 64,300 gpm intake) which was judged to have no measurable impact on streamflow or pool elevation.[1]

Existing thermal discharges from Watts Bar Nuclear and Steam Plants under variable discharge conditions from Watts Bar Hydroelectric Plant will utilize most, if not all, of the maximum allowable temperature rise in the Tennessee River when the waste heat park begins operation. In addition, natural temperatures in this section of the river have exceeded the maximum temperature criteria.

B.3.1.2 Ground Water

Several options are available for the park's potable water supply, including the existing facilities listed in Section A.1.2 of Appendix A and the construction of additional wells. If wells are drilled in the recharge areas to springs feeding the Yellow Creek impoundment, there is a possibility that withdrawals will impact the flow of springs in this area. The extent of the impact would depend on the withdrawal rate and the location of wells relative to the springs. Mutual pumpage interference, resulting in a reduction of available yield, could occur between the existing Watts Bar potable supply wells and the waste heat park supply wells. However, because of the type of aquifer and the park's relatively low ground water requirements, such a drawdown in any of the wells would be minimal.

B.3.1.3 Water Quality

Impacts Due to Park Construction--The potential significant impacts to surface and ground water quality during park construction are:

1. Increased sediment loads in the river resulting from soil erosion in the disturbed areas due to stormwater runoff.

2. Increased sediment loads and possible releases of heavy metals or other pollutants to the river due to instream construction of water use facilities (including maintenance dredging).

3. Pollutant loads to surface water from the following sources:

   a. Improperly treated sanitary wastes (e.g., BOD, fecal coliform bacteria, settleable and suspended solids).

   b. From improperly treated concrete batch plant wastes (e.g., alkalinity, high pH, settleable and suspended solids).

   c. Improperly treated chemical wastes from preoperational system cleaning operations (e.g., metals, acidity, low or high pH).

4. Pollutant loads (e.g., organics, metals, minerals, nutrients, high or low pH) to ground water from the improper disposal of solid wastes generated during the construction of the project.

<u>Impacts Due to Operation of Central Park Facilities</u>--The potential significant impacts to surface and ground water quality due to the operation of the central park facilities are pollutant loads from the following sources:

1. Improperly treated sanitary wastes (e.g., BOD, fecal coliform bacteria, settleable and suspended solids).

2. Improperly treated and managed liquid and solid wastes from the central backup and heat augmentation systems (e.g., metals, suspended solids, oil and grease, acidity, low or high pH, etc.).

3. Improper management of stormwater runoff from the park (e.g., metals, acidity, nutrients, low or high pH, suspended and settleable solids).

4. Improper disposal of solid waste (sludges) from any required treatment of potable and raw process water (e.g., metals, minerals, solids).

<u>Impacts Due to the Operations of Industrial Park Users</u>--The identification of potential surface and ground water quality impacts are grouped into three categories:

1. <u>Those potential park users where there exists sufficient information to specifically identify the impacts and address mitigation requirements.</u>

   a. <u>Greenhouses, soil warming, and grain drying</u>--These users will have no surface discharges beyond those from the central park facilities, thus resulting in no additional impact on surface water quality. Potential sources of ground water contamination are solid wastes including empty pesticide containers, the storage lagoon for the recycleable nutrient solution from the hydroponic greenhouses, and nutrients applied to the soil warming plots. Leachates from soil warming plots should be monitored to assess the impact on ground water supplies due to normal fertilizer use for agricultural production. If any of these users require backup or heat augmentation systems, the fuel area could represent a source of surface and ground water contamination due to accidental spillage during transportation, storage, or use.

b. Aquacultural facilities--Potential pollutants to the river are settleable and suspended solids, nutrients, fecal coliform bacteria, and low levels of oxygen-consuming organic matter. Significant impacts could result from the discharges of these pollutants, especially oxygen-consuming organics and ammonia. Potential sources of ground water contamination are solid waste including empty pesticide containers.

c. Production of concrete products--Potential pollutants to the river are high pH, alkalinity, settleable and suspended solids. Potential sources of ground water contamination are impoundments for the treatment of liquid wastes and the small volume of office solid waste.

2. Those park users which have the potential for generating significant quantities of oxygen-demanding wastes and for which there is insufficient information to identify impacts and mitigation requirements.

If there is insufficient information to identify impacts and mitigation requirements, additional studies will be required to determine if the river has sufficient assimilative capacity to tolerate any further discharge of such wastes and to assess the potential impacts of these industries. Such studies would be conducted by industrial candidates with methods and results subject to approval by TVA via its NEPA review processes. Subsequent studies would be required as appropriate to evaluate treatment effectiveness. The industries included in this group are livestock production and slaughtering, fish and meat processing, vegetable processing, and other food processing.

3. Those park users which have the potential for generating significant quantities of toxic and hazardous wastes and for which there is insufficient information to adequately address their impact on water quality.

There is insufficient information to adequately assess the impact of the industries listed below on surface and ground water quality. Each SIC number includes industries which have a wide variety of processes. These processes utilize or generate a varying range of materials or wastes which are potentially toxic or hazardous. The industries included in this group are wood preserving, medicinal chemicals and botanical products, cyclic crudes and intermediates, dyes and organic pigments, soybean processing, adhesives, leather tanning and products, electroplating, truck and bus bodies, and ethanol production for gasohol.

Before these types of industries could be located in the park, an environmental evaluation will be conducted by the respective industry and reviewed and approved by TVA.

Effects on the Watts Bar Nuclear Plant--This section addresses the effects of the central park facilities and the first category of park users (greenhouse, soil warming, grain drying, aquaculture, and concrete products facilities) on the condenser cooling water for the Watts Bar Nuclear Plant. Maximum CCW requirements for these facilities will be approximately 80,000 gpm, of which 42,000 gpm will be utilized for closed-cycle convective heat transfer, 8,000 gpm for evaporative pad heat exchangers, and up to 30,000 gpm diverted from the CCW for direct-contact use. The first two uses of the CCW represent 50 percent of the total CCW system (100,000 gpm) to be utilized in the waste heat park. The third use of the CCW represents 30 percent of the total CCW system. The impact of the direct use of the CCW as process water for aquaculture and fish and plant production for animal waste reclamation could be significant to the maintenance of proper concentration factors and flows for condenser cooling systems. Therefore, as aquaculture facilities are proposed for the park, a case-specific evaluation by TVA will be required of the CCW system and raw water requirements. The results of this evaluation could limit the scope of aquaculture operations.

B.3.2 Mitigative Measures

B.3.2.1 Surface Water

Mitigation measures required to protect the surface water features at the site include diverting surface runoff away from disturbed areas, re-establishing vegetation on areas disturbed during construction, and providing sedimentation control measures to protect downstream watercourses.

Open-system CCW users, with the exception of aquaculture and fish and plant production for animal waste reclamation, will typically recycle the CCW back to the plant cooling system immediately after use. Discharges from aquaculture raceways, and if necessary from plant production beds, will be routed to holding ponds or other appropriate treatment facilities before return to the cooling system or discharge. There should be sufficient retention time in the ponds to ensure negligible park-induced thermal effects resulting from discharges. However, because specific discharge schemes cannot be specified at this time, each discharge (especially aquaculture applications) will be reviewed before construction for environmental effects on surface water. All users of waste heat will be encouraged to use resource recovery technology to conserve energy and plant nutrients in the interest of conservation.

B.3.2.2 Ground Water

Appropriate conditions will be included in easement agreements to assure the protection of ground water reserves from contamination or other adverse impacts. Careful selection of well locations with respect to springs should reduce impacts. Observation wells should be located to define the area where water level elevations are affected by ground-water withdrawals. Supply wells should be constructed a minimum distance of 2000 feet from the existing Watts Bar potable supply system to avoid pumpage interference.

TVA feels that a separation of 2000 feet is more than adequate to avoid pumpage interference between the nuclear plant wells and a 500 gal/min potable water supply for the waste heat park.

B.3.2.3 Water Quality

For the heat park, mitigation measures will either be required by the appropriate regulatory agency as a permit requirement or it will be a condition of agreements between the involved parties. At a minimum, all waste streams will have to be treated as dictated by applicable performance standards for that industry and/or water quality standards applicable to the receiving stream; all point source effluent streams will be controlled and monitored in accordance with a specific NPDES permit for that industry; and all point source effluents will be subject to use classifications and specific water quality criteria of the State of Tennessee. Also, any proposal for dredge or fill activities will be reviewed by the U.S. Army Corps of Engineers and certified by the Tennessee Division of Water Quality Control prior to the issuance of a dredge or fill permit by the Corps in accordance with Sections 401 and 404 of the Federal Water Pollution Control Act. The Corps review of the dredge or fill proposal is conducted in conformance with EPA's environmental guidelines for review of proposals regarding discharge of dredged or fill materials (40 CFR Part 230). Analogous to the State's issuance of an NPDES permit for a discharger, the State must certify that the proposed discharge of dredged or fill materials will not result in a violation of the water quality standards for the receiving stream.

Park Construction--Each park user, as well as the responsible organization for the central park, will be required to obtain an NPDES permit for their construction wastewater discharges. The same type of wastewater from several construction sites could be combined and handled as one point source or each facility could handle their waste separately. The following identifies the required mitigation for each constmuction impact identified in Section B.3.1.3. When appropriate, these can be made conditions of easement agreements.

1. During site preparation and project(s) construction, stormwater runoff will be managed by the use of best management practices, which are the most practical and effective measure or combination of measures which, when applied to the construction activity, will prevent or reduce the runoff of pollutants to a level compatible with the receiving stream water quality. Such measures

involve the staging of construction, the site-specific use of erosion prevention techniques, good housekeeping, holding ponds, diversion ditches, dikes, and other devices, which have been developed by the construction industry and which have been proven successful in limiting erosion and siltation losses to the aquatic environment.

2. Instream construction for water use facilities will be required for the raw water supply and discharge structures. However, such construction should not significantly impact the water quality of the river due to (a) the short-term and localized nature of the activity, (b) the river substrate being mostly gravel, thus minimizing the potential for release of metals and trace organics, and (c) the volume of water available for dispersion of sediments released by the construction activity. Also, if possible, dredging should be conducted during low flow periods, preferably during periods of no release from Watts Bar Dam.

3. Sanitary wastes generated by construction personnel will receive appropriate treatment to meet permit limitations. It is anticipated that the volume of these wastes will be very low (approximately 5,000 to 10,000 gpd); after treatment the residual oxygen demand will be very low and, hence, the river in the site vicinity should have sufficient assimilative capacity to handle this small increase in oxygen demand.

4. Concrete batch plant wastewater will be treated to meet appropriate permit limitations. The release of effluents meeting these limitations should have no significant impact on the water quality of the river in the site vicinity.

5. Chemical cleaning wastes from preoperational system cleaning will be treated by sedimentation and chemical treatment as appropriate to meet permit limitations. As discussed in Section A.3.3 of Appendix A, levels of metals in the river in the site vicinity are fairly low and, furthermore, the flow is quite substantial. Therefore, the discharge of effluent meeting permit limitations should have no significant impact on water quality.

6. Recyclable solid waste, such as scrap lumber and metals, will be sold or set out for public salvage. Other solid wastes generated during construction will be disposed of in a State-approved landfill. Problem or hazardous waste generated during construction will be handled in compliance with applicable solid or hazardous waste management procedures.

Central Park Facilities Operation--To mitigate the operational impacts identified in Section B.3.1.3 for the central park facilities, the following measures will be implemented as an easement condition by the organization responsible for the central park facilities:

1. Sanitary wastes (estimated at 10,000 to 30,000 gpd) will receive the necessary treatment to meet applicable NPDES permit limitations. Since the volume of this discharge will be

low and since required treatment will remove 85 to 90 percent of the oxygen-demanding pollutants from the effluent, the river with its limited assimilative capacity should be capable of assimilating this discharge.

2. Wastewater discharges from the backup and heat augmentation systems will be treated to meet applicable NPDES permit limitations. Treatment of the waste streams (fly ash, bottom ash, cooling tower blowdown, material storage runoff, metal cleaning wastes, boiler blowdown, and scrubber and low-volume wastes) from the two coal-fired units prior to discharge may include but not necessarily be limited to sedimentation, neutralization, coagulation, and precipitation. Based on the data summarized in Section A.3.3 of Appendix A, the relatively small size of the units, the intermittent operation of the units, and the volume and characteristics of the heated discharges, the impact on surface water quality from these units should not be significant. Solid waste from the units (fly ash, bottom ash, wastewater treatment sludges, and scrubber sludge) will be disposed of in a manner designed to protect the quality of the ground water. The ultimate design of the solid waste disposal systems will be subject to review by regulatory agencies acting under the authority of the Resource Conservation and Recovery Act (RCRA). Regulations pursuant to this act have not been fully promulgated. Office solid wastes will be disposed of in a State-approved landfill. A Spill Prevention Control and Countermeasures (SPCC) Plan will be prepared for <u>each</u> facility.

3. Stormwater runoff will be managed utilizing best management practices as previously defined for park construction with the necessary modifications for an operational facility.

4. Sludges from the treatment of potable and raw process water will be managed in a manner to protect the ground water. Sludge disposal areas will be lined if the characteristics of the sludge present the potential for generating leachates which could adversely impact the ground water.

<u>Park Users</u>--As discussed in Section B.3.1.3, only a few users are being assessed for surface and ground water quality impacts in this statement. Future studies and assessments will be conducted when a specific user proposes to locate in the park. The following describes the necessary mitigation for those users for which the impacts of their operation can be identified at this time.

1. <u>Greenhouses, Soil Warming, and Grain Drying</u>

   Protection of ground water from contamination by nutrients from the recyclable nutrient solution holding lagoon (hydroponic greenhouses) will be accomplished by the lining of the lagoon system. The soil warming operation will be conducted in a manner to minimize excessive applications of nutrients by performing soil tests to determine minimum nutrient requirements for adequate plant growth. Solid waste generated by these users will be disposed of in a State-approved landfill. Fungicide and pesticide drums, bags, and containers will be triple rinsed, with the rinse water used as makeup water, and also disposed of in the landfill. The management of solid waste will be in a manner consistent with applicable regulations.

Fuel storage areas will be lined and diked to sufficiently retain 110 percent of the capacity of the fuel tanks. SPCC plans will be prepared for the plant site(s).

2. Aquacultural Facilities

EPA in 1974 proposed "Best Available Technology Economically Achievable" (BATEA) effluent guidelines for existing facilities and "New Source Performance Standards" for Fish Hatcheries and Farms.[2] These guidelines and standards are listed in Table B.3-1. TVA pilot-scale waste treatment studies[3] at the Gallatin Steam Plant Catfish Project revealed that concentrations of oxygen-consuming pollutants in the treated effluent were low and that only concentrations of settleable solids and fecal coliform bacteria exceeded the proposed guidelines and standards. It is the opinion of TVA's technical staff that (1) sedimentation (minimum detention time of 15 minutes) and disinfection along with "good housekeeping practices," can result in a quality of effluent which will comply with the proposed guidelines and standards, and (2) the proposed guidelines and standards represent environmentally acceptable wastewater effluent limitations. Therefore, aquaculture facilities at the heat park will be required to meet the proposed standards listed in Table B.3-1 as a goal being that discharge of these levels will not result in an adverse impact on the water quality of Chickamauga Reservoir.

The State of Tennessee will be setting permit effluent limitations on the aquaculture facilities. If the permit limitations are less stringent than the proposed standards specified in Table B.3-1, the proposed industry will conduct an evaluation and make a determination of whether or not the more stringent requirements should be followed.

Solid waste (including pesticide containers) will be managed consistent with the procedure previously specified for greenhouses, soil warming, and grain drying. Sludge from the wastewater treatment system, after stabilization, could be utilized as fertilizer or soil conditioner.

3. Production of Concrete

Wastewater will be treated to meet NPDES new source permit limitations; discharge of the treated wastewater will not result in significant water quality impacts at the site. The sediments collected in the impoundment are inert and do not represent a threat to ground water. Solid waste will be disposed of in a State-approved landfill.

B.3 REFERENCES

1. Nuclear Regulatory Commission. Final Environmental Statement related to operation of Watts Bar Nuclear Plant Unit Nos. 1 and 2, Tennessee Valley Authority, Docket Nos. 50-390 and 50-391. December 1978.

2. Environmental Portection Agency, Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards for Fish Hatcheries and Farms, 1974.

3. TVA Power Research Staff, Utilization of Waste Heat from Power Plants for Aquaculture, Gallatin Catfish Project, 1974 Annual Report.

Table B.3-1

BATEA EFFLUENT LIMITATIONS GUIDELINES AND NEW SOURCE PERFORMANCE STANDARDS PROPOSED BY EPA FOR FISH HATCHERIES AND FARMS

	Daily Maximum	Daily Average	Maximum Instantaneous
Suspended Solids (lb/day/100 lb fish)	1.7	1.3	-
Setteable Solids (ml/l)	-	<0.1	0.2
Ammonia Nitrogen (lb/day/100 lb fish)	0.12	0.09	-
Fecal Coliform Bacteria (organisms/100 ml)	-	-	200

Source: Environmental Protection Agency, Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards for Fish Hatcheries and Farms, 1974.

B.4 HEALTH AND SAFETY

B.4.1 Noise

B.4.1.1 Construction and Operation Impacts

Temporary increases in nearby community sound levels will occur from construction work and from motor vehicle traffic. Sound levels will be highest during the ground clearing and earth moving phases and will decrease when structural work begins. These construction noises will be largely confined to the reservation although some construction sounds will occasionally be audible offsite.

