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H. B. ROBINSON
STEAM ELECTRIC PLANT
316 DEMONSTRATION

CP&L
Carolina Power & Light Company

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1.0 Introduction

Volume II of the H. B. Robinson Steam Electric Plant 316 demonstration contains the results of extensive environmental studies as well as plant operating data which support Carolina Power and Light Company's contention stated in Volume I that "a balanced, indigenous population of shellfish, fish, and wildlife" is present in the Robinson Impoundment.

The studies were based on the enclosed study program agreed upon by the Environmental Protection Agency. Additions were made to the program as needs for additional information were identified and substitutions were made when necessary to insure a sound study program.

Additional raw data which were summarized in this volume are presented in Volume III.

H. B. Robinson Steam Electric Plant

316 Demonstration Study Program

(as submitted December 13, 1974)

PLANT OPERATING DATA

The following plant operating data are planned for inclusion in the Robinson Impoundment and Black Creek 316 study program:

1. Cooling water discharge for each unit and total for all units.
2. Time vs. delta temperature profile for condenser cooling water (at load factors of 1.0 and 0.8) from natural ambient through the cooling system to the point of discharge into the receiving water body and return to ambient.
3. Daily time vs. delta temperature profile at point of discharge under normal seasonal loads and maximum load conditions.
4. Schematic or construction drawings adequate to characterize intake configuration from point of intake to and including the screens.
5. Illustration and description of screening devices including operation cleaning, nekton return and debris disposal.
6. Profile (to scale) of intake velocity from point of intake from source of water to intake screens.
7. Schematic drawing and narrative describing configuration and velocity of discharge.
8. Description of condenser and intake cleaning methods to include types, quantities, effluent concentrations and application of biocides.

ENVIRONMENTAL DATA

The following environmental data are planned for inclusion in the Robinson Impoundment and Black Creek 316 study program:

1. Narrative description and scale drawings showing physical configuration of cooling water source.
2. The surface area, volume, mean depth, retention time and stratification of Robinson Impoundment.
3. Appropriate pool elevations.
4. Stream hydrology characters.
5. Scale drawings and tabulations at 2°C intervals of the thermal plume in three dimensions under full load conditions for summer and winter conditions. Robinson Impoundment does not exhibit fall or spring turnover.
6. Meteorological data used as input to thermal modeling and solar radiation effects on Robinson Impoundment.

BIOLOGICAL DATA

A map of the Robinson Impoundment showing sampling transects and points is presented in Figure 1. Transects are identified as A, B, C, CA, D, E, F, G, H, I, J, and K. Along transects A, B, C, CA, D, and E, three sampling stations, 1, 2, and 3, are identified, with sampling stations 1 and 3 located approximately one-quarter of the way across the impoundment from their respective shores, and sampling station 2 located at the transect middle. (Transect E-3 is located at the mouth of the discharge.)

PHYSICAL AND CHEMICAL ANALYSIS OF ROBINSON IMPOUNDMENT

Water temperature and dissolved oxygen concentrations are recorded monthly at three-foot intervals at each station identified in Table 1 with a portable dissolved oxygen and temperature field unit. Winkler titration (Standard Methods for the Examination of Water and Wastewater, 13th ed., 1971, APHA) may be utilized as a backup to the field unit. Temperatures are recorded in °C (XX.X) and converted to °F (XX.). Temperature data are also plotted to provide temperature isotherms on the surface and at various depths. Dissolved oxygen is recorded in ppm (XX.X) and correlated with sampled water temperatures to calculate percent saturation of oxygen.

Additionally, temperature will be taken monthly in the area of discharge (Figure 2). Transect lines will be run from the mouth of the discharge outward at angles of approximately 20, 40, 60, and 80 percent of the angle formed by the shoreline. Temperatures (°F) will be recorded on the surface at various points along these transects (dependent upon the location of the 1°, 2°, and 3° isotherms).

pH is sampled monthly at each station identified for water chemistry sampling using a field pH unit. Measurement is recorded to XX.X pH units.

Secchi disk depth is sampled monthly at water chemistry sampling stations by lowering a standard shallow water Secchi disk (20 cm.) over the side of the boat and noting the depth at which it disappears and the depth at which it reappears. The average of these two observations is recorded as the Secchi disk depth (in feet, X.X).

Water chemistry samples are collected monthly in the indicated area with a water sampler and transferred to labeled plastic bottles which are chilled and stored in a dark area prior to their return to the CP&L laboratory for analysis. Analytical methods of chemical parameters performed by the CP&L laboratory as of November 1, 1974, are indicated.

Parameter	Method of Analysis	Preservation Technique	Routine Laboratory Reporting Limit	Significance In Reporting Data
Alkalinity, (as CaCO ₃) Total	ASTM Standards, pt. 23, 1972, D1067 Method A (Electrometric Titration) - Standard Methods for the Examination of Water and Wastewater 13th Ed., 1971, APHA, Art 102 (Potentiometric Method for low alkalinity)	Analysis as soon as possible	0.5 mg/liter	X.mg/liter
Aluminum (Al) Total	Atomic Absorption Spectrophotometer (Digestion with HNO ₃ - HCl)	Freezing or acidification to 0.15% HNO ₃	0.1 mg/liter	.Xmg/liter
Aluminum, (Al) Dissolved	Standard Methods for the Examination of Water and Wastewater 13th Ed., 1971, APHA, Art 103B (Eriochrome Cyanine R Method)	Filtration followed by acidification to 0.15% HNO ₃	0.01 mg/liter	.XXmg/liter
Ammonia, (as N)	Standard Methods for the Examination of Water and Wastewater 13th Ed., 1971, APHA, Art 132-132C (Distillation followed by phenate-method or ammonia select-ion electrode)	Freezing or add'n of HgCl ₂ and storage at 4°C	0.02 mg/liter	.XXmg/liter
Calcium, (Ca) Total	Atomic Absorption Spectrophotometer (Digestion with HNO ₃ - HCl)	Freezing or acidification to 0.15% HNO ₃	0.05 mg/liter	.XXmg/liter
Chemical Oxygen Demand, (COD)	Standard Methods for the Examination of Water and Wastewater 13th Ed., 1971, APHA, Art 220	Freezing or acidification with H ₂ SO ₄	0.1 mg/liter	X.mg/liter
Chloride, (Cl ⁻)	ASTM Standards, pt. 23, 1972, D512, Reference Method A (Mercuric Nitrate Titration)	Freezing	0.25 mg/liter	.XXmg/liter
Chromium, (Cr ⁺⁶) Hexavalent	Standard Methods for the Examination of Water and Wastewater 13th Ed., 1971, APHA, Art 117A (s- diphenylcarbazide method)	Freezing	0.005 mg/liter or 5.0 µg/liter	.XXXmg/liter X.X µg/liter

Parameter	Method of Analysis	Preservation Technique	Routine Laboratory Reporting Limit	Significance In Reporting Data
Copper, (Cu) Total	Method for Collection and Analysis of Water Samples for Dissolved Minerals and Gases, Bk.5, Ch. A-1, Techniques of Water-Resources Investigations of the United States Geological Survey, pp. 83-85 (Atomic absorption methods - direct or chelation - extraction)	Freezing or acidification to 0.15% HNO ₃	0.05 mg/liter	.XXmg/liter
Copper, (Cu) Dissolved	Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases, Bk.5, Ch. A-1, Techniques of Water-Resources Investigations of the United States Geological Survey, pp. 83-85 (Filtration through 0.45 micron filter followed by atomic absorption methods - direct or chelation-extraction)	Filtration followed by acidification to 0.15% HNO ₃	0.05 mg/liter	.XXmg/liter
Hardness, (as CaCO ₃)	Standard Methods for the Examination of Water and Wastewater 13th Ed., 1971, APHA 122B (EDTA Titrimetric Method)	Freezing	2.0 mg/liter	X.mg/liter $\frac{1}{8}$
Iron, (Fe) Total	Atomic Absorption Spectrophotometer (Digestion with HNO ₃ - HCl)	Freezing or acidifi-	0.05 mg/liter	.XXmg/liter
Lead, (Pb) Total	Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases, Bk.5, Ch. A-1, Techniques of Water-Resources Investigations of the United States Geological Survey, pp. 105-106 (Atomic absorption methods - direct or chelation - extraction)	Freezing or acidifi- cation to 0.15% HNO ₃	0.05 mg/liter	.XXmg/liter

Parameter	Method of Analysis	Preservation Technique	Routine Laboratory Reporting Limit	Significance In Reporting Data
Orthophosphate, (as P) Total	Standard Methods for the Examination of Water and Wastewater 13th Ed., 1971, APHA, Art 223 (Ascorbic Acid Method)	Freezing	0.01 mg/liter	.XXmg/liter
Phosphate, (as P) Total	Standard Methods for the Examination of Water and Wastewater 13th Ed., 1971, APHA, Art 223 (Persulfate Digestion followed by Ascorbic Acid Method)	Freezing	0.01 mg/liter	.XXmg/liter
Silica, (as SiO ₂) Dissolved	Standard Methods for the Examination of Water and Wastewater 13th Ed., 1971, APHA, Art 151B-151C (Heteropoly Blue Method)	Freezing after collection in a plastic container	0.1 mg/liter	.Xmg/liter
Sodium, (Na) Total	Atomic Absorption Spectrophotometer (Digestion with HNO ₃ - HCl)	Freezing or acidification to 0.15% HNO ₃	0.05 mg/liter	.XXmg/liter
Solids, Total Dissolved (Filterable)	Methods for Chemical Analysis of Water and Wastes, 1971, EPA, pp. 275-277 (Glass Fiber Filtration Method, 180°C) - Data reported below 10 mg/liter for all solids is not really significant, but indicates order of magnitude	Freezing or analysis as soon as possible	1.0 mg/liter	X.mg/liter
Solids, Total Suspended (Non-filterable)	Methods for Chemical Analysis of Water and Wastes, 1971, EPA, pp. 278-279 (Glass Fiber Filtration Method, 103-105°C)	Freezing or analysis as soon as possible	1.0 mg/liter	X.mg/liter

Parameter	Method of Analysis	Technique	Reporting Limit	Reporting Data
Magnesium, (Mg) Total	Atomic Absorption Spectrophotometer (Digestion with HNO ₃ - HCl)	Freezing or acidification to 0.15% HNO ₃	0.05 mg/liter	.XXmg/liter
Manganese, (Mn) Total	Atomic Absorption Spectrophotometer (Digestion with HNO ₃ - HCl)	Freezing or acidification to 0.15% HNO ₃	0.05 mg/liter	.XXmg/liter
Mercury, (Hg) Total	Methods for Chemical Analysis of Water and Waste, 1971, EPA, pp. 121-130 (Cold-vapor technique)	Freezing or acidification to 0.15% HNO ₃	0.001 mg/liter or 1.0 µg/liter	.XXXmg/liter X.Xµg/liter
Nickel, (Ni) Total	Method for Collection and Analysis of Water Samples for Dissolved Minerals and Gases, Bk.5, Ch. A-1, Techniques of Water-Resources Investigations of the United States Geological Survey, pp. 115-116 (Atomic absorption methods - direct or chelation - extraction)	Freezing or acidification to 0.15% HNO ₃	0.05 mg/liter	.XXmg/liter
Nickel (Ni) Dissolved	Method for Collection and Analysis of Water Samples for Dissolved Minerals and Gases, Bk.5, Ch. A-1, Techniques of Water-Resources Investigations of the United States Geological Survey, pp. 115-116 (Filtration through 0.45 micron filter followed by atomic absorption methods - direct or chelation - extraction)	Filtration followed by acidification to 0.15% HNO ₃	0.05 mg/liter	.XXmg/liter
Nitrate (as N)	Methods for Chemical Analysis of Water and Wastes 1971, EPA, pp. 170-174 (Brucine-Sulfate Method)	Freezing or add'n of HgCl ₂ and storage at 4° C	0.05 mg/l	.XX mg/l
Nitrogen, (N) Organic	Standard Methods for the Examination of Water and Wastewater 13th Ed., 1971, APHA Art 135, 132C - Digestion and distillation followed by phenate method or ammonia select-ion electrode (Ammonia Nitrogen plus Organic Nitrogen = Total or Kjeldahl Nitrogen)	Freezing or add'n of HgCl ₂ and storage at 4° C	0.02 mg/liter	.XXmg/liter

Parameter	Method of Analysis	Preservation Technique	Routine Laboratory Reporting Limit	Significance In Reporting Data
Solids, Total Volatile	Methods for Chemical Analysis of Water and Wastes, 1971, EPA, pp. 282-283 (Gravimetric Method, 550°C)	Freezing or analysis as soon as possible	1.0 mg/liter	X.mg/liter
Solids, Total	Methods for Chemical Analysis of Water and Wastes, 1971, EPA, pp. 280-281 (Gravimetric Method, 103-105°C)	Freezing or analysis as soon as possible	1.0 mg/liter	X.mg/liter
Sulfate	ASTM Standards, pt. 23, 1972, D516, Reference Method A (Turbidimetric Method)	Freezing, Filtration prior to analysis	1.0 mg/liter	.Xmg/liter
Turbidity	Standard Methods for the Examination of Water and Wastewater 13th Ed., 1971, APHA, Art 163A (nethelometric method)	Freezing	0 FTU	X.X FTU
Zinc, (Zn) Dissolved	Atomic Absorption Spectrophotometer (Filtration through 0.45 micron filter)	Filtration followed by acidification to 0.15% HNO ₃	0.05 mg/liter	.XXmg/liter
Zinc, (Zn) Total	Atomic Absorption Spectrophotometer (Digestion with HNO ₃ - HCl)	Freezing or acidifi-	0.05 mg/liter	.XXmg/liter

PLANKTON POPULATION MONITORING AT ROBINSON IMPOUNDMENT

Plankton samples will be taken in accordance with the schedule presented in Table 1. Pigment concentration, primary productivity, and standing crop will be determined from which species diversity and spatial and temporal abundance can be calculated.

Pigments - Samples for pigment analysis are taken monthly at each of the plankton stations with a water sampler. The water sampler is large enough to allow for subsamples to be taken for pigment analysis, primary productivity, and standing crop whenever scheduling requires that more than one analysis be performed. Samples are taken at various depths, depending upon Secchi depth, as follows:

_____	surface
_____	1/2 Secchi depth
_____	Secchi depth/or bottom
_____	2x Secchi depth/or bottom
_____	4x Secchi depth/or bottom

Samples are transferred from the sampler to labeled plastic bottles, preserved with magnesium carbonate, chilled, and stored in a dark area before being returned to the laboratory for immediate filtration and extraction. Analysis includes spectrophotometric and/or fluorametric determinations from acetone extracts of millipore filter concentrates as described in Strickland and Parsons (1968) and Golterman (1969). Significance in reporting data is X.X $\mu\text{gm/liter}$.

Primary productivity - In situ primary productivity is determined once quarterly by use of the C^{14} fixation method at each of the plankton sampling stations. Water samples are taken with the Wildco Beta bottle water sampler from depths as described previously. From each depth, initial, zero time control and light bottle samples are taken. The initial samples are stored on ice in the dark for alkalinity determinations; the zero time control samples are inoculated with C^{14} , immediately fixed with Lugol's iodine and stored in the dark; and the light bottles are inoculated with C^{14} , incubated in situ for three hours and fixed at the end of the inoculation time with Lugol's iodine.

Counting of C^{14} samples is by liquid scintillation. Laboratory analysis procedures and calculations follow established methods based on the original work of Nielsen (1952) and revised as described in Vollenweider, ed. (1969). Use of a zero time control was suggested by Dr. John E. Hobbie of North Carolina State University based on the work of Morris, Yentsch and Yentsch (1971).

Standing crop - Once quarterly, whole water samples are collected from the depths described previously at each of the plankton sampling stations. Concentrated net samples are also collected using a #20 mesh Wisconsin type plankton net. All samples are fixed in the field with Lugol's iodine, stored in a dark, cool area, and returned to the laboratory for phytoplankton and zooplankton identification, enumeration, and biomass estimates; Identification and enumeration methods include use of a 1 ml. Sedgwick-Rafter cell using a variable number of cells (at 100x) and a variable number of random fields (at 100x and 200x) and/or Utermohl sedimentation with an inverted microscope using a variable number of chambers (at 100x) and a variable number of random fields (at 100x, 200x, and if necessary, 400x and 1000x). All organisms are identified to the lowest taxon practicable using standard taxonomic references.

Biomass estimates are made using a Whipple grid micrometer to determine average volume per cell. Calibration is performed with a stage micrometer at 100x, 200x, 400x, and 1000x. Biomass is reported in XX $\mu\text{gm/liter}$.

Analysis of standing crop is performed for both number and biomass. These data can then be incorporated into a PL-1 computer program which can be used to calculate the Shannon-Werner index of general species diversity for both number and biomass (Copeland and Birkhead, 1972).

MACROBENTHIC MONITORING AT ROBINSON IMPOUNDMENT AND BLACK CREEK

Benthos samples will be taken in accordance with the schedule presented in Table 1. Samples will be analyzed for identification of organisms from which species diversity and spatial and temporal abundance can be analyzed.

Samples are collected monthly from two stations (deep and shallow) on each of nine permanent transects (Table 1) using a petite ponar grab and/or artificial substrate samplers. Three replicate samples are collected from each station. Samples are washed through a U. S. Standard No. 30 sieve and preserved in formalin.

Samples are sorted in the laboratory and preserved in 70% alcohol. Biological stains, rose bengal and phyloxine B, are frequently used as aids to sorting. All organisms are identified to the lowest taxon practicable using binocular and compound microscopes and standard taxonomic references.

After 24 hours of storage in fresh water, representative organisms from all samples are weighed to the nearest 0.001 gm.

Data are reported monthly in tabular form, expressing number of organisms/unit area and fresh weight biomass (gm/unit area) for each station.

FISHERIES MONITORING AT H. B. ROBINSON IMPOUNDMENT AND BLACK CREEK

Purpose: Collection and analysis of representative samples of the fish population of the Impoundment pursuant to the requirement for a 316(a) Demonstration.

Objectives:

1. Determine species composition relative abundance, and standing crop of fishes in various areas of the Impoundment.
2. Determine food habits, age, growth rate, maturity, and fecundity of representative species in the Impoundment.
3. Determine the extent of reproductive activity in the immediate area of discharge and evaluate potential damage to the fishery by entrainment of ichthyoplankton.

Sample Period:

1. Annually - cove sample with rotenone
2. Quarterly - gill nets, wire traps, and seine
3. At minimum bi-weekly* during the spawning season - entrainment and spawning activity.

Sample Design:

1. Stations 1 and 3 on transects A, C, E, and G, (Figure 1) will be sampled with 100-foot experimental gill nets (equal panels of 1/2, 1, 1 1/2, 2-inch bar mesh) and wire traps (1-inch poultry netting) for approximately 48 hours. One stream station above and two stream stations below the Impoundment (H, J, and K) will be sampled with 50-foot experimental gill nets (1/2, 1, 1 1/2, and 2-inch bar mesh) and wire traps. Nets and traps will be checked at least every 24 hours and catches will be reported as number and/or weight per unit time. Shoreline stations on these transects will be sampled with a small mesh bag seine over a constant area and catches reported as number or weight per haul. All fish collected are identified, counted, weighed, and measured. Live fish in good condition are tagged and released when possible. A reference collection will be made and maintained, and representative samples of largemouth bass, bluegill, and white catfish will be retained for age-growth, stomach, and gonad analysis.

*Bi-weekly is used to indicate monitoring which occurs once each two weeks.

2. Selected coves of the impoundment (upper, mid, and lower area) and three stream stations (H, J, and K) will be blocked off with small mesh nets and rotenone applied by accepted methods. All fish recovered will be identified, counted, weighed, and measured. These data will be used in estimating the standing crop of fishes in the Impoundment and Black Creek. Largemouth bass, bluegill, and white catfish collected will be used in age-growth, stomach, and gonad analysis.
3. Largemouth bass, bluegill, and white catfish will be examined for food habits, age, growth rate, maturity, and fecundity. Stomach contents will be removed, sorted, identified, and quantified volumetrically. Scales (pectoral spines from white catfish) are read in the laboratory to determine annual growth increments. Age-growth relationships will be computed if sufficient numbers of fish are obtained. Gonad maturity will be determined by gross inspection to determine spawning periods and fecundity will be estimated using gravimetric subsampling techniques.
4. The immediate discharge area will be examined during the spawning seasons to evaluate spawning and nursery areas. Plankton sampling techniques will be employed to determine the relative abundance of fish eggs and larvae. Visual observations will be combined with seining and other techniques such as larval fish nets and electrofishing at night in near shore areas to determine the presence or absence of spawning adults and young-of-the-year. Entrainment of ichthyoplankton in the plant cooling water system will be monitored bi-weekly* during the major spawning period by sampling the intake area with accepted ichthyoplankton sampling techniques. Samples will be collected more frequently if numbers collected indicate potential damage to the fishery. Estimates will be made of the total number of fish eggs and larvae entrained.

*Bi-weekly is used to indicate monitoring which occurs once each two weeks.

TERRESTRIAL MONITORING OF ROBINSON IMPOUNDMENT AND BLACK CREEK

Purpose: Implement a sampling program pursuant to the requirements for a 316(a) Demonstration.

- Objectives:**
1. Identify those vertebrate species (except fish) living adjacent to, on, or in the Robinson Impoundment and Black Creek which are dependent upon the aquatic ecosystem for some portion of their life cycle.
 2. Determine the nature and extent of dependence upon the aquatic ecosystem by those organisms from above.
 3. Provide a scale map showing major beds of vascular plants and maintain herbarium specimens of all species collected.
 4. Determine the possible effects of thermal discharge on those species dependent on the Impoundment ecosystem.

Sample Period: Quarterly.

Sample Design - Avifauna

1. Establish two 10-mile survey routes, one each on the east and the west shores of the Impoundment. Locate observation points at 1-mile intervals along each survey route. (11 points per route)
2. Spend five minutes at each point listening and observing. Record sightings by species and number.
3. Travel by boat at approximately 12 mph between points. Observations between stops will also be recorded.
4. Four surveys will be conducted during each quarterly sample. One morning and one evening survey will be conducted along each route.

5. Morning surveys begin at official sunrise, and evening surveys end at official sunset.
6. Stations H and K on Black Creek below the Impoundment will be sampled once daily during each sample period.

Sample Design - Mammals

1. Set live traps at selected points along the shoreline for a minimum of three nights during each sample period.
2. Observe nocturnal activity using boats and spotlights.
3. Observe shoreline areas for tracks and other signs.
4. Observations will also be made in conjunction with other aspects of the sample program.

Sample Design - Herptiles

1. Observe and identify reptile and amphibian species during all phases of the study.
2. Special emphasis will be placed on attempting to determine the extent of amphibian reproductive activity during spring and summer near the discharge site. This will involve cooperation with the aquatic sampling program.

Sample Design - Vegetation

1. Map major areas of aquatic vascular vegetation in the Impoundment and Black Creek (at stations H, J, and K).
2. Compile and maintain a species list and herbarium specimens for all plants collected.

TABLE 1

FIELD SAMPLING SCHEDULE AND SAMPLING LOCATIONS

	A			B & CA			C			D			E			F	G	H	I	J	K
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3						
Abiotic																					
Water Temperature (Monthly)																					
Surface	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Every 3 feet bottom	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dissolved Oxygen (Monthly)																					
Surface	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Every 3 feet to bottom	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Water Chemistry (Monthly) ^a																					
Surface	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	X	X	X	X	X	X
Bottom	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	-	-	-	-
Biotic																					
Plankton																					
Pigment (Monthly)	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	-	-	-	-
Primary Productivity (Quarterly)	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	-	-	-	-
Standing Crop (Quarterly)	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	-	-	-	-
Benthos (Monthly)																					
	b			-	-	-	b			b			b			b	b	-	b	b	
Fishery (Quarterly)																					
	c			-	-	-	c			-			c			-	c	c	-	c	c

^aA complete list of water chemistry parameters is provided in Table 2.

^bAlong designated transect at deep and shallow stations.

^cAlong designated transect.

TABLE 2

CHEMICAL PARAMETERS TO BE MONITORED

Total solids	Sulphate	Total zinc †
Total volatile solids	Total alkalinity (CaCO ₃)	Dissolved zinc* †
Total suspended solids	Hardness	Total sodium †
Total dissolved solids	Dissolved silica	Total aluminum
Ammonia (As N)	Chloride (Cl ⁻)	Dissolved aluminum †
COD	Total chromium (hexavalent)	Total mercury
Niteldahl nitrogen	Total copper †	Total calcium †
Nitrate (As N)	Dissolved copper* †	Total magnesium †
Ortho-phosphate (As P)	Total iron	Total manganese †
Total phosphate (As P)	Total lead †	Total nickel †
	pH (field analysis)	Dissolved nickel* †
		Turbidity

Dissolved copper, zinc, aluminum, and nickel will be measured only when the total levels of these metals exceed a level of 0.05 ppm.

Parameters to be analyzed twice yearly.

ROBINSON IMPOUNDMENT AND BLACK CREEK SAMPLING
TRANSECTS AND SAMPLING POINTS

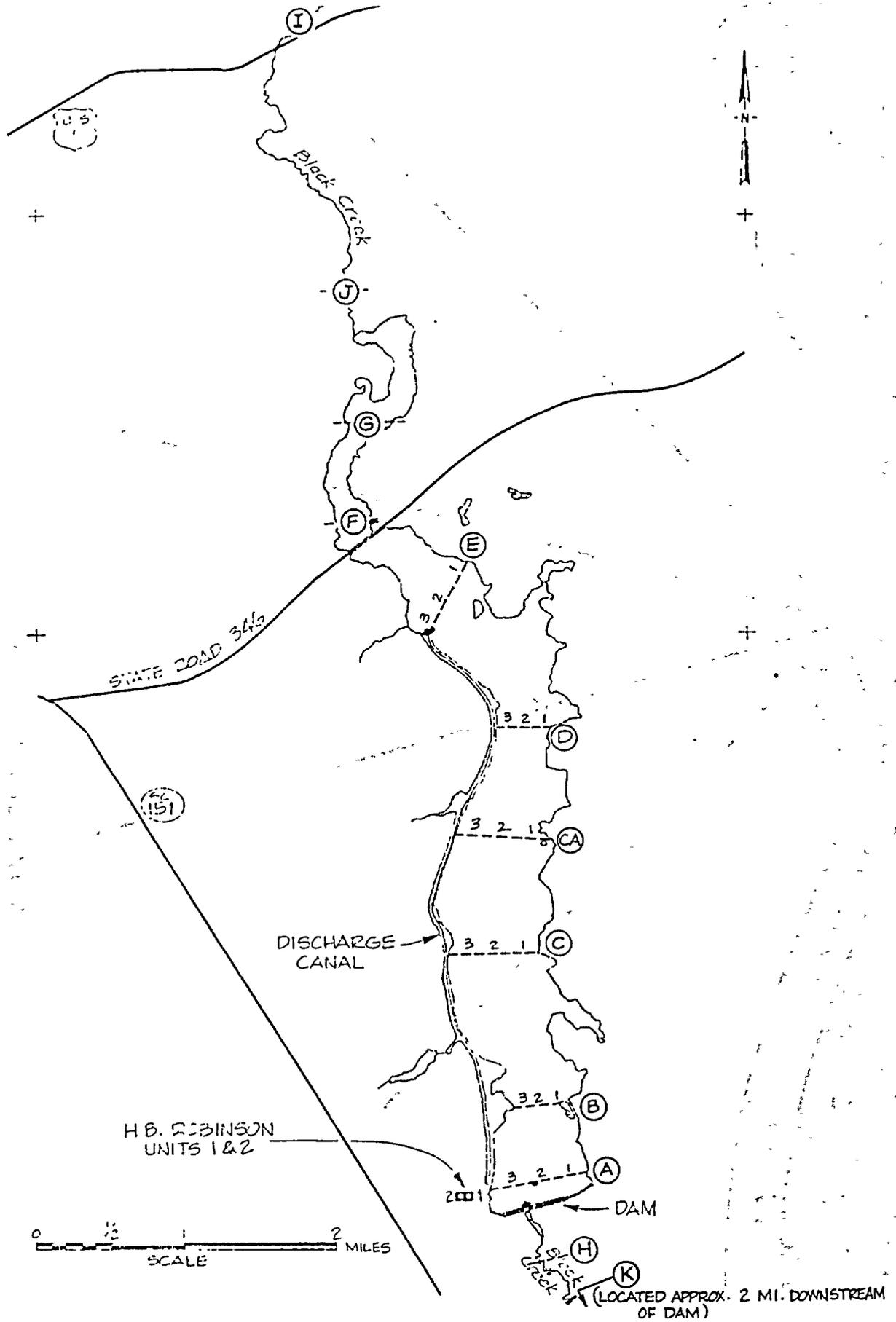
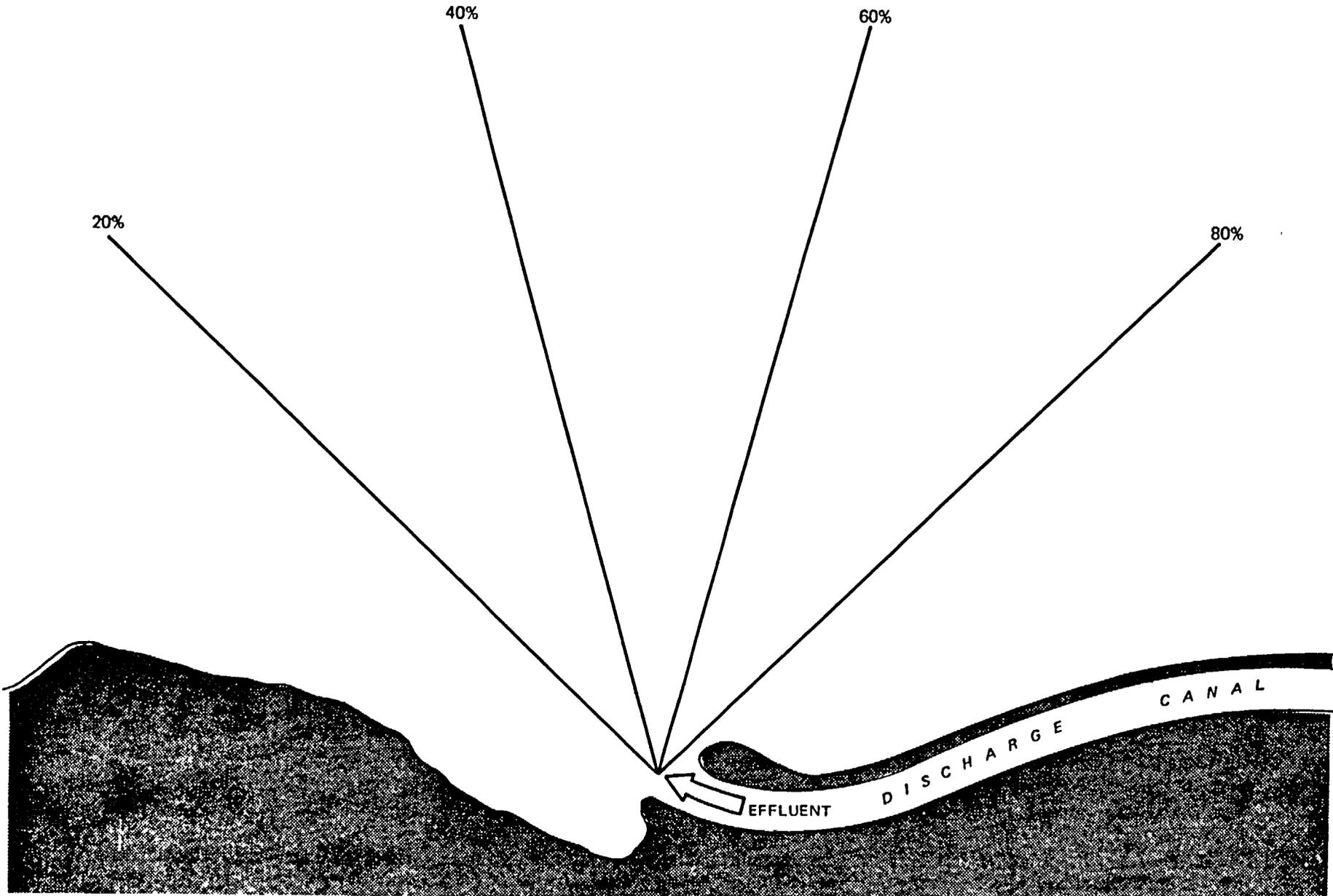


FIGURE 2. H. B. ROBINSON EFFLUENT SAMPLING TRANSECTS

1-22



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2.0 Plant Operating Data

2.1 Circulating Water System

The circulating water system for the H. B. Robinson plant provides for the condensation of steam from the main turbines of both units. Circulating water is withdrawn from the impoundment near the dam, passed through the main condensers for both units, and returned via the discharge canal to the impoundment approximately 6.7 km (4.2 miles) north of the plant (Figure 2.1.1).