Noise sources will include earthmoving equipment, trucks, power tools, and employee work vehicles. Significant amounts of rock drilling and blasting are not anticipated. As a consequence, park construction should have lesser offsite effect than construction at Watts Bar Nuclear Plant had.

Operational noise will originate from truck deliveries, employee work traffic, and processing equipment such as pumps, cooling and refrigerating systems, blowers, fans, and dryers. None of the prospective processes are inherently noisy. Although process sounds such as the ventilation for grain drying will occasionally be audible at offsite locations, most operational sounds are controllable and will be confined to the park reservation.

B.4.1.2 Mitigative Measures

Although there are no local or federal noise regulations applicable to the Watts Bar Waste Heat Park at this time, park users will be required by deed provision to be in compliance with any future noise control regulations. A maximum L_{eq} of 65 dB or less at the park boundary is considered to be acceptable at this time.

B.4.2 Radiological Considerations

B.4.2.1 Operation Impacts

Liquid Effluents--As noted in Section A.4.2.1 of Appendix A, the manner in which the heated water is obtained for the waste heat park should preclude the occurrence of radionuclides in water systems.

Gaseous Effluents--Impacts on the environment surrounding Watts Bar Nuclear Plant (WBN) will not be altered by the presence of the waste heat park. Gaseous effluents from WBN are not expected to impact significantly any of the products from the waste heat park.

Other--Potential environmental radiological impacts from one year's operation of a coal-fired heat augmentation boiler for the waste heat park have been assessed. Two sources of radiological emissions were evaluated: (1) particulate emissions from a stack with a release height of 100 meters and (2) fugitive dust emissions from a 30-day coal stockpile. Maximum individual doses from stack releases are predicted to occur at 2,000 meters in the NNE sector, where total body and bone doses are 0.8 and 1.3 mrem/yr, respectively. At 500 meters in the NNE sector, total body and bone doses due to fugitive dust emissions from the coal stockpile are 0.3 and 0.5 mrem/yr, respectively. Doses result from ingestion and inhalation of radioactive particulates. Doses from radon emissions and external radiation are negligible. Radionuclide concentrations in air at these exposure locations are five orders of magnitude less than the 10 CFR Part 20 non-occupational radionuclide air concentration limits used here as guidelines.

B.4.2.2 Radiological Impacts of Accidents

An evaluation has been conducted to assess the radiological impacts associated with various accident scenarios to the personnel involved in the construction and operation of the WBWHP. For these sectors the site boundary distance has been substituted with the shortest distance between the reactors and the inner perimeter of the waste heat park facility. Meteorology consists of χ/Q's for the following: eight-hour centerline at the site boundary locations; eight-hour sector-average values at the site boundary; and sixteen-hour sector-average values at downwind distances.

Results of this assessment are presented in Table B.4-1. The severity of the postulated accidents increases with the class number. Although the potential severity is increased, it should be noted that the probability of occurrence diminishes so that the environmental risk is extremely small. The impacts of the evaluated class accidents are all noted to be appreciably less than the limits specified in 10 CFR Section 20.3.

The principal pathways for potential effects from a transportation accident involving irradiated fuel arise from increased direct radiation levels and from gaseous releases of noble gases and iodines. The direct external radiation dose rate to a person 100 feet away from the road at the WBWHP would be less than 1 mrem per hour under accident conditions. Doses from a gaseous release to a person at the WBWHP are expected to be less than those evaluated for a person standing 50 feet from the cask during the entire accident in the direction of the prevailing wind. Such an individual was predicted to receive a wholebody dose of about 2 mrem, a skin dose of about 86 mrem, and a thyroid dose of about 5 rem.[2] In addition, the radiological impacts have been evaluated for an accident involving a shipment of tritiated water. The release of the entire contents of a 3,700-gallon container of tritiated water with a tritium concentration of 2.5 $\mu Ci/cm^3$ was predicted to result in a maximum dose of 260 mrem,[2] which is less than the annual dose limit to an individual of the general public based on 10 CFR Part 20[3] criteria.

Should there be a fire at the Onsite Storage Low Level Radwaste Facility involving one section of a storage module, resultant doses to WHP personnel would be within the dose criteria given in 10 CFR Part 20.

B.4.2.3 Mitigative Measures

Liquid and gaseous effluents from WBN are not expected to affect the products from the waste heat park. Product sampling will be conducted to confirm this expectation. Should this program reveal significant impacts from WBN to these products, measures will be implemented to restrict the production and use of the products as necessary.

B.4.3 Safety

B.4.3.1 Impacts

Several of the proposed park applications could involve workplace health and safety hazards. The use of pesticides in greenhouses, soil-warming areas, and aquaculture facilities could result in contamination from accidental spills or runoff. Agricultural uses such as grain drying and anaerobic digestion or industrial applications including soybean processing and distillation of industrial alcohol could present explosion hazards.

B.4.3.2 Mitigation

All the industries locating at the waste heat park will be subject to regulation by the Occupational Safety and Health Administration. To minimize impacts from accidental pesticide releases, pesticide users will follow applicable guidelines on storage, emergency planning, and recovery operations. Safety precautions for industrial processes with explosion potential will include prohibiting ignition sources nearby, using approved electrical equipment and procedures, providing proper ventilation, and establishing minimum distance requirements for locating those facilities.

As each potential user applies for park occupancy, TVA will evaluate process details and corresponding health and safety hazards.

B.4 REFERENCES

1. U.S. Nuclear Regulatory Commission, "Preparation of Environmental Reports for Nuclear Power Stations," Regulatory Guide 4.2, July 1976.

2. Tennessee Valley Authority, Environmental Statement on the Watts Bar Nuclear Plant Units 1 and 2, November 1972; Section 2.1 and Appendix A.

3. Code of Federal Regulations, Title 10 Part 20, "Standards for Protection Against Radiation."

Table B.4-1

SUMMARY OF RADIOLOGICAL CONSEQUENCES OF POSTULATED ACCIDENTS AT SITE BOUNDARY[1]

LOCATIONS

Accident Class	Event	Individual Total Body Doses[2] (mrem)	Fraction of 10CFR20 Guideline[3]
3.0	Radwaste System Failure	25	0.051
5.2	Off Design Transients	0.2	0.0004
5.3	Steam Generator Tube Rupture	1.6	0.0032
7.1	Fuel Assembly Drop	0.1	0.0002
7.2	Heavy Object Drop Onto Fuel Rack	0.08	0.0001
7.3	Fuel Cask Drop	0.001	0.000002
8.1	Small Loca	0.017	0.00003
8.1	Large Loca	12	0.023
8.2	Rod Ejection	1.2	0.0024
8.3	Steamline Break - Small	0.002	0.000004
8.3	Steamline Break - Large	0.002	0.000004

1. The site boundary is considered to be 1,200m with the following exceptions: 625m for the SSE sector; 640m for the S sector; 610m for the SSW sector; 580 for the SW, W, and WNW sectors; and 670m for the WSW sector.

2. Total body doses are assumed to result from external gamma exposure.

3. The 10 CFR Part 20 limit for total-body exposure to an individual in the general public is 500 mrem/yr.

B.5 TERRESTRIAL ECOLOGY

B.5.1 Construction Impacts

The development of the proposed waste heat utilization facility could eventually result in clearing or alteration of approximately 400 acres of terrestrial habitat, much of which was previously disturbed by nuclear plant construction.

Removal or disruption of early successional, riparian, and wooded areas would have an adverse impact on species dependent upon these habitats for food and cover requirements. Some species, tolerant of disturbance, would continue to inhabit the area, however, in reduced numbers.

Most mobile organisms such as birds and larger mammals will vacate the site during construction or disturbance. Because of the phenomena of habitat-carrying capacity and territoriality in many species, most displaced animals will perish unless they can find suitable underpopulated habitats nearby. Most established populations exist at or near carrying capacity of the habitat. An intrusion of additional animals would probably place the population above the carrying capacity, resulting in depletion of food and cover and an eventual reduction of numbers. Less mobile organisms would be destroyed onsite as the land is cleared and prepared for construction.

Construction and development activities in the open field areas would have maximal impact on resident species having small home ranges and may adversely affect foraging habitat available to white-tail deer. Depending upon the nature and type of waste heat development on the western portion of the site, construction of facilities could have an adverse impact on the adjacent Tennessee Wildlife Resources Agency, Yellow Creek Wildlife Management Area. Construction activities would produce noise and disturbances adversely affecting both wildlife and users of the management area. Migrant-wintering waterfowl and other wetlands wildlife species may avoid the area during these activities. Large buildings or facilities adjacent to the management area boundary would also create a visual obstruction to management area users.

B.5.2 Operation Impacts

To the extent that operation of the facility produces noise and visual disturbances to the area, wildlife and visitor use at the adjacent Yellow Creek Wildlife Management Area could be affected.

B.5.3 Mitigative Measures

A condition of the easement agreement between TVA and park management will provide for the establishment of a buffer zone of riparian vegetation between the waste heat park and Yellow Creek to preserve existing habitats and isolate the Yellow Creek Wildlife Management area from the waste heat park.

B.6 AQUATIC ECOLOGY

B.6.1 Construction-Associated Impacts

Construction of the proposed waste heat park will result in limited instream construction activity and site runoff. Primary concerns would be the introduction of large quantities of suspended solids and physical habitat disruptions which could cause mortality to immobile benthic forms (including endangered mussel species). Therefore, whenever instream construction is anticipated, current specific information will be aquired to assess impacts and prescribe appropriate mitigation. Likewise, discharge of suspended solids will also be carefully evaluated. Isom[1] and others have identified the importance of continuing sediment accumulation as a major factor in restricting the extent of suitable mussel habitat. The fauna in this reach is represented by taxa which generally cannot tolerate sediment-laden waters nor significant silt deposition over the substrate.

Regulatory evaluation of potential effects on aquatic organisms due to the construction of water use facilities (including maintenance dredging) is the responsibility of the State of Tennessee and the U.S. Army Corps of Engineers, with the concurrence of EPA, and would be performed in accordance with Sections 401 and 404 of the Clean Water Act. Possible instream construction activities were addressed to facilitate Section 10/404 permitting by the U.S. Army Corps of Engineers. This discussion is included in the EIS as Appendix D. Such construction will also be subject to additional TVA review under section 26a of the TVA Act.

B.6.2 Operational Impacts

Agricultural Applications--Process wastewater from the hydroponic greenhouses will contain nutrients (nitrogen and phosphorous) and suspended solids, and may have a biological oxygen demand (BOD). As necessary this water will be routed to evaporation lagoons which will have no discharge and, therefore, no impact on the aquatic organisms inhabiting Yellow Creek or the Tennessee River.

The condenser cooling water used for space heating in the hydroponic and conventional greenhouses will be altered only as a result of the heat exchange process. This will cause a slight concentration of total dissolved solids similar to the effect expected if the water had passed through the cooling towers. This water will be routed back to the cooling system and will not be discharged, except as eventual cooling tower blowdown.

Waste heat used for soil warming will not involve contact with the soil and will result in impacts as described for the space heating of the hydroponic greenhouses. Irrigation and stormwater runoff will contain nutrients, suspended solids, and dissolved solids. Implementation of best engineering practices to control suspended solids and avoidance of discharge to unique areas will preclude significant impact.

Aquaculture Applications--The CCW will be directly used for raising fish for commercial sale as described in Section 4.2. Wastewater from this facility will contain suspended and settleable solids, nutrients (nitrogen and phosphorous), fecal coliform bacteria and could have significant chemical and biological oxygen demand before treatment.

Because the Watts Bar Dam tailwater area currently contains very low concentrations of dissolved oxygen, waste streams from the park which would further reduce the instream oxygen concentrations should not be released. There has been a decline in the number of mussels per square meter in the Watts Bar Dam tailwater (TVA 1980) and the periodic low dissolved oxygen concentrations which occur in the river only aggravate the problem. Restriction of the oxygen-demanding wastes is particularly important in view of the endangered species. Applicants proposing to discharge oxygen-demanding wastes will conduct studies as appropriate to determine the quantity of oxygen-demanding waste which can be discharged without further depression of instream dissolved oxygen concentrations. As appropriate, subsequent studies may be required to evaluate effectiveness of treatment to protect instream resources. This information will be used by TVA in the evaluation of park applicants and will also be available for use by appropriate regulatory agencies.

Assessment of the potential effects of chlorination of the discharge from the aquaculture facility, as well as from any other applications, will be addressed when individual design criteria and operational procedures are proposed and when they are implemented.

A potential fishery impact resulting from operation of the WBWHP will be the additional raw water intake of 1.9 m^3/s (30,000 gpm). Estimated yearly larval fish entrainment for WBNP ranged from 0.5 to 1.5 percent of the total transported population for the four years sampled. Average total yearly entrainment for that period was 1 percent of the total transported population. These estimates were made based on an estimated makeup water intake of 3.5 m^3/s (125 cfs). Operation of the Waste Heat Park would have the potential to double this entrainment estimate, resulting in a potential entrainment of 3 percent of the total transported population. Analysis of the most recent samples collected at Watts Bar Nuclear Plant indicated that 75 percent of the total transported population consisted of Clupeids and 4.5 percent game species (Percichthyids, Centrarchids, and Percids). TVA will continue to review data as it becomes available, and will ensure the protection of fishery resources (including mussels).

Industrial Applications--Impacts that might be associated with instream construction activities or with the discharge of oxygen-demanding wastes have been discussed above. Other industrial effluent components are often product- and company-dependent, and because no specific industrial applications have been identified, specific waste stream characterization data is unavailable. The potential for cumulative aquatic impacts compounds TVA's inability to provide specific assessments at this time, and further accentuates the need for future evaluation. Each application for operation within the waste heat park will be reviewed by TVA to ensure that significant negative impacts to aquatic organisms will not occur. Following its independent review, TVA will cooperate with the State of Tennessee, the U.S. Army Corps of Engineers, and the U.S. Environmental Protection Agency in an attempt to further ensure that park occupants are compatible with the maintenance or enhancement of a balanced indigenous aquatic community and with the fish and wildlife management goals of the citizenry of the Tennessee Valley.

In the event of an accidental chemical spill, the extent of harm to aquatic organisms would be dependent upon the nature and volume of the spilled material, as well as the nature and expediency of cleanup procedures. Development and implementation of a comprehensive SPCC Plan, in accordance with Federal regulations will be required.

B.6.3 Mitigative Actions

When specific uses are identified, TVA will assess plans for construction and operations under NEPA and TVA's implementing procedures, and if necessary place conditions in easements to ensure protection of public health and safety, the environment, and other interests of the United States. Examples of the types of mitigative actions which may be necessary include the following: Routing all stormwater runoff (construction and operational) to a sedimentation pond or other appropriate treatment facility before discharge; development of an Erosion and Sedimentation Control Plan (ESCP) for the site, to include use of defined best management practices; insurance that wastewaters are not discharged in the immediate vicinity of identifiably unique or productive areas; relocating riverbed construction activities to avoid productive or unique areas including the mussel areas discussed in Section A.6; avoiding major instream construction activity (depending on the nature and location) during the fishery spawning season, March to August; discharging certain process wastewater to evaporation lagoons, which will have no discharge; and development of a comprehensive SPCC plan to avoid potential adverse spill impacts.

As raw water needs are anticipated and defined, TVA will review current ecological data and ensure installation as necessary of what is determined necessary for the protection of fishery resources (including mussels). Likewise TVA will ensure through a NEPA review that instream activities are evaluated against current instream data, and designed to minimize impacts to productive or unique areas.

All process wastewaters will be treated to comply with applicable performance standards, as well as water quality criteria and/or levels commensurate with assimilative capacity of the receiving water body. All wastewater streams will be evaluated and appropriate conditions applied to ensure that instream dissolved oxygen levels are not further depressed and that waste stream components do not otherwise adversely impact the propagation of aquatic life. Bioassay procedures and/or instream monitoring may be required as appropriate (commensurate with potential impacts) to facilitate assessments and subsequently design mitigative measures.

B.6 REFERENCES

1. Isom, Billy G. 1979. The Mussel Resource of the Tennessee River. Malacologia. 7(1-3): 197-425.

2. Watts Bar Nuclear Plant Preoperational Aquatic Monitoring Report, 1973-1977. Prepared by R. D. Harned, C. E. Mulkey, W. J. Pardue, and E. B. Robertson. TVA, Division of Water Resources, April 1980.

B.7 ENDANGERED OR THREATENED SPECIES

B.7.1 Construction Impacts

B.7.1.1 Aquatic Invertebrates and Fish

Construction of the waste heat park will result in some site runoff, and limited instream activities. Primary concerns would be the introduction of large quantities of suspended solids and physical habitat disruptions. Refer to Section B.6.1 for a more complete discussion.

B.7.1.2 Terrestrial Wildlife

If large trees found along Watts Bar Reservoir are left undisturbed, loss of habitat for the bald eagle and osprey should be minimal. No significant impacts to local gray bat, small-footed myotis, and Tennessee cave salamander populations are expected during or following construction activites.

Disruption of wetlands on the site will result in some loss of foraging habitat for a variety of waterfowl species, e.g., the great-blue heron, sandhill crane, and red-shouldered hawk. Alteration of hayfields, revegetated borrow areas, and brushy fields will result in habitat loss for local populations of the marsh hawk, grasshopper sparrow, green anole, six-lined racerunner, and northern pine snake. The continued existence of tracts of these early successional habitats on the site during the construction activities should reduce the detrimental impacts to these species.

If proper water quality control measures are used, there should be no significant impacts to populations of the Cumberland turtle in Watts Bar Reservoir.

B.7.2 Operation Impacts

Impacts similar to those listed for nonfishery resources in Section B.6.2 could be expected for the endangered mussel species. As indicated, particular attention will be paid to the potential effects of anticipated discharges or instream activities on resident commercial and endangered species of mussels.

Future bald eagle and osprey nesting activity in the area of the project could be negatively impacted if local noise levels are too high.

B.7.3 Mitigative Measures

B.7.3.1 Aquatic Species

When specific activities are proposed for the waste heat park, they will be reviewed by TVA under NEPA and TVA's inplementing procedures, and if necessary, conditions will be placed in easements to ensure the protection of threatened or endangered species as specified in Section B.6.

B.7.3.2 Terrestrial Species

A condition of the easement agreement between TVA and park management will provide for the establishment of a buffer zone of riparian vegetation between the waste heat park and Yellow Creek to preserve existing habitats and isolate the Yellow Creek Wildlife Management area from the waste heat park.

B.7.4 Conclusions

Based on the information presented in Section A.7 and the mitigative measures proposed in Sections B.7.3.1 and B.7.3.2, the development of the proposed Watts Bar Waste Heat Park should not jeopardize the continued existence of any Federally proposed or listed endangered or threatened species nor inhibit opportunities for the recovery of such forms at the regional or national level.

B.7 REFERENCES

1. Isom, Billy G. 1979. The Mussel Resource of the Tennessee River, Malacologia. 7(1-3): 197-425.

B.8 LAND USE

B.8.1 Local Impacts

The land use changes proposed are consistent with the Rhea County land use plan and therefore the only consequences will be the potential preclusion, relocation, or greater controls of other uses considered for the reservation. Considering current plans, the location of a waste heat park at this site will allow TVA to maximize the land use potential of this property.

B.8.2 Recreation Impacts

There are no existing or proposed recreational facilities located within the confines of the proposed waste heat industrial park. Therefore, there will be no direct construction impacts on recreational facilities. Potential effects on recreational hunting at Yellow Creek Wildlife Management Area are discussed in Section B.5.

There will be no foreseen recreational impacts requiring mitigative measures (see Section B.5).

B.8.3 Mitigative Measures

None are required (see Section B.5).

B.9 SOCIOECONOMICS

Development of the waste heat park will result in the employment of people to construct the facilities, operate the greenhouse and aquaculture facilities, and fill the new manufacturing jobs. Possible impacts associated with the development of the waste heat park are discussed in the following sections.

B.9.1 Construction Impacts

The construction manpower required to lay the pipes and build the infrastructure and buildings will be temporary employment and will occur in stages. The peak employment for park development will be about 200 workers. Individual industry construction may require more. The skills needed in these jobs are available in the local labor force and therefore no population increase caused by inmoving workers are expected. The availability of labor is illustrated by the fact that approximately 70 percent of the peak construction work force of 3400 (2400 workers) at the Watts Bar Nuclear Plant was within commuting distance according to TVA construction employee surveys. In addition, employment at the plant is declining. Therefore, it is reasonable to assume that the significantly smaller labor requirements for the waste heat park could be filled locally and that the number of inmoving workers would be insignificant.

B.9.2 Operation Impacts

Operation of the greenhouse and aquaculture facilities is expected to employ 500 to 800 people in field project development. The majority of skills necessary to carry out these jobs are available locally and therefore little population increase caused by inmoving workers is expected. The industrial component of the park is estimated to employ from 300-500 persons under full development conditions. These estimates are based on typical employment levels associated with the most likely candidate waste heat users. Skills associated with the potential waste heat park industries are available locally or within reasonable commuting range. The wage rates for these jobs are generally equal to or greater than those found in the labor shed around Watts Bar. As a result few inmovers are expected to fill jobs created by new manufacturing opportunities associated with the park.

B.9.3 Mitigative Measures

If large numbers of inmover workers were required, additional burdens on schools, roads, and public utilities could result. However, since most of the jobs needed to construct and operate the park are expected to be filled by local residents or commuters, no stress on community support facilities is anticipated. Further, as a result of the Watts Bar Nuclear Plant construction, the local economy was stimulated by the creation of new jobs and the influx of construction workers associated with the project. At peak construction in 1977, the total population influx (workers and dependents) in the nearby counties resulting from nuclear plant construction totaled approximately 2700 persons. Any influx associated with the waste heat park would be significantly less than that for the nuclear plant. Growth in the housing industry and expansion of local services have been adequate to accommodate the population influx associated with construction of the nuclear plant. The construction work force at the nuclear plant is declining and, as a result, there are sufficient community services and facilities to accommodate the smaller work force projected for the waste heat park.

B.10 AESTHETICS

B.10.1 Construction Impacts

Activities associated with land preparation and construction of project facilities will create highly evident visual effects, but as noted in Section A.10 of Appendix A, the site is within an existing industrial landscape. Thus, construction-related aesthetic impacts should not represent significant adverse aesthetic impacts to visitors, boaters, motorists, or others who view the site.

B.10.2 Operation Impacts

The design of the industrial structures and associated landscaping will determine the primary aesthetic impact from operation of the project. As noted in Section A.10 of Appendix A, the site is within an existing industrial landscape and its development should not represent an adverse visual impact. (Odor and noise considerations are discussed in Sections B.2 and B.4.)

B.10.3 Mitigative Measures

The overall plant layout is located on a river terrace overlooking Chickamauga Lake and surrounded by steep, wooded slopes which already offer some degree of visual screening. Proper landscaping and facility design should combine to provide adequate mitigative measures with respect to visual aesthetic concerns.

B.11 CULTURAL RESOURCES

B.11.1 Impacts

One cultural resource, archaeological site 40RH64, has been determined by both GAI Consultants, Inc., and TVA to be eligible for the National Register of Historic Places. No site alteration activities are currently planned which would impact this resource.

B.11.2 Mitigation

TVA will submit eligibility determination data for 40RH64 to the Tennessee State Historic Preservation Officer. In accordance with procedures in 36 CFR Part 800, TVA will either avoid adverse impacts on the site through preservation or develop and implement a research design for excavation which will satisfactorily mitigate any adverse impact on the site by project construction or operation. Any mitigation plan would be conducted under a memorandum of agreement between TVA and the Advisory Council on Historic Preservation with the concurrence of the Tennessee State Historic Preservation Officer.

B.12 FLOODPLAINS AND WETLANDS

B.12.1 Construction and Operation Impacts - Floodplains

No construction of permanent structures will be permitted below the 1-percent-chance flood elevation (697'), and none where flood damage would be significant or impact TVA reservoir operations below the TVA structure profile elevation. The only facilities to be placed within the 1-percent-chance floodplain (base floodplain) are the open-field soil warming area, aquaculture retention ponds, and necessary support facilities such as roads, parking areas, and utilities, none of which are critical actions for which flood risks must be kept to a minimum nor are incompatible with TVA restrictions for reservoir shoreline development as required for effective operation of the reservoir system. Erosion may be temporarily increased during the construction of these facilities and during cultivation of the soil-warming plot, but since much of these areas have been extensively disturbed for borrow material for the nuclear plant, these uses may provide a stabilizing effect over the long term. Some fill material may be placed in the floodplains during site grading. Risk of flooding upstream on Yellow Creek is not expected to be increased due to the construction of dikes for the retention ponds because the dikes will be less than 1 m (3 ft) high. Existing floodplain values such as natural, cultural, or water resources are not expected to be significantly altered. Some floodplain values may be restored or enhanced by the reclamation of previously disturbed borrow areas. Cultivated resource values will be enhanced by the aquacultural and agricultural uses.

Storm runoff from the three intermittent drainageways that flow through the site will be controlled by site grading and will present no flooding hazard to the park facilities. Development of noncritical actions within the base floodplain allows the utilization of land which has been removed from production or land which is under other restrictions such as transmission rights-of-way.

B.12.2 Mitigative Measures - Floodplains

B.12.2.1 Alternatives to Floodplain Development

No Action--Restricting all development to elevations above the base floodplain or the TVA structure profile would preclude much of the park site from being developed. For an adequate demonstration of a large-scale, multiple-use complex, additional land outside the reservation boundary would have to be acquired. This would remove the waste heat park from the source of waste heat and would result in the following: additional impacts to land presently in agricultural production; increased pumping of waste heat water to supplement the gravity flow now planned; additional thermal losses of waste heat due to longer transmission; and additional costs for piping, land acquisition, and site preparation in steeper terrain. The no-action alternative would essentially remove all the benefits of the demonstration of waste heat utilization at this site and is not deemed practical.

Alternative Sites--Because a waste heat park must be near the source of waste heat, alternative sites are limited to areas adjacent to generating plants, all of which would have floodplain impacts similar to those at Watts Bar. Because of other conditions identified in Section 2.2, these alternatives were eliminated from consideration as impractical for the initial large-scale waste heat park demonstration.

Because no other practicable alternatives exist and because impacts to the floodplain and to facilities from this type of development will be minimal, the construction of the proposed soil warming area and aquaculture retention facilities within the base floodplain is acceptable.

B.12.2.2 Other Mitigation

Impacts to the 1-percent-chance floodplain (base floodplain) will be avoided or adjusted to by (1) reducing the hazard and the risk of flood loss, (2) minimizing the impact of floods on human safety, health, and welfare, and (3) restoring and preserving the natural and beneficial floodplain values when practical. For those activities for which a 1-percent chance of flooding would be too great (critical action), location of facilities will be above the TVA structure profile.

The use of resources and the construction of facilities and structures will be consistent with the flood hazard involved. Because none of the activities proposed for the base floodplain constitute critical actions, other mitigative measures which can be considered include structure elevation or protection; planting crops or cover vegetation on soil-warming areas and pond dikes; and planning and conducting park construction activities to minimize land erosion, siltation, and river turbidity. Normal site grading will protect park structures and facilities from storm runoff from the three existing intermittent drainageways. Construction will be in accordance with the standards and criteria of the National Flood Insurance Program and TVA restrictions for reservoir shoreline development as required for the effective operation of the reservoir system.

B.12.3 Construction and Operation Impacts - Wetlands

Siting and construction of specific facilities will be evaluated when proposed to assure they are consistent with TVA policy on protection of wetlands. Wetlands identified on the site will be avoided in the location of structures and facilities, fill, or drainage systems. Other site locations are deemed impractical based on the considerations outlined above for floodplain siting.

B.12.4 Mitigative Measures - Wetlands

Mitigative measures to protect wetlands on the site will be commensurate with the significance of the wetland identified, and could include leaving or establishing a wooded buffer strip around wetlands of major importance. If, in the evaluation of specific development proposals, it should be determined that no practicable alternative exists to wetlands alteration, appropriate measures to minimize harm to affected wetlands would be consistent with TVA's policy on wetland protection.

APPENDIX C

STEAMFLOW DATA

TABLE C-1

WATTS BAR DAM MONTHLY DISCHARGES

Calendar Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
	Monthly and Yearly Discharges in Cubic Feet Per Second												
1945	30,431	36,996	36,810	22,560	21,702	20,464	20,299	23,197	22,647	19,486	17,893	45,700	26,515
46	71,496	61,953	28,402	15,231	17,830	17,260	20,326	22,899	22,799	24,569	23,880	24,487	29,096
47	63,749	34,364	27,826	19,340	20,038	16,043	14,926	15,884	16,647	15,822	20,386	23,554	24,036
48	22,510	47,317	32,524	22,758	20,605	20,692	16,631	17,767	20,185	20,442	24,826	51,009	26,372
49	59,784	38,539	25,675	19,937	19,442	18,057	29,773	31,002	33,167	31,467	39,817	52,922	33,302
1950	51,490	96,920	37,546	23,267	20,545	19,667	17,842	22,133	24,205	30,844	32,633	38,589	34,235
51	31,759	42,287	35,408	24,400	21,650	20,660	17,730	22,050	20,860	23,490	20,310	56,790	28,073
52	38,460	37,890	35,760	19,050	14,160	16,940	18,620	16,970	16,320	17,910	14,780	22,990	22,466
53	24,980	42,010	32,250	21,960	19,040	22,400	19,170	21,420	16,720	14,810	14,830	17,830	22,161
54	43,790	22,860	25,590	16,810	17,120	19,060	20,550	18,460	15,890	12,200	13,750	19,410	20,481
1955	26,810	23,830	44,840	19,560	19,350	21,980	21,870	25,090	21,890	19,930	20,350	19,650	23,792
56	15,180	43,820	34,900	24,230	18,580	18,050	19,500	22,230	24,310	22,660	25,030	29,550	24,750
57	35,700	105,190	31,390	24,960	22,610	21,030	18,240	20,970	21,220	26,290	48,830	64,980	36,306
58	36,550	33,920	22,920	19,300	40,810	32,700	21,290	27,620	29,090	28,340	23,070	18,110	27,780
59	26,130	21,810	21,740	13,200	14,490	15,540	17,920	18,560	20,530	31,480	34,050	49,090	23,760
1960	35,830	31,630	28,570	20,890	15,970	20,890	18,930	22,200	33,340	24,670	26,050	23,320	25,154
61	21,884	29,943	49,026	18,797	20,032	20,243	26,239	30,787	29,947	26,729	25,020	54,832	29,518
62	53,988	61,807	66,448	29,836	25,616	22,117	26,077	21,194	20,440	22,800	26,273	29,600	33,720
63	24,906	27,504	75,623	22,490	17,748	15,630	15,100	20,390	23,263	23,371	18,713	19,097	25,360
64	23,258	24,438	36,274	26,854	23,868	25,170	18,752	19,329	22,550	27,655	34,953	38,290	26,790
1965	38,464	28,929	34,684	30,473	21,845	17,050	24,145	26,848	23,510	25,013	26,550	19,877	26,450
66	17,332	28,272	18,735	12,637	15,113	17,203	19,306	31,935	25,117	20,971	30,510	40,955	23,150
67	32,355	30,050	39,881	11,803	11,061	25,283	32,820	32,845	36,917	34,019	35,903	61,971	32,140
68	60,929	25,786	14,997	9,307	10,335	23,350	28,297	31,416	10,070	19,177	22,950	20,758	23,180
69	19,650	37,320	16,920	10,650	15,660	20,070	22,390	20,670	17,930	21,490	24,040	28,580	21,180
1970	40,000	30,180	21,550	20,820	18,300	18,570	22,680	25,600	22,880	15,520	23,300	20,390	23,280
71	24,460	39,300	25,990	13,450	25,830	27,080	21,290	29,580	24,280	27,000	37,000	41,320	27,990
72	55,970	41,530	34,750	21,020	28,400	27,550	26,970	29,510	26,360	31,860	41,840	78,240	37,060
73	47,910	40,170	55,720	27,730	48,940	45,230	28,590	33,400	25,460	20,860	30,320	51,690	38,040
74	103,370	74,260	41,230	38,990	31,160	30,660	30,300	31,980	25,900	24,730	25,200	33,560	40,790
1975	49,460	62,900	69,980	48,980	28,090	31,750	32,760	28,670	20,530	18,300	27,300	27,370	37,020
76	36,620	28,280	21,930	14,480	14,470	23,390	26,640	29,340	21,900	25,300	25,430	34,240	25,190
77	34,590	20,100	22,590	48,560	25,570	27,130	25,330	22,650	22,630	25,680	47,670	63,750	32,188
78	53,110	40,750	28,090	17,440	15,450	21,210	22,790	29,510	24,850	13,790	13,450	28,210	25,670
Average	39,790	40,970	34,600	22,110	21,220	22,360	22,470	24,830	23,070	23,190	26,970	36,780	27,370