Table 2.1.1 lists the circulating water system flow rates, temperature rise across the condenser, and the average heat rejected for both units.

The intake structures for both units are located on the west bank of the impoundment near the dam. Unit 1 has two pumps, Unit 2 has three pumps, each with a separate intake bay. The entire structure is 13.2 meters (43.4 feet) wide, 19.7 meters (64.5 feet) long, and 13.9 meters (45.5 feet) high. Water is withdrawn from the impoundment between 5.5 meters (18 feet) and 11.0 meters (36 feet). Plan views and vertical sections for Units 1 and 2 are shown in Figures 2.1.2 through 2.1.5.

Flow velocity magnitudes were measured across selected cross sections of the H. B. Robinson Units 1 and 2 intake structures and the common discharge canal. These measurements were used with other data sources, specifically, design flow rates, geometrical configurations, and observation, to construct expected flow velocity profiles within the intake structures from point of entry to the face of the traveling screens and within the canal from the origin to the weir. The measurements are generally expected to be accurate to within 10%.

A detailed presentation of the flow measurements and analysis is included as Exhibit 1.0 (VOL. III). Figures 2.1.11 and 2.1.12 show side views of the Unit 1 intake bays with assumed streamlines and measured velocity magnitudes included. The velocities given are simple averages of five measurements taken laterally at the elevations shown. Similar results for the three

bays of the Unit 2 intake structure are presented in Figures 2.1.13, 2.1.14, and 2.1.15. In Tables 1.1 through 1.6 of the exhibit, all the individual intake velocity measurements are given.

Within the Unit 1 intake structure, the flows were generally below .46 m/sec (1.5 ft/sec). The profile is somewhat skewed away from the bottom because of the 4.73 m (15.5-foot) vertical section of the bay floor. There appeared to be local high-velocity spots near the edges of the horizontal support columns and there was a recirculation region near the water surface.

Within the Unit 2 bays, the vertical profiles were fairly flat and velocities generally ranged from .31 m/sec to .92 m/sec (1.0 to 3.0 ft/sec) except in the recirculation region near the surface where flows were generally less than .31 m/sec (1 ft/sec). The design flow per bay of 6.1×10^5 l/min (160,700 gpm), or $102 \text{ m}^3/\text{sec}$ ($358 \text{ ft}^3/\text{sec}$), would imply an average velocity of .5 m/sec (1.65 fps) at the smallest physical cross-sectional area within the bay. The measured velocities compare reasonably with this result. Again, high velocities near the horizontal support columns were apparent, especially at a depth of 3.89 m (12.75 ft) in Bay A where the only flows above .92 m/sec (3 ft/sec) were recorded. This high velocity channel appeared to be a localized phenomenon since velocities measured 1.22 m (4.0 ft) above and below this depth were below .61 m/sec (2 ft/sec) (Figure 2.1.13).

Screening devices for both units are redundant traveling water screens with .95 cm (3/8-inch) mesh (Figure 2.1.6). The screens travel vertically at two speeds, 3 meters (10.0 feet) per minute, and .76 meters (2.5 feet) per minute. All material washed from the screens during the daily cleaning is flushed via the storm drains into Black Creek below the impoundment.

Each generating unit has its own separate condenser. Unit 1 has a two pass condenser with two water boxes. The Unit 2 condenser is a once-through type with four water boxes. To control fouling in the condenser tubes, a 15% sodium hypochlorite solution is fed to the condenser boxes for one-half hour once each day. Maximum daily effluent concentration from the condenser is .5 mg/l free available chlorine not to exceed a

monthly average of .2 mg/l. Once each month approximately 45 kilograms (100 lbs.) of ferrous sulfate is added to the condenser to help protect the tubes.

The condensers are periodically cleaned by passing scrapper plugs through the tubes. Unit 1 is cleaned by this method two to three times per year; Unit 2 is normally cleaned during the annual outage. Debris from these operations is washed back to the impoundment via the discharge canal.

After passing through the condensers, the circulating water from both units is routed into a common discharge canal by a sealwell structure. The discharge canal runs along the west shore of the impoundment and terminates with a weir located 6.8 km (4.2 miles) north of the plant. Diagrams of the discharge canal and the weir are shown in Figures 2.1.7 and 2.1.8.

Flow measurements were made at 20% and 80% depths at various positions across the discharge canal at a point approximately .97 km (0.6 miles) from the canal origin. The results of these measurements are shown in Figure 2.1.16. This is expected to be typical of the flow pattern all along the canal since the basic cross section is unchanged. It is seen that the flow over most of the canal varies between .45 m/sec and .76 m/sec (1.5 and 2.5 ft/sec). This range of velocities is generally consistent with discharge canal design flows at the weir.

Flows over the weir were measured at half-depth .61 m (2 feet) and found to be nearly constant laterally at around 2.01 m/sec (6.6 ft/sec). Figure 2.1.17 gives the five measured velocities and the measurement positions.

Table 2.1.2 provides the average monthly circulating water system parameters from April, 1975 through May, 1976. Comparing Table 2.1.2 with Table 2.1.1 indicates that the plant load is rarely equal to the design generating capacity on a monthly average, and that the rise across the condensers seldom approaches the rise with a load factor of 1.0. The average delta temperature profiles for the plant circulating water system at load factors 1.0 and 0.8 are shown in Figure 2.1.9. The daily delta temperature profile for the circulating water system is shown in Figure 2.1.10.

Table 2.1.1 Circulating water system, Robinson Plant (Load factor = 1.0)

Average CWS Flow, Unit 1	5.52 m ³ /sec	(87,500 gpm)
Average CWS Flow, Unit 2	30.42 m ³ /sec	(482,100 gpm)
Average Service Water Flow, Unit 2	1.51 m ³ /sec	(24,000 gpm)
Average Plant Discharge	37.45 m ³ /sec	(593,600 gpm)
Average Condenser Rise - Across Unit 1	13.33°C	(24°F)
Average Condenser Rise - Unit 2	11.11°C	(20°F)
Average Condenser Rise - Both Units	11.28°C	(20.3°F)
Average Heat Rejected - Unit 1	3.08 x 10 ⁸ W	(1.05 x 10 ⁹ BTU/hr)
Average Heat Rejected - Unit 2	1.46 x 10 ⁹ W	(5.00 x 10 ⁹ BTU/hr)
Average Heat Rejected - Both Units	1.77 x 10 ⁹ W	(6.05 x 10 ⁹ BTU/hr)

Table 2.1.2 H. B. Robinson Steam Electric Plant
 average monthly circulating water system parameters
 April 1975 - May 1976.

Month	Robinson** Impoundment Discharge m ³ /Sec.	Average Hourly Gross Plant Generation (MWe)	CWS Flow m ³ /Sec	Average*** Intake Temperature °C	Average Discharge Temperature °C	Average Plant Rise °C
Apr. '75	9.3	364.8	26.7	19.9	24.8	4.9
May '75	7.6	234.3	24.0	23.0	27.3	3.4
June '75	5.2	687.7	34.5	28.6	37.4	8.8
July '75	12.7	776.4	36.6	29.0	38.9	9.9
Aug. '75	6.2	812.2	37.4	31.2	41.4	10.2
Sept. '75	8.1	762.1	36.7	29.0	38.2	9.2
Oct. '75	6.3	735.4	35.5	25.4	34.5	9.1
Nov. '75	6.7	129.6	20.7	18.8	21.6	2.8
Dec. '75	7.4	461.6	31.0	12.6	18.0	5.4
Jan. '76	8.8	669.3	29.2	11.4	21.9	10.5
Feb. '76	8.1	750.5	32.5	15.4	25.7	10.3
Mar. '76	7.4	728.2	33.5	19.6	29.1	9.5
Apr. '76	5.0	685.1	31.9	22.3	31.8	9.5
May '76*	5.8	618.6	32.0	25.2	35.3	10.1

*Preliminary

**Apr-Sept 1975 USGS water resources data; Oct 75-Apr 76 USGS provisional record

***Measured at condensers

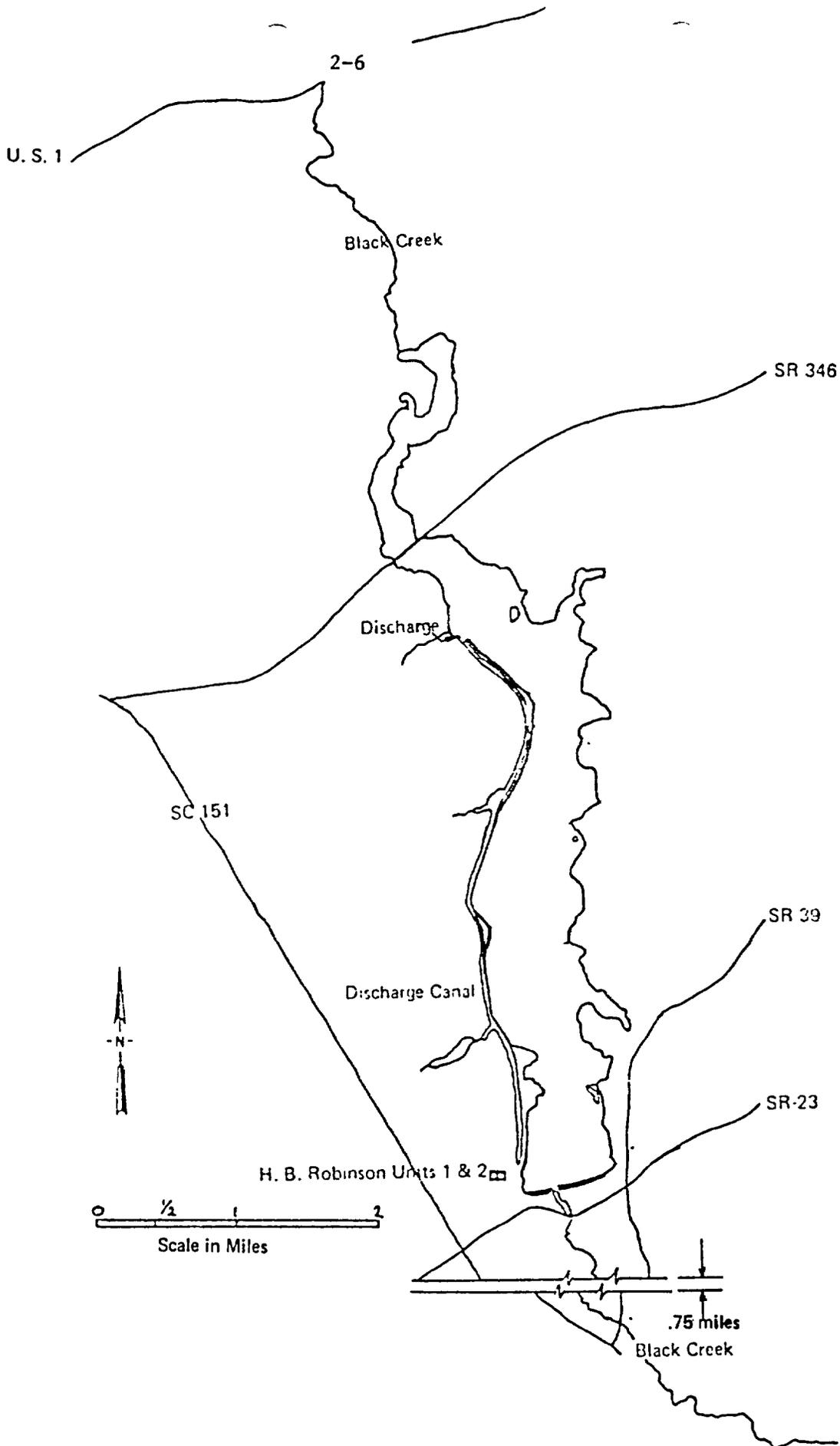


Figure 2.1.1 Robinson Impoundment

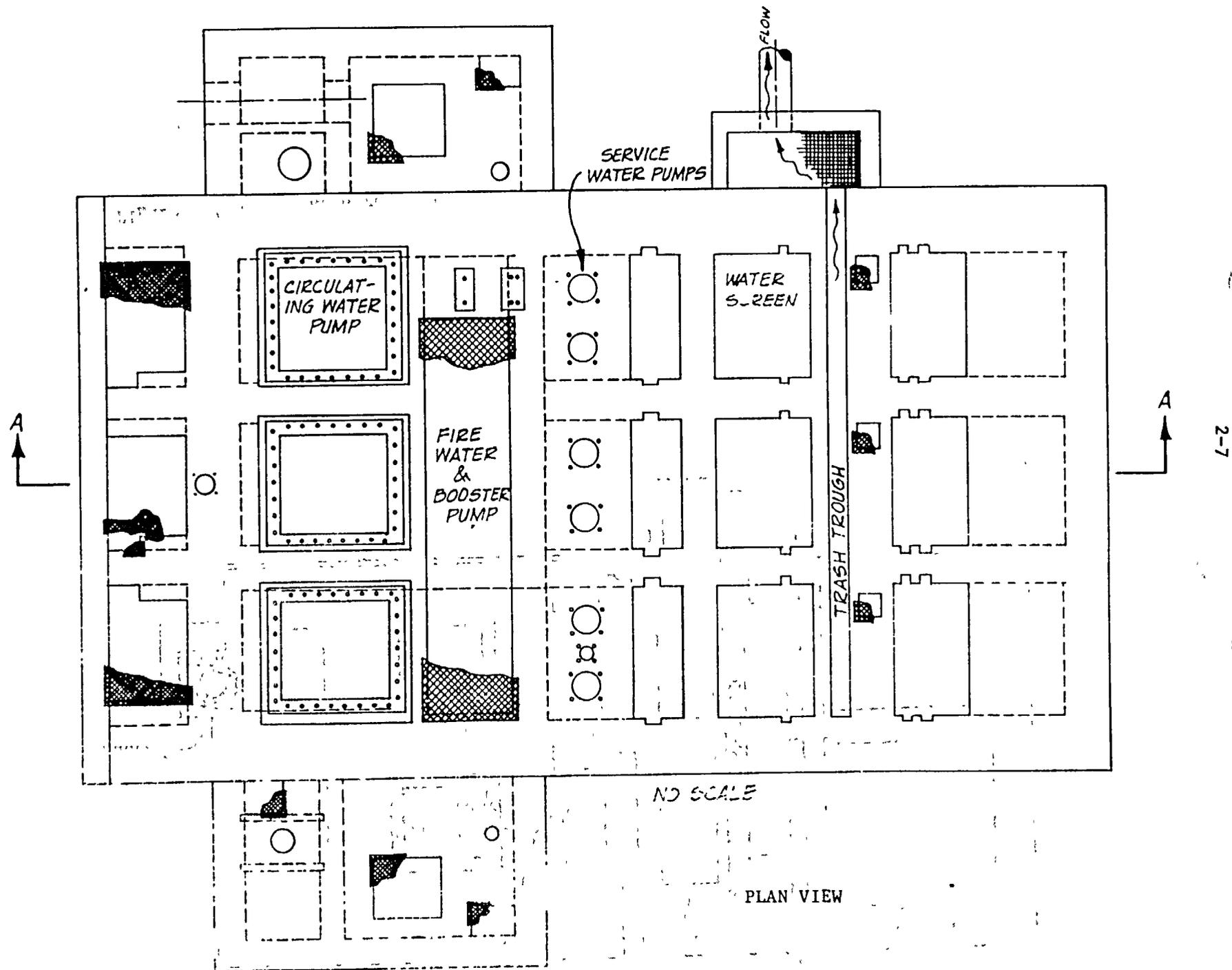


Figure 2.1.2 Intake structure, Unit 2, plan view

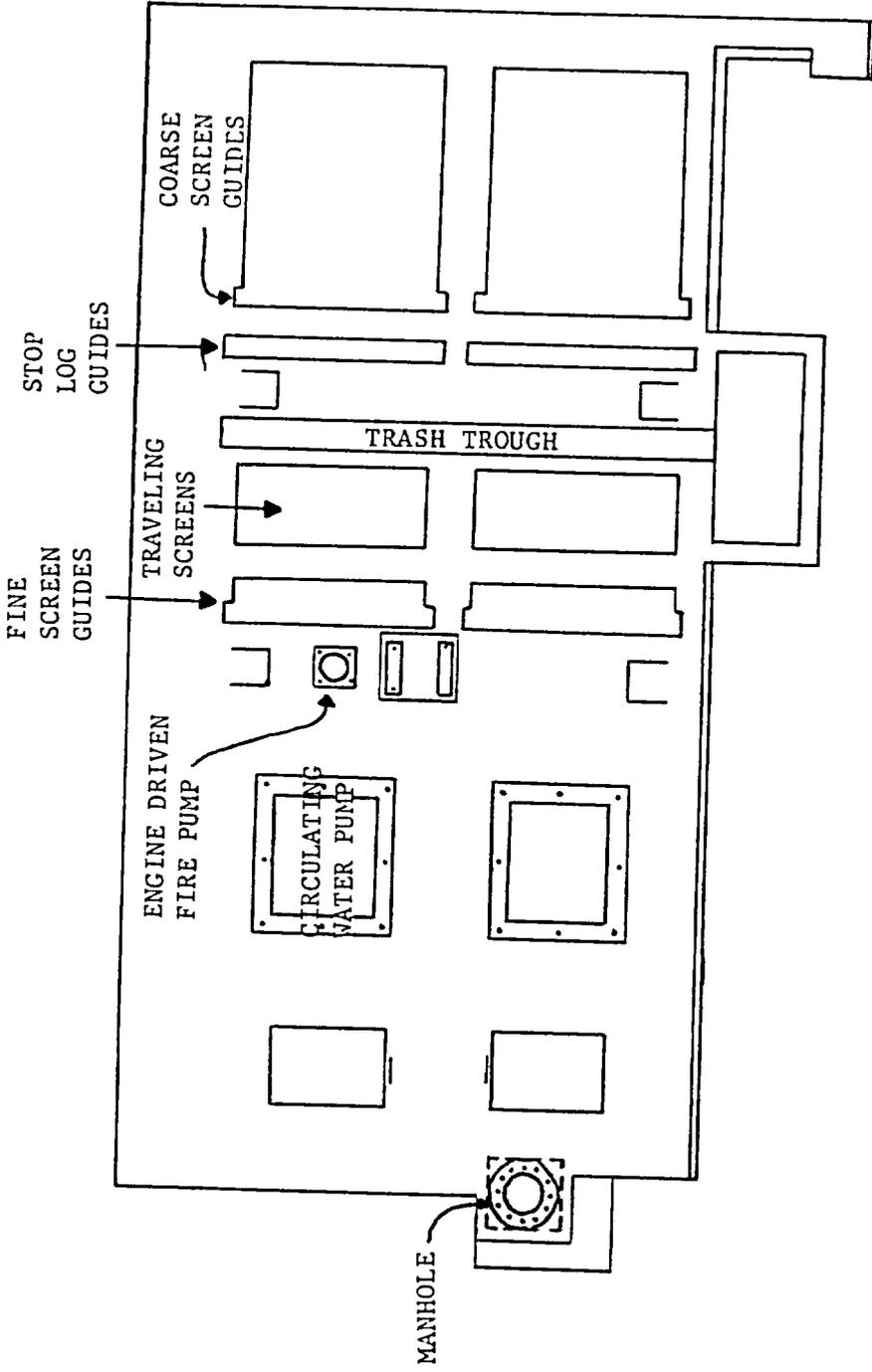


Figure 2.1.1.3 Intake structure, Unit 1, plan view

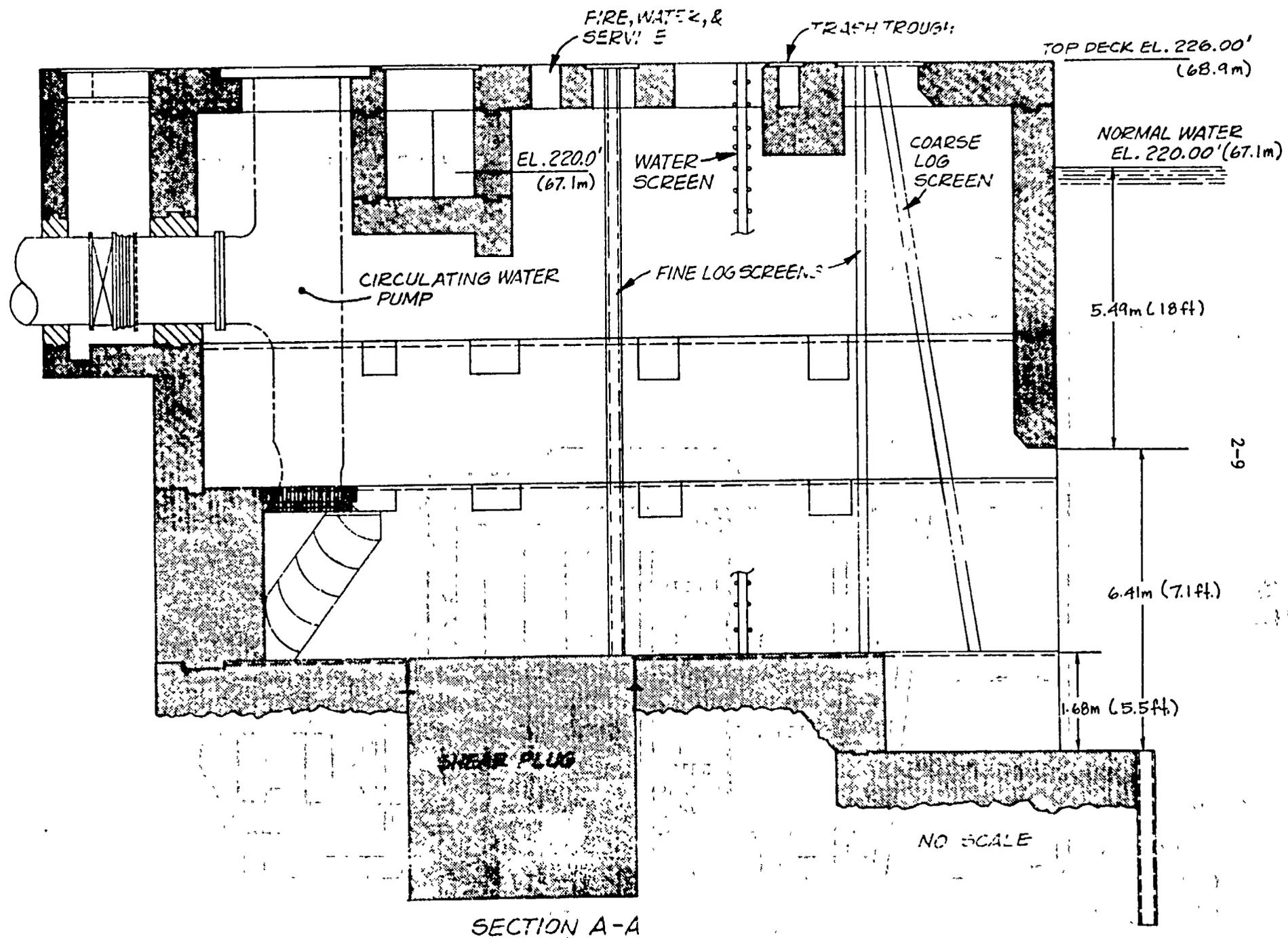


Figure 2.1.4 Intake structure, Unit 2, vertical section

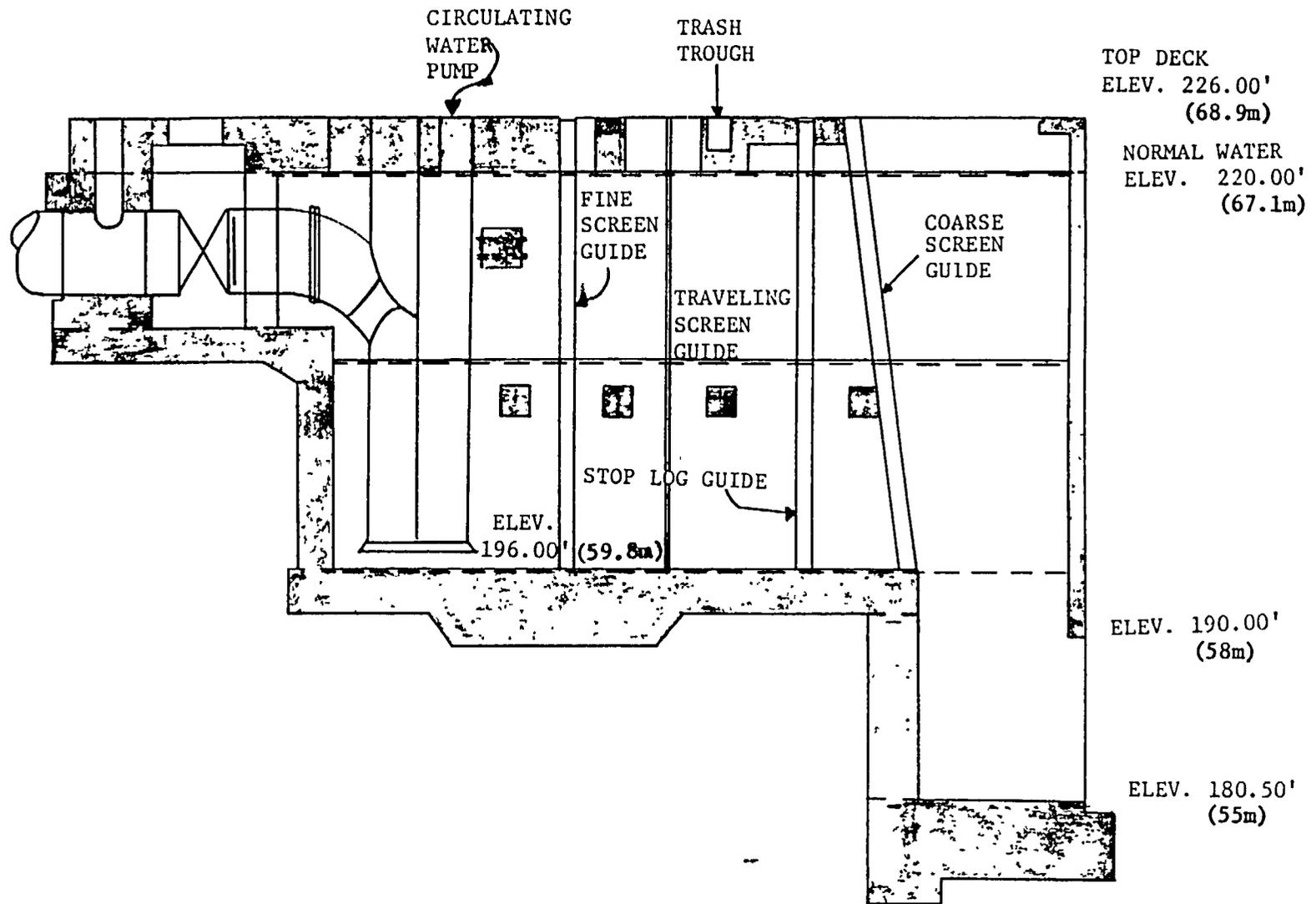
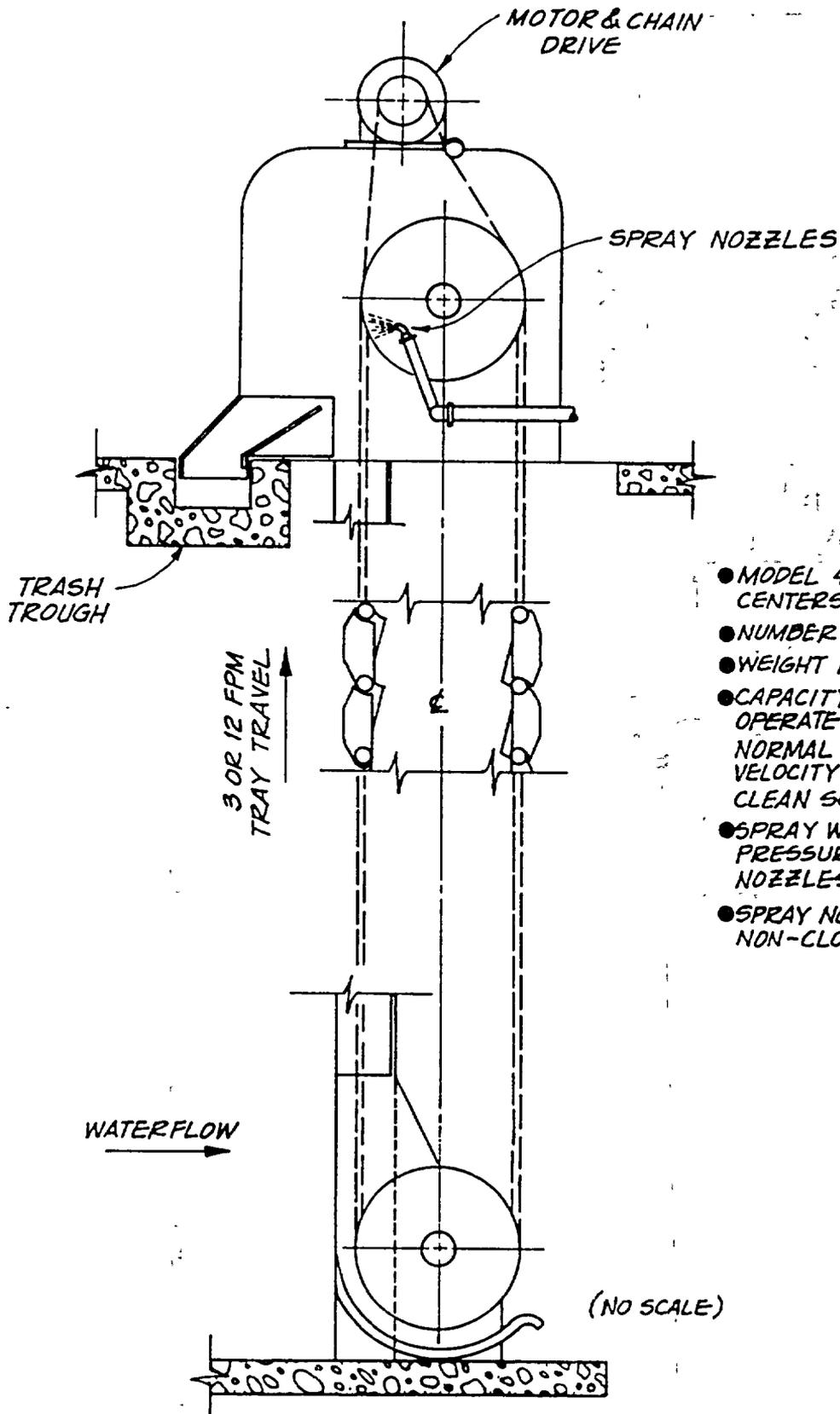


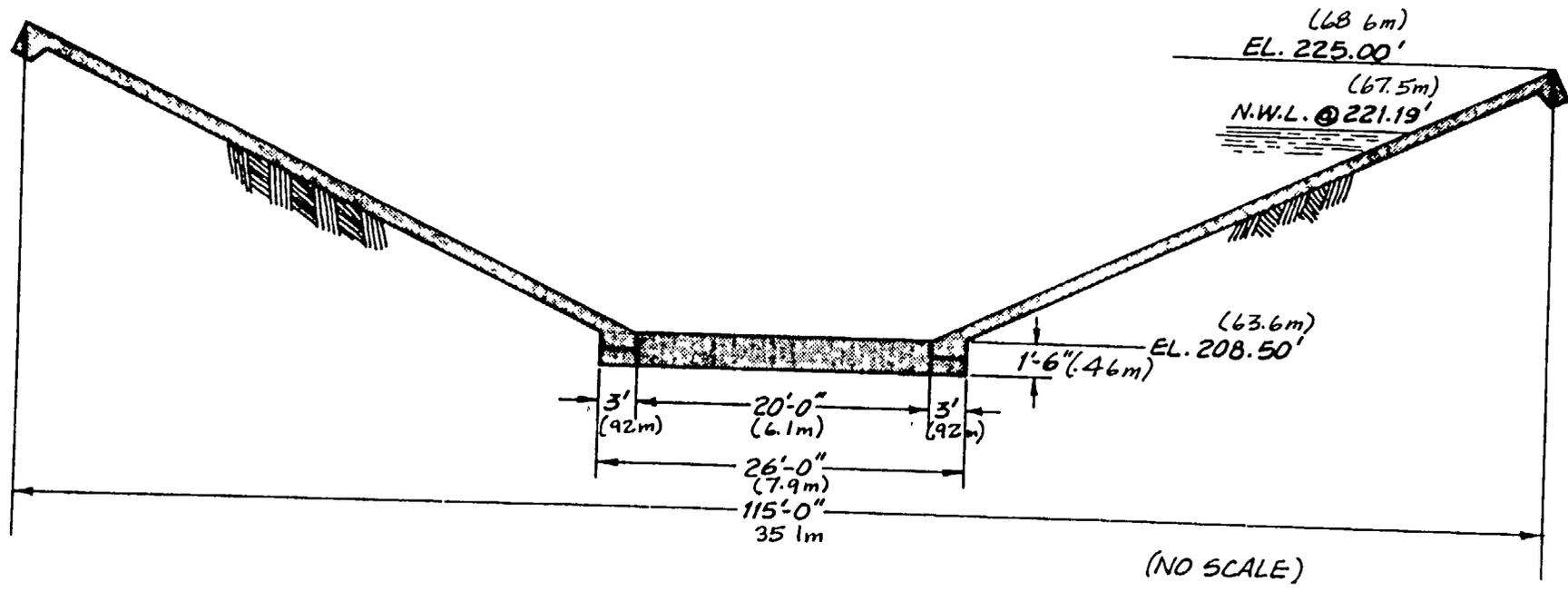
Figure 2.1.5 Intake structure, Unit 1, vertical section

NOTES:

- MODEL 45A SCREEN, 41'-0" SHAFT CENTERS, 10'-0" WIDE TRAYS
- NUMBER OF UNITS - 3
- WEIGHT PER UNIT - 28,735 LBS.
- CAPACITY - WATER SCREEN WILL OPERATE AT 162,900 GPM WITH NORMAL WATER DEPTH AT 1'-0" AT A VELOCITY OF 1.82 FPS THROUGH 100% CLEAN SCREEN CLOTH
- SPRAY WATER - 248 GPM AT A PRESSURE OF 50 PSI AT THE SPRAY NOZZLES
- SPRAY NOZZLES - 14 BRASS NON-CLOGGING NOZZLES

Figure 2.1.6 Intake screens, Unit 2

- NORMAL WATER LEVEL @ EL. 221.19 (67.5m)
- WATER DEPTH \approx 13' (4.0m)



2-12

Figure 2.1.7 Discharge canal, cross section

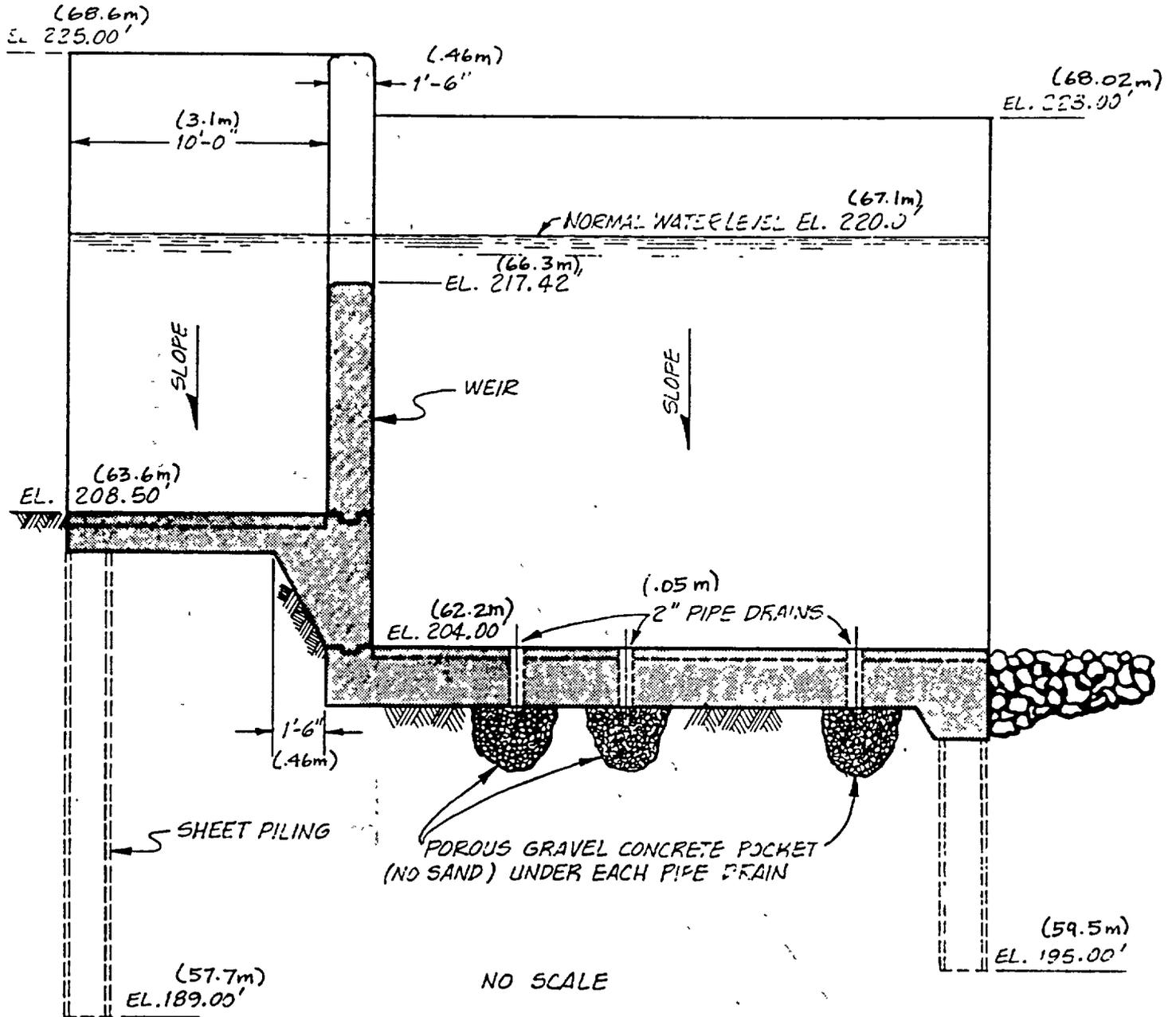


Figure 2.1.8 Discharge canal intersection with impoundment

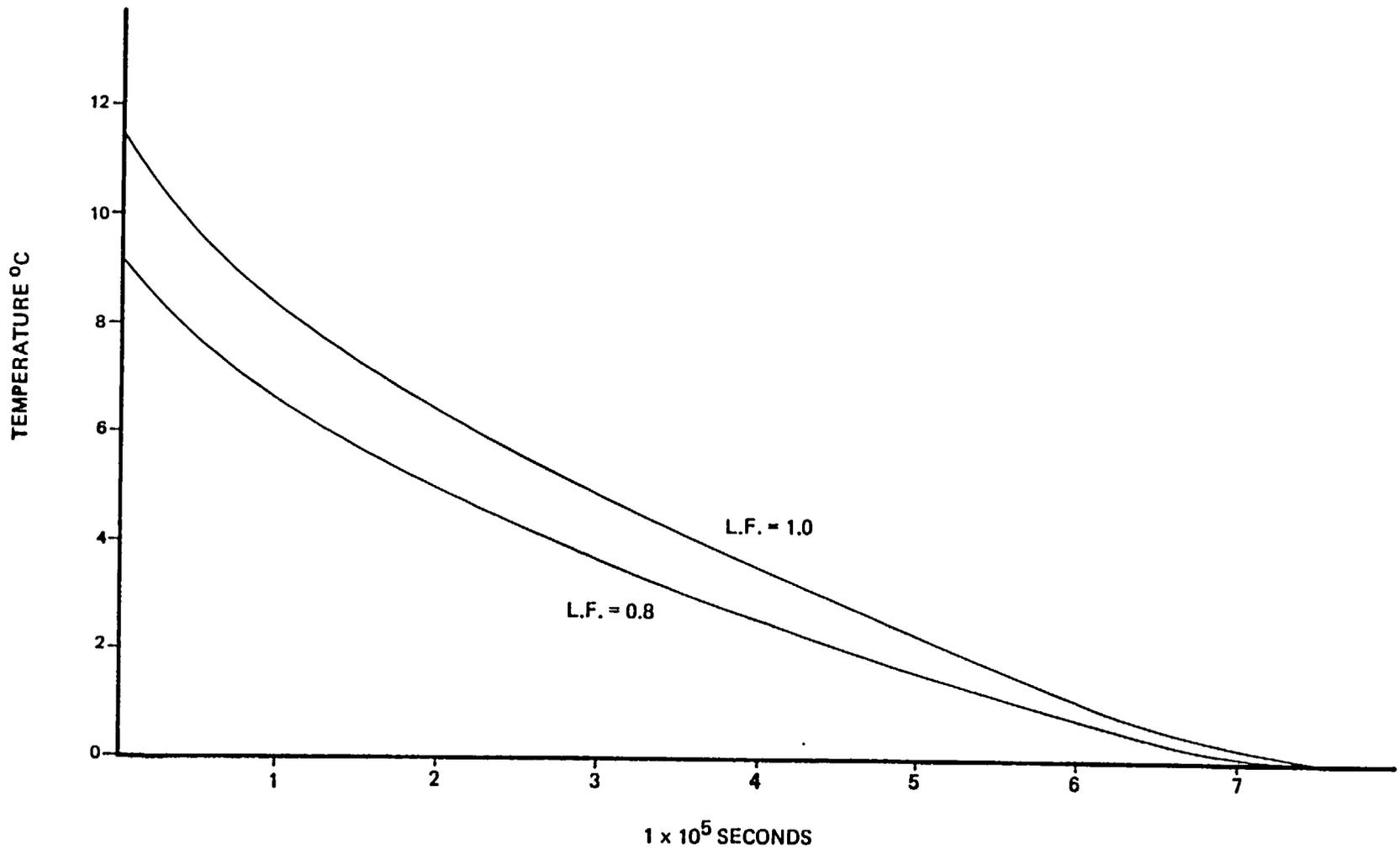


Figure 2.1.9 Circulating Water System,
Time vs. Temperature Profile

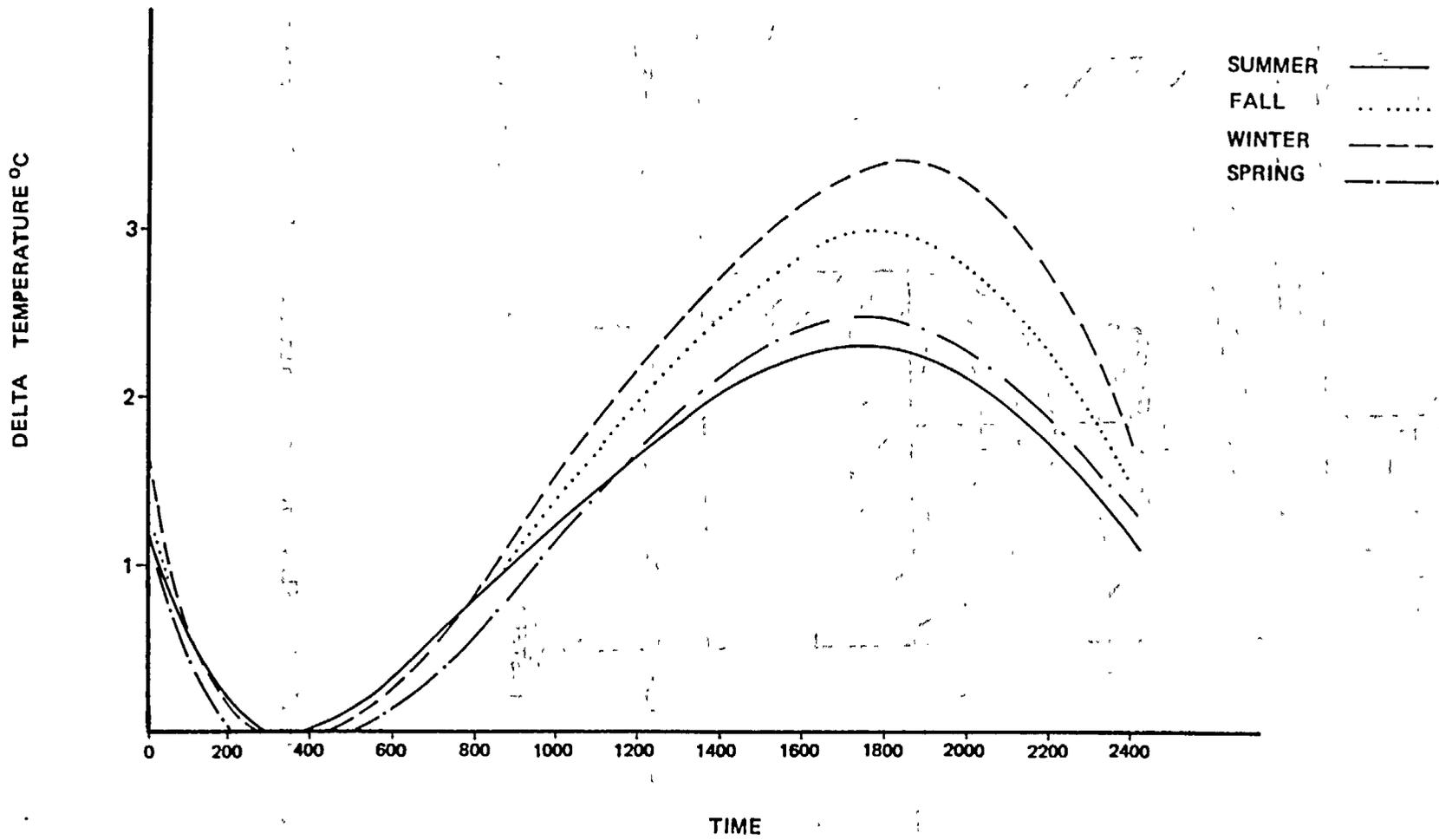


Figure 2.1.10 H. B. Robinson Steam Electric Plant
 Typical Daily Variation in the
 Temperature of Plant Discharge

2-16
CENTER LINE, STOP-LOG

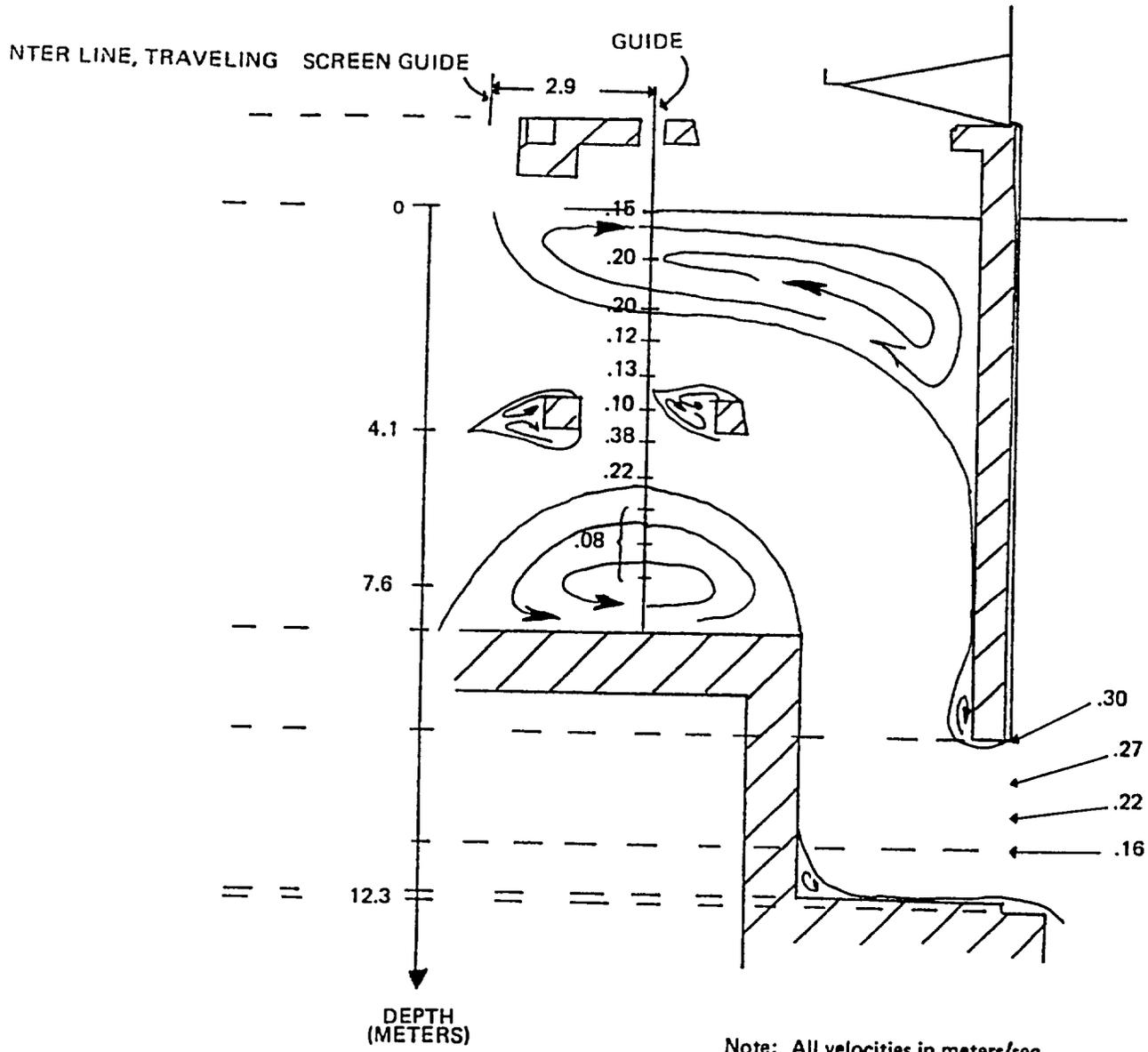


Figure 2.1.11. Flow pattern within Bay A, Unit 1 intake structure

CENTER LINE, STOP-LOG

CENTER LINE, TRAVELING SCREEN GUIDE

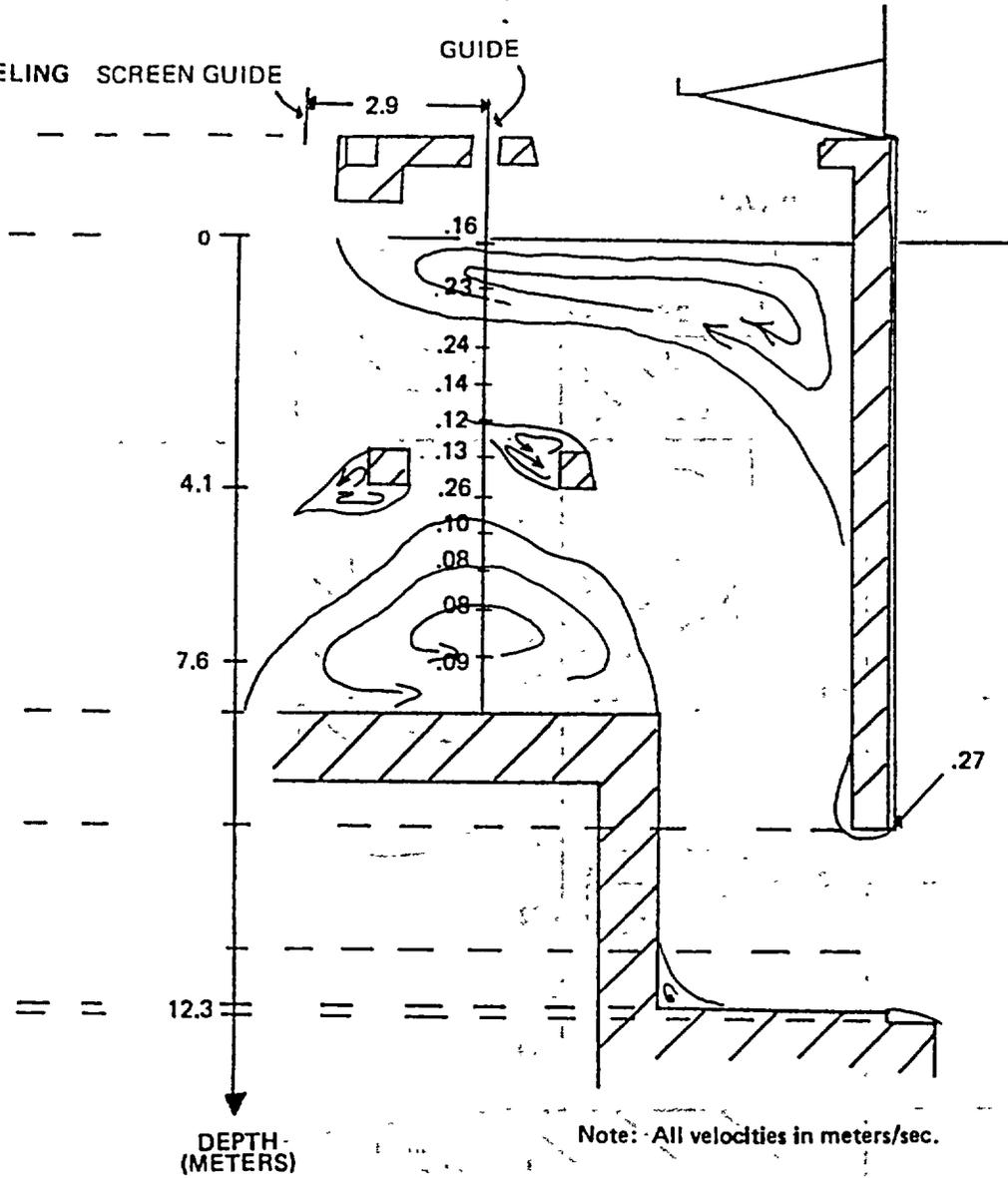


Figure 2.1.12 Flow pattern within Bay B, Unit 1 intake structure

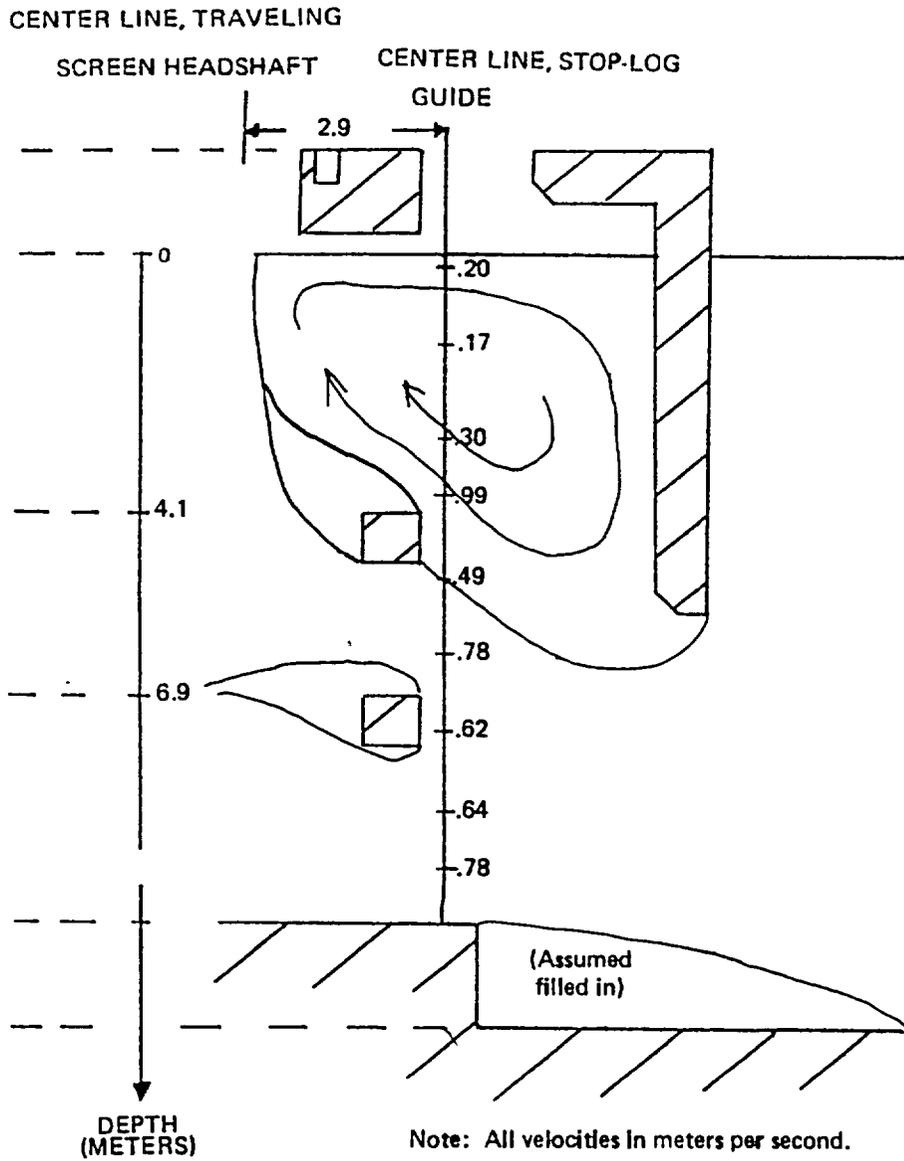


Figure 2.1.13 Flow pattern within Bay A, Unit 2 intake structure

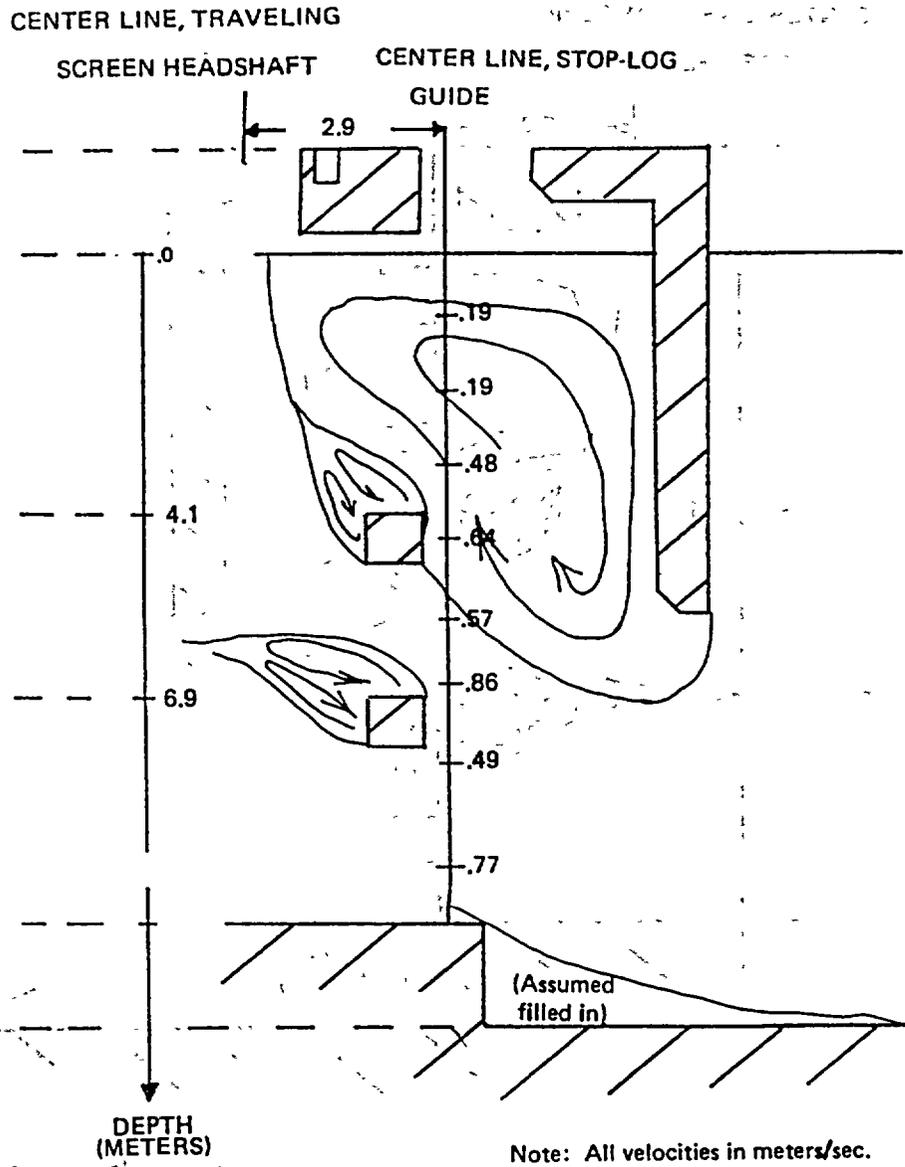
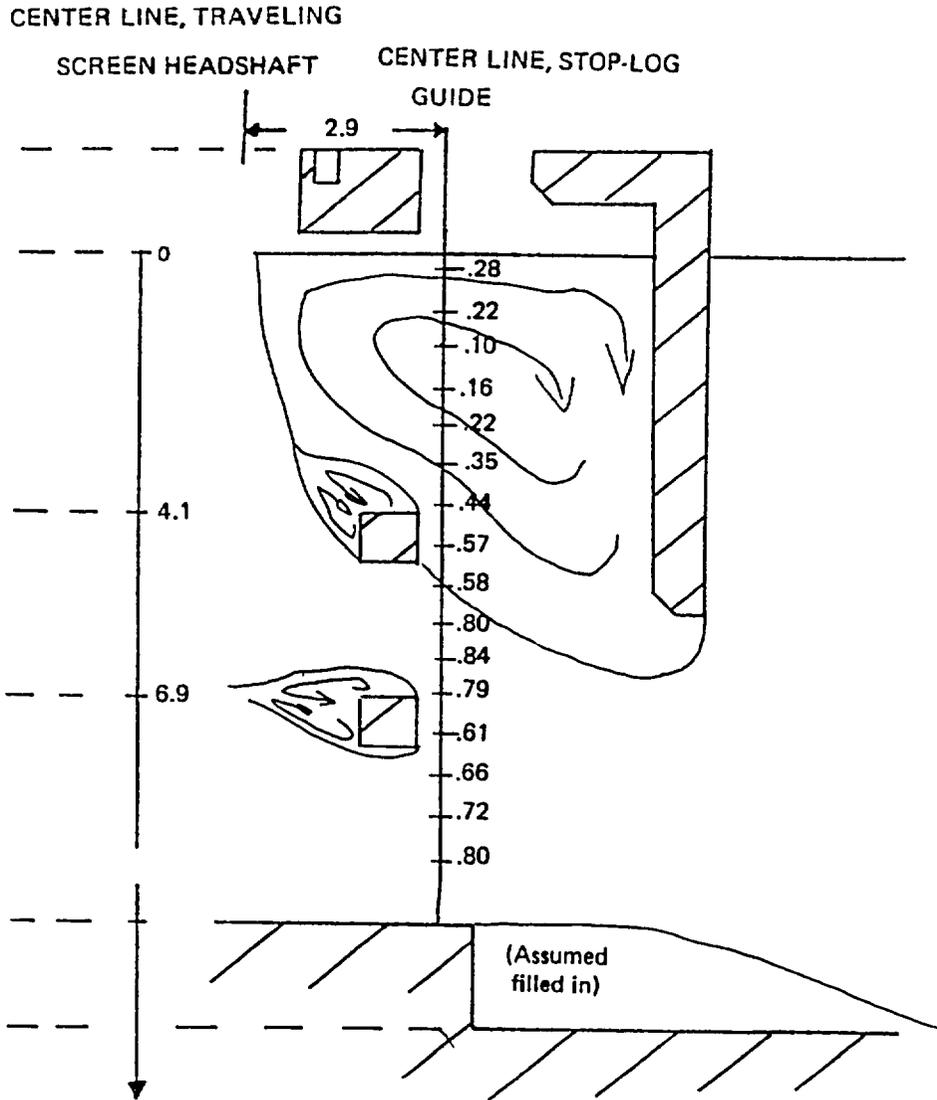


Figure 2.1.14 Flow pattern within Bay B, Unit 2 intake structure



Note: All velocities in meters/sec.