TABLE C-2

CHICKAMAUGA DAM MONTHLY DISCHARGES

Calendar Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
	Monthly and Yearly Discharge in Cubic Feet Per Second												
1945	35,910	47,332	42,814	23,399	29,864	24,596	24,706	27,648	27,713	24,813	22,781	56,087	32,305
46	91,305	81,533	37,207	21,326	29,493	24,664	25,965	29,067	31,032	30,677	30,727	32,099	38,536
47	86,972	44,371	36,868	21,479	25,469	21,730	20,026	21,419	21,900	19,642	25,773	28,777	31,187
48	27,793	63,444	43,190	27,916	25,821	24,492	20,864	23,301	25,459	25,643	36,240	69,581	34,360
49	80,699	53,057	34,446	25,915	28,270	23,563	40,231	38,116	41,257	41,347	51,492	64,987	43,630
1950	67,335	112,480	52,611	28,631	26,414	27,000	25,710	30,230	35,843	38,608	39,357	49,299	44,030
51	40,575	55,625	48,904	33,030	27,050	26,790	23,880	27,130	26,690	28,960	28,920	71,970	36,555
52	51,010	48,280	51,670	23,310	19,720	23,590	23,880	23,310	20,950	23,600	19,260	28,780	29,768
53	34,170	55,360	41,980	23,400	27,620	26,360	24,210	25,650	21,430	18,010	18,210	23,070	28,131
54	60,460	29,100	33,070	19,240	22,300	24,570	24,210	22,900	19,390	15,580	17,000	24,230	26,045
1955	34,600	34,620	53,290	26,830	25,670	28,830	28,540	31,620	24,790	25,710	26,100	25,720	30,534
56	19,350	59,300	44,420	29,850	23,810	22,440	24,680	27,530	28,710	26,730	29,830	36,670	30,993
57	42,910	123,620	37,880	32,480	29,450	28,750	24,060	25,570	30,520	34,320	65,470	74,740	45,247
58	43,940	42,140	32,410	24,230	50,060	38,440	28,710	32,710	34,470	34,480	28,680	22,040	34,327
59	31,970	27,790	27,100	18,470	18,560	19,540	23,120	22,520	24,970	36,130	38,670	58,600	29,001
1960	42,230	40,760	38,000	22,710	20,140	25,120	22,750	27,920	38,810	31,400	32,950	29,840	31,014
61	27,765	42,335	62,919	22,460	25,306	27,333	33,371	37,016	34,853	32,890	30,707	71,539	37,427
62	64,919	76,186	76,816	37,220	30,929	28,743	31,203	26,503	23,090	27,529	32,490	34,248	40,640
63	31,761	34,693	92,439	23,887	25,461	20,670	23,003	25,619	26,100	27,877	23,357	23,539	31,600
64	33,303	34,438	52,036	42,370	34,500	31,613	25,616	26,084	27,850	35,500	41,520	47,600	36,040
1965	45,909	38,014	49,206	36,584	27,871	22,607	28,732	30,465	27,383	30,287	31,840	23,548	32,700
66	21,661	37,654	25,352	13,067	21,513	20,483	22,945	36,148	30,153	29,452	39,577	48,078	28,800
67	40,142	38,589	45,855	12,063	17,039	31,900	46,000	41,942	43,123	40,506	47,484	79,319	40,420
68	74,025	31,348	21,216	11,383	14,855	27,557	32,265	34,655	12,583	24,323	28,040	25,713	28,240
69	26,570	51,250	22,610	13,020	20,010	24,290	26,320	25,080	22,750	27,580	29,780	34,300	26,810
1970	48,870	36,820	26,480	25,450	21,350	22,530	26,850	28,890	26,870	21,230	29,160	25,860	28,320
71	32,400	51,270	34,420	15,650	29,400	29,650	26,160	35,640	28,450	32,410	41,410	49,380	33,770
72	70,490	48,780	42,630	23,770	34,340	32,060	31,060	33,800	29,260	37,390	47,800	91,480	43,660
73	57,740	49,160	73,050	32,980	56,870	54,230	35,330	39,050	30,110	26,750	37,830	64,760	46,550
74	121,500	90,580	48,620	44,760	35,960	34,990	35,370	36,110	28,800	28,190	29,550	38,400	47,530
1975	58,200	74,290	80,870	57,000	32,780	35,350	36,380	31,730	26,110	26,110	35,120	35,790	43,960
76	46,500	36,300	26,750	18,440	19,100	29,980	34,080	33,340	24,980	29,700	29,810	40,100	30,780
77	41,190	23,370	30,020	56,950	29,400	30,430	28,800	26,150	29,880	33,000	59,020	72,470	38,390
78	64,990	46,670	34,250	17,870	20,700	24,960	25,140	33,790	27,990	17,470	16,450	32,070	30,150
Average	49,980	51,870	44,160	26,680	27,270	27,630	28,060	29,960	28,070	28,940	33,600	44,195	35,040

Table C-3

WATTS BAR DAM
AVERAGE AND DAILY MAXIMUM AND MINIMUM FLOWS (cfs)
1945 - 1978

Year	Average Flow	Maximum Day	Minimum Day
1945	26,515	81,818	5,238
46	29,096	139,008	0
47	24,036	113,870	469
48	26,372	175,396	1,979
49	33,302	109,722	3,162
1950	34,235	144,907	600
51	28,073	107,300	6,400
52	22,466	76,100	5,900
53	22,161	65,500	700
54	20,481	120,900	600
1955	23,792	95,900	300
56	24,750	97,700	2,500
57	36,306	156,600	7,100
58	27,760	68,600	2,200
59	43,100	23,760	0
1960	25,154	46,300	3,600
61	29,518	136,000	5,900
62	33,720	131.600	5,500
63	25,360	161,300	100
64	26,790	73,500	1,100
1965	26,450	123,900	5,700
66	23,150	72,000	0
67	32,140	105,800	1,900
68	23,180	96,000	1,300
69	21,180	157,200	0
1970	23,280	133,500	3,200
71	27,990	59,900	2,000
72	37,060	135,600	7,600
73	38,040	180,400	7,700
74	40,790	142,700	10,300
1975	37,020	135,800	5,500
76	25,190	45,400	6,300
77	32,240	161,200	9,900
78	25,670	79,500	7,500

Table C-4

CHICKAMAUGA DAM
AVERAGE AND DAILY MAXIMUM AND MINIMUM FLOWS (cfs)
1945 - 1978

Year	Average Flow	Maximum Day	Minimum Day
1945	32,305	97,990	11,783
46	38,536	191,726	17,741
47	31,187	156,545	12,010
48	34,360	179,212	16,492
49	43,630	148,585	16,224
1950	44,030	164,976	17,221
51	36,555	127,100	13,200
52	29,768	109,300	5,700
53	28,131	95,400	5,300
54	26,045	166,100	3,600
1955	30,534	107,600	5,900
56	30,993	143,800	4,900
57	45,247	182,000	8,900
58	34,327	100,400	6,000
59	29,001	102,700	3,000
1960	31,014	70,200	8,700
61	37,427	157,700	6,700
62	40,640	162,700	3,300
63	31,600	199,200	6,400
64	36,040	101,300	10,100
1965	32,700	149,100	9,600
66	28,800	94,700	3,200
67	40,420	129,500	1,700
68	28,240	125,700	0
69	26,810	155,700	3,700
1970	28,320	159,200	4,300
71	33,770	76,800	4,700
72	43,660	145,600	8,200
73	46,550	219,000	7,700
74	47,530	151,000	5,300
1975	43,960	134,300	8,200
76	30,780	55,800	7,900
77	38,460	148,500	8,500
78	30,150	99,600	9,300

Table C-7

WATTS BAR DAM TAILWATER

RANGE IN WATER-LEVEL FLUCTUATIONS

CALENDAR YEAR 1976

Month	Maximum Daily Fluctuations		Minimum Daily Fluctuations	
	Feet	Date	Feet	Date
January	5.84	26	0.07	7
February	6.17	7	3.26	4
March	6.46	13	0.77	28
April	4.41	5	1.10	18
May	2.80	4	0.53	12
June	2.83	17	1.22	6
July	2.88	23, 24	0.61	25
August	3.84	2	0.98	7
September	3.23	4	0.81	17
October	2.87	17	0.31	30
November	5.04	24	0.90	1
December	5.92	29	1.02	14

DAY	JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE	
	RESERVOIR ELEVATION	STORAGE VOLUME	RESERVOIR ELEVATION	STORAGE VOLUME	RESERVOIR ELEVATION	STORAGE VOLUME	RESERVOIR ELEVATION	STORAGE VOLUME	RESERVOIR ELEVATION	STORAGE VOLUME	RESERVOIR ELEVATION	STORAGE VOLUME
1	676.28	224	676.60	227	675.82	209	678.45	246	680.80	285	683.01	326
2	676.45	227	676.38	225	675.55	207	678.50	247	681.05	290	682.65	320
3	676.87	232	676.36	225	675.65	208	678.05	241	681.18	292	682.55	318
4	676.88	232	676.22	223	675.50	205	678.22	243	681.37	296	682.53	318
5	676.74	230	675.88	212	675.60	207	678.49	247	681.45	297	682.76	322
6	676.66	230	675.38	206	675.92	211	678.65	249	681.55	299	682.52	317
7	676.61	229	676.26	215	675.88	209	678.83	252	681.71	302	682.56	318
8	676.45	227	675.94	211	675.68	208	678.92	253	681.85	305	682.72	321
9	676.24	224	675.76	209	675.35	208	679.00	255	681.92	306	682.70	320
10	676.01	221	675.57	206	675.67	211	679.20	258	682.08	309	682.32	314
11	675.98	214	675.75	210	676.09	213	679.60	265	682.26	312	682.28	313
12	675.73	211	675.85	209	675.71	210	679.60	265	682.18	311	682.40	315
13	675.85	214	675.85	211	675.55	207	679.72	267	682.36	314	682.24	312
14	676.21	222	675.59	206	675.65	207	679.80	268	682.40	315	681.86	305
15	676.50	227	675.60	206	675.69	207	679.82	268	683.46	334	681.73	304
16	676.95	233	675.60	206	675.99	211	680.04	272	683.54	338	681.46	302
17	677.05	232	675.22	203	675.79	209	680.24	275	683.68	338	681.63	305
18	676.66	225	675.74	214	675.83	210	680.21	275	683.20	329	681.66	306
19	676.18	217	676.22	218	675.90	210	680.30	277	682.69	320	682.38	315
20	675.72	209	676.14	219	675.80	208	680.25	276	682.57	318	682.62	319
21	675.63	209	676.24	215	676.10	213	680.18	274	682.66	320	682.75	321
22	675.50	207	675.74	208	676.40	217	680.20	275	682.60	319	682.65	320
23	675.65	207	675.55	212	676.30	215	680.29	276	682.50	317	682.50	317
24	675.74	208	675.67	207	675.74	210	680.42	279	682.40	315	682.16	310
25	675.69	207	675.70	211	675.55	205	680.36	278	682.50	317	681.46	298
26	676.66	226	675.54	208	675.30	202	680.34	277	682.33	314	681.60	305
27	677.63	242	675.50	213	675.53	205	680.28	276	682.40	315	682.50	318
28	677.67	240	675.82	209	675.68	207	680.30	276	682.55	319	682.82	322
29	677.54	234	675.67	207	675.72	208	680.40	278	683.64	338	682.60	322
30	677.15	227			676.64	228	680.54	281	683.57	336	682.82	326
31	676.74	222			677.85	245			683.19	329		
MAXIMUM	677.90	242	676.77	227	677.85	245	680.75	281	683.79	338	683.33	326
MINIMUM	675.01	207	674.93	203	675.00	202	677.55	241	680.40	285	680.92	298
CHANGE	1.18	14	-1.07	-15	2.18	38	2.69	36	2.65	48	-0.37	-3

DAY	JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
	RESERVOIR ELEVATION	STORAGE VOLUME	RESERVOIR ELEVATION	STORAGE VOLUME	RESERVOIR ELEVATION	STORAGE VOLUME	RESERVOIR ELEVATION	STORAGE VOLUME	RESERVOIR ELEVATION	STORAGE VOLUME	RESERVOIR ELEVATION	STORAGE VOLUME
1	682.94	324	681.37	299	680.40	280	680.89	287	679.70	269	677.69	240
2	682.72	321	681.55	300	680.24	280	680.60	282	679.66	266	677.31	234
3	682.20	311	681.26	294	680.30	279	680.42	279	679.60	265	677.09	230
4	682.20	311	681.03	289	680.75	285	680.51	280	679.50	266	676.50	219
5	683.04	327	680.80	285	680.88	287	680.53	281	679.43	266	676.60	220
6	683.07	327	680.80	288	681.00	289	680.78	285	679.25	261	676.88	224
7	682.67	320	680.95	292	681.15	292	680.72	284	678.80	251	676.57	227
8	682.36	315	681.14	295	680.96	288	680.66	283	678.65	250	677.00	232
9	681.96	307	681.17	292	680.98	293	680.60	282	678.47	248	677.20	234
10	681.95	309	680.93	288	681.01	289	680.50	283	678.32	244	677.30	230
11	681.91	307	680.74	285	681.11	291	680.84	286	678.40	245	676.78	231
12	681.67	302	680.50	280	680.93	288	680.52	281	678.32	244	676.51	226
13	681.65	301	680.38	281	681.04	289	680.31	277	678.33	244	676.61	227
14	681.57	300	680.44	283	681.00	289	680.16	274	678.10	241	676.61	227
15	681.52	299	681.00	290	680.86	286	680.07	273	677.85	237	676.65	228
16	681.75	307	680.82	286	680.82	287	680.14	274	677.67	235	676.57	227
17	682.08	313	680.65	286	680.99	290	679.67	266	677.67	235	676.43	224
18	681.96	307	680.50	281	681.17	292	679.46	265	677.11	227	676.01	220
19	681.81	304	680.40	282	681.02	289	679.41	265	677.20	233	675.90	213
20	681.83	304	680.34	278	681.03	289	679.53	267	677.05	226	675.73	217
21	681.60	300	680.53	284	680.80	285	679.47	266	676.76	221	675.90	218
22	681.05	290	681.01	293	681.03	290	679.53	266	676.76	224	676.14	221
23	680.86	291	681.08	295	681.11	291	679.46	262	676.96	225	676.03	220
24	680.97	291	681.04	289	681.13	291	679.20	261	677.57	233	675.81	215
25	681.52	303	680.86	286	681.14	291	679.50	266	677.36	230	676.14	214
26	681.64	301	680.60	282	681.20	293	680.17	277	677.00	225	676.27	215
27	681.32	295	680.03	276	680.95	288	680.07	274	676.93	224	675.48	205
28	681.27	294	680.27	278	680.90	289	679.87	270	677.46	232	675.36	207
29	680.98	288	680.87	288	681.19	292	679.40	265	677.70	236	675.77	215
30	681.20	293	680.75	284	681.15	292	679.64	269	677.70	239	676.32	222
31	681.27	298	680.58	282			679.74	268			676.32	223
MAXIMUM	683.11	327	682.13	300	681.43	293	681.15	287	679.76	269	677.92	240
MINIMUM	680.49	288	679.71	276	679.68	279	678.07	261	676.19	221	675.02	205
CHANGE	-1.55	-28	-0.69	-16	0.57	10	-1.41	-24	-2.04	-29	-1.38	-16

1975-1976 WATER YEAR

	DATE	HOUR	ELEVATION	STORAGE	
MAXIMUM	MAY 30	3:00 AM	683.79	MAY 16	338
MINIMUM	FEBRUARY 25	7:00 AM	674.93	MARCH 26	202

1976 ANNUAL YEAR

	DATE	HOUR	ELEVATION	STORAGE	
MAXIMUM	MAY 30	3:00 AM	683.79	MAY 16	338
MINIMUM	FEBRUARY 25	7:00 AM	674.93	MARCH 26	202

MAXIMUM ELEVATION OF RECORD 686.10 AT 4:00 A.M., MARCH 18, 1973.
MINIMUM ELEVATION SINCE INITIAL FILLING, 673.27 AT 3:00 P.M., JANUARY 21, 1942.
RESERVOIR ELEVATIONS SHOWN ARE DETERMINED BY THE 1929 GENERAL ADJUSTMENTS OF THE U.S.C. AND G.S.

TABLE C-8 (Continued)

TENNESSEE VALLEY AUTHORITY
RIVER MANAGEMENT BRANCH

WATTS BAR DAM
DISCHARGE IN DAY-SECOND-FEET

PLATE NO. 57
1976

	JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE	
DAY	TURBINE	OTHER	TURBINE	OTHER	TURBINE	OTHER	TURBINE	OTHER	TURBINE	OTHER	TURBINE	OTHER
1	36,900	500	33,100	600	20,000	300	28,200	600	9,700	200	17,500	500
2	36,300	300	36,200	600	18,300	200	21,500	600	8,300	200	16,900	500
3	39,300	300	36,300	600	19,900	300	22,100	500	14,600	400	21,100	500
4	43,400	500	41,700	600	16,500	300	13,800	500	13,500	500	24,800	500
5	43,400	500	39,300	600	12,900	300	20,200	500	14,000	500	23,300	500
6	43,400	500	32,100	600	20,700	300	16,400	600	14,100	500	16,600	400
7	44,300	500	31,400	600	13,900	500	13,300	600	13,600	500	21,100	300
8	43,600	500	26,800	600	22,500	500	13,300	600	9,400	600	19,600	400
9	44,800	500	32,300	600	28,700	500	15,900	400	5,700	600	19,400	500
10	44,900	500	29,200	600	30,800	500	12,900	300	13,000	600	20,000	600
11	37,900	500	24,500	600	24,100	500	9,600	300	11,700	600	21,600	600
12	33,500	500	24,700	600	30,800	500	11,900	300	7,700	600	18,100	500
13	35,800	500	28,000	600	20,700	500	15,300	500	8,300	600	13,000	500
14	39,500	500	21,900	500	14,500	500	17,300	500	12,100	600	22,600	500
15	38,600	500	16,800	300	22,400	600	11,400	600	10,700	500	30,500	500
16	37,400	300	20,200	500	25,500	600	12,100	600	14,300	300	21,300	500
17	36,300	300	16,800	500	26,400	600	9,200	600	25,800	500	31,500	500
18	30,400	300	23,200	500	30,500	600	6,900	600	17,800	500	34,800	500
19	29,000	300	28,100	500	25,900	600	12,900	600	19,100	500	30,100	300
20	29,400	200	29,900	500	16,000	500	13,100	600	17,600	500	19,800	400
21	33,300	500	29,300	500	13,000	600	11,200	600	27,300	500	23,700	500
22	29,200	500	24,400	500	18,000	600	14,300	600	13,600	400	21,500	500
23	29,500	400	25,600	500	22,700	600	13,900	500	7,300	300	22,900	500
24	26,300	200	26,500	500	24,100	600	9,100	600	11,600	300	17,800	500
25	23,400	500	29,000	500	23,100	600	8,200	400	12,800	300	15,500	500
26	33,500	300	29,400	400	17,200	600	14,200	500	12,200	300	29,600	500
27	40,600	500	30,700	300	12,700	600	12,600	500	11,500	300	34,700	500
28	42,500	600	21,800	300	7,500	600	12,300	300	13,600	300	26,000	600
29	38,800	600	16,000	300	15,100	600	12,800	300	29,100	300	25,500	600
30	28,000	600			31,300	500	13,600	300	17,300	400	26,200	600
31	27,900	600			38,600	500			17,600	500		
TOTAL	1,121,300	13,800	805,200	14,900	664,300	15,600	419,500	15,000	434,900	13,700	687,000	14,800
AVERAGE	36,170	450	27,770	510	21,430	500	13,980	500	14,030	440	22,900	490

	JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
DAY	TURBINE	OTHER	TURBINE	OTHER	TURBINE	OTHER	TURBINE	OTHER	TURBINE	OTHER	TURBINE	OTHER
1	23,100	600	31,600	500	22,900	600	15,300	500	32,300	500	29,700	500
2	19,400	600	31,800	600	26,800	600	15,800	500	31,600	500	31,100	500
3	17,200	300	15,500	500	25,300	600	14,500	500	31,200	500	34,100	500
4	17,600	200	21,400	500	28,800	600	18,800	500	31,600	500	28,700	500
5	29,800	0	27,000	300	16,500	500	18,200	500	31,400	500	23,700	500
6	18,200	400	26,400	300	19,600	500	18,600	500	26,700	500	28,500	500
7	18,400	500	39,300	200	25,800	400	18,400	500	20,300	300	30,100	500
8	21,000	500	32,700	0	25,000	300	17,300	500	28,300	500	40,000	500
9	23,000	500	24,900	200	31,200	300	22,800	500	24,900	500	41,400	500
10	27,300	500	23,300	300	26,500	300	26,700	500	23,900	400	39,400	500
11	28,300	400	24,200	500	17,100	300	29,500	500	27,000	300	35,700	500
12	22,700	500	26,700	500	6,300	400	24,200	500	26,900	500	35,900	0
13	24,000	600	32,900	500	20,000	200	23,900	500	27,200	500	41,500	0
14	23,500	600	38,100	600	23,100	200	25,700	500	22,400	500	41,800	0
15	23,200	600	27,000	600	26,900	200	27,000	500	24,700	500	40,200	0
16	29,300	600	28,500	600	22,000	500	27,700	500	23,700	500	38,100	0
17	29,500	500	26,700	500	22,900	500	19,400	500	26,400	500	38,600	0
18	22,000	600	27,800	500	17,300	500	27,200	500	24,400	500	35,800	0
19	20,600	600	29,300	500	12,800	500	27,000	500	25,200	500	39,400	200
20	26,600	600	26,300	500	19,700	500	28,600	500	18,400	500	38,100	500
21	25,400	600	34,900	600	24,800	500	26,700	500	16,100	500	36,100	500
22	26,600	600	30,900	600	27,000	500	28,500	500	24,200	500	40,100	500
23	33,100	600	36,300	600	25,800	500	25,800	500	31,600	500	34,500	500
24	36,100	600	27,900	500	25,900	500	23,600	500	28,200	500	33,000	500
25	42,100	600	28,300	600	16,700	500	28,000	300	15,800	500	34,300	500
26	33,700	600	24,800	600	9,900	400	35,300	500	15,900	500	26,100	500
27	28,500	600	28,700	600	17,000	500	27,900	500	16,100	500	23,000	300
28	28,700	600	38,600	600	25,500	500	31,400	500	15,800	500	25,700	100
29	27,800	600	34,900	600	19,000	500	28,500	500	27,500	500	29,700	500
30	27,600	600	23,200	600	15,400	500	35,100	500	28,800	500	29,300	500
31	35,100	600	24,400	600			31,600	500			26,700	500
TOTAL	809,400	16,300	894,300	15,200	643,500	13,400	769,000	15,300	748,500	14,500	1,050,300	11,100
AVERAGE	26,110	530	28,850	490	21,450	450	24,810	490	24,950	480	33,880	360

	1975-1976 WATER YEAR DISCHARGE		1976 ANNUAL DISCHARGE	
	TOTAL	AVERAGE	TOTAL	AVERAGE
TURBINE	8,674,000	23,700	9,047,200	24,720
OTHER	172,900	470	173,600	470
COMBINED	8,846,900	24,170	9,220,800	25,190

MAXIMUM DAILY AVERAGE DISCHARGE 45,400 ON JANUARY 10.
MAXIMUM DAILY AVERAGE DISCHARGE SINCE CLOSURE
(JANUARY 1, 1942) 187,000 ON DECEMBER 30, 1942.
OTHER DISCHARGE IS STEAM PLANT USE AND/OR GATE DISCHARGE.
DISCHARGE DOES NOT INCLUDE LOCKAGE.

APPENDIX D

EVALUATION FOR SECTION 10/404 PERMITTING

D. EVALUATION FOR SECTION 10/404 PERMITTING

D.1 INTRODUCTION

The objective of this section is to address the potential impact of constructing and operating waste heat park intake and discharge structures on the Tennessee River. Two generic alternatives are presented. The data base for this evaluation includes existing environmental literature, and engineering design information generated specifically for the project. The focus of this section centers around information and details required for Section 10/404 permitting by the Army Corps of Engineers. Impacts were assessed for the following structures:

- Raw Water System

  Case I: One centralized large water intake and one return pipe discharge structure designed to serve the entire Park.

  Case II: A series of small raw water intake and return discharge pipes serving several industries.

- Waste heat return pump station overflow pipe discharge.
- Sanitary sewage treatment plant effluent discharge pipe.
- Dredged spoil land disposal area drainage system/discharge pipe.

Aquatic impacts assessed are limited to those related to the construction and operation of the above structures. Thermal or chemical pollutant effects are not discussed. Where it is felt that other sections of the Environmental Impact Statement adequately addresses an issue, reference is made to the appropriate discussions.

D.2 DESCRIPTION OF THE SITE AREA

The site area description focuses on the Waste Heat Park shoreline and aquatic environment. Only those resources which could be measurably impacted are addressed. The project area lies along the north shore of the Tennessee River (Chickamauga Reservoir) from just downstream of Tennessee river mile (TRM) 527 to near TRM 528.

D.2.1 Aquatic Ecology

Nonfisheries--Section A.6 describes aquatic ecological resources associated with the project area. Of the groups of species discussed, benthic species are most immotile and therefore most susceptible to site-specific disturbances.

The most unique benthic resources at this site are the mussel populations. The proposed intake and discharge structures are located within a zone in the Watts Bar Dam tailwater where the mussel fauna is exceptionally diverse (TRM 528.1-526.1).

Fish and Fishery Resources--Fishery resources are summarized more completely in Sections A.6 and A.7. Over fifty species have been found in the project area, which supports a good sport fishery for both migratory and resident species.

D.2.2 Terrestrial Ecology (Wetlands)

Wetlands in the shoreline zone of the proposed intake and discharge structures occur along tributaries to the Tennessee River and along its shoreline. Wetlands are made up primarily of lowland hardwood species as described in Section A.5.1. These wetlands are concentrated between Yellow Creek and a small natural drainage creek to the east (Figure A.12.1). The acreage of vegetation involved is relatively small and in a strand distribution, being restricted to immediate shoreline or creek bank habitats.

D.2.3 Hydrology

As described in Section A.3.1, the Tennessee River streamflow past the site is completely regulated by the Chickamauga Dam (downstream), and the Watts Bar Dam (upstream). Table C-5 provides an approximate relationship between flow and stage near the proposed intake/discharge locations. These data have been used, in conjunction with the bathymetry in the region (Watts Bar Nuclear Plant Project Drawing, TVA), to estimate average river velocities in the site vicinity during low water levels at Chickamauga Dam. The results are tabulated below:

Water Surface Elevation (Ft MSL)	Average River Velocity (Ft/Sec)
675	0.00
677	0.20
679	0.37
681	0.49
683	0.60

The three consecutive day low flow with a twenty year recurrence interval (3Q20) is estimated at 2650 cfs. This corresponds to an average velocity of less than 0.2 feet per second. It is reasonable to assume the velocity is not uniform at this flow rate, i.e., the flow may be stratified and the velocity near zero in the proposed intake/discharge locations.

The average flow discharged from Watts Bar Dam was 27,370 cfs, over the period 1945-1978. This flow corresponds to an average river velocity of 0.52 and 0.34 feet/second at the normal minimum (675 ft MSL) and normal maximum (682.5 ft MSL) water surface elevations at the lake, respectively. These average velocities are also low enough to assume uniform flow does not occur at these conditions.

D.2.4 Endangered or Threatened Species

In the vicinity of potential intake/discharge structure locations, two species of mussels (*Lampsilis orbiculata* and *Dromus dromas*) and one fish species (*Percina tanasi*) classified as endangered by the Federal government (*Federal Register*, 1980) are found. *P. tanasi* has been collected in Sewee Creek, which flows into the Tennessee River at TRM 524.9. *D. dromas* has been collected near mile point TRM 521 and downstream (TVA, 1980). *L. orbiculata* has been collected at TRM 527.4, as well as downstream to TRM 517 and upstream to the Watts Bar Dam. TRM 527.4 is the potential location of the raw water intake structure for the proposed park, which is within the boundaries of an area of high mussel concentration. Lower densities of all species occur downstream of TRM 517. The mussel species involved probably either spawn in the spring and release larvae in the summer, or spawn in the summer and release larvae the following spring. *P. tanasi* spawns in the early spring (February through early April).

Refer to Section A.7.2 for a more complete description of these species. Current comprehensive information on the status of these species in the immediate site vicinity is not available.

D.3 DESCRIPTION OF PROPOSED INTAKE AND DISCHARGE STRUCTURES

Design and siting considerations for potential intake and discharge structures are depicted in Figures D-1 through D-10. Operational characteristics are provided in Section D.4. The figures presented include:

The spoil area shown in Figures D-1 and D-6 is designed to contain dredged material generated by construction activities. Only under excessive rain conditions should water flow from the stand pipe to the river. In the Case I plan about 4000 cubic yards of dredged material could be deposited in this area. Under a Case II plan each individual intake structure will generate about 100 cubic yards of dredged material. The number, size, and location of Case II intakes and discharges is dependent on specific park industrial development requirements. There is a potential for as many as 20 of these structures, which would result in a total dredging of 2000 cubic yards of material.

D.4 IMPACTS OF PROPOSED INTAKE AND DISCHARGE SYSTEMS

D.4.1 Aquatic Ecology

D.4.1.1 Construction Impacts

Construction impacts on aquatic ecological resources arise from habitat loss for benthic species, as well as increased turbidity and siltation resulting from dredging operations and runoff from construction areas. Siltation affects benthic substrate, clogs gills of fishes and smothers benthic species. As one consequence, siltation could reduce the percentage of survival of larval fish and mussels. Increased water turbidity also reduces phytoplankton production and, therefore, near field oxygen supplies available to aquatic species.

Of the two potential raw service water supply alternatives presented, Case II (several intakes and discharges) would likely result in greater habitat loss for benthic organisms and potentially mussel populations. From a turbidity and siltation standpoint, Case II is expected to provide less impact, particularly if the smaller systems are constructed over an extended period of time.

Any rip rap construction beneath river waters would provide suitable riverine benthic habitat.

D.4.1.2 Operational Impacts

Entrainment of small aquatic organisms and life stages (including fish), and impingement of larger fish are the principal aquatic ecological impacts related to intake operations. Entrainment along with wastewater discharge impacts are discussed in Section B.6.2.

Impingement of fish against trash screens, which normally results in mortality, is influenced by location and design of the intake structure, intake volume and veolcity, water quality and temperature, and fish swimming speed and behavior. The potential maximum intake velocity of 1.8 ft/s might be excessive unless compensated for by mitigative features of the screen. A number of options are available which could protect fishery and mussel resources. Threadfin shad (*Dorosoma pentenense*) and gizzard shad (*D. cepedienum*) are apparently the two most abundant fish species in the Tennessee River near the site (Watts Bar Nuclear Power Plant Preoperational Studies, 1980). Their impingement is closely related to water temperature with up to 98 percent occurring when water temperatures are below 10°C. (Loar, et al., 1976).

In addition to direct effects on fish populations there is a possible indirect link to the endangered mussels. Mussel larvae spend part of their lives encysted in fish. This loss should be minimal, however, since the cysts are only present in the summer, the time of greatest avoidance ability.

Two potential alternative intake configurations are presented. Both would withdraw the same volume of water at the same velocity, thus, location of the intake is the main design feature which relates to impingement. In Case I, the pipe would draw water from just above the bottom. Bottom fish would be most susceptible. In Case II, the multiple intakes would draw water from the whole water column. This would make the shad more susceptible.

D.4.1.3 Mitigation Actions

Dredging and instream construction will be conducted in accordance with all applicable Federal, State, and local regulations, policies, and guidelines. Additionally, stabilization of areas surrounding submerged and shoreline structures with rip rap will minimize erosion, bank sloughing, and provide some additional habitat for benthic species. Construction during winter months when larvae should be least abundant would minimize impact to the fishery. Refer to Section B.6.3 for a more complete discussion of mitigation for the protection of aquatic resources.

D.4.2 Terrestrial Ecology

D.4.2.1 Construction Impacts

Terrestrial impacts of potential consequence involve wetland habitat loss. The only facilities which may affect wetlands are the Case I raw water discharge near the mouth of Yellow Creek and the Case II intake and discharge options involving several industry specific structures located downstream of the service area. In both instances wetland impacts will be minimized by routing lines outside of wetland habitats or, if necessary, through lower grade wetlands (i.e., disturbed or in a stage of transition to an upland state). Because the wetland types are neither unique nor rare in the region and because they are of small size, impacts of proposed intake and discharge systems should not be significant.

D.4.2.2 Operational Impacts

Impacts on terrestrial and wetland communities related to the proposed intake and discharge will occur primarily during the construction period. No significant impact on these resources is expected as a result of facility operation.

D.4.2.3 Mitigation Actions

Mitigation measures include the above identified wetland avoidance procedures.

D.4.3 Hydrology

D.4.3.1 Construction Impacts

Impacts on river hydrology primarily are related to the operation phase.

D.4.3.2 Operational Impacts

The centralized raw water system, with one intake and one discharge structure, should not have a significant impact on the flow and current patterns in the river. A flow rate of 111 cfs (50,000 gpm) represents only about 4.2 percent of the three day minimum flow with a 20 year recurrence interval (3Q20) and 0.4 percent of the average flow at the site. Thus, although intake and discharge velocities up to about two feet per second are expected, they should affect only the immediate vicinity of the structures involved. The intake will withdraw from a point approximately 12 feet below normal minimum water level, and approximately 20 feet below normal maximum water level. The discharge will return water to the surface of the river.

The individual raw water systems, utilizing multiple intake and discharge structures, should not have any more hydrological impact than the centralized systems. Ultimate development would involve about the same flow rates of 4.2 percent at the 3Q20 and 0.4 percent of the average river flow. Partial development would involve proportionately less of the river flow. The design intake and discharge velocities range up to about two feet per second, which is the same as the centralized system. Thus, they should have the same effect on the local flow and current patterns as the centralized system, assuring ultimate development. These velocities would affect proportionately smaller areas under partial development. The intakes for this system would withdraw water from the full water column between elevation 667 and the water surface. The discharges would return water to the surface of the river.

The waste heat return pump station overflow pipe discharge is sized to carry an average of 56 cfs (25,000 gpm) and a maximum of 163 cfs (73,000 gpm). These represent 2.1 and 6.2 percent at the 3Q20, respectively, and .2 and .6 percent of the average river flow, respectively. As was the case with the raw water systems, this discharge will enter the river at the water surface, at a velocity less than or equal to 2 feet/second. This discharge should only affect flow and currents near the outfall structure.

The sanitary sewage treatment plant effluent is expected to discharge a maximum of 0.23 cfs (150,000 gpd). This flow represents less than .01 percent of the 7Q20 and .0008 percent of the average river flow. This flow will discharge at about 0.7 feet per second. The discharge is through an 8-inch diameter pipe submerged a minimum of ten feet below normal minimum water level. The impact of this discharge should be insignificant.

The drains from the dredged spoils area will discharge to the surface of the river. At this time, no estimate of the flow rate is available.

D.4.4 Endangered and Threatened Species

D.4.4.1 Construction Impacts

Dredging for placement of raw water intake structures (either case), the waste heat return overflow pipe, and discharges and drains from the sanitary sewage treatment plant and dredged material disposal area will cause siltation and habitat disruption which could potentially affect populations of *Lampsilis orbiculata* and *Dromus dromas*. Refer to Sections B.6.1 and D.4.1.1 for a more complete discussion of potential impacts.

D.4.4.2 Operational Impacts

It is felt that impact risks to endangered mussels and fish are greatest during construction. Because the host fish species for *L. orbiculata* and *P. tanasi* distribution are not known, the effects of entrainment and impingement cannot be estimated.

D.4.4.3 Mitigation Actions

Pre-construction investigations will be used to determine optimum instream locations and designs for minimizing impacts to *P. tanasi*, *D. dromas*, and *L. orbiculata*. Mussels could be collected from construction areas and relocated into suitable habitat upstream. Construction during the winter months could also minimize construction impacts. All proposed mitigative measures would be subject to U.S. Fish and Wildlife Service review prior to finalization and implementation.

For a more complete description of mitigation to protect aquatic resources, refer to Sections B.6.3 and D.4.1.3.

D.5 CONCLUSIONS

This section summarizes potential project design characteristics and potential impacts. With proper mitigation, no project alternatives are expected to result in significant impacts.