Figure 2.1.15 Flow pattern within Bay C, Unit 2 intake structure

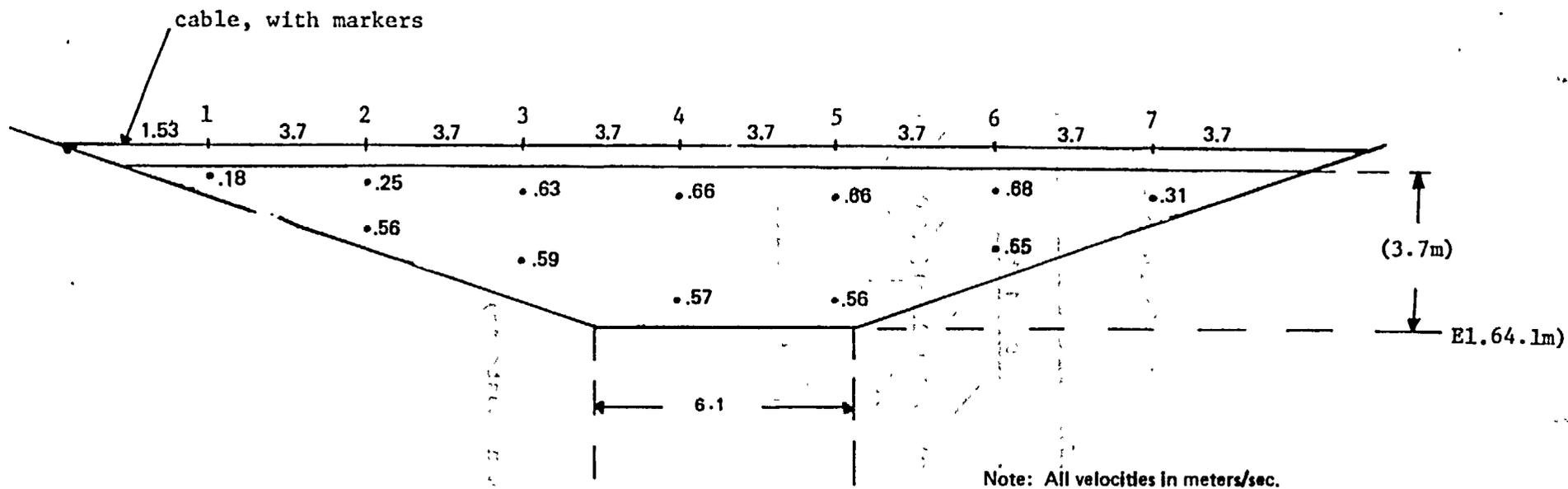


Figure 2.1.16 Approximate discharge canal cross section at test site (looking upstream)

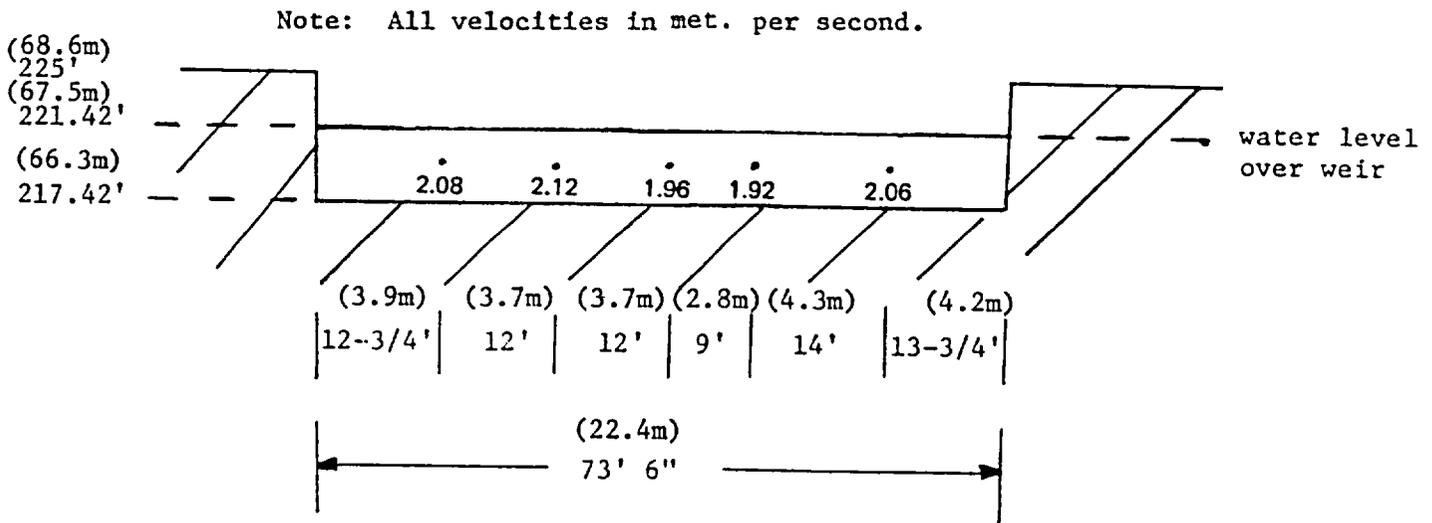


Figure 2.1.17 View of weir (looking upstream)

3.0 Environmental Data

3.1 Introduction

Physical and chemical characteristics determine both the habitat and type of biological community which can exist in a defined ecosystem. Environmental data relative to these physical and chemical characteristics have been defined as hydrology and morphology; temperature; and water chemistry.

Hydrological and engineering data have been compiled to describe the hydrology and morphology of the Robinson Impoundment and Black Creek. Both pre-operational (baseline) and operational data have been used.

Temperature studies include the results of intensive sampling of water temperatures throughout the impoundment and Black Creek during 1973, 1974, 1975, and 1976. In addition, one year of pre-operational data for Black Creek above and below the impoundment (1959 and 1960) and data for impoundment water temperatures during the summer and winter of 1963 (prior to the operation of Unit 2) are available. Thermal models have also been developed which describe predicted summer maximum, winter maximum, and equilibrium temperatures in the impoundment. These data have been used to document thermal conditions, to identify cooling patterns, and to determine the effects of warmed discharge waters on natural thermal conditions.

Water chemistry studies include data from 1973, 1974, 1975, and 1976. Results of water chemistry analyses have been evaluated to determine the water quality of the Robinson Impoundment and Black Creek and to determine the effects of plant operation on various chemical variables. Since pre-operational water chemistry data are essentially nonexistent, the quality of water entering the impoundment from Black Creek has been considered an ongoing baseline.

3.2 Hydrology and Morphology

3.2.1 Methods

U. S. Geological Survey data for the State of South Carolina and engineering plans and documents were utilized to describe and deduce pertinent physical parameters of the Robinson Impoundment and Black Creek.

3.2.2 Results and Discussion

The circulating water system for the H. B. Robinson Steam Electric Plant includes Robinson Impoundment (Figure 3.2.1), a cooling impoundment created in 1959 by the damming of Black Creek. The pertinent physical parameters of the impoundment and Black Creek are shown in Table 3.2.1; Figure 3.2.2 contains the area capacity curves for the impoundment.

At the normal water elevation of 67 m (220 ft) msl, Robinson Impoundment has a surface area of 911 ha (2,250 acres), a volume of $5.06 \times 10^7 \text{ m}^3$ (41,000 acre-ft) and an average depth of 5.5 m (18 ft). Theoretical average retention time within the impoundment is 86 days while circulation of impoundment water occurs approximately every 16 days.

The major inflow of water into the Robinson Impoundment is from Black Creek, an intrastate stream which rises in the fall zone near Pageland, South Carolina, and flows through Chesterfield, Darlington, and Florence counties to its confluence with the Pee Dee River east of Darlington, South Carolina (Figure 3.2.3). The creek flows through the Carolina Sandhills, and its drainage area is generally secondary pine growth with some open agricultural land. The soils of this region are generally of low fertility, and acidic, with a pH value around 5.0. Additional inflow into the impoundment is provided by various small creeks, streams, and flowing groundwater wells near the shore of the impoundment.

The drainage area at the Robinson dam is approximately 448 km² (173 mi²). Discharge to Black Creek occurs either over the dam or from low level release valves. Average discharge to Black Creek (1960 - 1974) was 6.8 m³/s (240 CFS).

3.3 Thermal

3.3.1 Methods

An intensive thermal monitoring program of the Robinson Impoundment and Black Creek was initiated in April, 1973, in conjunction with initial environmental studies. Five transects (A, B, C, D, and E) were established (Figure 3.3.1). Across each transect three sampling stations (1, 2, and 3) were utilized. In addition, two stations, consisting of a single point at F and G, were sampled.

In August, 1973, two temperature sampling stations on Black Creek were added: one below the impoundment (H) and one above the impoundment (I). An additional impoundment transect (CA) and an additional creek station (K) were added in August, 1974.

In April, 1975, a grid covering an area of approximately 74 ha (184 acres) and identifying 33 sampling points was established in the area of discharge (Figure 3.3.2). Beginning in August, 1975, at the recommendation of the U. S. Environmental Protection Agency, Region IV, the number of sampling points was reduced by one-half; three sampling stations were added in the area where Big Beaverdam Creek enters the impoundment (UBBC, MBBC, and LBBC); and an additional transect, DA, was added.

Water temperatures were sampled between April, 1973, and March, 1976, at least once monthly. Between the period May, 1975, and November, 1975, with the exception of June, 1975, when equipment failure prevented completion of sampling, water temperatures were sampled twice monthly. At each sampling station, water temperatures were recorded on the surface and at 3-foot intervals. Equipment used for sampling included: Yellow Spring Instrument (YSI)

54 Oxygen and Temperature Meter, International Biophysics Corporation (IBC) Temperature and Dissolved Oxygen Monitoring Unit, and Hydrolab TDO-2.

On June 12, 1975, continuous strip chart temperature recorders were placed at the Spillway, at the West Tower (south of C-3), at Station F, in the discharge canal immediately south of the discharge canal weir, and on Black Creek at Station K (Figure 3.3.1). All temperatures were recorded continuously at a depth of approximately 3 feet. Hourly readings were noted throughout each day, from which daily averages were calculated and daily maximum and minimum values determined. The continuous recording units used for this study were Atkins Technical, Inc. Model #22348-09.

Temperature data measured in the field specifically for environmental studies was supplemented by three additional studies: (1) during the years 1959, 1960, 1972, 1973, and 1974 on Black Creek above the impoundment (Station I) and below the impoundment (Station H), water temperatures were sampled approximately once per week, thus providing baseline data comparable to operational data; (2) sampling of impoundment stations along Transects A, B, C (approximately), and D was made in 1963; and (3) temperature prediction models were developed (USNRC, 1975; Edinger and Geyer, 1965; Edinger, et al., 1974; Graves and Geyer, 1973).

3.3.2 Results and Discussion

Intensive sampling temperature data for 1973, 1974, 1975, and 1976 are presented as CP&L Exhibit 2.1. Continuous recorder data indicating daily averages, maxima and minima temperatures are indicated in CP&L Exhibit 2.2. Black Creek water temperature data for 1959, 1960, 1972, 1973, and 1974 are included in CP&L Exhibit 2.3.

Circulating Patterns

Data indicated that during all periods of the year discharge waters were well mixed as they flowed into the impoundment. Warmed waters then dispersed, forming a surface layer over cooler bottom waters which entered the

discharge area from the upper impoundment and Black Creek drainage area. Normal circulation patterns were southward to the dam and the plant. Warmed surface waters occasionally moved northward above the SR 346 bridge; but such movement was limited by the SR 346 road bed and the relatively small span of the bridge [<61 m (200 ft)]. Indication of heated surface waters moving as far northward as Station G was not observed.

Thermal Stratification

Seasonal variation of surface and vertical temperature patterns in the impoundment was noted. During early fall, winter, and late spring waters were well mixed at Station G and at stations south of Transect DA; generally uniform temperatures were recorded for each water column, especially at the deeper southernmost transects (A and B) during winter periods (Figures 3.3.3-3.3.5). In spring and fall, overturn occurred (Figures 3.3.6-3.3.8). Between these periods a temperature gradient generally was maintained with variation of surface and bottom temperatures ranging between 4°C - 6°C (7°F - 11°F); and during summer temporary stratification was noted (Figures 3.3.9-3.3.11).

Throughout the entire year artificial stratification occurred in the area of discharge as warmed discharge waters layered over cooler bottom waters. An artificial thermocline was generally present in the discharge area where depths were 2.7 m (9 ft) or greater. In this area, during summer months when discharge temperatures were at maximum, variation between surface and bottom temperatures was generally 6°C - 7°C (11°F - 13°F).

Temperature Stability

A summary indicating temperature stability and general thermal trends between hours, within 24-hour periods, and between days is presented in Table 3.3.1. Temperature fluctuation was not great in the lower impoundment, while temperatures in the discharge canal varied directly with the intensity of fluctuation of Unit 2 operation. Areas immediately north of the SR 346 bridge were intermittently affected by plant discharges and are described as being in

a fringe area of the extension of the thermal effluent. Temperature fluctuation in this area occasionally exceeded 7°C (13°F) during a 24-hour period.

Maximum and Minimum Thermal Conditions

Maximum thermal conditions were observed during July and August, 1975, when discharge temperatures generally remained above 40°C (104°F), temperatures in the upper impoundment were above 23°C (73°F), and temperatures in the lower impoundment remained above 26°C (79°F). Modeling indicated that the summer of 1975 had higher-than-average impoundment temperatures, based on analysis of the meteorological conditions which affect impoundment water temperatures. The result was that during late August, 1975, the plant produced the highest recorded discharge temperatures since operation of Unit 2 commenced.

Under normal operating conditions annual minimum thermal conditions occurred during January and February. In 1976 discharge temperatures fell below 25°C (77°F), water temperatures in the upper impoundment fell to 5°C (41°F), and minimum temperatures in the lower impoundment were 11°C (52°F).

Ambient Thermal Conditions

Data collected in 1963, during a period when only Unit 1 was in operation and warmed discharge waters were returned to the impoundment 1.2 mi (1.9 km) north of the plant, indicate that temperatures within the impoundment ranged between 26.6°C and 30°C (80°F- 86°F) during summer (Figures 3.3.12-3.3.14). During winter periods temperatures dropped to 5.6°C (42°F) in the lower impoundment.

Data collected on Black Creek above the impoundment (Station I) and below the impoundment (Station H), prior to the commercial operation of the H. B. Robinson Plant and during the period when the initial filling of the impoundment occurred, indicate naturally occurring temperatures and the warming effects of solar radiation on impoundment waters. From May to November, 1959, the natural increase in temperature across the impoundment due to solar radiation averaged 4.1°C (7.4°F), and between December, 1959, and April, 1960, natural rise averaged 1.4°C (2.6°F). Comparing these figures with data

collected during periods when Robinson Units 1 and 2 were commercially operated (1972, 1973, and 1974) indicates that between May and December the average increase in temperature in Black Creek below the dam which can be attributed to plant operation was 1.8°C (3.2°F). For the period December to April the rise attributed to plant operation was 3.2°C (5.7°F) (Table 3.3.2).

Temperature Prediction Models

Models used to determine impoundment equilibrium temperatures without the influence of plant operation indicated that naturally occurring surface temperatures within the impoundment under normal meteorological conditions would be approximately 29.4°C (85°F). Under extreme meteorological conditions temperatures would approach 32°C (90°F). During winter periods under normal meteorological conditions, temperatures would fall below 10°C (50°F), while under extreme meteorological conditions temperatures would be slightly above 10°C (50°F) (USNRC, 1975).

The predicted, typical summer and winter surface isotherms for the impoundment are presented in Figure 3.3.15. Predicted maximum summer conditions indicated a discharge temperature of approximately 44.5°C (112.1°F) under adverse meteorological conditions and 100% plant load for at least five consecutive days (Figure 3.3.16). Predicted maximum winter conditions indicated a discharge temperature of approximately 28°C (82°F). Meteorological data used for modeling are included in Table 3.3.3.

3.4 Water Chemistry

3.4.1 Methods

Water chemistry samples were collected monthly between April, 1973, and February, 1976, from the surface and bottom at three stations within the impoundment: A-2, E-3, and G, and from Black Creek above the impoundment (I, surface) and below the impoundment (H, surface). In September, 1974, two additional Black Creek chemistry sampling stations were added: one below the impoundment (K, surface) and one above the impoundment (J, surface). Sampling at Station J was discontinued in November, 1974 (Figure 3.3.1).

Samples were collected with a beta bottle sampler and transferred to labeled plastic containers, which were chilled and stored in the dark prior to analyses. All chemical analyses followed standard procedures accepted by the U. S. Environmental Protection Agency. Analytical methods used by the CP&L Analytical Laboratory as of January 1, 1976, are presented in CP&L Exhibit 2.4.

3.4.2 Results and Discussion

Results of all 1973, 1974, 1975 and 1976 water chemistry analyses for Robinson Impoundment and Black Creek are presented in CP&L Exhibit 2.4.

Water Quality

Selected Robinson Impoundment water chemistry data compared with data from other coastal rivers and lakes, are presented in Table 3.4.1. The acidic nature of the waters of Robinson Impoundment was well within the range found for other coastal rivers and drainages of this general area. Ammonia was approximately the same, whereas NO_3 -Nitrogen and Kjeldahl-Nitrogen were considerably less than that found in the Cape Fear River, but comparable to the selected acid water bodies. Iron and sodium were also comparable to the range of values found in other waters of this area.

Effects of Plant Operation

Although extensive pre-1973 data is lacking, the contemporary quality of the inflowing stream, Black Creek, provides the essential information as to the nature and magnitude of materials in suspension and solution entering Robinson Impoundment. This permits assessment of changes that occur on passage through the impoundment. The following analyses and comparisons are based on the concept that the contemporary quality of Black Creek, as determined at Station I, is a baseline for assessment of change due to the operation of Robinson Impoundment as a cooling impoundment.

The water quality data collected in Robinson Impoundment for the three years 1973, 1974, and 1975 have been organized in tables which indicate

mean values and describe similar locations: Table 3.4.2 described the water quality of the inflowing water of Black Creek (Stations I and J) and the quality of the water of Black Creek after discharge from Robinson Impoundment (Stations H and K). In Table 3.4.3 the same parameters are used to describe the quality for three impoundment stations (G, E, and A), in downstream sequence. This tabulation includes values for surface as well as bottom samples. The organization of data in this manner permits ready comparison of key locations and separates stations of flowing water from those of standing water.

Within certain clusters of parameters, such as solids, clearly defined trends of increasing quantity from 1973 to 1975 were evident. In other instances, such as for $\text{NH}_3\text{-N}$, the trend was a consistent decrease over the three-year period. In still other examples consistent changes in quantity of a specific constituent occurred between the samples taken from the inflowing water and the impoundment stations. Additionally, on other cases the changes were not in any particular direction in a consistent fashion nor do they appear to change to any significant degree.

To define these changes in a more rigorous fashion the statistical t-test for significance of difference of the annual mean values were carried out on year-to-year comparisons as well as station-to-station comparisons (Tables 3.4.4 and 3.4.5). The annual mean values at three stations: I, inflowing water; A, impoundment and cooling water intake location; and H, downstream of Robinson Impoundment, were used to compare the changes between 1973/1974, 1974/1975, and 1973/1975. These yearly comparisons were tested for those parameters which appeared to be making shifts of sufficient magnitude, either increasing or decreasing, to be statistically significant. The t-test for significant difference of mean values was calculated only for the mean values of surface samples. Those t values with their probability of being at a significant difference at both 95% and 99% level of probability are identified, as well as the direction of change.

The use of Station I as a station for baseline data places in perspective changes that were occurring in the impoundment as well as downstream that might have resulted from interactions within the impoundment.

All values for the t-test of the various parameters compared are shown, but only those with a significant difference are of interest and concern. It is clear that the solids content of the water, particularly total, volatile, and dissolved, increased in a consistent manner over the three-year period. The magnitude of the change increased to the point where the number of significant differences was considerably greater in the 1974-1975 comparison than that of 1973-1974. The 1974-1975 comparison showed that the difference of the mean values for total, volatile and dissolved solids were significantly different in the surface samples both at Station I, inflowing water, as well as Station H, outflowing water, whereas only the volatile solids were at a significant difference at Station A. The comparison between the values for 1973 and 1975 showed that over the two-year period total, volatile and dissolved solids all changed significantly at all three stations and suspended solids only at Station H. This direction of change in solids content was characteristic of all stations and would appear to be a change characteristic of the entire drainage rather than any effect limited to Robinson Impoundment.

Changes in quantity of COD that were at significant levels in the 1973-1974 comparison were found only at Station I and H and not at A. These changes, which were increases in COD, did not persist in the comparison of 1974-1975. $\text{NO}_3\text{-N}$ had a significant increase in the comparison of 1973 and 1974 data at all three stations, a condition which was no longer evident in the 1974-1975 comparison. However, the difference was of sufficient magnitude to be statistically significant when 1973 values were compared to 1975 at Station A and H. Although $\text{NO}_3\text{-N}$ was not significantly different in the 1974-1975 comparison, the decrease in $\text{NH}_3\text{-N}$ normally associated with increases in $\text{NO}_3\text{-N}$ was at a significantly different level, decreasing at both Stations I and A in the 1974-1975 comparison.

Total phosphate-P and total dissolved phosphate-P had significant increases at Station A between 1974-1975 which were not apparent at Stations I and H. The comparison of 1973 to 1975 found only dissolved phosphate-P significantly different, increasing at Stations I and H but not at A.

Dissolved silica and chloride, two conservative constituents, were tested for significance of difference of the annual mean values to establish

the magnitude of the t-test at their minimum levels of difference. None of their differences were at significant levels.

Alkalinity showed a significant decrease in the 1973-1974 comparisons at Stations I, H, and A. In the two-year comparison, 1973-1975, all three stations had significant differences, decreasing in quantity. Sulfate increased significantly in only one instance: at Station I in the comparison of 1974-1975.

Of the metals tested for significant difference in these year-to-year comparisons, lead had a consistent pattern of decreasing quantity. These differences were at significant levels at all stations. This implies that the inflowing water of Black Creek had a decreasing quantity each year, and this in turn was reflected in the waters of the impoundment and downstream with little or no change during impoundment retention. Aluminum levels significantly decreased at Station A in the comparison of 1973-1974 quantities but at no other station or in any of the other year-to-year comparisons.

In Table 3.4.5 significance of difference of annual mean values of water quality parameters with each year, using Station I as a baseline station, are compared. The data in Table 3.4.5 are grouped under nonconservative substances: those nitrogen and phosphorus components which are biologically intereactive; a second group of conservative substances: silica, chloride, and sulfate which are nominally nonbiologically intereactive (although silica might be significantly changed by a diatom bloom); and a third group of metals. The metals selected appeared from cursory examination of the data to either be of significant quantity or have indicated moderate to large levels of change. In each instance the t-test for significance of difference was carried out for all of the parameters.

From this analysis it is evident that none of the nonconservative or conservative constituents tested had changes at any statistically significant level whether they were within the impoundment or in downstream location of the impoundment as compared to the baseline Station I. However, of the five

metals so tested, several trends are apparent in the data. The quantity of copper at the impoundment Stations E and A and downstream at H, went from nonsignificant differences in 1973 to a significant difference in 1974 (Station A compared to I) and to very significant differences when Station I was compared to E, A, and H in 1975. It is noteworthy that the copper content at Station G did not show a significant difference in 1975. This station is upstream of the recirculating discharge point in Robinson Impoundment.

The difference, at a significant level, of the quantity of iron between Stations I and H in 1973 was no longer discernible in 1974 and just below the 95% level of probability in 1975. Zinc was at no time in either of the three years significantly different in any of the comparisons between I and the other four stations. Aluminum, in contrast, started the series of years with a significant difference between Station I and Stations G, E, and H, all increasing in downstream direction. This difference disappeared in the 1974 comparison with Station I and appeared once more only in a comparison of Station I and H in 1975 where the difference, an increase at Station H, was just significant at the 95% level.

Robinson Impoundment Water Quality Levels and National Water Quality Criteria

In the ultimate assessment of the Robinson Impoundment or any other body of water used for industrial purposes, changes within the impoundment due to industrial operation are required to meet water quality criteria which do not affect the indigenous biota. Contemporary water quality criteria might still be considered in a state of flux and discussion as new information and data are assembled to define, describe, and assess impact of change on the indigenous biota within the characteristics of local waters. For those water quality constituents determined in Robinson Impoundment, CP&L Exhibit 2.4 includes a description of recommended 1983 water quality goals for the various water quality constituents in question. Specific applicability of these criteria to the highly colored acidic waters characteristic of the coastal drainages of this area may not be valid due to the chelating nature of the humic acids in colored waters. However, this comparison will at least establish some perspective as to the meaning of concentrations found, the changes detected and their significance with reference to impact on indigenous aquatic life.

For all of the water quality constituents indicated in the 1983 water quality goals, the waters of Robinson Impoundment would appear to meet all recommended water quality goals as defined at this time with one exception. (The impact of temperature is not considered due to the pending decision by EPA on the 316 Demonstration exemption request.) The quantities of copper may be at the moment in excess of water quality goals not only within the impoundment but in the inflowing stream. The effects of these higher concentrations of copper on the biota are unknown at the present time.

3.5 Dissolved Oxygen

3.5.1 Methods

Monthly dissolved oxygen (DO) sampling was initiated in April, 1973, at Station 2 of each of 5 transects, A, B, C, D, and E, and at Stations F and G (Figure 3.3.1). Water samples were taken from surface, mid, and bottom depths and analyzed in the field using the Winkler titration method.

Beginning in July, 1973, and continuing until March, 1976, portable dissolved oxygen meters were used to sample DO on the surface and at 3-foot intervals at each sampling station established for water temperature sampling (Figure 3.3.1 and Figure 3.3.2). Exceptions to this schedule occurred when equipment malfunction prevented sampling. Equipment used for sampling included: Yellow Spring Instrument (YSI) 54 Oxygen and Temperature Meter, International Biophysics Corporation (IBC) Temperature and Dissolved Oxygen Monitoring Unit, and Hydrolab (TDO-2).

3.5.2 Results and Discussion

The 1975 Robinson Impoundment dissolved oxygen concentrations from representative impoundment stations are presented as Table 3.5.1; and 1973, 1974, 1975, and 1976 DO profiles are included in CP&L Exhibit 2.5.

Dissolved oxygen concentrations followed seasonal patterns with generally uniform DO concentrations from surface to bottom between mid-fall and mid-spring. Dissolved oxygen concentrations below 4 mg/l at or near the bottom of the deeper impoundment stations occurred during late spring, summer, and early fall, with temporary dissolved oxygen stratification occurring in summer at deeper stations.

3.6 Summary and Conclusions

Hydrology and Morphology

The Robinson Impoundment is a man-made impoundment of a flowing body of water which is designed specifically for the retention, withdrawal, and recirculation of water for cooling of the H. B. Robinson Plant. Circulation of water in the impoundment is similar to other man-made industrial reservoirs and impoundments (Wunderlich, 1971).

Thermal

Seasonal variation of thermal patterns occurs in Robinson Impoundment. In the lower impoundment, stratification occurs during the warmer, summer months although its intensity is most likely limited and influenced by the flows associated with the plant circulating water system. During all seasons of the year, heated discharge waters form a layer over considerably cooler bottom waters in the mid-impoundment area.

Maximum thermal conditions occur during July and August while minimum thermal condition occur during January and February (with normal plant operation). Annual variation in discharge temperatures is in excess of 15°C (27°F). In the event of an outage of Unit 2 during winter periods seasonal variation of discharge temperatures could be in excess of 27°C (47°F).

Natural temperatures within the impoundment have been recorded as high as 30°C (86°F) (Figures 3.3.12-3.3.14). Models indicate that equilibrium temperatures, under average meteorological conditions, would be approximately 29.4°C (85°F), due solely to the effects of solar radiation; under extreme meteorological conditions, temperatures would approach 32°C (90°F). Modeled temperatures as

well as observed temperatures during summer indicate that surface temperatures at the dam are warmed by about 2°C (3°F-4°F).

Water Chemistry

The acid pH of the water of Robinson Impoundment as well as the inflowing waters of Black Creek is characteristic of the drainages of the coastal areas of this region. The considerable quantities of humic materials produce both the color as well as the acidic nature of these waters. Historically such waters have always been recognized as being of low biological activity.

The variations in quantity of chemical constituents in Robinson Impoundment, both of conservative and nonconservative nature, over the three years of observation were statistically significant in only a few isolated instances. It would appear there was no overall pattern of change from the quality of the waters of Black Creek flowing into Robinson Impoundment, changes in the quality on passage through the impoundment and changes downstream of the impoundment that could be attributed to the operation of the impoundment as a source of cooling water for the H. B. Robinson Steam Electric Plant. The exception to the pattern of differences which were nearly all at non-significant levels is an increase in quantity of copper at the stations affected by plant discharge. Other quantity variations appeared to be associated with some overall environmental factor since these changes were found up- as well as downstream of Robinson Impoundment.

All water quality constituents of Robinson Impoundment, with one exception, appear to meet recommended federal water quality goals. Data, as analyzed, indicate that copper, both in the inflowing stream as well as within the impoundment, is approaching levels that could exceed federal water quality criteria. Concentrations of copper sulfate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) that have been reported as being algastatic are .024-.075 mg/l (as copper .008-.026 mg/l) (Fitzgerald, 1971). This is with the concentration range found in 1975 in Robinson Impoundment. However, if this reflects primarily an accumulation from natural sources

in the drainage area, the existing algal population is one that has the capability of growth and survival under these circumstances.

The question as to whether the magnitude of increase in temperature over ambient levels, as recorded in Robinson Impoundment at the cooling water discharge stations, significantly affects chemical reactions has been extensively reviewed (Lee and Veith, 1971). Such temperature variations might affect both equilibria conditions, rates of equilibria for acid-base reactions, precipitations, gas transfer, oxidation-reduction, sorption and biochemical reactions. It has been concluded that the thermal effects that might be found in the cooling water discharge from a stream electric generating plant have only minimal effects on such chemical equilibria reaction rates and little or no effect on chemical parameters of water quality. It has also been noted that whereas temperature might increase growth rates of algae, it is the nutrient flux rather than temperature which establishes the total biomass that might be found during the maximum growth period.

Dissolved Oxygen

In deeper areas during warmer periods, temporary oxygen depletion occurs in most man-made impoundments which do not receive thermal discharge. Throughout other parts of the year, generally uniform DO concentrations are noted within each water column due to the natural tendency of an impoundment to mix during these periods (Frey, 1963). Robinson Impoundment DO concentrations generally follow these patterns. Dissolved oxygen stratification is temporarily established during summer, but its intensity is most likely limited and influenced by the flows associated with the plant circulating water system. Isolated instances of oxygen depletion at deeper stations is most likely associated with the decomposition of bottom sediments.

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Table 3.2.1 Physical parameters of Robinson Impoundment and Black Creek

Normal Water Level (NWL)	Elevation 67 m	(220 ft)
Capacity at NWL	$5.06 \times 10^7 \text{ m}^3$	(41,000 acre-ft)
Area at NWL	911 ha	(2,250 acres)
Average Depth at NWL	5.5 m	(18 ft)
Maximum Depth at NWL	12 m	(40 ft)
Maximum Length at NWL	12 km	(7.5 mi)
Width at Plant at NWL	1,210 m	(4,000 ft)
Design Low Water Level	Elevation 64 m	(210 ft)
High Water Level	Elevation 67.5 m	(221.67 ft)
Design Flood Flow	$1,133 \text{ m}^3/\text{s}$	(40,000 ft^3/s)
Crest of Dam	Elevation 70 m	(230 ft)
Maximum Height of Dam	21 m	(70 ft)
Low Level Release Intake	Elevation 54 m	(178 ft)
and	Elevation 56.5 m	(185.5 ft)
Retention Time of Impoundment:		
For Average Creek Flow		85 Days
For Average Circulating Water Flow		15.6 Days
Average Discharge to Black Creek (1960-1974)	$6.8 \text{ m}^3/\text{s}$	(240 ft^3/s)
Maximum Recorded Discharge to Black Creek	$56.9 \text{ m}^3/\text{s}$	(2,010 ft^3/s)
Minimum Recorded Discharge to Black Creek	$1.4 \text{ m}^3/\text{s}$	(51 ft^3/s)
Drainage Area at Dam	448 km^2	(173 mi^2)

Table 3.3.1 H. B. Robinson continuous recorders: normal fluctuation patterns with maximum/minimum recorded daily average temperatures °C (°F)

<u>Station</u>	<u>Normal Fluctuation between Instantaneous Hourly Readings</u>	<u>Normal Fluctuation within 24-Hour Periods</u>	<u>Normal Fluctuation of Average Temperatures between 24-Hour Periods</u>	<u>Maximum Temperature</u>	<u>Minimum Temperature</u>
Spillway	<+1°C(1.8°F)	<+2°C(3.6°F)	<+2°C(3.6°F)	33°C(91°F)	7°C(45°F)
West Tower	<+1°C(1.8°F)	<+3°C(5.4°F)	<+2°C(3.6°F)	36°C(97°F)	7°C(45°F)
Discharge	<+1°C(1.8°F) ¹	<+2.5°C(4.5°F)	<+2°C(3.6°F) ¹	44°C(111°F)	10°C(50°F) ²
Station F	<+2°C(3.6°F) ³	<+4°C(7.2°F) ⁴	<+2°C(3.6°F)	37°C(99°F)	3°C(38°F)
Station K	<+1°C(1.8°F)	<+1.5°C(2.7°F)	<+1°C(1.8°F)	33°C(91°F)	7°C(45°F)

¹<+1°C(1.8°F) fluctuation occurred except during periods when power output of Unit 2 fluctuated. Temperatures at the end of the discharge canal were directly proportional to the power output of Unit 2, as evidenced by data collected on December 12, 1975, as Unit 2 returned to power after refueling. Also noted was the fact that approximately 3 hours were required for water to travel from the plant to the end of the discharge canal.

²Unit 2 off line.

³Occasionally, variations of +3°C(5.4°F) to 4°C(7.2°F) were noted. Whenever increases or decreases in temperature occurred, immediate change generally had occurred.

⁴Occasionally exceeding 7°C(12.6°F).

Table 3.3.2 Effects of solar radiation vs. plant operation on temperatures in Black Creek

Baseline Periods

May - November, 1959

SC 23 average water temperature	23.4°C (74.1°F)
US 1 average water temperature	19.3°C (66.7°F)
average Δt =	<u>4.1°C (7.4°F)</u>

December, 1959 - April, 1960

SC 23 average water temperature	10.4°C (50.8°F)
US 1 average water temperature	9.0°C (48.2°F)
average Δt =	<u>1.4°C (2.6°F)</u>

Δt 's prior to operation of either Units 1 or 2 is attributed to the effects of solar radiation.

Operational Periods

May - November, 1972, 1973, and 1974

SC 23 average water temperature	25.4 (77.8°F)
US 1 average water temperature	19.6 (67.2°F)
average ΔT =	<u>5.9°C*(10.6°F)</u>

December - April, 1972, 1973, and 1974

SC 23 average water temperature	15.7°C (60.3°F)
US 1 average	11.1°C (52.0°F)
average ΔT =	<u>4.6°C (8.3°F)</u>

ΔT for 1972, 1973, and 1974 is attributed to the effects of plant operation and solar radiation.

Operational Periods Compared with Baseline Periods

May to November

average ΔT 1972, 1973, and 1974 (plant operation and solar radiation)	5.9°C*(10.6°F)
average Δt 1959 (solar radiation)	4.1°C (7.4°F)
effect of plant operation	<u>1.8°C (3.2°F)</u>

December to April

average ΔT 1972, 1973, and 1974 (plant operation and solar radiation)	4.6°C (8.3°F)
average Δt 1959 and 1960 (solar radiation)	1.4°C (2.6°F)
effect of plant operation	<u>3.2°C (5.7°F)</u>

* Actual values were recorded in Fahrenheit. In converting values to centigrade, accuracy to the tenths decimal place was lost. Computation of average ΔT 's °C was derived by conversion from °F to °C.

Table 3.3.3 Meteorological data for thermal modeling

Month	Average Dry Bulb Temperature		Average Wet Bulb Temperature		Wind Speed		Percent Sunshine	Solar Radiation		Brunt's Coefficient
	°C	°F	°C	°F	km/hr	mi/hr		W/m ²	BTU/Day/ft ²	
January	8.3	46.9	5.3	41.6	11.3	7.0	59	156	1190	0.71
February	9.1	48.4	5.8	42.5	12.4	7.7	60	202	1540	0.71
March	12.4	54.4	8.6	47.5	13.5	8.4	65	290	2210	0.72
April	17.6	63.6	13.0	55.4	13.8	8.6	68	340	2590	0.72
May	22.3	72.2	17.3	63.2	11.3	7.0	67	381	2905	0.73
June	26.5	79.7	21.3	70.3	10.9	6.8	64	387	2950	0.74
July	27.6	81.6	22.6	72.6	10.8	6.7	64	387	2950	0.74
August	26.9	80.5	22.4	72.4	9.8	6.1	67	363	2765	0.73
September	24.1	75.3	19.9	67.8	10.1	6.3	64	313	2385	0.73
October	18.2	64.7	14.3	57.8	9.8	6.1	68	247	1880	0.72
November	12.1	53.7	8.9	48.0	10.5	6.5	64	193	1470	0.72
December	8.0	46.4	5.2	41.4	10.6	6.6	63	152	1155	0.71

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Table 3.4.1 Water quality of Robinson Impoundment and comparison with coastal plain waters

	Robinson Impoundment Data Average 1973-1975					N.E. Cape Fear, N.C. ¹	Satilla R. Ga. ²		Creeping Swamp, N.C. ³	Par Pond S.C. ^{4,5}
	STA. I	STA. G	STA. E	STA. A	STA. H	1970	1969	1970	1974-1975	1973
pH	5.1	5.2	5.3	5.4	5.3	5.9	4.8	5.4	5.5-6.4	7.7
M.O. Alk. mg/l	-	-	-	-	-	-	-	-	-	-
Alk. (CaCO ₃) mg/l	1.9	1.3	1.8	1.3	1.7	8.0	-	-	-	15
NH ₃ -N mg/l	0.4	0.3	0.6	0.3	0.6	.25	-	-	.10	-
NO ₃ -N mg/l	.20	.21	.23	.22	.22	1.2	-	-	.04	.035
Kjel-N mg/l	.28	.34	.39	.32	.36	2.0	-	-	.48	-
Total Phosphate-P mg/l	.09	.07	.08	.05	.06	.22	-	-	.04	.008
Dissolved Oxygen mg/l	-	-	-	-	-	-	-	-	-	7.1
Secchi Depth (meters)	1	1	1	1	1	-	-	-	-	2.5
C.O.D. mg/l	22	25	26	28	24	-	-	-	-	-
Total Solids mg/l	141	131	141	135	142	-	-	-	-	-
* Total Dis. Solids mg/l	99	97	101	103	100	-	-	-	-	-
** Total Susp. Solids mg/l	26	23	23	20	26	-	-	-	-	-
Sulfate mg/l	2.64	2.61	3.39	3.05	3.63	-	.8	1.1	-	-
Chloride mg/l	2.86	2.68	2.45	2.77	2.82	-	5.8	5.4	-	-
Fe ug/l	639	714	842	830	868	-	750	1250	1700	-
Al ug/l	303	287	325	237	332	-	100	420	700	-
Cr ⁺⁶ ug/l	13.0	12.2	12.6	12.6	12.6	-	-	-	-	-
Cu ug/l	27.7	32.8	57.5	47.9	42.4	-	-	-	-	-
Na ug/l	1925	1867	2034	1940	2125	-	4760	2800	4200	-
Zn ug/l	60	39	54	128	47	-	-	-	-	-

¹Keup et al., 1970

²Beck, 1972

³Kuenzler, 1976

⁴Tilly, 1973a

⁵Tilly, 1973b

NOTE: For the purpose of statistical evaluation all data reported as "less than" the reporting limit was assigned a finite number equal to the mid-point between zero and the reporting limit. It is therefore possible for mean values to fall below the detection limit and/or contain significant figures which are not indicated in the original analysis results.

(*) Total filterable residue and (**) total nonfilterable residue (4/73 - 7/73: 0.75 - 1.25 μ filter; 8/73 - 12/75: 1.20 μ filter).

Table 3.4.1 (continued)

	Alligator Lake, N.C. ⁶	Catfish Lake, N.C. ⁷	Jones Pond N.C. ⁸		Singletary Lake N.C. ⁸		Salters Lake, N.C. ⁸	Lake Waccamaw N.C. ⁹			Great Lake N.C. ⁷	
	1965	1965	1974	1975	1974	1975	1974	1957	1958	1959	1960	1965
pH	4.6	4.7	4.4	3.3	4.4	3.4	4.5	6.6	6.8	6.8	4.6	4.6
M.O. Alk. mg/l	-	-	-	-	-	-	-	15.0	24.0	20.0	-	-
Alk. (CaCO ₃) mg/l	-	-	-	-	-	-	-	2.5	5.0	10.0	30.5	16.3
NH ₃ -N mg/l	-	-	.03	.07	.04	.04	.03	-	-	-	1.1	-
NO ₃ -N mg/l	-	-	-	-	-	-	-	-	-	-	.39	-
Kjel-N mg/l	-	-	.29	.48	.25	.31	.32	-	-	-	-	-
Total Phosphate-P mg/l	-	-	<.005	.007	<.005	.006	<.005	-	-	-	-	-
Dissolved Oxygen mg/l	7.9	6.1	8.0	8.1	9.2	8.9	9.0	8.1	7.9	8.5	3.9	-
Secchi Depth (meters)	-	-	1	.6	1	.6	.7	-	1.3	1.2	6.9	6.1
C.O.D. mg/l	-	-	-	-	-	-	-	-	-	-	-	-
Total Solids mg/l	-	-	-	-	-	-	-	-	-	-	-	-
* Total Dis. Solids mg/l	-	-	-	-	-	-	-	-	-	-	-	-
** Total Susp. Solids mg/l	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate mg/l	-	-	-	-	-	-	-	-	-	-	-	-
Chloride mg/l	-	-	-	-	-	-	-	-	-	-	-	-
Fe ug/l	-	-	-	-	-	-	-	-	-	-	-	-
Al ug/l	-	-	345	-	165	-	-	-	-	-	-	-
Cr ⁺⁶ ug/l	-	-	-	-	-	-	320	-	-	-	-	-
Cu ug/l	-	-	-	-	-	-	-	-	-	-	-	-
Na ug/l	-	-	-	-	-	-	-	-	-	-	-	-
Zn ug/l	-	-	-	-	-	-	-	-	-	-	-	-

⁶ Crowell, 1965

⁷ Bayless, 1965

⁸ Weiss and Kuenzler, 1976

⁹ Davis, 1965

NOTE: For the purpose of statistical evaluation all data reported as "less than" the reporting limit was assigned a finite number equal to the mid-point between zero and the reporting limit. It is therefore possible for mean values to fall below the detection limit and/or contain significant figures which are not indicated in the original analysis results.

(*) Total filterable residue and (**) total nonfilterable residue (4/73 - 7/73: 0.75 - 1.25 μ filter; 8/73 - 12/75: 1.20 μ filter).

Table 3.4.2. Black Creek annual mean value water quality parameters

Inflow (Stations I, J) and Discharge (Stations H, K), Surface Samples
1973, 1974, 1975

All Values mg/l

T = Total, D = Dissolved

Station	I			J			H			K	
	Year (N)	73 (9)	74 (11)	75 (12)	74 (3)	73 (9)	74 (11)	75 (12)	74 (4)	75 (12)	
T-Solids		85	118	203	115	92	120	201	112	222	
T-Volatile Solids		52	55	121	72	60	68	125	74	132	
*T-Suspended Solids		10	28	35	19	10	28	35	21	33	
* T-Dissolved Solids		60	80	145	54	61	84	145	58	158	
COD		14	31	20	8	16	33	20	19	21	
T-N ₂		.378	.209	.282	.140	.793	.205	.185	.162	.335	
NO ₃ -N		.117	.296	.190	1.19	.066	.316	.253	.555	.260	
NH ₃ -N		.095	.037	.014	.036	.133	.038	.018	.030	.069	
T-Phosphate-P		.184	.063	.041	.020	.169	.018	.028	.067	.029	
TD-Phosphate-P		.011	.013	.021	.010	.007	.010	.020	.010	.022	
T-Ortho Phosphate-P		.087	.009	.019	.010	.102	.009	.008	.014	.007	
TD-Ortho Phosphate-P		.005	.006	.005	.005	.005	.005	.006	.010	.005	
D-Si		4.14	3.82	3.52	4.06	3.48	3.65	3.49	2.91	3.34	
Cl ⁻		3.14	3.19	2.43	3.73	2.98	2.85	2.70	3.57	2.52	
SO ₄		2.48	3.66	1.83	3.00	4.00	4.26	2.77	3.75	3.22	
T-Alk		4.30	.700	1.42	1.33	4.22	.90	.69	1.37	.875	
T-Ca		.857	.738	1.27	.997	1.11	.914	1.51	1.22	1.38	
T-Na		2.02	1.88	1.901	2.19	2.12	2.02	2.15	2.61	4.59	
T-Mg		.460	.456	.487	.443	.481	.468	.513	.547	.513	

NOTE: For the purpose of statistical evaluation all data reported as "less than" the reporting limit was assigned a finite number equal to the mid-point between zero and the reporting limit. It is therefore possible for mean values to fall below the detection limit and/or contain significant figures which are not indicated in the original analysis results.

(*) Total filterable residue and (**) total nonfilterable residue (4/73 - 7/73: 0.75 - 1.25 μ filter; 8/73 - 12/73: 1.20 μ filter).

Table 3.4.2 (continued)

Inflow (Stations I, J) and Discharge (Stations H, K), Surface Samples
1973, 1974, 1975

All Values mg/l Except pH and Turbidity (NTU)

T = Total, D = Dissolved

Station	I			J	H			K		
	Year (N)	73 (9)	74 (11)	75 (12)	74 (3)	73 (9)	74 (11)	75 (12)	74 (4)	75 (12)
Hex-Cr		.019	.007	.014	.010	.017	.007	.014	.008	.014
T-Cu		.036	.025	.025	.023	.041	.040	.045	.044	.048
D-Cu		.021	.025	.025	-	.021	.025	.025	-	.034
T-Fe		.547	.668	.669	.907	.882	.774	.936	1.04	.920
T-Mn		.022	.025	.025	.025	.022	.025	.025	.025	.025
T-Pb		.043	.032	.025	.025	.045	.032	.025	.025	.025
T-Zn		.065	.053	.065	.037	.043	.038	.067	.042	.054
D-Zn		.025	.025	.025	-	.025	.025	.025	-	.029
T-Al		.237	.392	.267	.115	.345	.313	.339	.206	.294
D-Al		.042	.012	.075	-	.025	.007	.072	-	.082
T-Hg		.0005	.0005	.0006	.0005	.0005	.0005	.0005	.0005	.0006
T-Ni		-	.031	.025	.033	-	.031	.025	.031	.025
D-Ni		.033	.030	.025	-	.033	.030	.025	-	.025
Hardness		-	9.3	4.24	3.2	-	8.4	4.8	15.9	4.86
pH		5.3	5.0	5.0	5.5	5.8	5.3	5.2	4.9	5.2
Turbidity		-	1.6	3.3	-	-	3.1	3.9	2.8	3.6

NOTE: For the purpose of statistical evaluation all data reported as "less than" the reporting limit was assigned a finite number equal to the mid-point between zero and the reporting limit. It is therefore possible for mean values to fall below the detection limit and/or contain significant figures which are not indicated in the original analysis results.

Table 3.4.3 Robinson Impoundment: annual mean values water quality parameters

1973, 1974, 1975
All Values mg/l
T = Total, D = Dissolved

Station	G			E			A			
	Year	73	74	75	73	74	75	73	74	75
	(N)	(9)	(11)	(12)	(9)	(11)	(12)	(9)	(11)	(12)
Surface/Bottom	S/B	S/B	S/B	S/B	S/B	S/B	S/B	S/B	S/B	S/B
T-Solids	71/93	125/155	183/197	78/75	126/134	200/195	69/77	132/125	188/200	
T-Volatile Solids	55/59	65/91	155/122	57/58	74/61	134/122	51/50	67/61	131/142	
** T-Suspended Solids	6.3/22	28/52	31/37	9/8	26/31	31/32	7/10	22/27	27/34	
* T-Dissolved Solids	51/56	84/96	143/131	51/50	90/89	148/156	56/53	97/97	144/157	
COD	19/23	33/34	23/21	22/20	31/40	24/24	20/20	26/26	35/25	
T-N ₂	.511/.333	.249/.700	.292/.275	.420/.329	.520/.237	.272/.223	.455/.437	.267/.293	.278/.292	
NO ₃ -N	.068/.053	.353/.310	.189/.189	.079/.084	.331/.310	.265/.239	.089/.075	.332/.265	.228/.249	
NH ₃ -N	.034/.041	.034/.230	.014/.012	.055/.055	.125/.080	.015/.012	.045/.047	.047/.053	.011/.030	
T-Phosphate-P	.183/.174	.019/.071	.039/.026	.221/.237	.015/.065	.028/.028	.138/.129	.014/.012	.029/.029	
TD-Phosphate-P	.005/.006	.011/.011	.022/.017	.008/.009	.01/.009	.017/.019	.025/.008	.010/.009	.022/.018	
T-Ortho Phosphate	.095/.069	.009/.015	.014/.007	.180/.083	.007/.009	.007/.007	.084/.081	.007/.007	.009/.008	
TD-Ortho Phosphate	.005/.005	.005/.005	.007/.006	.005/.006	.005/.006	.005/.006	.009/.006	.007/.006	.007/.007	
D-Si	3.60/3.33	3.23/3.33	3.22/3.45	2.62/2.84	3.38/3.36	3.29/3.40	2.47/2.62	3.77/3.45	3.25/3.50	
Cl ⁻	3.23/2.43	2.51/2.86	2.52/2.02	3.03/3.10	2.89/3.07	2.23/2.14	2.77/2.70	3.02/2.95	2.56/2.24	
SO ₄	3.20/2.98	2.94/2.81	1.85/1.68	4.00/2.85	3.58/3.19	2.75/2.37	3.42/3.42	3.01/3.51	2.81/2.27	
T-Alk	2.35/3.31	.900/.700	.783/.592	4.13/5.07	1.25/1.20	.683/1.08	2.37/4.26	1.10/1.05	.750/.692	
T-Ca	.836/.843	.697/.687	1.21/1.62	1.08/1.04	1.07/.967	1.78/1.35	1.09/1.04	.988/.963	1.34/1.25	
T-Na	1.95/1.98	1.82/1.91	1.85/1.67	2.03/2.19	2.102/1.97	1.98/1.92	2.056/2.197	1.926/2.216	1.87/1.84	
T-Mg	.414/.423	.383/.423	.450/.438	.457/.591	.472/.442	.483/.486	.451/.513	.454/.474	.482/.482	

NOTE: For the purpose of statistical evaluation all data reported as "less than" the reporting limit was assigned a finite number equal to the mid-point between zero and the reporting limit. It is therefore possible for mean values to fall below the detection limit and/or contain significant figures which are not indicated in the original analysis results.

(*) Total filterable residue and (**) total nonfilterable residue (4/73 - 7/73: 0.75 - 1.25 μ filter; 8/73 - 12/75: 1.20 μ filter).

Table 3.4.3 (continued)

1973, 1974, 1975
 All Values mg/l Except pH and Turbidity (NTU)
 T = Total, D = Dissolved

Station	G			E			A			
	Year	73	74	75	73	74	75	73	74	75
	(N)	(9)	(11)	(12)	(9)	(11)	(12)	(9)	(11)	(12)
Surface/Bottom	S/B									
Hex-Cr	.016/.017	.007/.007	.014/.014	.017/.017	.007/.007	.014/.014	.017/.017	.007/.007	.014/.014	.017/.017
T-Cu	.039/.045	.029/.029	.032/.028	.056/.057	.053/.039	.062/.059	.053/.075	.042/.051	.049/.049	.028/.025
D-Cu	.021/.021	.025/.025	.025/.025	.021/.021	.025/.025	.028/.043	.021/.021	.025/.025	.028/.025	.025/.025
T-Fe	.775/.653	.587/.968	.780/.669	.934/1.02	.727/.918	.869/.842	.867/1.21	.852/.910	.784/1.04	.025/.025
T-Mn	.022/.022	.025/.025	.025/.025	.022/.022	.025/.025	.025/.025	.022/.022	.025/.025	.025/.025	.025/.025
T-Pb	.044/.045	.032/.032	.025/.025	.045/.045	.032/.032	.025/.025	.045/.045	.032/.032	.025/.025	.025/.025
T-Zn	.038/.031	.034/.072	.047/.042	.046/.064	.057/.054	.057/.057	.168/.056	.132/.045	.062/.042	.025/.025
D-Zn	.025/.025	.025/.025	.025/.025	.025/.025	.025/.025	.025/.025	.025/.025	.025/.025	.025/.025	.025/.025
T-Al	.312/.343	.336/.794	.230/.297	.337/.433	.404/.391	.251/.254	.276/.527	.203/.375	.236/.359	.078/.085
D-Al	.045/.042	.008/.012	.097/.070	.025/.025	.005/.005	.084/.082	.025/.025	.055/.005	.078/.085	.0005/.0005
T-Hg	.0005/.0005	.0005/.0005	.0006/.0006	.0005/.0005	.0005/.0005	.0005/.0005	.0005/.0005	.0005/.0005	.0005/.0007	.025/.025
T-Ni	- / -	.037/.031	.025/.025	- / -	.031/.031	.025/.025	- / -	.050/.031	.025/.025	.025/.025
D-Ni	.033/.033	.030/.030	.025/.025	.033/.037	.03/.030	.025/.025	.033/.033	.030/.030	.025/.025	.025/.025
Hardness	- / -	6.7/7.0	3.7/3.6	- / -	6.5/6.4	4.18/4.16	- / -	6.9/7.5	4.9/4.4	4.9/4.4
pH	5.4/5.3	5.1/5.1	5.3/5.2	6.0/5.7	5.0/5.0	5.3/5.3	5.9/5.8	4.9/5.0	5.5/5.3	5.5/5.3
Turbidity	- / -	1.3/2.6	3.6/3.4	- / -	3.5/3.0	3.7/3.5	- / -	3.0/3.0	2.8/4.9	2.8/4.9

NOTE: For the purpose of statistical evaluation all data reported as "less than" the reporting limit was assigned a finite number equal to the mid-point between zero and the reporting limit. It is therefore possible for mean values to fall below the detection limit and/or contain significant figures which are not indicated in the original analysis results.

Table 3.4.4 Comparison of the annual means of selected water quality parameters at stations I, A, and H.

t - Test for Significance of Difference of Mean Values of Surface Samples
 Significant at 95% Probability $t > 2.1^*$
 Significant at 99% Probability $t > 2.9^{**}$
 Direction of Change; (+) increase, (-) decrease

Parameter	Years Compared			1973/1974			1974/1975			1973/1975		
	Station	I	A	H	I	A	H	I	A	H		
Total - Solids	1.5	2.7*(+)	1.1	2.9**(+) 1.8	2.8*(+)	4.2**(+) 4.1**(+) 3.4**(+) 3.4**(+) 2.7**(+) 2.1*(+)						
Total - Volatile Solids	0.3	0.9	0.4	3.2**(+) 2.9*(+)	2.8*(+)	3.4**(+) 3.9**(+) 2.7**(+) 2.1*(+)						
**Total - Suspended Solids	1.4	1.2	1.5	0.4	0.3	0.4	1.9	1.7	2.1*(+)			
* Total - Dissolved Solids	1.1	2.2*(+)	1.0	2.4*(+)	1.7	2.2*(+)	3.4**(+) 3.4**(+) 2.7*(+)					
COD	2.1*(+)	1.0	2.2*(+)	1.3	0.9	1.8	1.2	1.6	0.9			
Total-N ₂	2.0	1.7	1.5	0.9	0.2	0.4	0.9	1.5	1.6			
NO ₃ -N	2.6*(+)	3.2**(+) 5.3**(+) 1.7	1.3	0.9	1.2	4.0**(+) 3.3**(+) 1.4						
NH ₃ -N	1.0	0.1	1.1	3.5**(-)	2.7*(-)	2.3	1.3	2.1	1.4			
Total Phosphate-P	1.0	1.4	1.4	0.5	3.7**(+) 2.0	1.2	1.2	1.3				
Total Dissolved Phosphate-PO ₄	0.8	1.6	1.8	1.8	3.2**(+) 0.2	3.0**(+) 0.3	4.3**(+) 0.01					
Dissolved Silica	0.3	1.5	0.2	0.3	0.6	0.2	0.6	1.1	0.01			
Chloride	0.2	0.5	0.2	1.4	0.8	0.2	1.7	0.5	0.5			
Total Alkalinity	3.1**(-)	2.0	3.0**(-)	1.1	1.4	1.0	2.2*(-)	2.6*(-)	3.3**(-)			
Sulfate	0.9	0.4	0.2	2.2*(+)	0.4	2.2	0.6	0.6	1.2			
Total Lead	2.1*(-)	2.6*(-)	2.6*(-)	2.4*(-)	2.4*(-)	2.4*(-)	4.3**(-)	4.8**(-)	4.9**(-)			
Total Aluminum	1.1	3.2**(-)	0.3	0.9	1.1	0.2	0.8	1.7	0.2			

NOTE: (*) Total filterable residue and (**) total nonfilterable residue
 (4/73 - 7/73: 0.75 - 1.25 μ filter; 8/73 - 12/75: 1.20 μ filter).

Table 3.4.5 Comparisons of the annual means of selected surface water quality parameters: Stations G, E, A, and H compared to Station I

t - Test for Significance of Difference Between
 Annual Mean Values of Surface Samples
 Significant at 95% Probability $t > 2.1^*$
 Significant at 99% Probability $t > 2.9^{**}$

Stations Compared	1973				1974				1975			
	I/G	I/E	I/A	I/H	I/G	I/E	I/A	I/H	I/G	I/E	I/A	I/H
Non-Conservative Substances												
Total Nitrogen	0.9	0.4	0.6	1.0	0.7	1.1	1.0	0.1	0.1	0.1	0.05	1.3
NO ₃ -Nitrogen	1.0	0.8	0.6	1.0	0.7	0.4	0.4	0.3	0.02	1.3	0.8	1.0
NH ₃ -Nitrogen	1.0	0.6	0.8	0.4	0.4	1.3	0.7	0.2	0.01	0.2	0.2	0.3
Total Phosphate-P	0.00	0.2	0.3	0.1	0.9	1.0	1.0	1.0	0.1	0.9	0.9	1.0
Total Dissolved Phosphate-P	1.7	1.0	1.4	1.4	0.3	1.4	1.6	1.4	0.02	1.1	0.2	0.2
Conservative Substances												
Dissolved Silica	0.5	1.6	1.7	0.6	0.7	0.5	0.03	0.2	0.3	0.3	0.3	0.01
Chloride	0.2	0.1	0.7	0.2	1.1	0.4	0.3	0.4	0.6	1.1	0.5	0.2
Sulfate	0.5	1.2	0.04	1.1	0.8	0.1	0.8	0.6	0.04	1.7	1.8	1.7
Metals												
Total Copper	0.3	1.9	1.4	0.5	0.5	1.9	2.2*	0.6	1.5	6.3**	3.1**	3.4**
Total Iron	1.1	2.2	1.9	2.2*	0.6	0.5	0.9	0.8	0.8	1.4	0.9	2.0
Total Zinc	1.9	1.4	1.0	1.5	1.0	0.2	0.9	0.8	1.0	0.5	0.2	0.1
Total Lead	0.2	0.3	0.3	0.3	0.1	0.00	0.1	0.1	0.00	0.00	0.00	0.00
Total Aluminum	2.2*	3.1**	1.5	3.2**	0.3	0.05	1.4	0.9	1.06	0.45	0.9	2.1*

Table 3.5.1 1975 H. B. Robinson dissolved oxygen concentrations (mg/l) and percent saturation from representative impoundment stations*

	A-2		B-2		C-2		D-2		E-2		F		G	
	D.O.	% Sat.												
January 16, 1975														
Surface	10.2	98	9.8	94	9.9	97	7.5	100	8.9	100	10.7	107	13.2	107
Middle	10.0	97	9.7	96	9.7	95	9.7	101	9.0	100	12.8	112	12.8	103
Bottom	10.2	98	9.8	97	9.7	96	10.0	103	9.4	102	13.3	112	12.6	102
February 5, 1975														
Surface	8.9	86	8.8	83	8.7	85	8.8	86	8.1	79	9.6	83	11.1	88
Middle	8.7	84	8.7	83	8.8	85	8.6	84	8.4	87	10.8	87	11.0	87
Bottom	8.7	84	8.8	85	8.8	85	8.6	84	8.7	87	10.6	86	14.0	112
March 5, 1975														
Surface	8.5	83	8.5	84	8.8	90	7.6	82	7.4	83	6.9	68	10.4	95
Middle	8.3	80	8.5	80	8.7	86	7.9	82	7.4	83	9.2	77	10.4	90
Bottom	8.0	76	8.4	81	8.5	83	8.5	84	8.0	87	9.0	75	10.2	88
May 12, 1975														
Surface	8.6	101	8.2	98	8.6	103	8.4	101	8.0	98	8.4	100	8.8	105
Middle	8.2	93	8.2	94	7.8	88	8.5	102	8.1	96	8.5	103	7.2	87
Bottom	5.2	58	5.4	60	4.8	53	8.3	97	7.9	93	7.0	75	7.0	73
June 10, 1975														
Surface	7.8	98	8.1	102	8.1	102	7.7	104	7.5	108	7.8	110	8.0	95
Middle	7.3	91	8.1	102	8.2	104	7.4	94	7.5	109	8.1	105	7.9	93
Bottom	7.9	100	2.3	28	6.8	84	5.5	69	7.3	100	6.8	84	7.5	88
July 1, 1975														
Surface	7.7	102	7.7	103	7.7	102	7.3	103	7.6	116	7.9	112	7.8	98
Middle	7.5	100	7.3	98	7.4	98	5.0	66	7.9	114	8.0	112	7.8	98
Bottom	0.7	8	1.9	24	5.8	76	3.0	39	3.9	50	6.0	76	6.1	72
August 5, 1975														
Surface	6.7	89	7.2	96	7.2	98	6.5	91	5.5	80	6.3	87	6.1	78
Middle	1.8	22	3.4	45	5.7	75	6.1	86	5.3	78	6.4	85	5.3	65
Bottom	0.0	0	0.0	0	0.4	4	5.7	80	4.0	52	4.6	57	5.0	61

Table 3.5.1 (continued)

	A-2		B-2		C-2		D-2		E-2		F		G	
	D.O.	% Sat.												
September 9, 1975														
Surface	7.3	98	7.5	100	7.0	94	6.4	91	5.8	88	7.3	103	7.7	102
Middle	2.9	37	5.5	72	6.1	80	5.1	67	6.1	89	7.3	101	5.0	63
Bottom	0.2	2	0.1	2	4.8	63	2.1	27	5.8	83	4.9	59	4.7	55
October 13, 1975														
Surface	7.5	94	7.4	93	7.3	93	7.1	93	6.3	85	7.0	91	5.3	61
Middle	4.6	54	5.2	62	5.1	60	5.7	69	6.2	85	7.3	87	4.9	53
Bottom	0.9	9	0.8	8	1.5	16	4.1	48	6.4	85	5.7	63	5.0	54
November 12, 1975														
Surface	8.4	94	8.4	94	8.6	97	8.1	92	8.1	92	8.0	89	6.4	68
Middle	8.1	91	8.4	94	8.5	96	8.0	91	7.8	90	7.9	85	6.4	68
Bottom	1.7	18	3.4	37	3.4	37	8.0	91	6.3	68	5.8	62	6.5	68
December 9, 1975														
Surface	8.2	75	9.5	87	8.7	80	9.2	85	9.1	87	9.5	82	10.8	99
Middle	8.0	73	9.4	87	8.6	78	9.2	85	9.0	85	9.4	82	10.8	99
Bottom	9.5	87	9.1	83	8.6	78	9.0	83	8.8	80	9.2	79	10.7	98

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*NOTE: Average depths for each station are as follows:

A-2: 11.0m (36 ft.)
 B-2: 10.1m (33 ft.)
 C-2: 8.3m (27 ft.)
 D-2: 3.7m (12 ft.)
 E-2: 1.8m (6 ft.)
 F : 2.7m (9 ft.)
 G : 2.7m (9 ft.)