Endangered mussels and fish are present in the site area. The site is within a State mussel sanctuary, and a tailwater area which supports a good sport fishery; however, impacts can be reduced to acceptable levels with proper mitigation. The U.S. Fish and Wildlife Service would be consulted with regard to mitigation for the protection of endangered species.

REFERENCES

Federal Register. Republication of lists of Endangered and Threatened Species and Corrections of Technical Errors and Final Rules. Vol. 45 (99) pp. 33767-33781. 1980.

Gross, A. C. Comparison and Prediction of Fish Impingement Rates at Power Plant Cooling Water Intake Sites in: L. D. Jensenled, 1976. Third National Workshop on Entrainment and Impingement. EA Communications, Melville, NY. 1976.

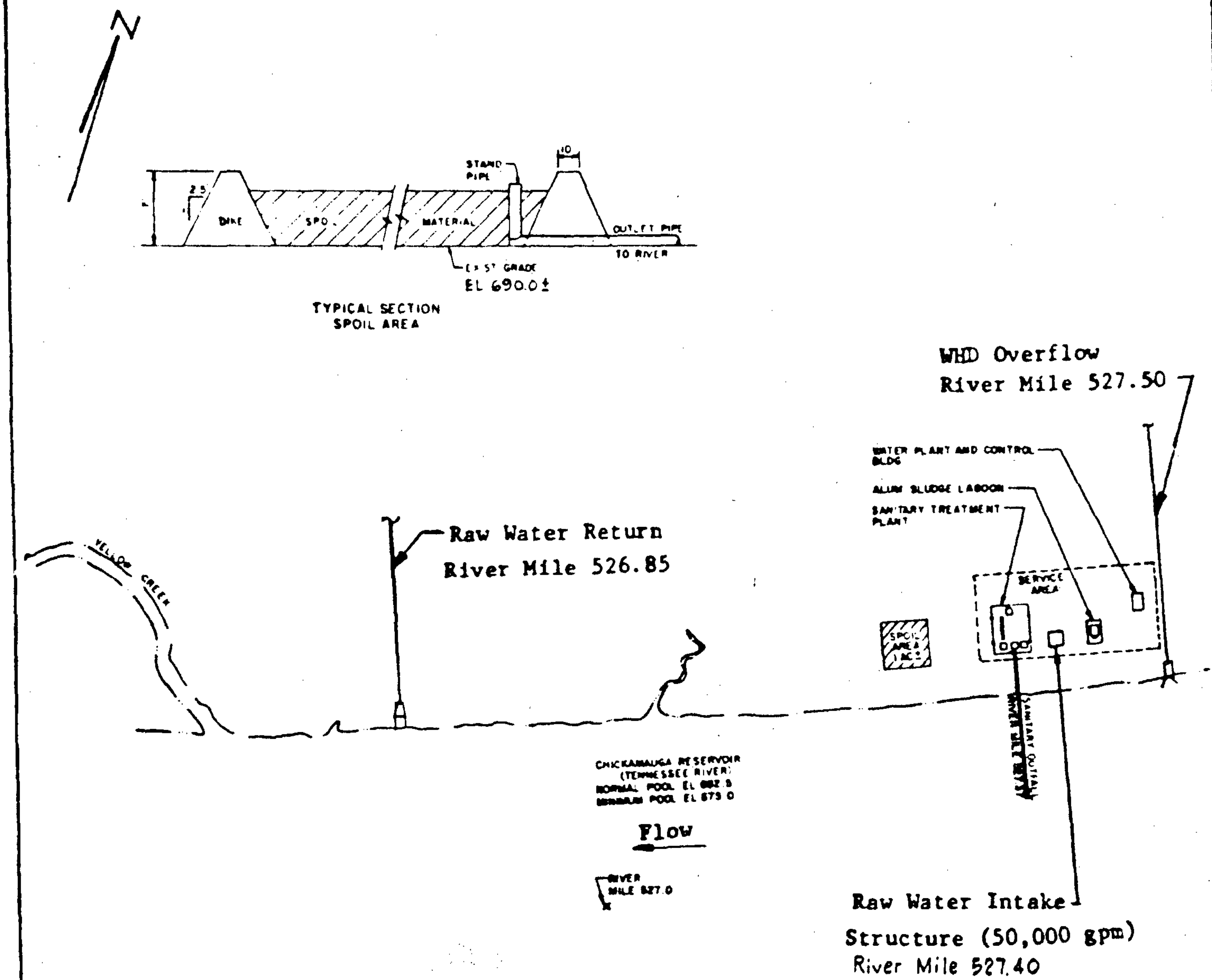
Loar, J. M., J. S. Griffith, and K. D. Kamar. An Analysis of Factors Influencing the Impingement of Threadfin Shad at Power Plants in the Southeastern United States. In: L. D. Jensen, (ed.) 1977. Fourth National Workshop on Entrainment and Impingement. EA Communications, Melville, NY. 1977.

TVA. Watts Bar Nuclear Plant Preoperational Aquatic Monitoring Report, 1973-1977. Prepared by R. D. Harned, C. E. Mulkey, W. J. Pardue, and E. B. Robertson, Tennessee Valley Authority, Division of Water Resources. 1980.

TVA. Environmental Statement, Watts Bar Nuclear Plant, Units 1 and 2. Tennessee Valley Authority. 1972.

TVA. Biological Investigations in the Vicinity of the Washington Ferry, Chickamauga Reservoir, June 1980. Internal memorandum, Division of Water Resources, July 1980.

Figure D-1



PLAN
Not To Scale

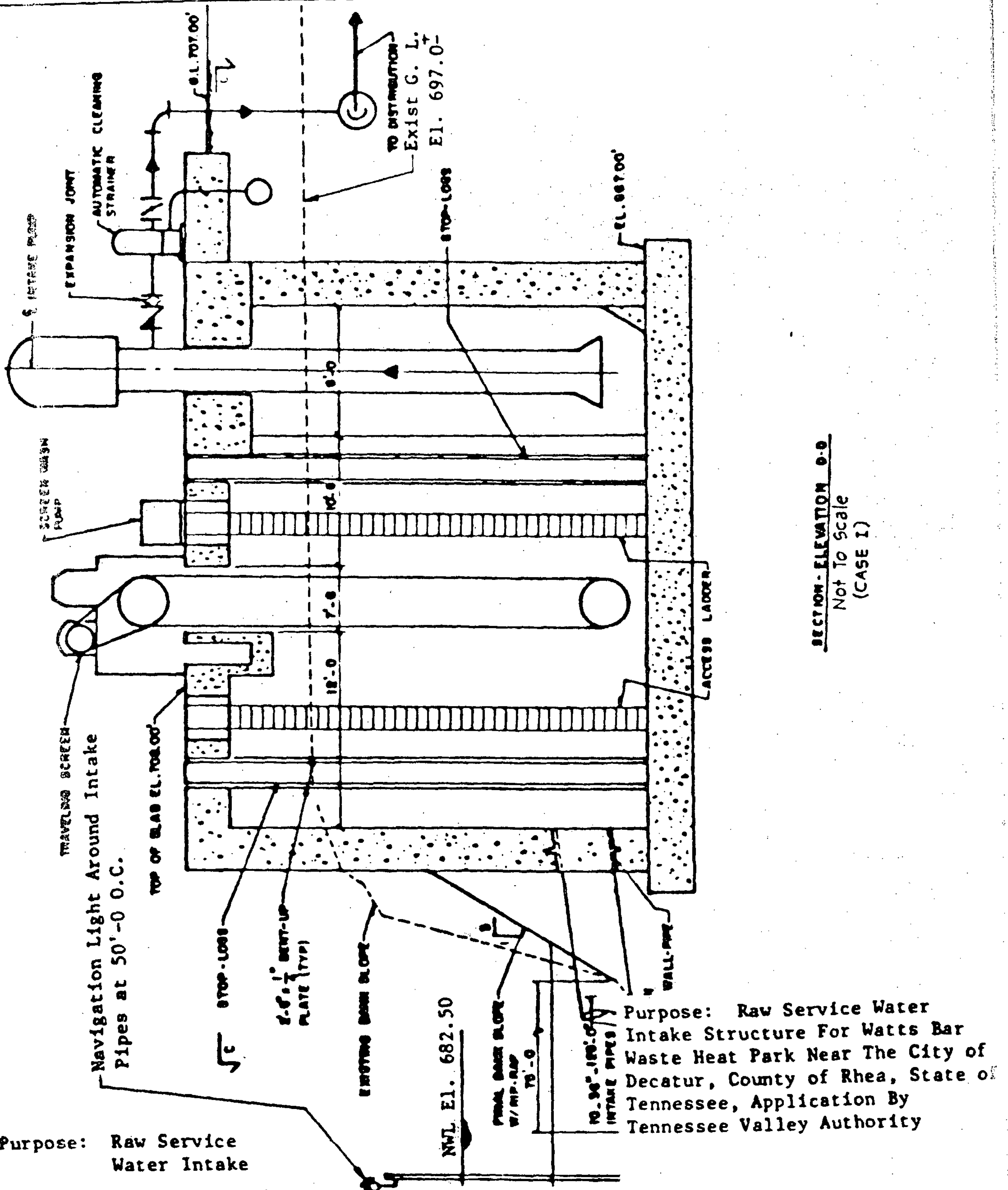
Purpose: Outfall Locations

Datum: Mean Sea Level

Proposed: Outfall Locations (Case I)
Watts Bar Waste Heat Park, Near The City of Decatur, County of Rhea, State of Tennessee

Application By: Tennessee Valley Authority

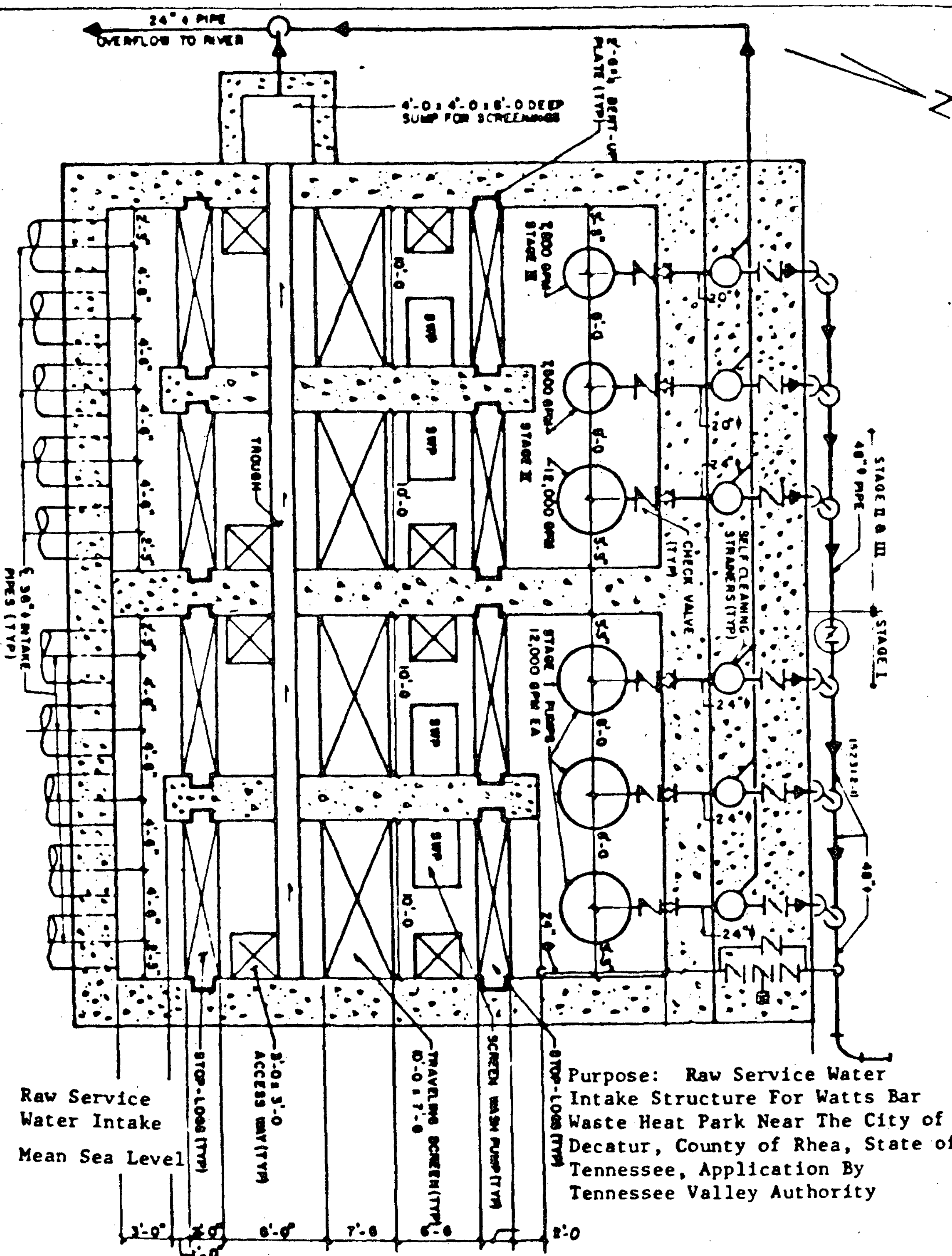
Figure D-2



Purpose: Raw Service Water Intake

Datum: Mean Sea Level

Figure D-3



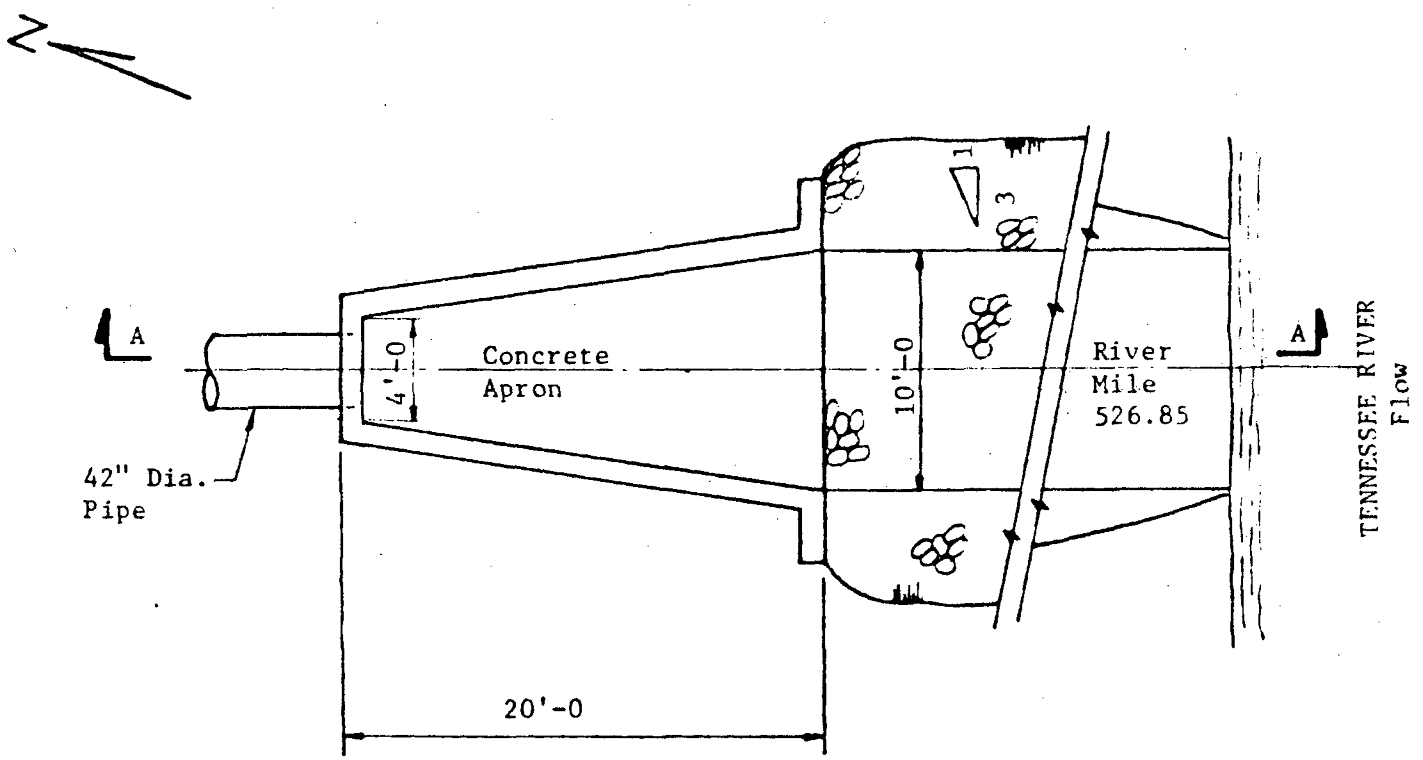
SECTION-PLAN C-C (NTS)
(CASE I)