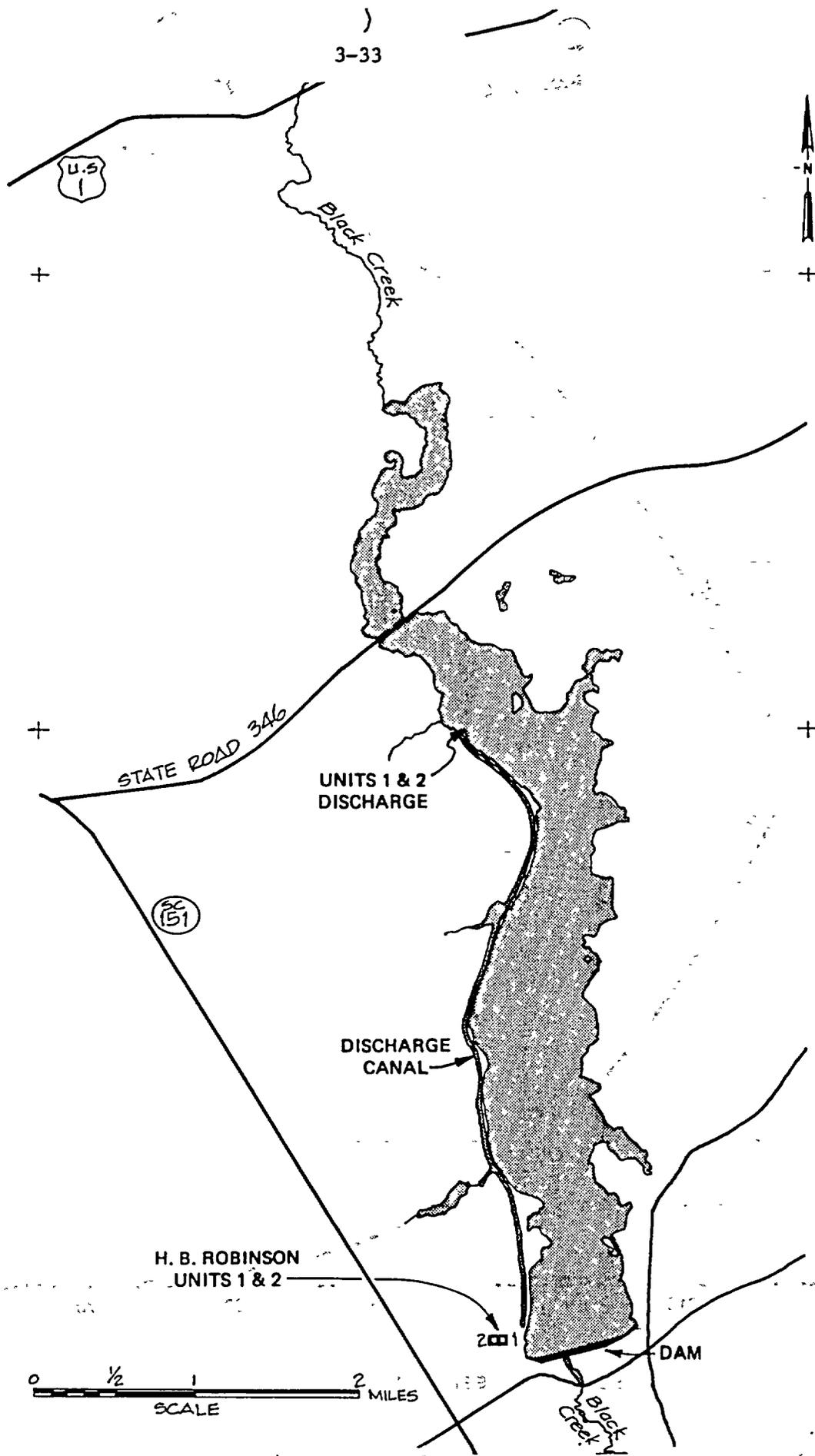


Figure 3.2.1 Robinson Impoundment and Black Creek

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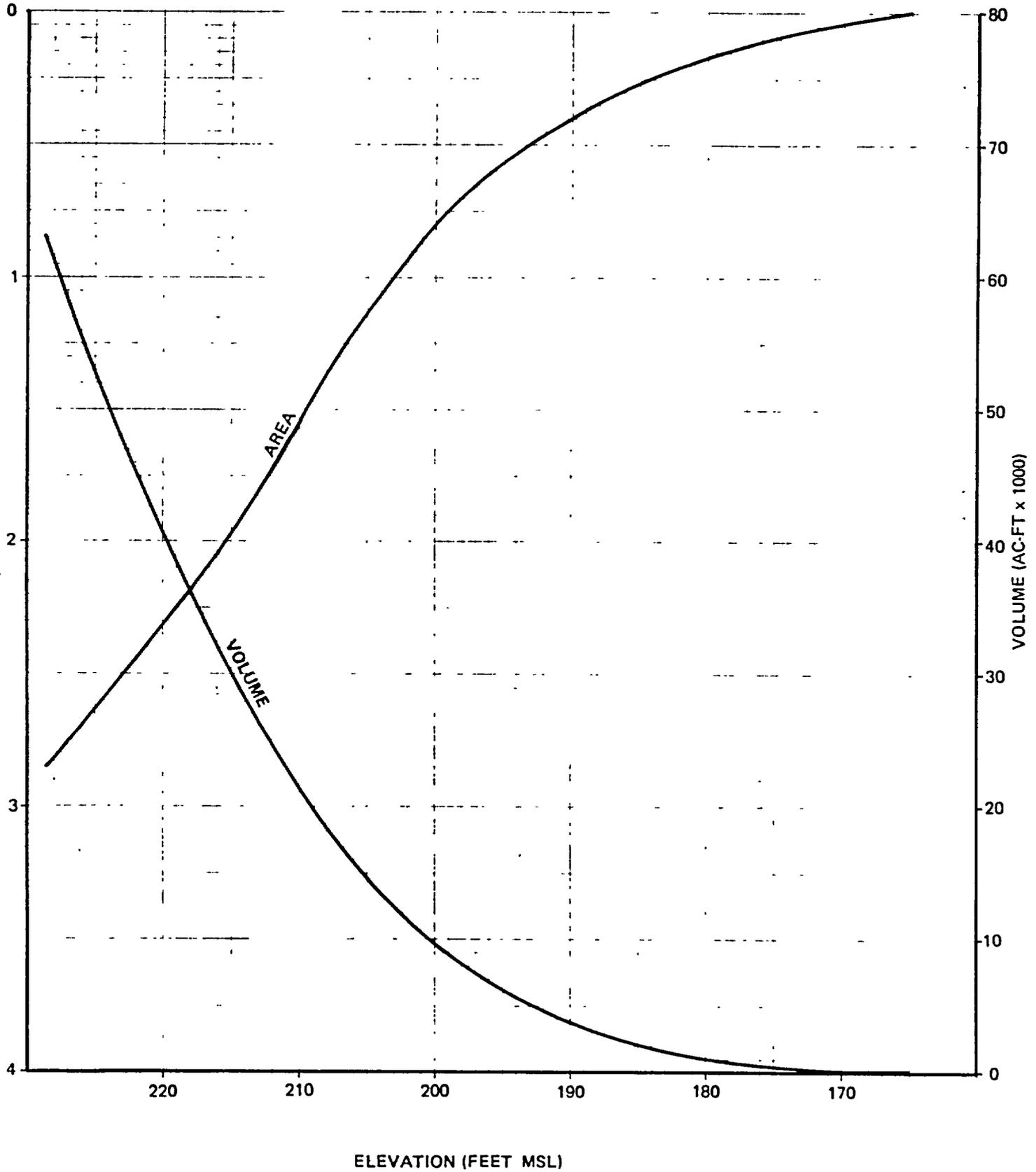


Figure 3.2.2 Area capacity curves for Robinson Impoundment

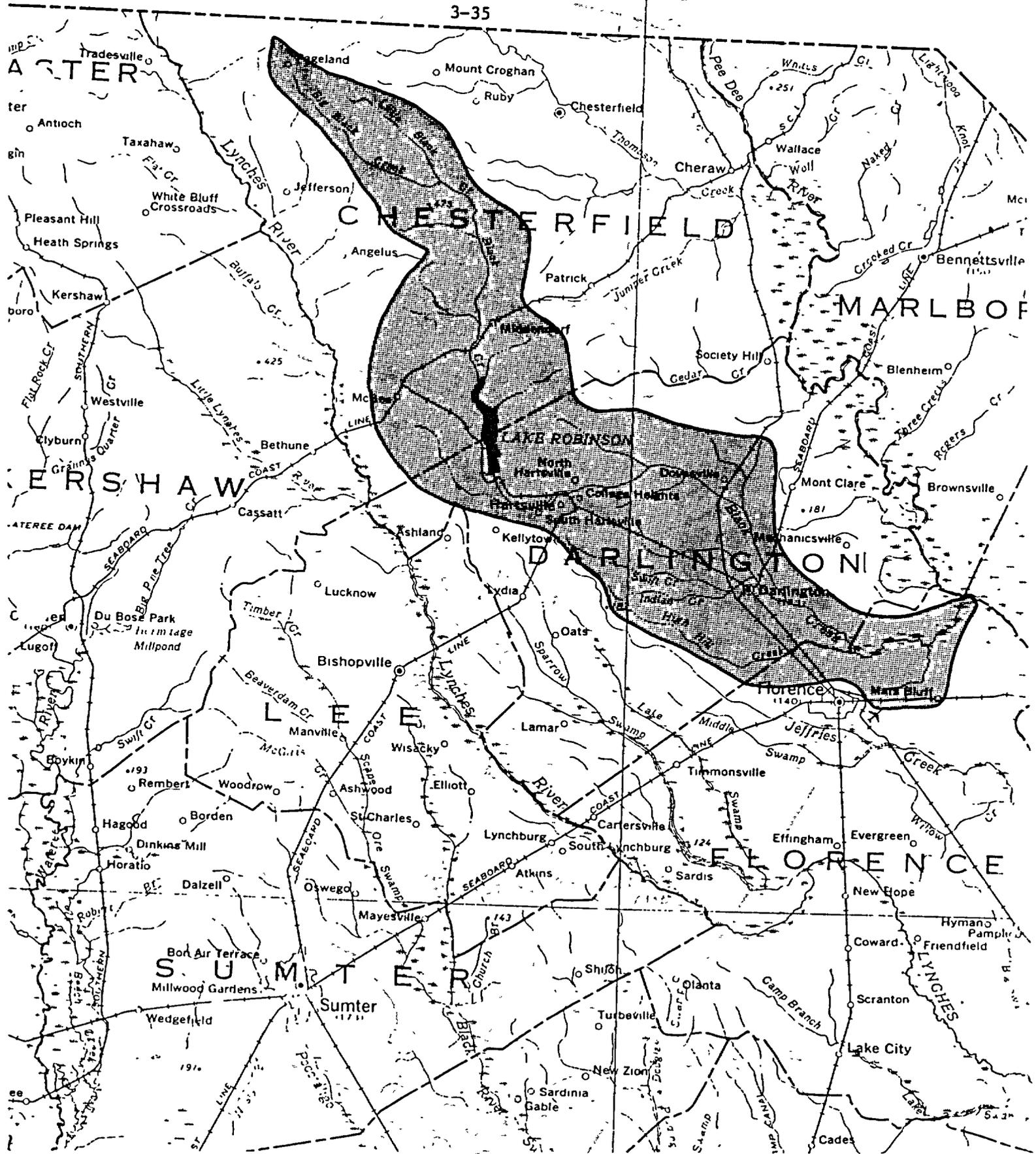


Figure 3.2.3 Black Creek drainage area

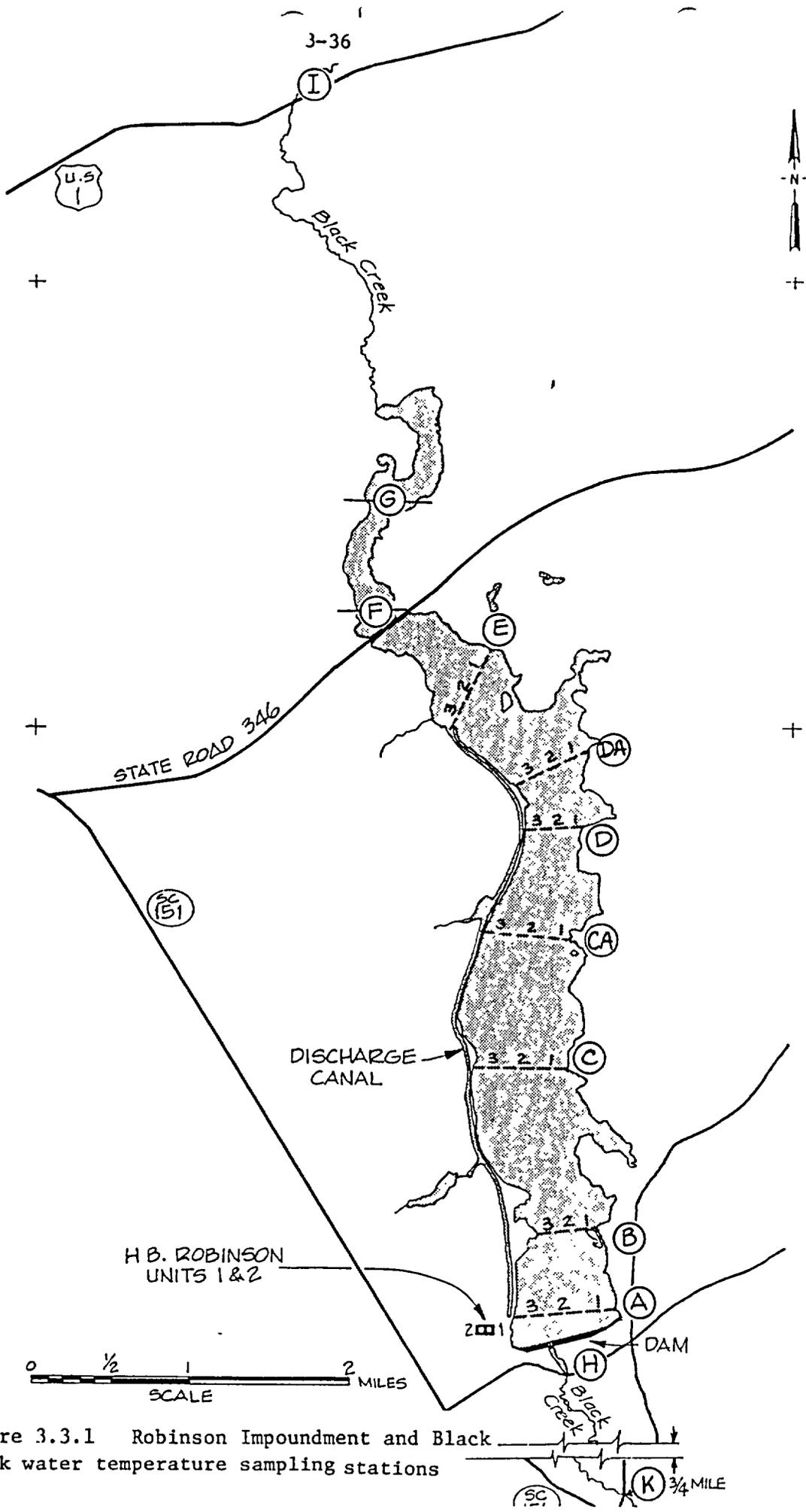


Figure 3.3.1 Robinson Impoundment and Black Creek water temperature sampling stations

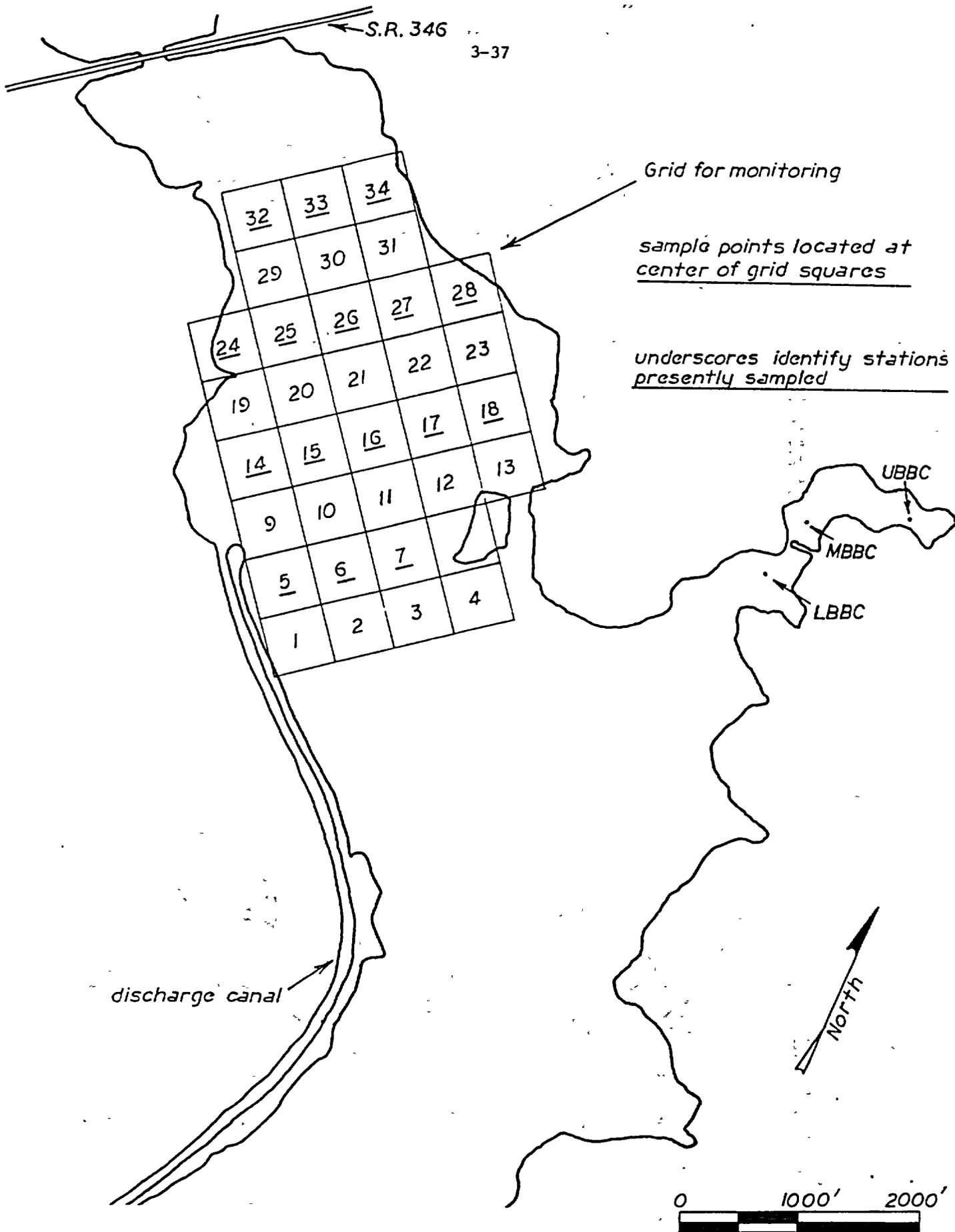


Figure 3.3.2 Robinson Impoundment water temperature sampling grid

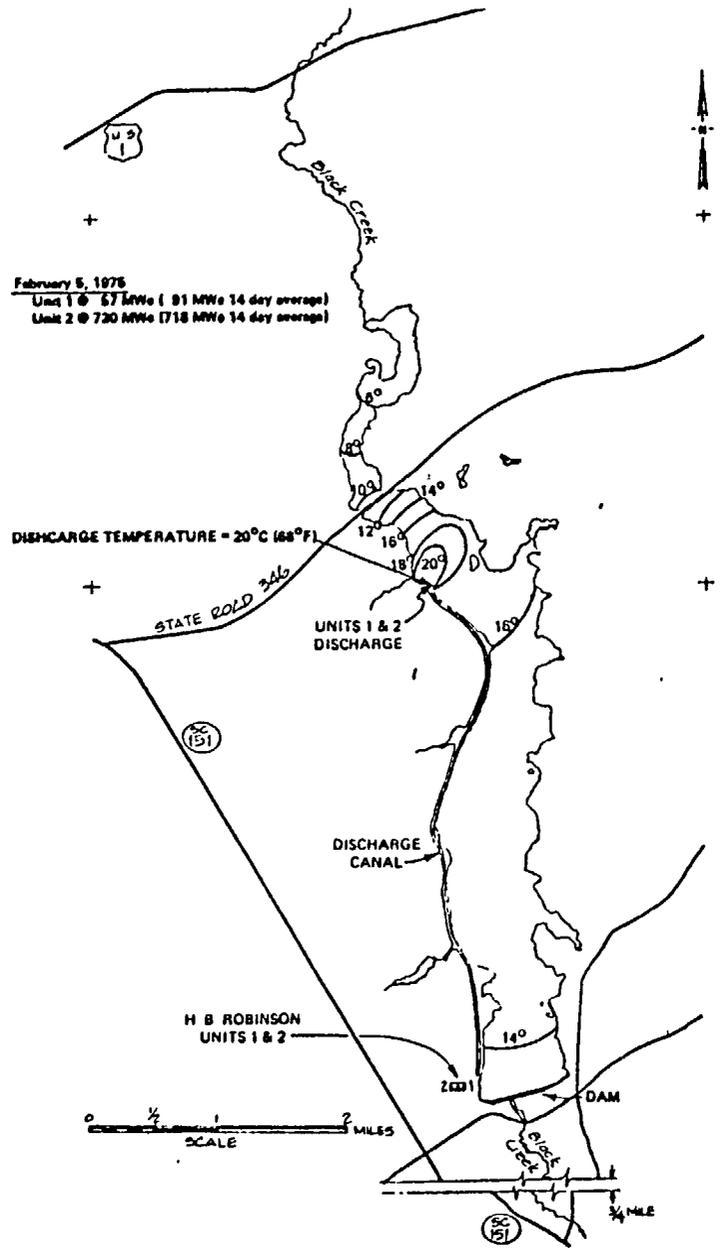
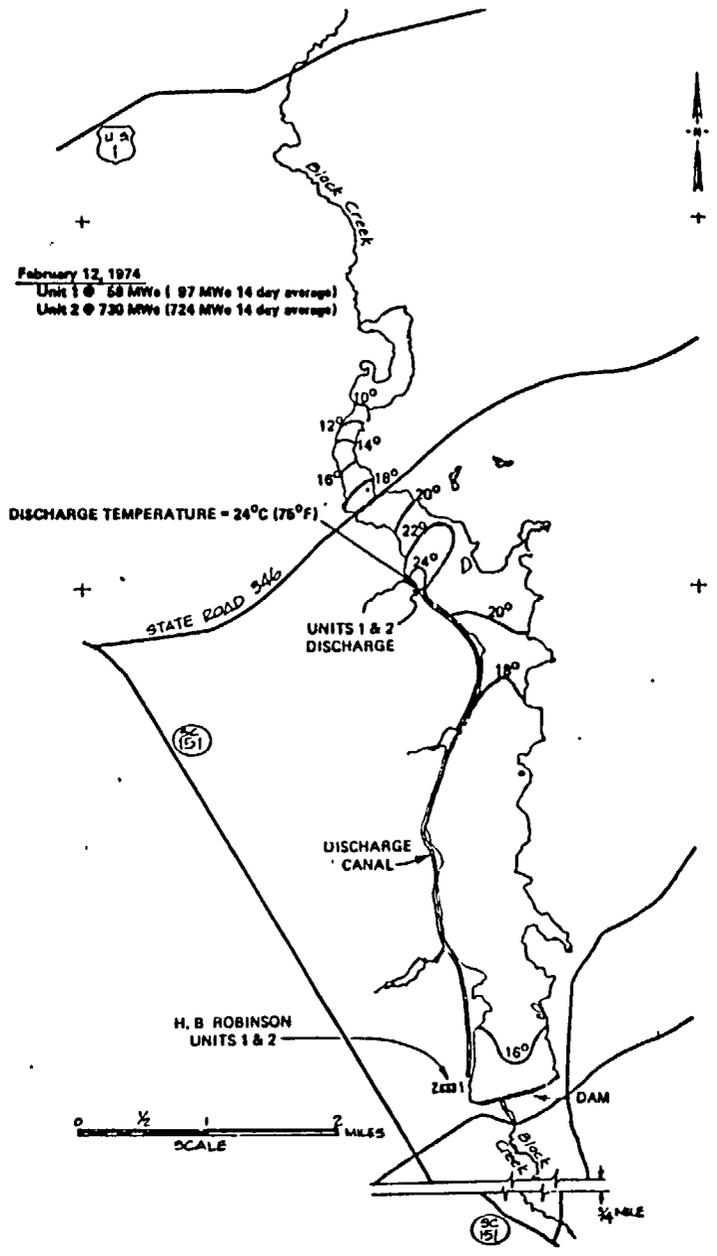


Figure 3.3.3 Robinson Impoundment 2°C surface isotherms, winter conditions: February 12, 1974 and February 5, 1975

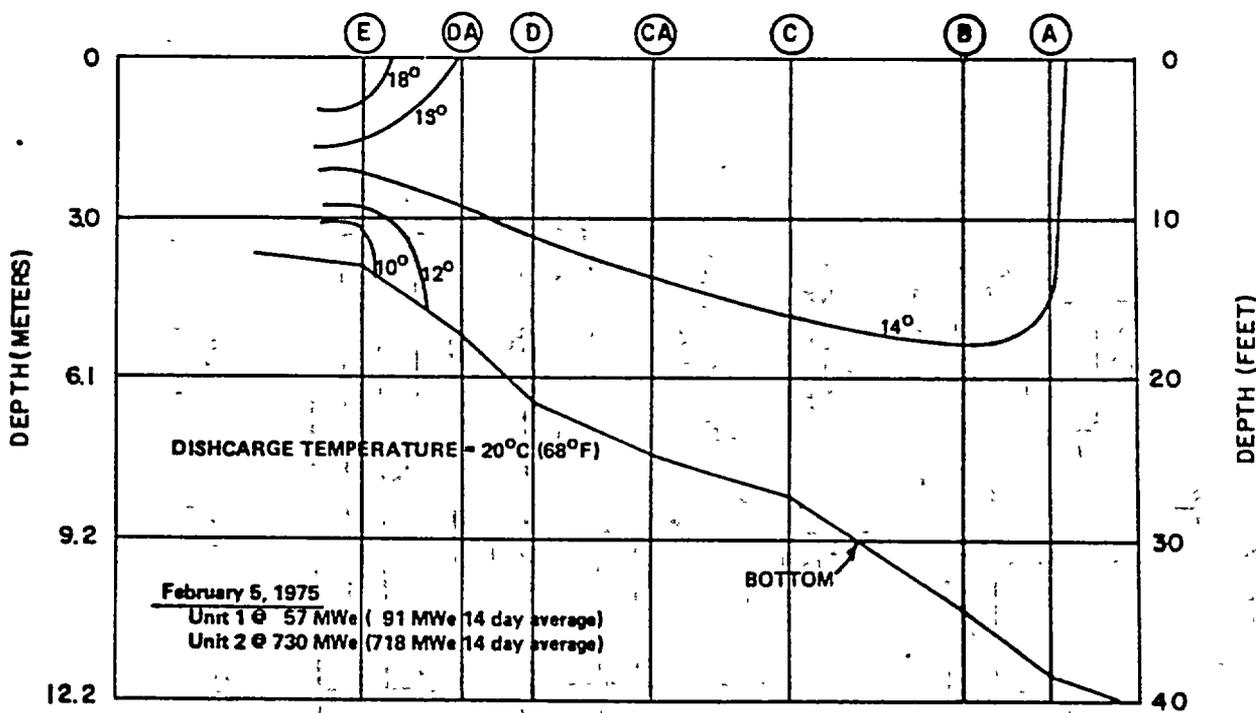
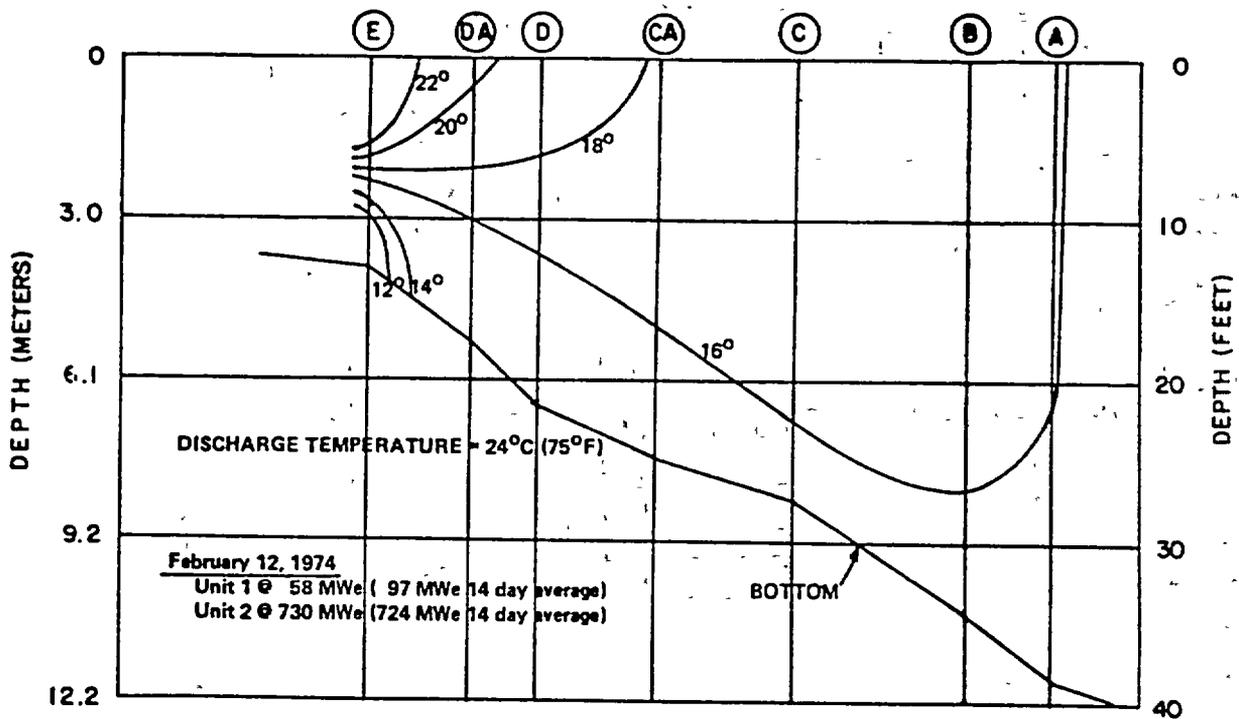
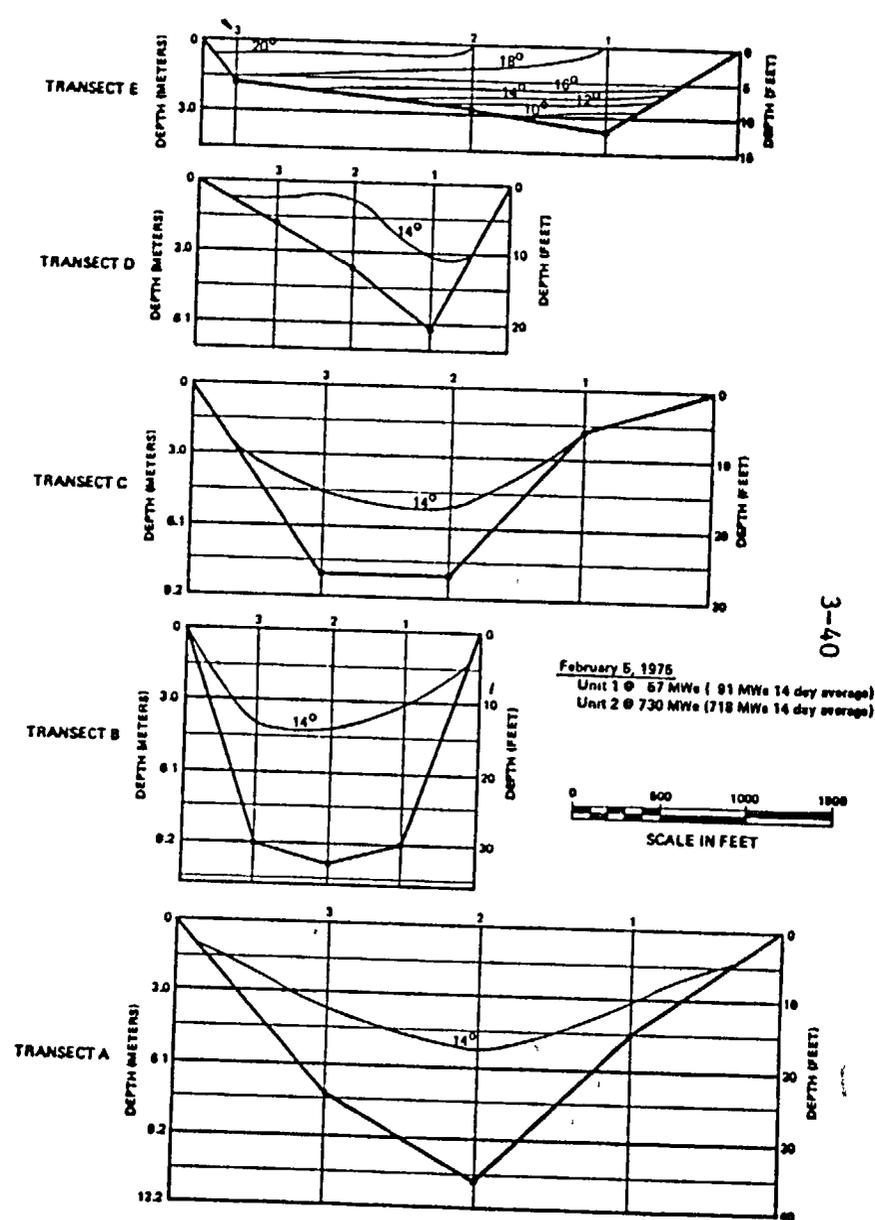
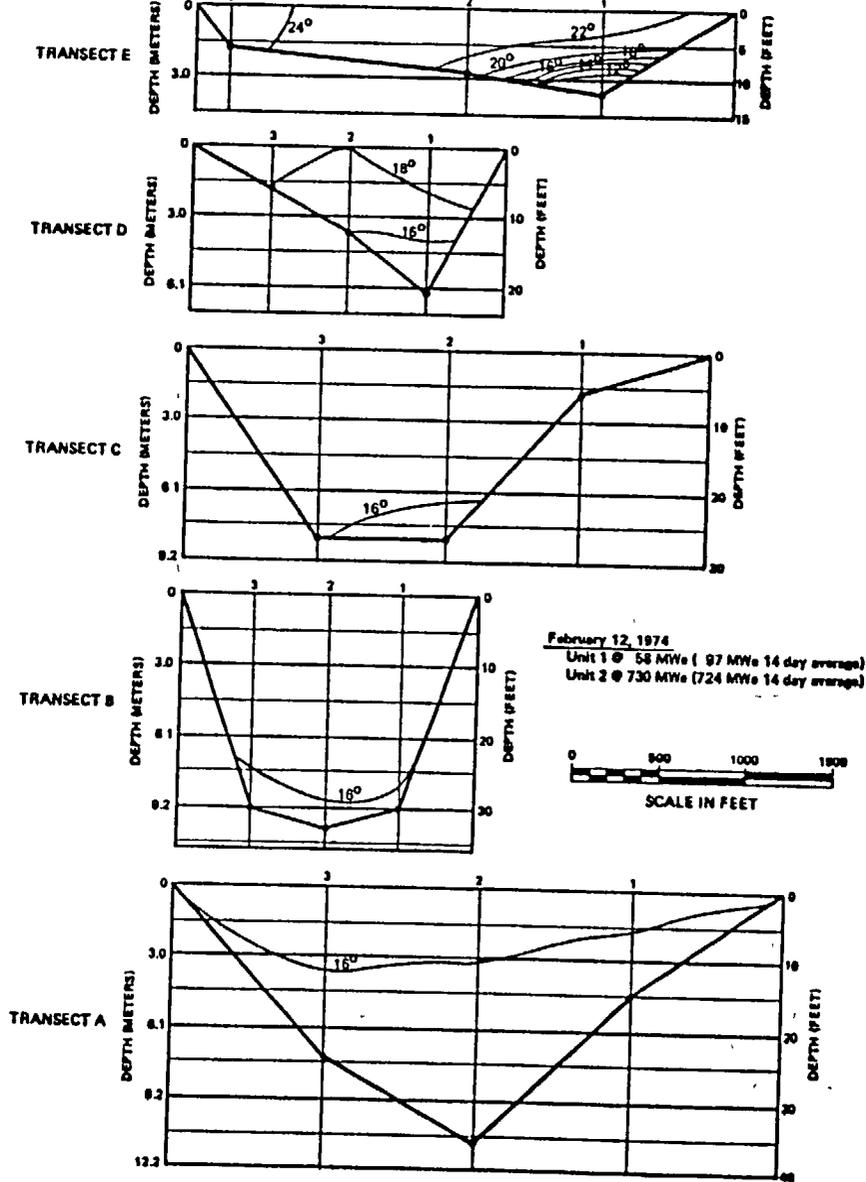


Figure 3.3.4 Robinson Impoundment 2°C vertical isotherms (north to south), winter conditions: February 12, 1974 and February 5, 1975 (indicating deepest station at each transect)



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Figure 3.3.5 Robinson Impoundment 2°C vertical isotherms (east to west), winter conditions: February 12, 1974 and February 5, 1975

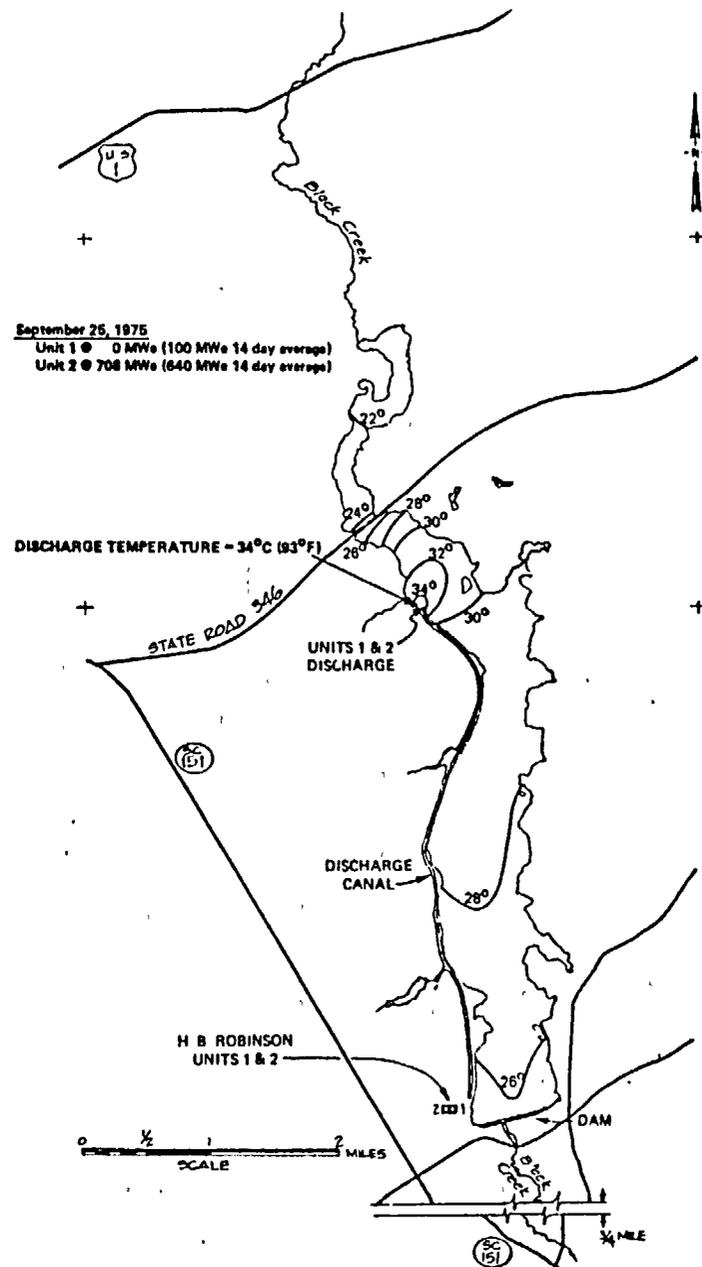
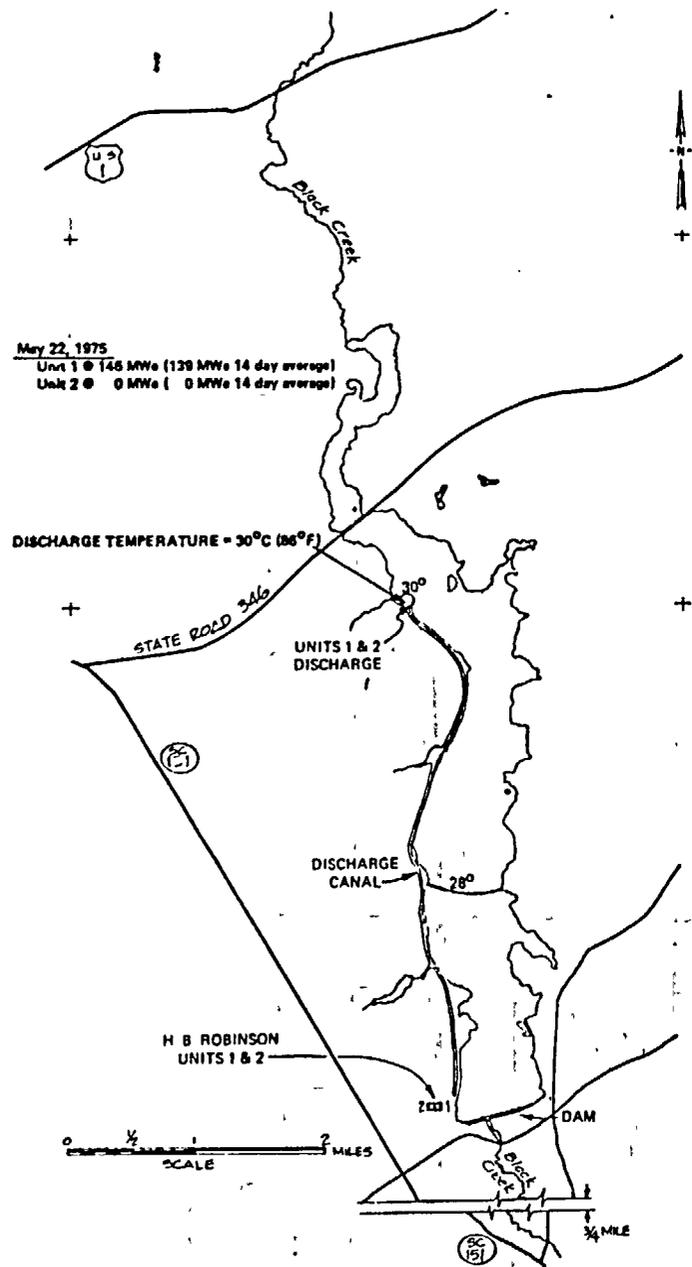


Figure 3.3.6 Robinson Impoundment 2°C surface isotherms, spring and fall mixing conditions: May 22, 1975 and September 25, 1975

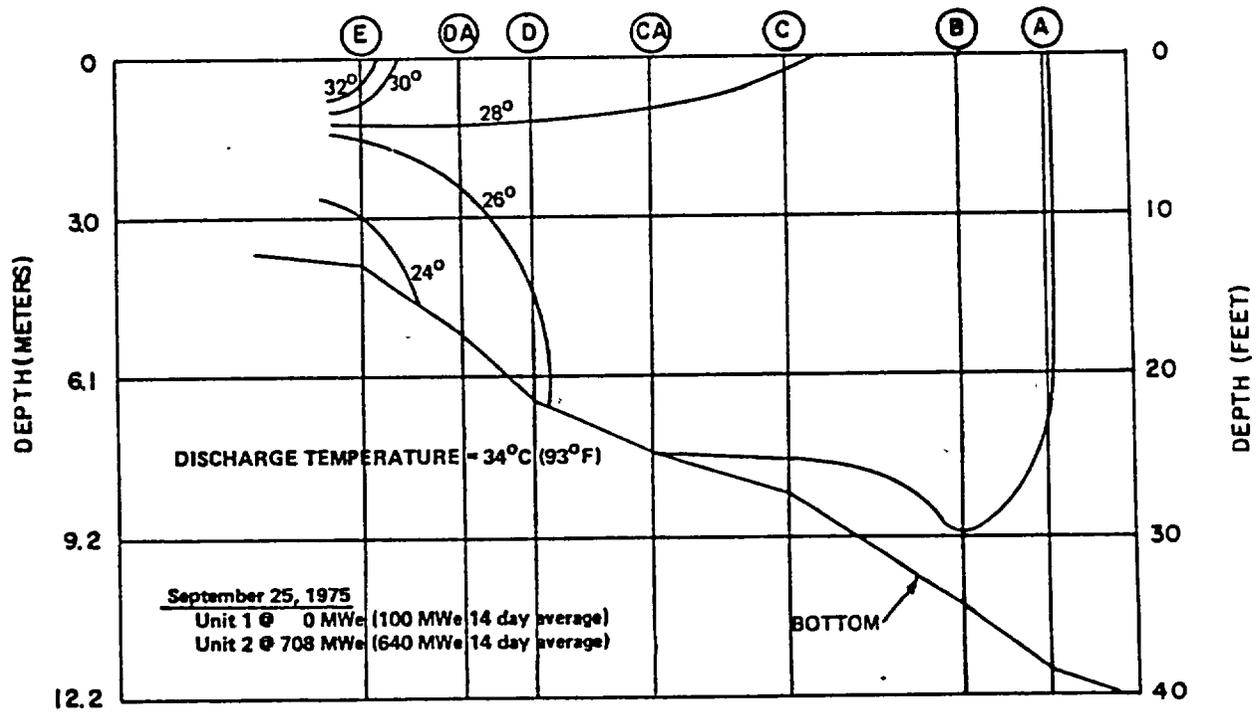
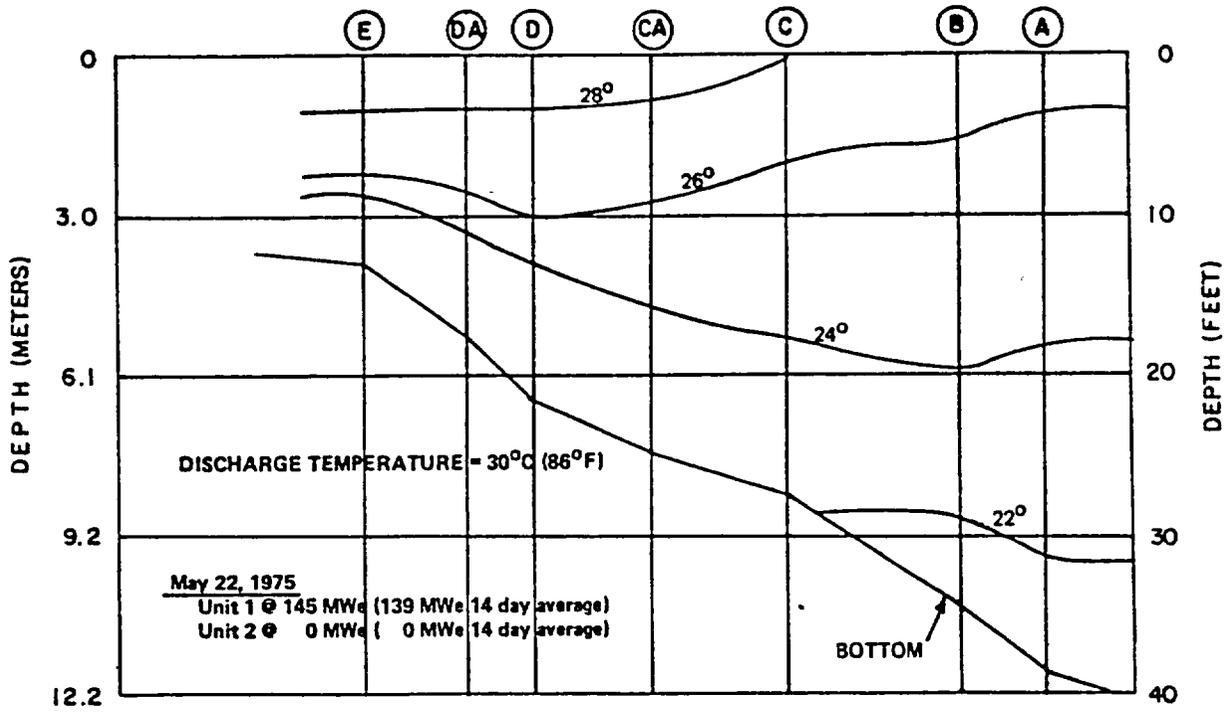


Figure 3.3.7 Robinson Impoundment 2°C vertical isotherms (north to south), spring and fall mixing conditions: May 22, 1975 and September 25, 1975 (indicating deepest station at each transect)

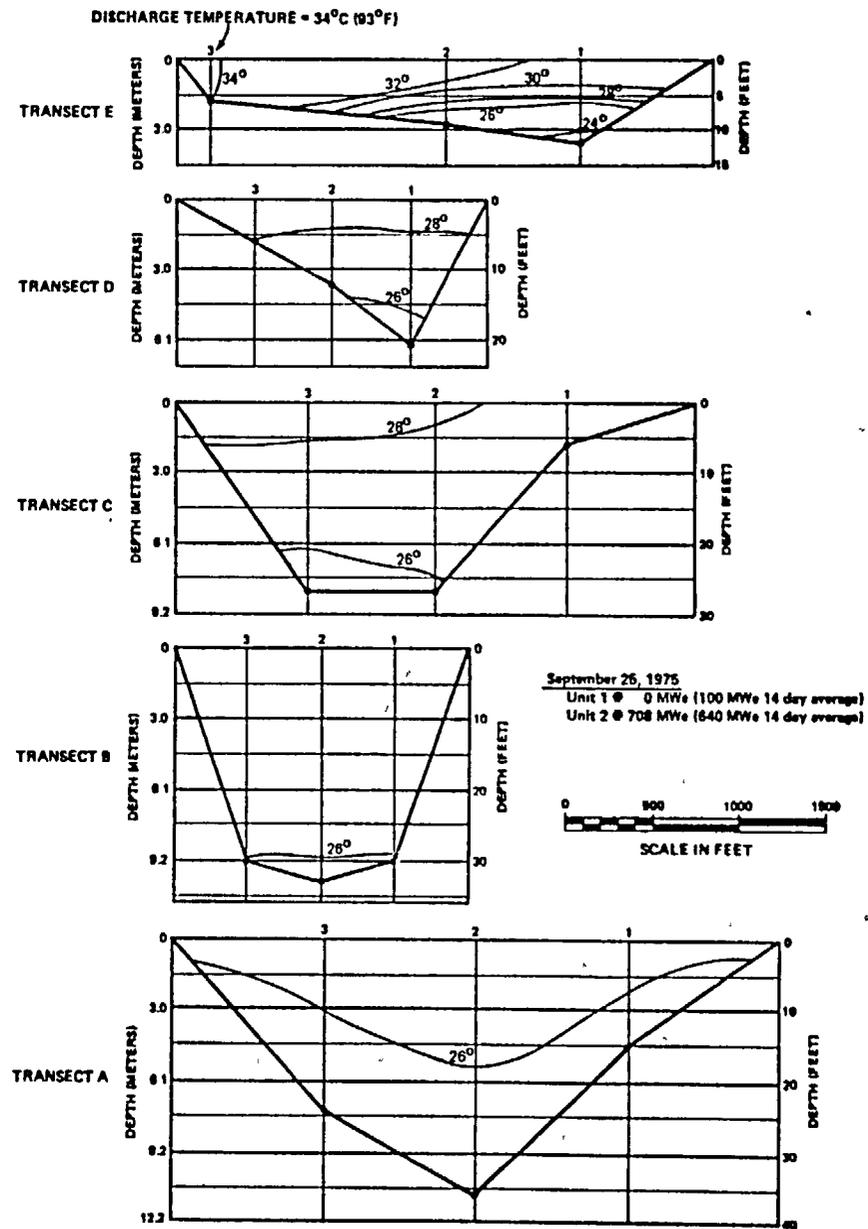
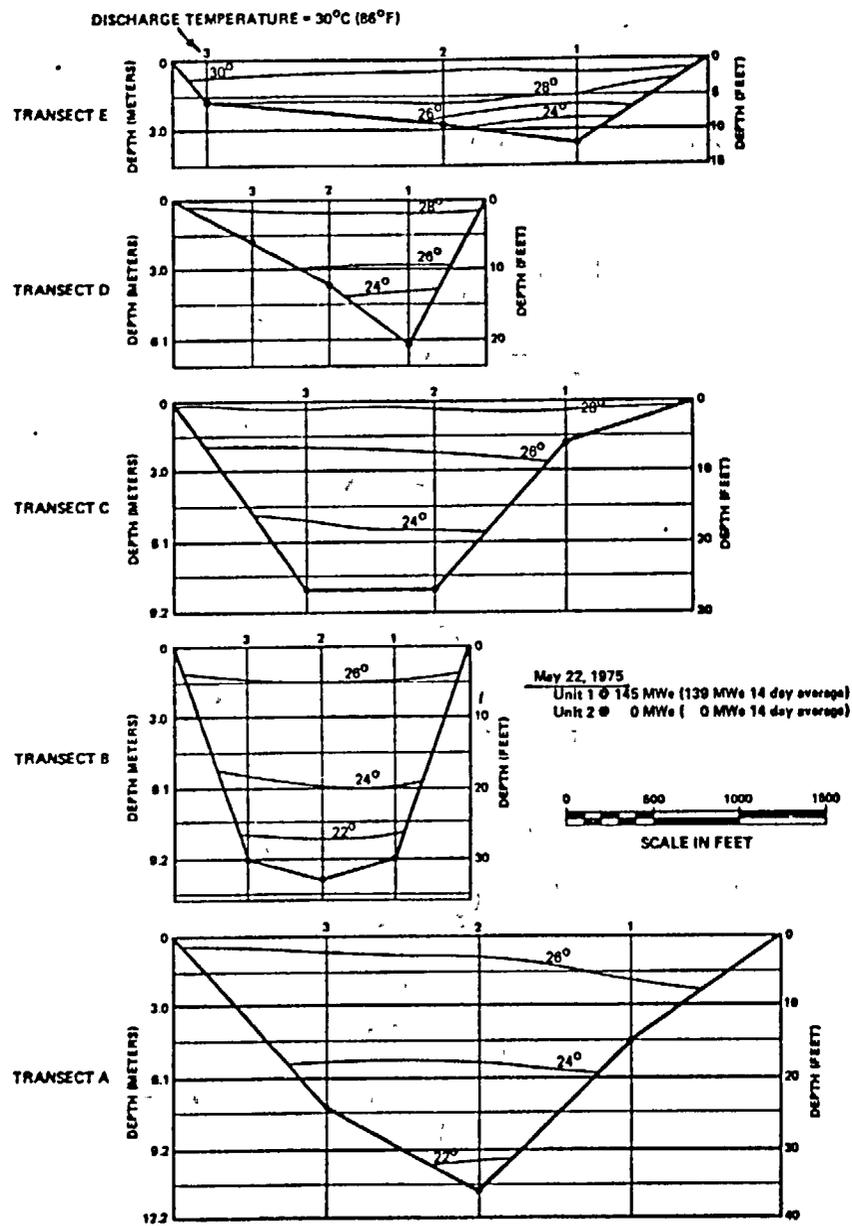
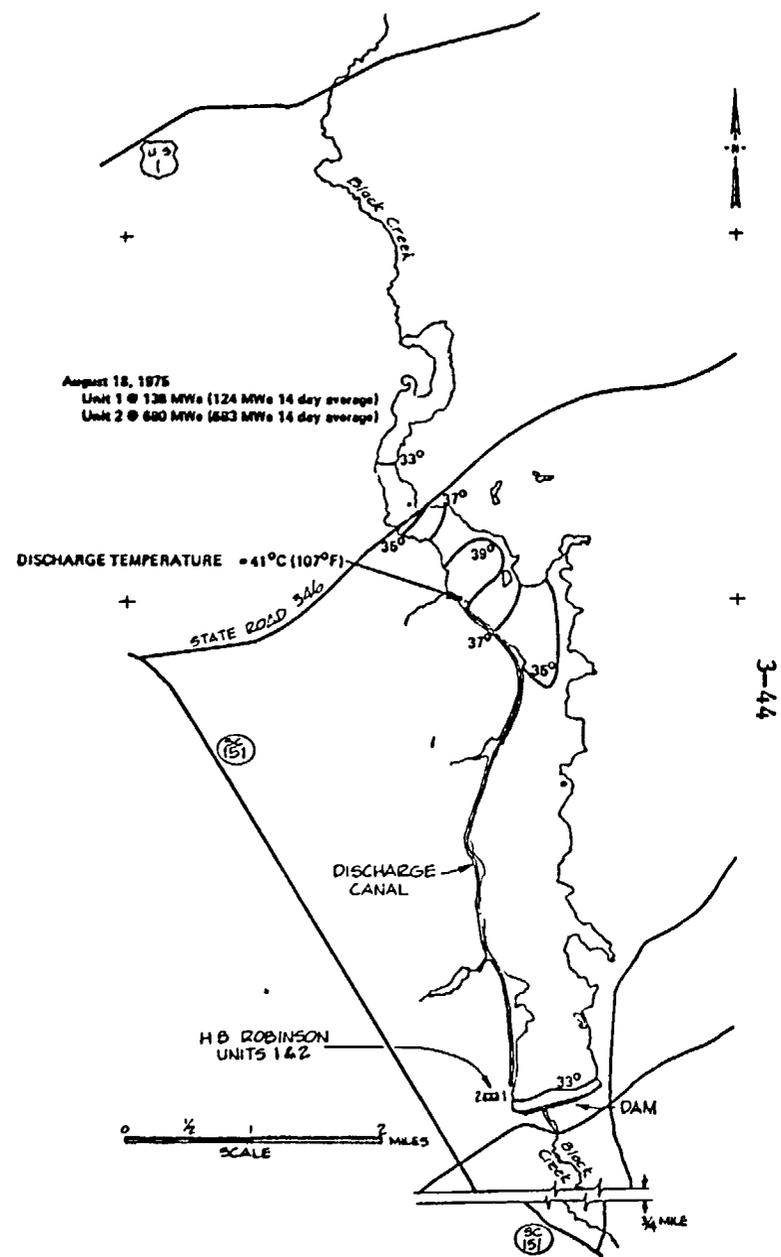
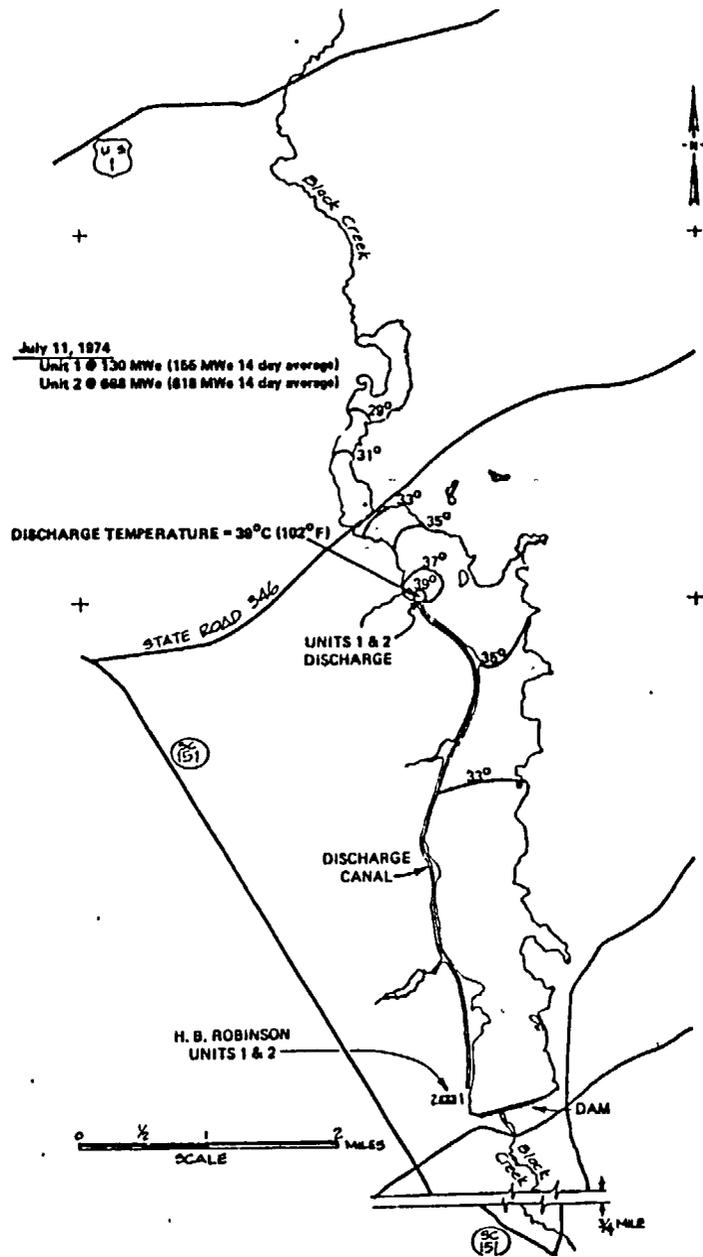


Figure 3.3.8 Robinson Impoundment 2°C vertical isotherms (east to west), spring and fall mixing conditions: May 22, 1975 and September 25, 1975



Figures 3.3.9 Robinson Impoundment 2°C surface isotherms, summer conditions:
 July 11, 1974 and August 18, 1975