Purpose: Raw Service Water Intake

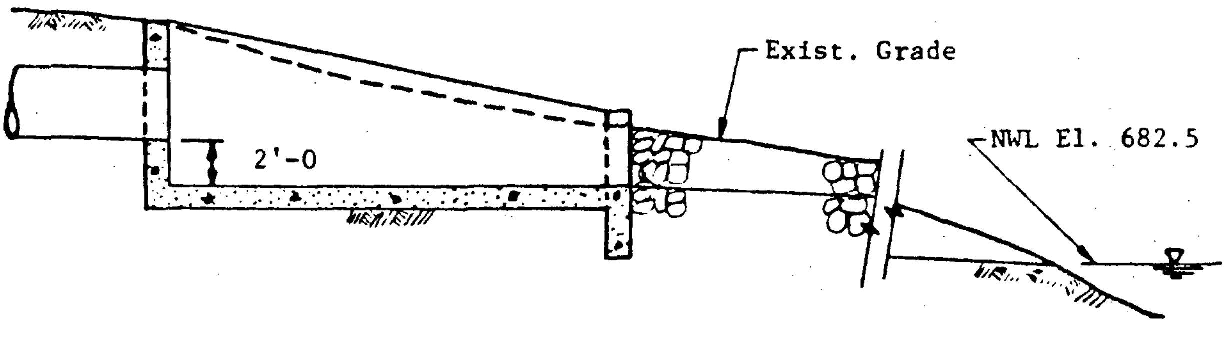
Datum: Mean Sea Level

Purpose: Raw Service Water Intake Structure For Watts Bar Waste Heat Park Near The City of Decatur, County of Rhea, State of Tennessee, Application By Tennessee Valley Authority

Figure D-4



Plan (Case I)
Not To Scale



SECTION A

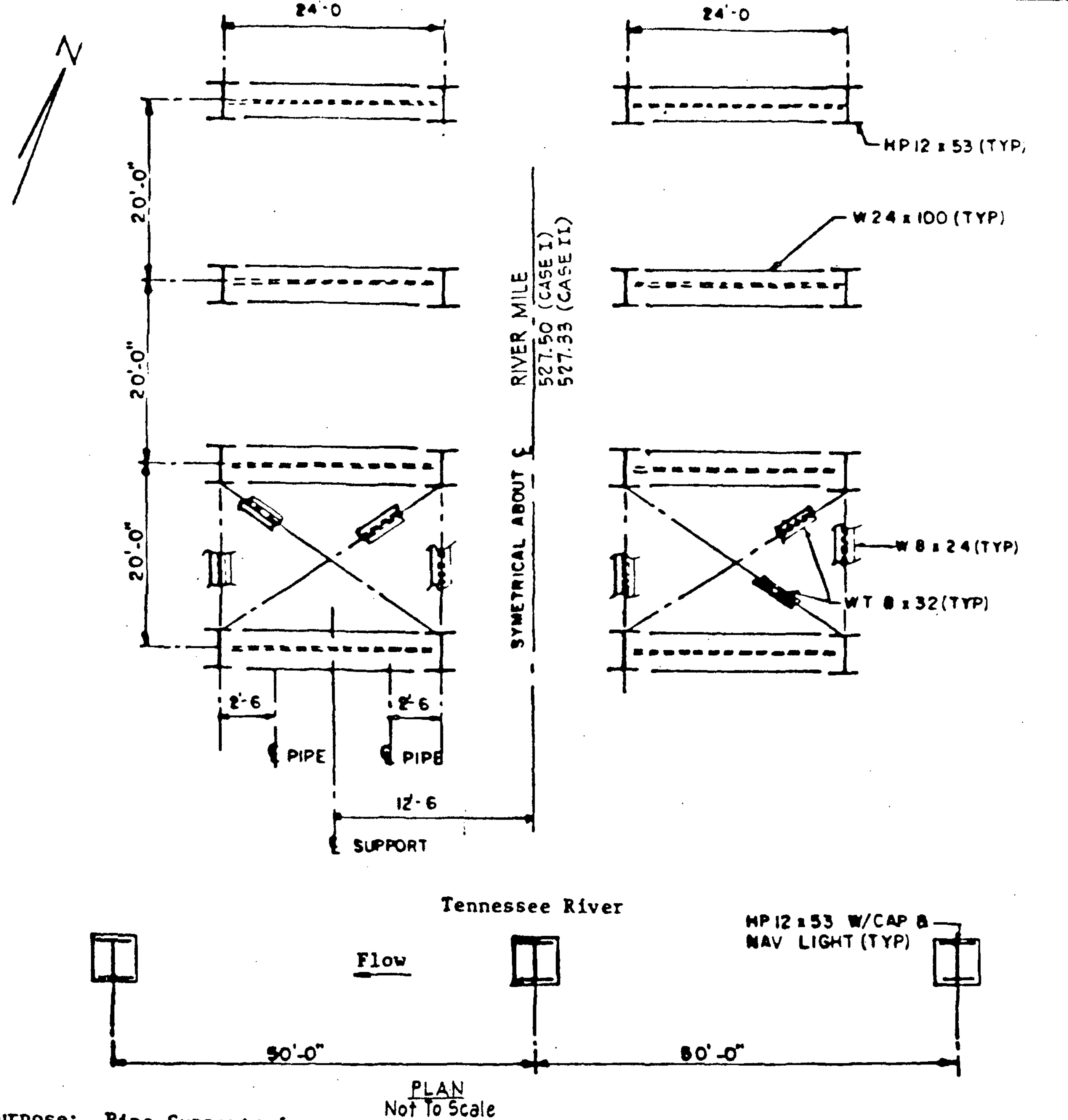
Purpose: Raw Water Discharge Structure

Datum: Mean Sea Level

Proposed: Raw Water Discharge Structures for Watts Bar Waste Heat Park Near the City of Decatur, County of Rhea, State of Tennessee

Application By: Tennessee Valley Authority

Figure D-5



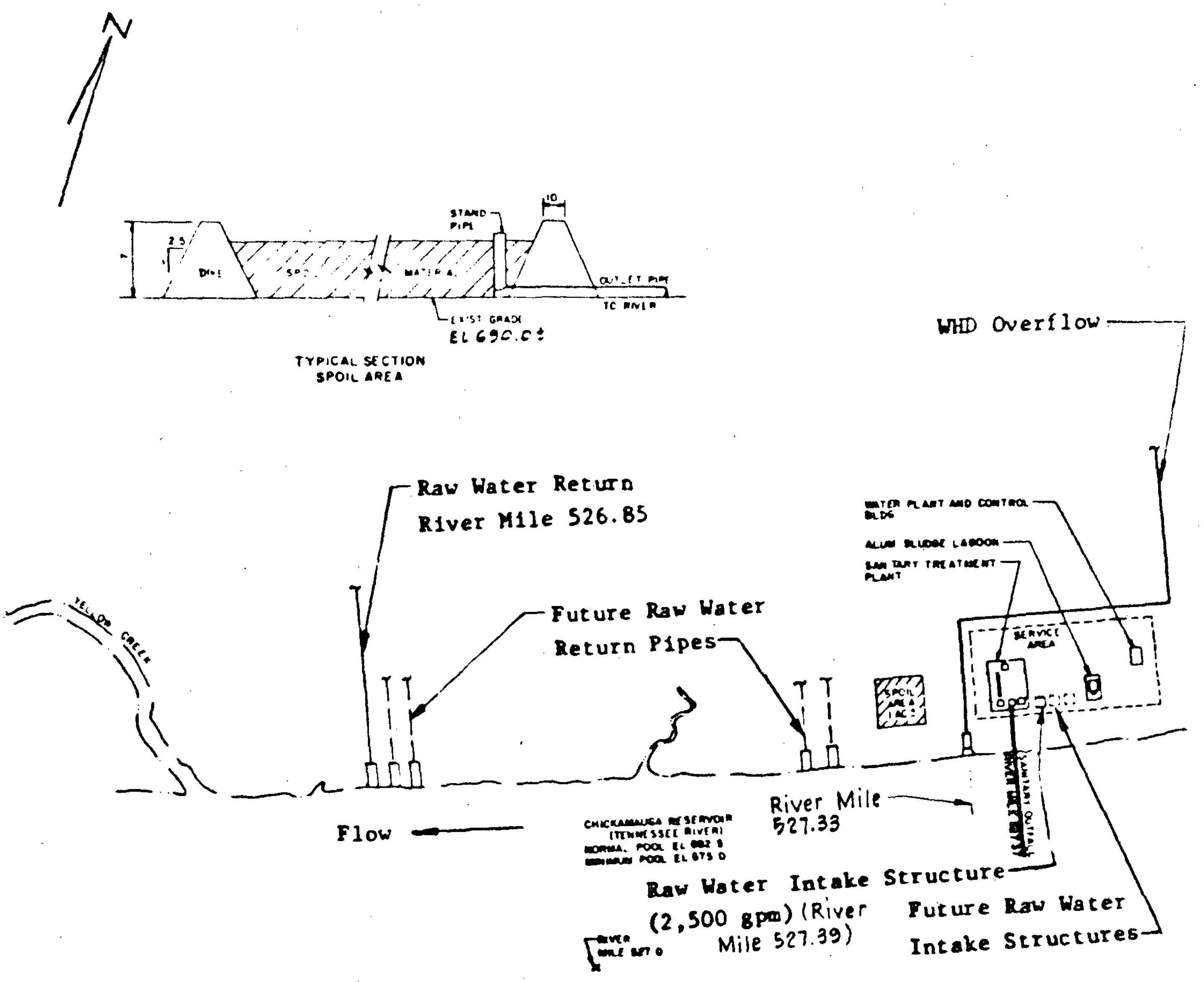
Purpose: Pipe Supports & Navigation Lights

Datum: Mean Sea Level

Proposed: Pipe Supports and Navigation Lights for Watts Bar Waste Heat Park Near The City of Decatur, County of Rhea, State of Tennessee

Application By: Tennessee Valley Authority

Figure D-6



PLAN
Not To Scale

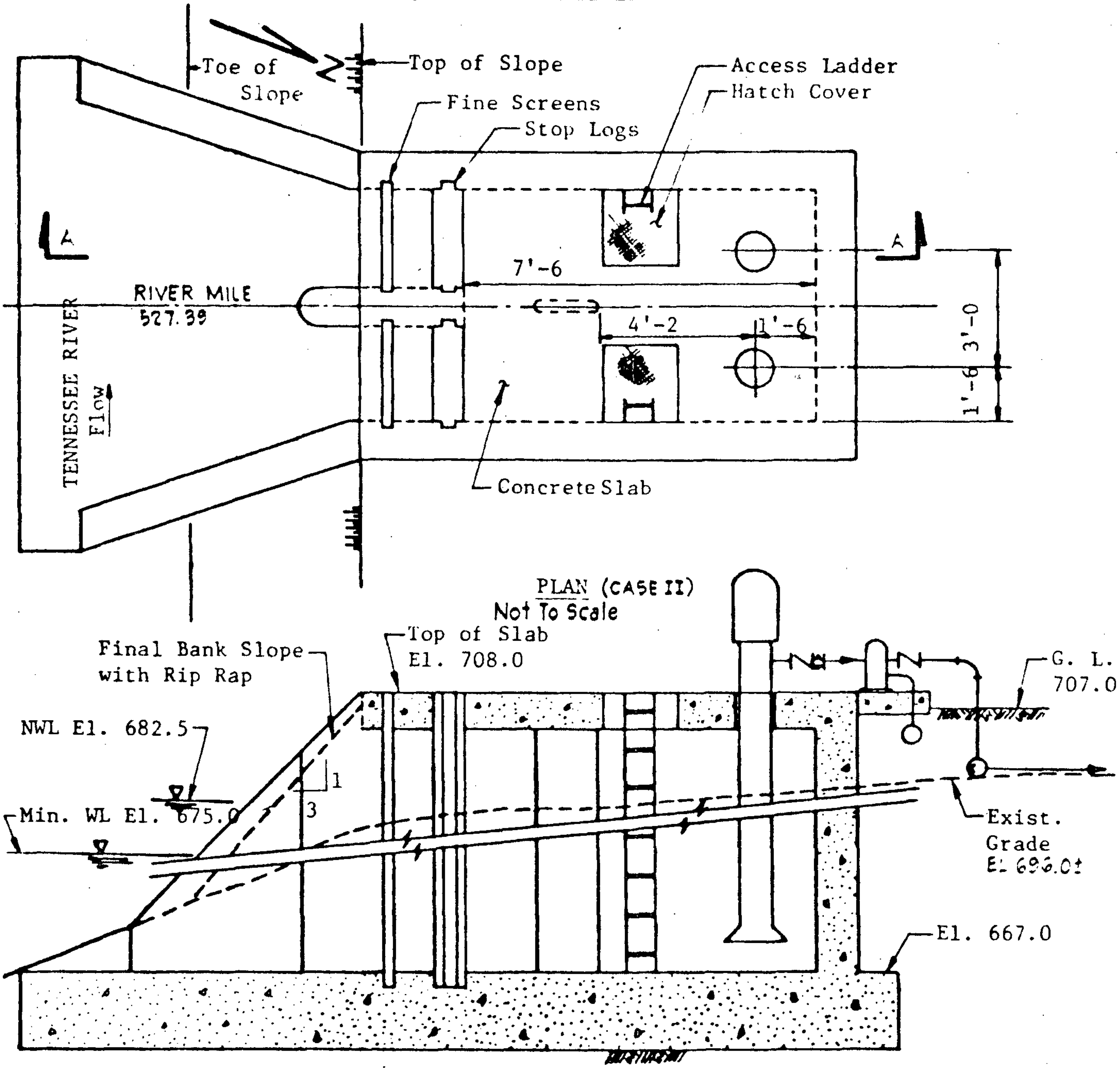
Proposed: Outfall Locations (Case II)
Watts Bar Waste Heat Park, Near The City of Decatur, County of Rhea, State of Tennessee

Application By: Tennessee Valley Authority

Purpose: Outfall Locations

Datum: Mean Sea Level

Figure D-7



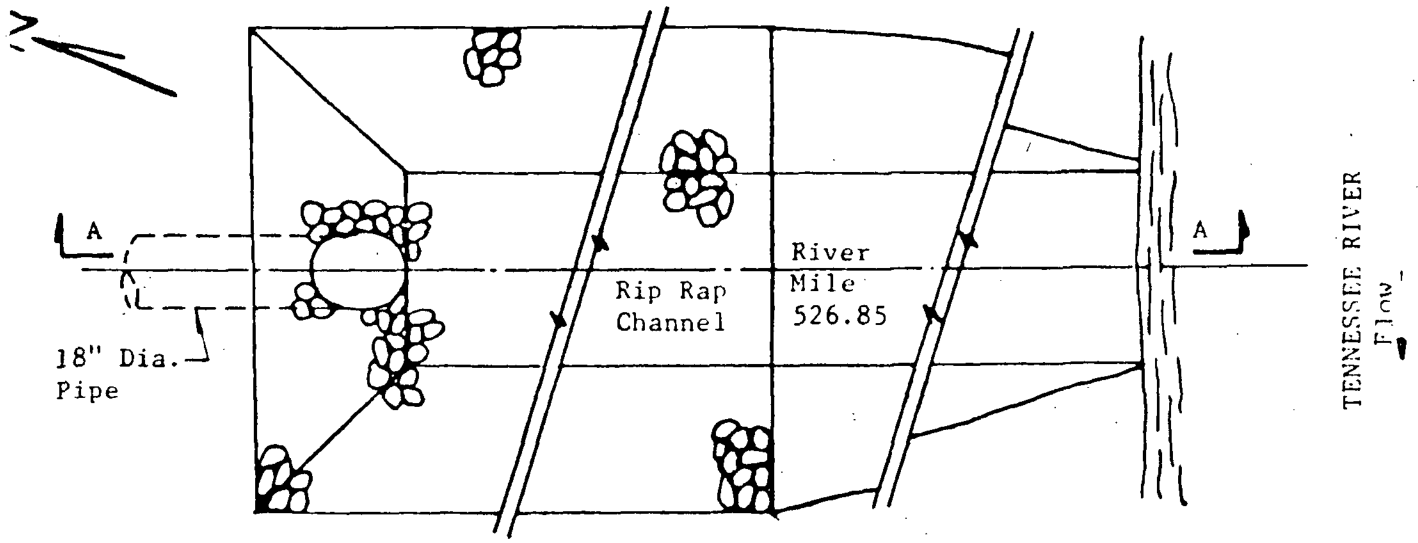
SECTION A

PROPOSE: Raw Water Intake Structure

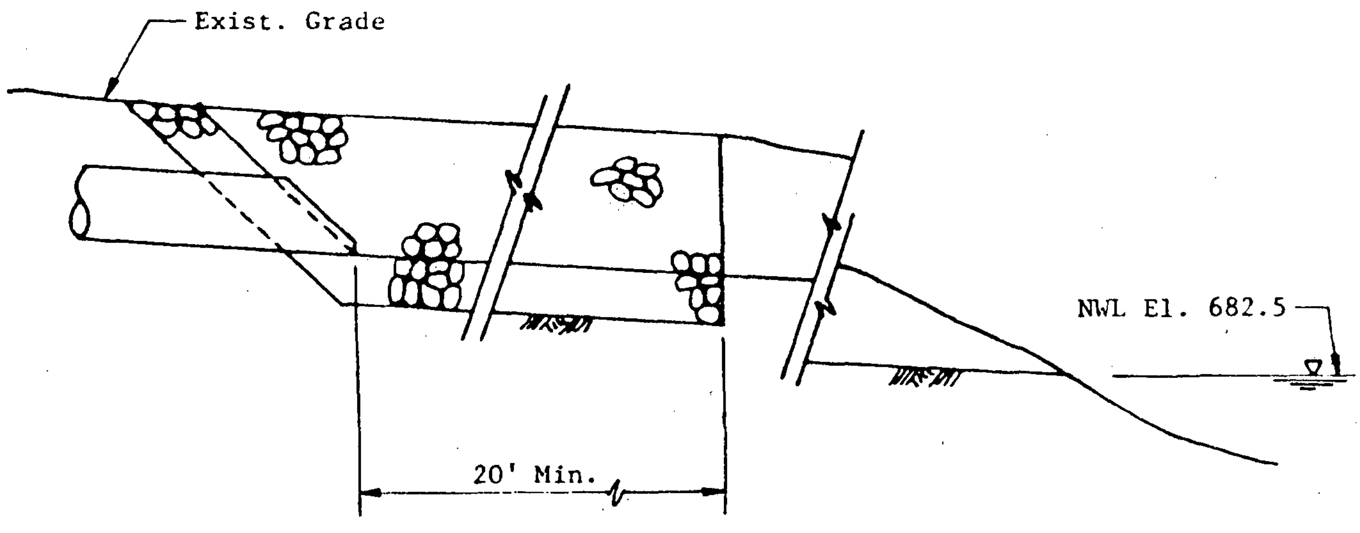
Datum: Mean Sea Level

Proposed Raw Water Intake Structure for Watts Bar Waste Heat Park
Near the City of Decatur, County of Rhea, State of Tennessee.
Application By Tennessee Valley Authority

Figure D-8



Plan (Case II)
Not To Scale



SECTION A

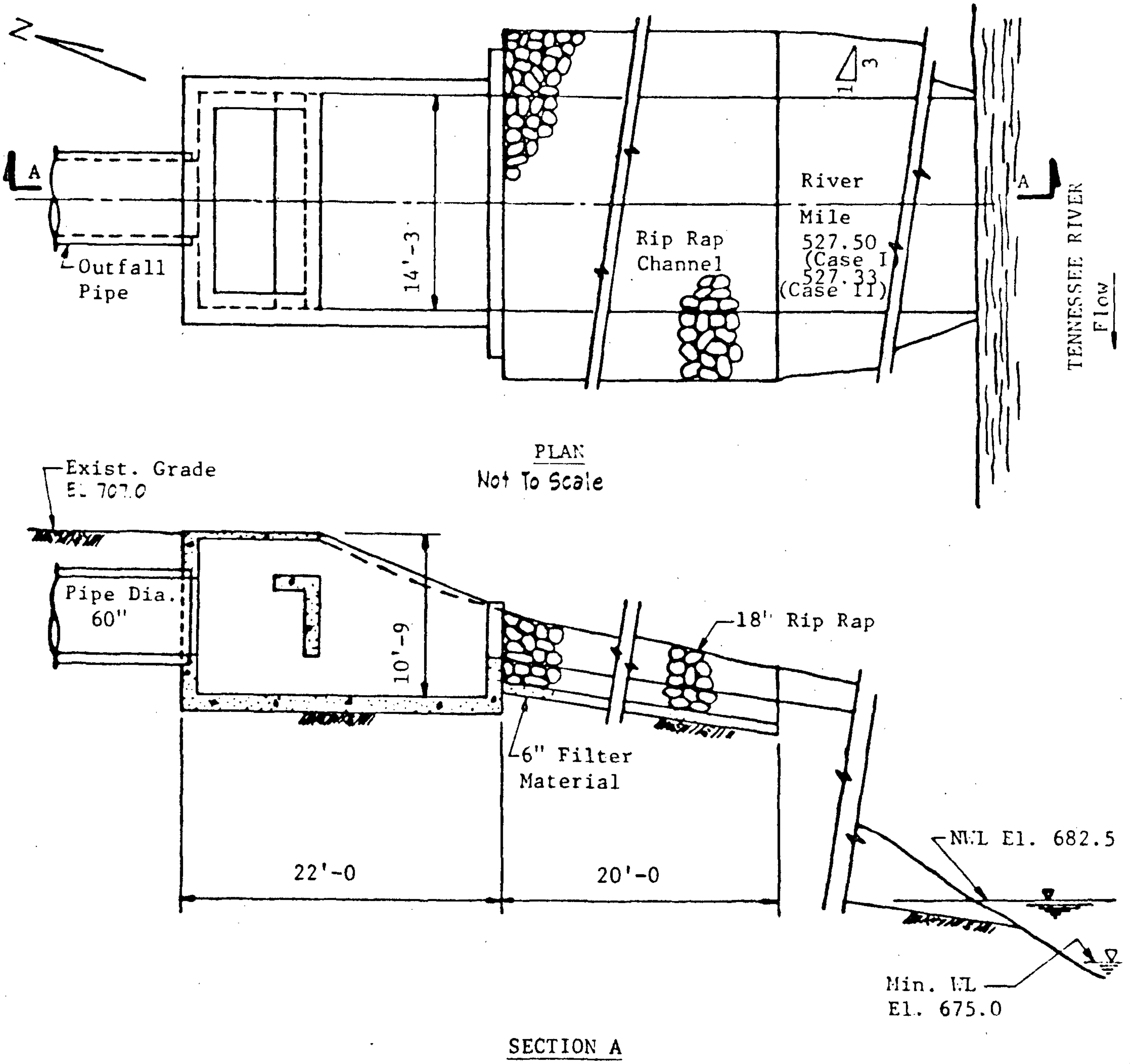
Purpose: Raw Water Discharge Structure

Datum: Mean Sea Level

Proposed: Raw Water Discharge Structures for Watts Bar Waste Heat Park Near the City of Decatur, County of Rhea, State of Tennessee

Application By: Tennessee Valley Authority

Figure D-9

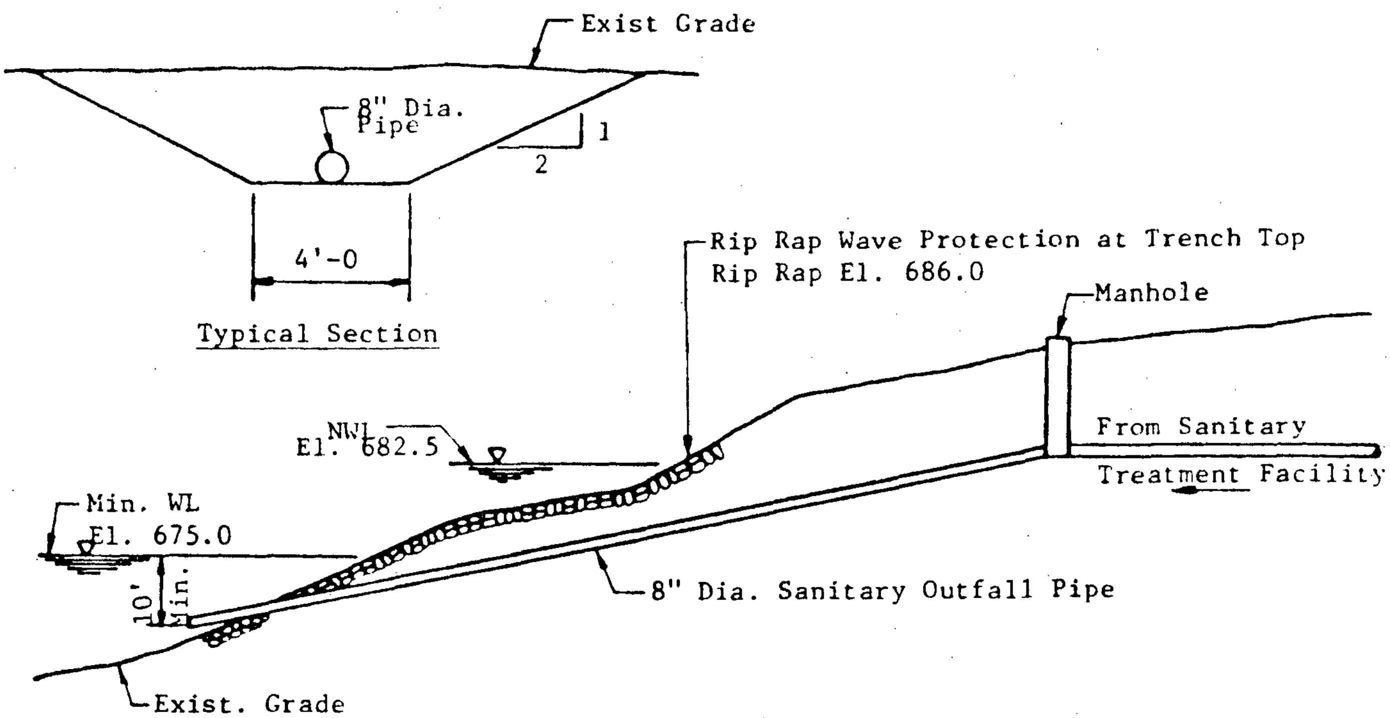


PURPOSE: Waste Heat Outfall Structure

Datum: Mean Sea Level

Proposed: Outfall Structure for Watts Bar Waste Heat Park
Near the City of Decatur, County of Rhea, State of Tennessee
Application By: Tennessee Valley Authority

Figure D-10



Profile Along Pipe
Not To Scale

PURPOSE: Sanitary Outfall Pipe at River Mile 527.37

Datum: Mean Sea Level

Proposed Sanitary Outfall Pipe for Watts Bar Waste Heat Park near the city of Decatur, County of Rhea, State of Tennessee.
Application By Tennessee Valley Authority

APPENDIX E

THREATENED AND ENDANGERED SPECIES CONSULTATION

October 4, 1979

Mr. Kenneth E. Black, Regional Director
U.S. Fish and Wildlife Service
Richard B. Russell Federal Building
75 Spring Street, SW
Atlanta, Georgia 30303

Dear Ken:

The Tennessee Valley Authority (TVA) is conducting an analysis of the potential environmental impacts associated with the development of a multiple use park with agricultural, aquacultural, and industrial applications utilizing waste heat produced by one of our steam-electric generating stations. Current proposals call for a park to be located on a tract of TVA-owned land adjacent to our Watts Bar Nuclear Plant in Rhea County, Tennessee. The nuclear plant is currently under construction and should be ready for fuel loading by the fall of 1980. TVA is preparing an Environmental Impact Statement on the proposed waste heat park (see 44 Federal Register, No. 146, Page 44312, July 27, 1979).

This letter serves as a request for the identification of species which are listed or proposed for listing as threatened or endangered and which may occur on or in the vicinity of the area proposed for development. TVA will prepare a biological assessment which will be included in the draft Environmental Impact Statement. The enclosed map indicates the area that is under investigation. If there are any questions or additional data are required, please contact Ralph Jordan at FTS 856-4411.

Sincerely,

Thomas H. Ripley, Manager
Office of Natural Resources

JRJ:LGH
Enclosure
cc (Enclosure):
M. T. El-Ashry, FOR B-N
H. G. Parris, 500A CST2-C
H. S. Sanger, E11B33 C-K

bc (Enclosure):
B. W. Brown, 259 401B-C
E. H. Lesesne, 448 EB-K
R. L. Morgan, Jr., FOR B-N
J. F. Weinhold, 1345 CUBB-C

xc: (Enclosure):
F. B. Fields, FOR B-N
R. B. Fitz, FOR B-N
J. R. Jordan, Jr., FOR B-N
J. M. Loney, FOR B-N

United States Department of the Interior
FISH AND WILDLIFE SERVICE
75 SPRING STREET, S.W.
ATLANTA, GEORGIA 30303

OCT 17 1979

Dr. Thomas H. Ripley
Manager, Office of Natural Resources
Tennessee Valley Authority
Norris, Tennessee 37828

Dear Dr. Ripley:

This acknowledges your letter of October 4, 1979, (received October 15, 1979) requesting information on whether any endangered, threatened, or proposed to be listed species may be present in the area of the proposed multiple use park adjacent to Watts Bar Nuclear Plant which is located in Rhea County, Tennessee. We have assigned log number 4-2-80-A-10 to this project, and we request that you refer to this number in all future correspondence.

We have forwarded the information that you provided to our Asheville Area Office for their review. Upon completion of their review, we will provide you with a list of species that may be present in the area of the proposed action, and the information needed in the biological assessment, if it is required.

We appreciate your interest and concern in the preservation of listed species.

Sincerely yours,

Kenneth E. Black

Regional Director

United States Department of the Interior
FISH AND WILDLIFE SERVICE
75 SPRING STREET, S.W.
ATLANTA, GEORGIA 30303

NOV [illegible]

Dr. Thomas H. Ripley
Manager, Office of Natural Resources
Tennessee Valley Authority
Norris, Tennessee 37828

Re: 4-2-80-A-10

Dear Dr. Ripley:

We have reviewed the proposed multiple use park adjacent to Watts Bar Nuclear Plant in Rhea County, Tennessee, as requested by letter of October 4, 1979 received October 15, 1979.

It appears that some endangered and/or threatened species and/or species proposed for listing may occur in the area of influence of this action.

The following is a list of species which we believe may be present in the area:

Dromedary pearly mussel (Dromus dromas) - endangered, Tennessee River.

Pink mucket pearly mussel (Lampsilis orbiculata orbiculata) - endangered, Tennessee River

Orange-footed pearly mussel (Plethobasis cooperianus) - endangered, Tennessee River

Section 7(c) of the Endangered Species Act of 1973, as amended in 1978, requires agencies to provide a biological assessment for the species which are likely to be affected. The biological assessment shall be completed within 180 days after the date on which initiated, or within a mutually agreed upon time-frame, before any contracts for construction are entered into, and before construction is begun. We do not feel that we can adequately assess the effects of the proposed action on listed species, species proposed for listing or Critical Habitat without a complete assessment. At a minimum the following information is requested:

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Tennessee Valley Authority
OFFICE OF NATURAL RESOURCES

1. Identification of the listed species, species proposed for listing and Critical Habitat determined to be present within the area affected by the proposal.

2. Description of the survey methods used to determine presence of listed species or species proposed for listing within the area.

3. The results of a comprehensive survey of the area.

4. Description of any difficulties encountered in obtaining data and completing proposed studies.

5. Description of the proposed construction project and associated activities.

6. Description of methods and results of studies made to determine the actual and potential impacts of project or associated activities on listed species, species proposed for listing, or Critical Habitat. In addition to the direct (site related) impacts of project construction the Biological Assessments should include, when applicable, descriptions of:

   A. Impacts associated with project operation.

   B. Secondary impacts from activities, such as development, which will be generated by the proposed project.

   C. The cumulative effects of the proposal on the species and/or its Critical Habitat. Cumulative effects are defined as the direct and indirect impacts of the Federal action under consideration coupled with the identifiable effects of other reasonably foreseeable actions of the Federal agency; other Federal, State, and local agencies; corporations; and individuals upon a species or its Critical Habitat.

7. Where impacts to listed species, species proposed for listing, or Critical Habitat are identified, the assessment should include a discussion of the efforts that will be taken to eliminate, reduce, or mitigate any adverse effects.

8. Conclusions of the agency including recommendations regarding further studies.

9. Any other relevant information.

Should you require additional information on this subject, please contact Mr. Gary Henry or Mr. Robert Currie in the Asheville Area Office, FTS 672-0321, commercial 704/258-2850, ext. 321.

After your agency has completed and reviewed the assessment, it is your responsibility to determine if the proposed action "may affect" any of the listed species or Critical Habitat. If the determination is "may affect," you are required to initiate consultation by a written request to this office. At this time you should provide a copy of the biological assessment and any other relevant information that assisted you in reaching your conclusion. If the determination is "no effect," consultation is not necessary, unless requested by the Fish and Wildlife Service.

If the species proposed for listing have not been listed in the period of time during which a biological assessment was conducted, consultation is not required. However, at any point in time that the species is listed, you are required to reinitiate consultation, if you determined that the proposed action "may affect" the species.

Your attention is also directed to Section 7(d) of the Endangered Species Act, as amended, which underscores the requirement that the Federal agency and the permit or license applicant shall not make any irreversible or irretrievable commitment of resources during the consultation period which in effect would deny the formulation or implementation of reasonable alternatives regarding their actions on any endangered or threatened species.

If we can be of further assistance, please advise.

Sincerely yours,

Ray R. Vaughn

Regional Director

TENNESSEE DEPARTMENT OF CONSERVATION
TENNESSEE HISTORICAL COMMISSION
4721 TROUSDALE DRIVE, NASHVILLE ~~37220~~ 37219
615/741-2371

July 7, 1980

Mr. Maxwell D. Ramsey
Program Manager
Cultural Resources
Tennessee Valley Authority
Norris, Tennessee 37828

Re: Watts Bar Waste Heat Park, Watts Bar Nuclear Plant, Rhea County, Tennessee

Dear Max:

The State Historic Preservation Officer and his staff have reviewed the excellent report prepared by Mr. Quentin Bass and Duane Lenhardt, GAI Consultants, Inc., Pittsburgh, Pennsylvania. We find the report a satisfactory investigation of archaeological resources in the Waste Heat Park area of environmental impact.

Based on the information presented in the report, we agree that the large site located during the survey (40 RH 64) is eligible for listing in the National Register under Criterion (d) (36 CFR 1202).

Since, as stated in your letter of June 6, 1980, the site (40RH64) will not be affected by planned development or construction activities, TVA has the option of declaring that it is outside the area of potential environmental impact and therefore will not need to request a determination of eligibility under 36 CFR 800. However, if there is any possibility that the project will be altered such that site 40 RH64 may be affected, then it would be prudent to request a determination of eligibility as you plan to do. We will be glad to review and comment on the formal documentation when submitted later.

In any event, we concur with your opinion that the project as currently planned will not affect any properties included in or eligible for inclusion in the National Register of Historic Places.

Thank you for your continued cooperation in this matter.

Sincerely,

Herbert L. Harper
Herbert L. Harper,
Executive Director and
State Historic Preservation Officer

HLH:GFF:sg

RECEIVED
DEC 9 1980
ENVIRONMENTAL ASSESSMENT
AND SUPPORT STAFF
#