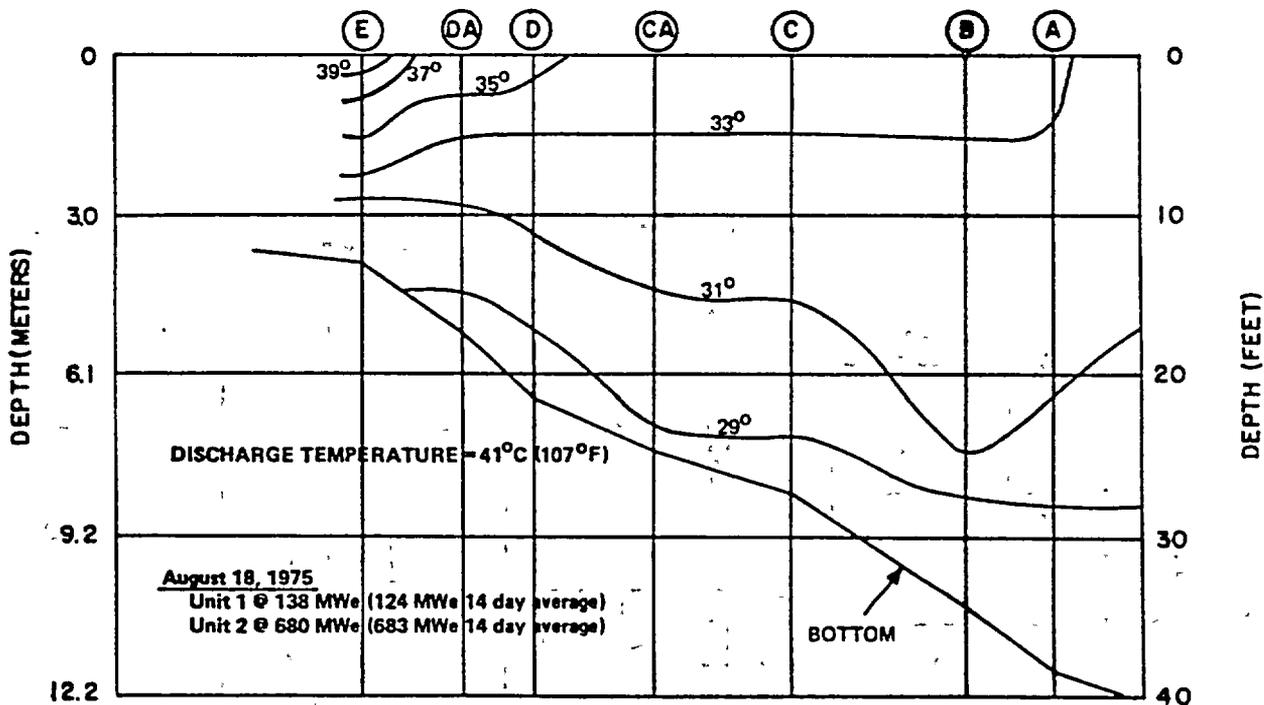
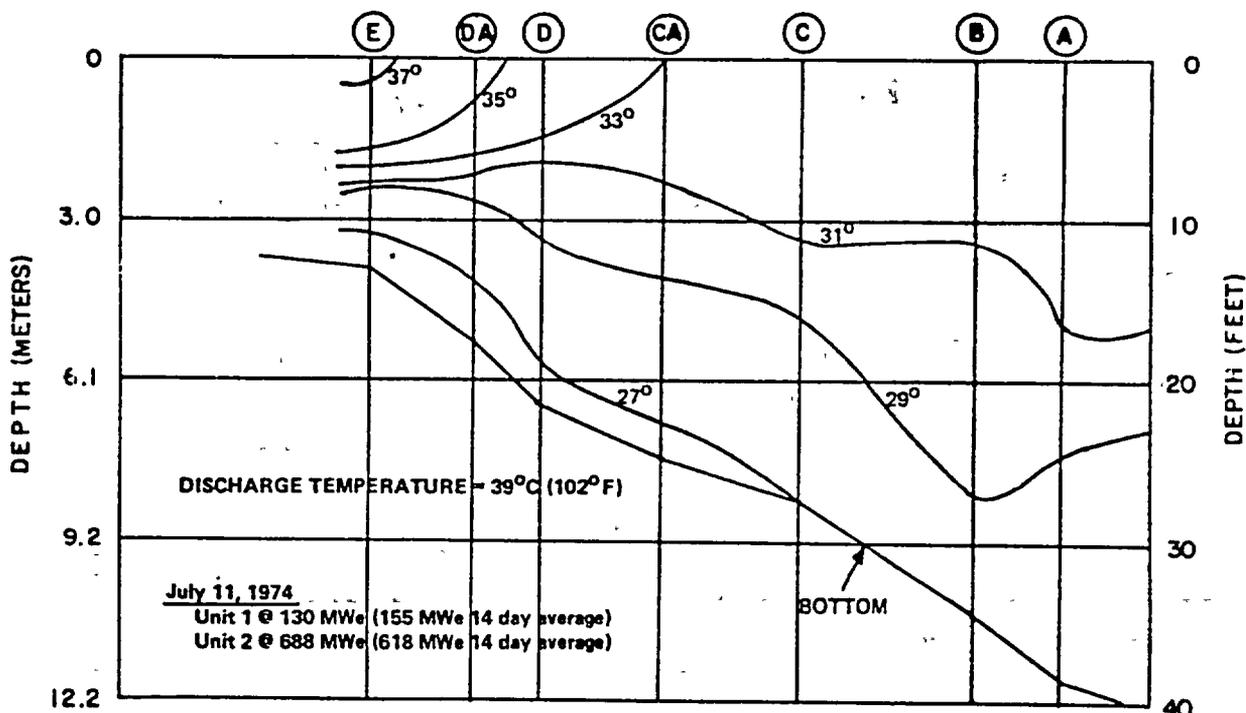
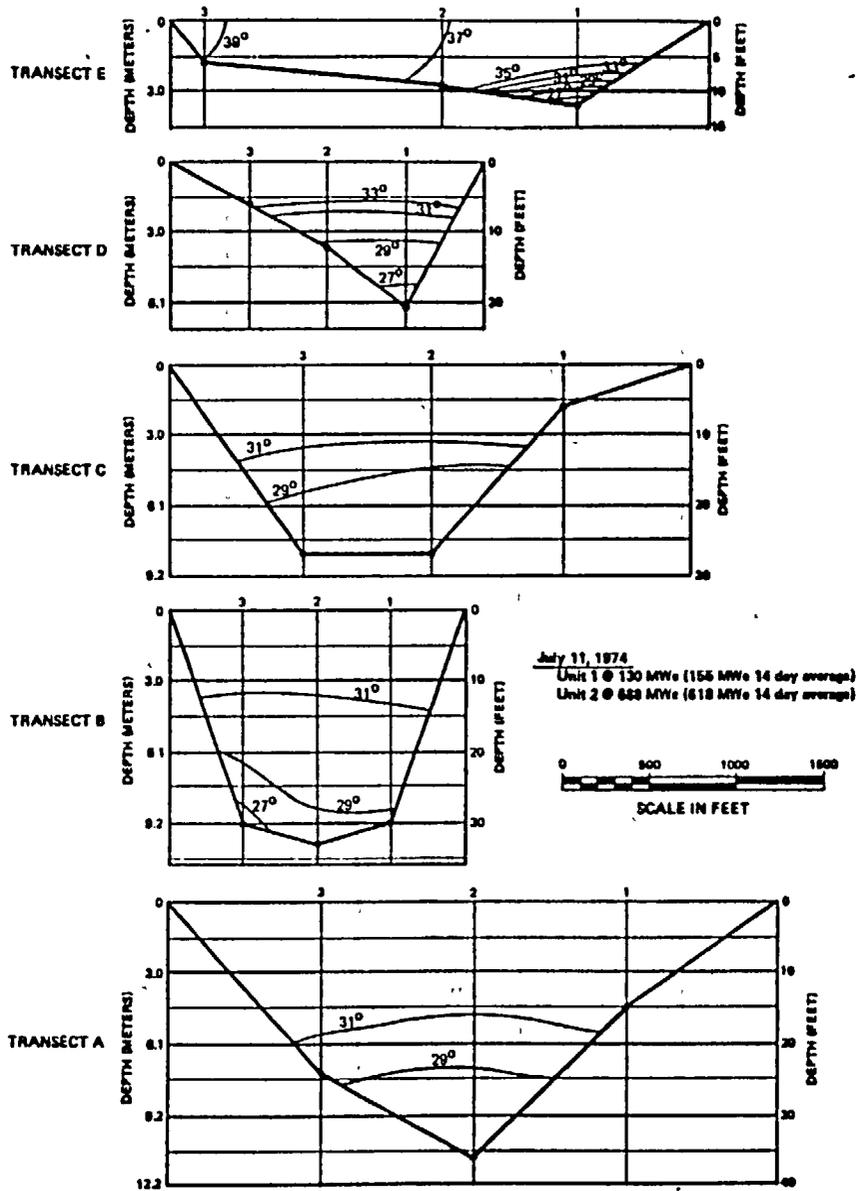


Figure 3.3.10 Robinson Impoundment 2°C vertical isotherms (north to south), summer conditions: July 11, 1974 and August 18, 1975 (indicating deepest station at each transect)

DISCHARGE TEMPERATURE = 39°C (102°F)



DISCHARGE TEMPERATURE = 41°C (107°F)

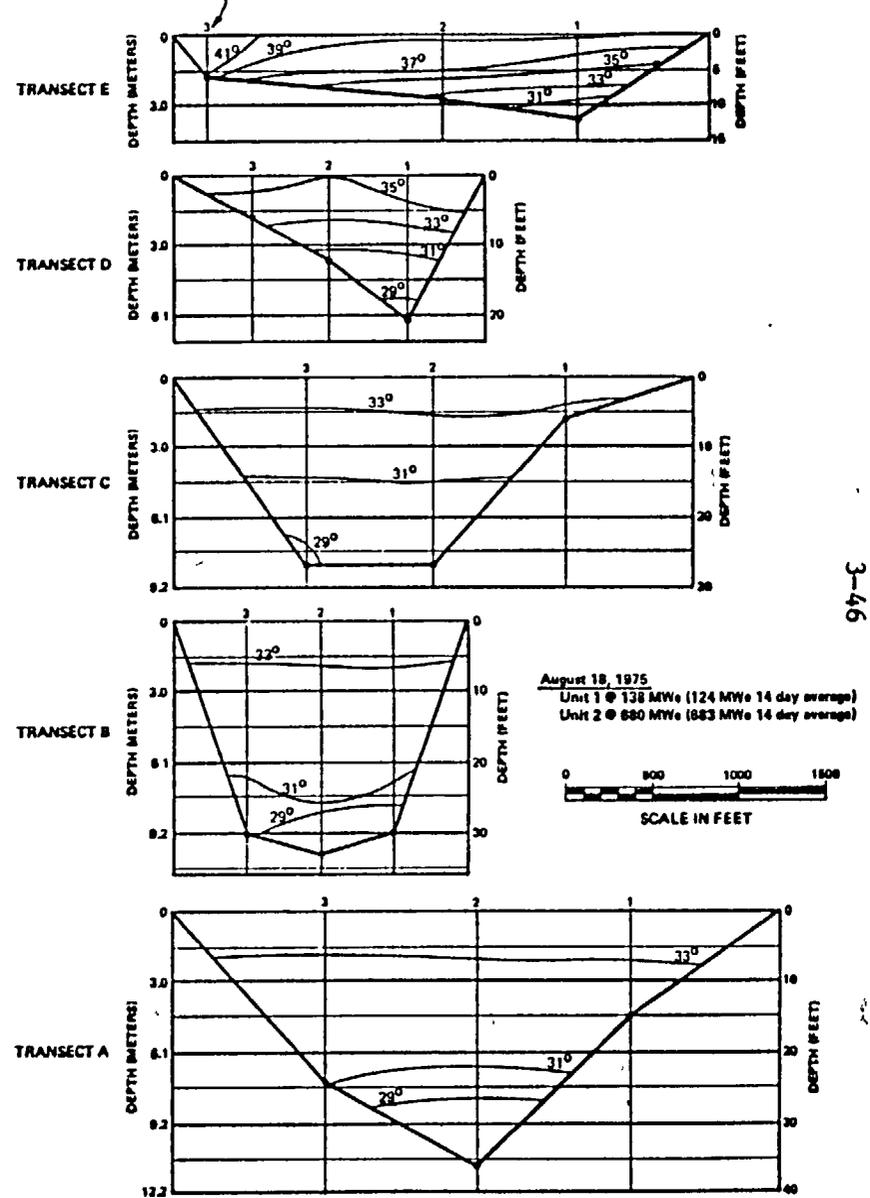


Figure 3.3.11 Robinson Impoundment 2°C vertical isotherms (east to west), summer conditions: July 11, 1974 and August 18, 1975

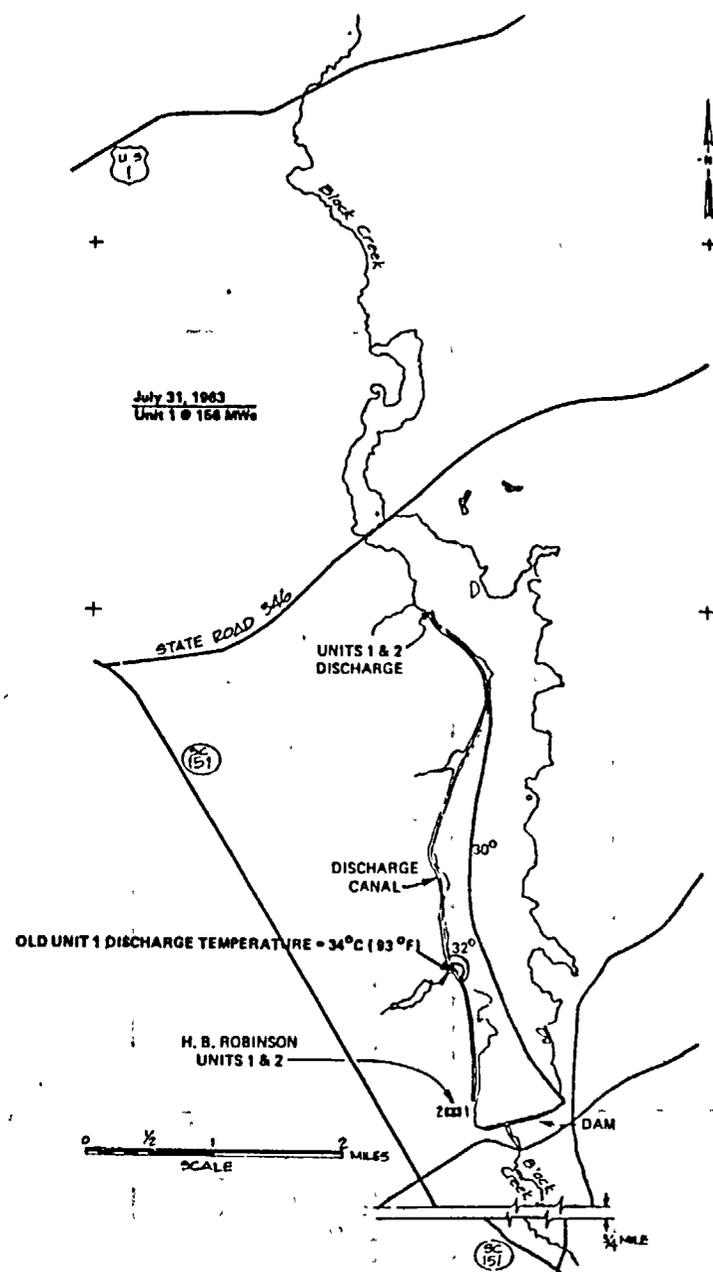
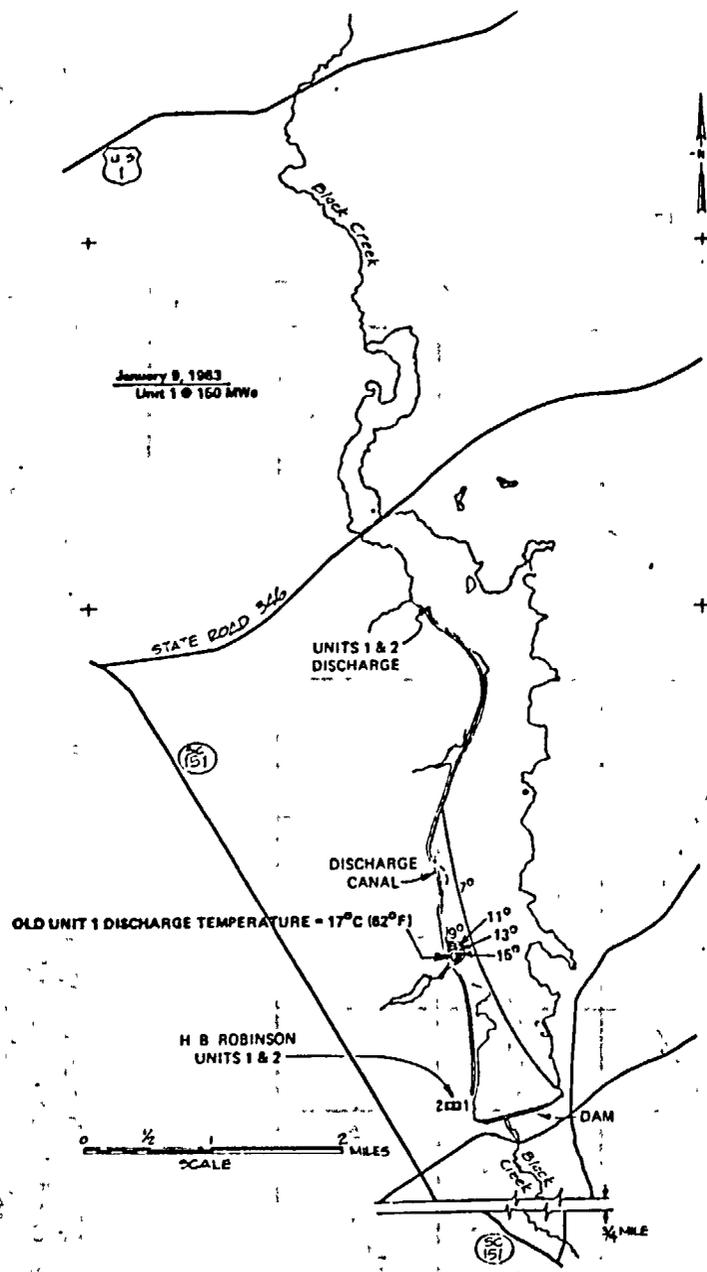


Figure 3.3.12 Robinson Impoundment 2°C surface isotherms, winter and summer conditions without the influence of Unit 2: January 9, 1963 and July 31, 1963

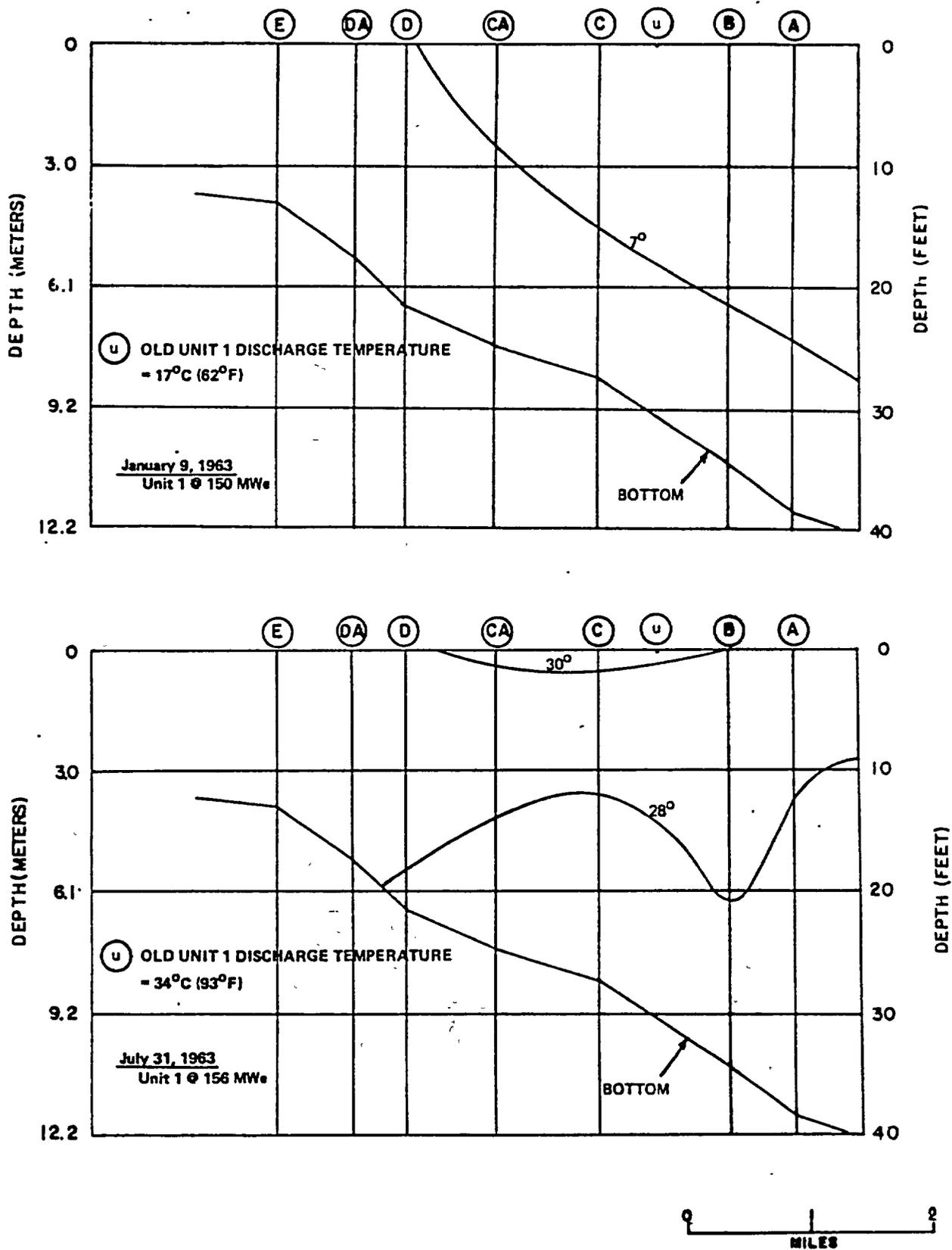


Figure 3.3.13 Robinson Impoundment 2°C vertical isotherms (north to south), winter and summer conditions without the influence of Unit 2: January 9, 1963 and July 31, 1963 (indicating deepest station from each transect; old discharge point indicated; no data available north of Transect D)

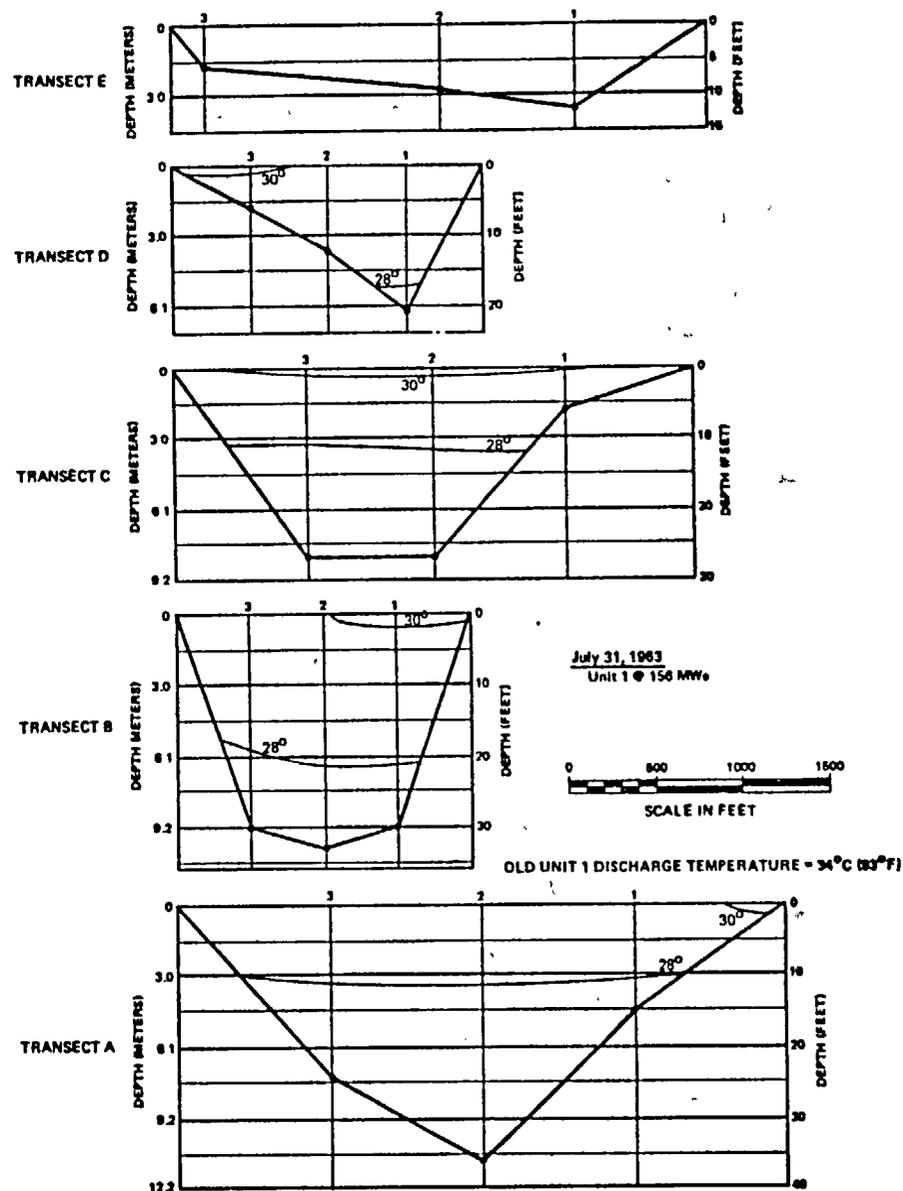
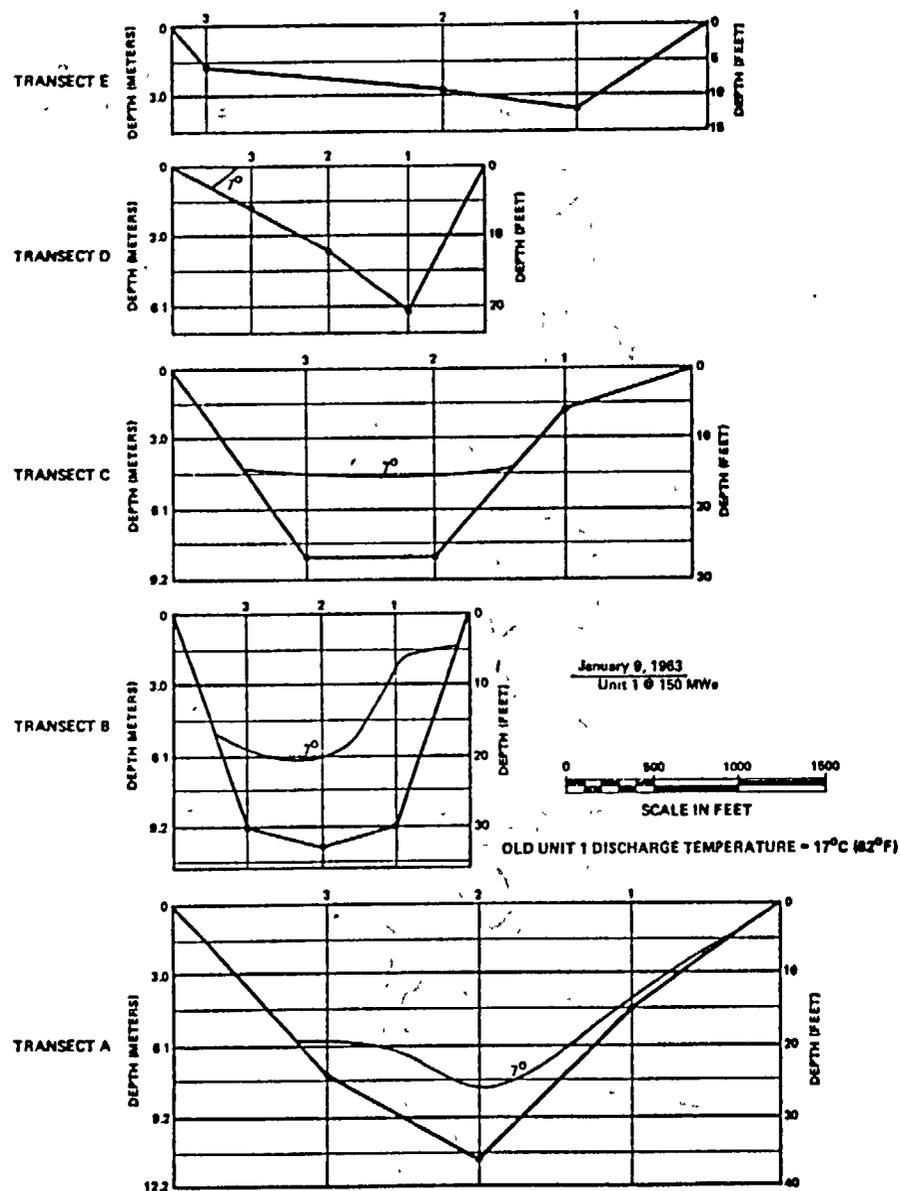


Figure 3.3.14 Robinson impoundment 2°C vertical isotherms (east to west), winter and summer conditions without the influence of Unit 2: January 9, 1963 and July 31, 1963 (no temperature data recorded at Transect E; Unit 1 discharge located between transects B and C)

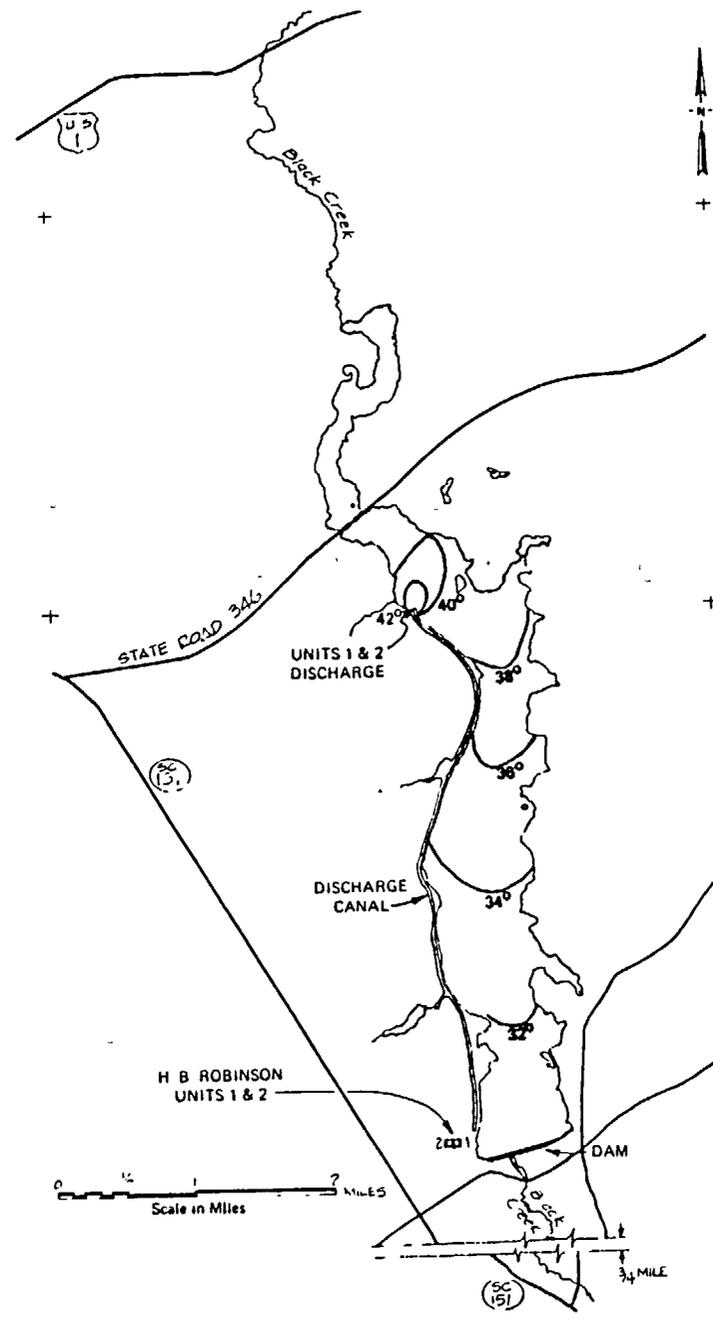
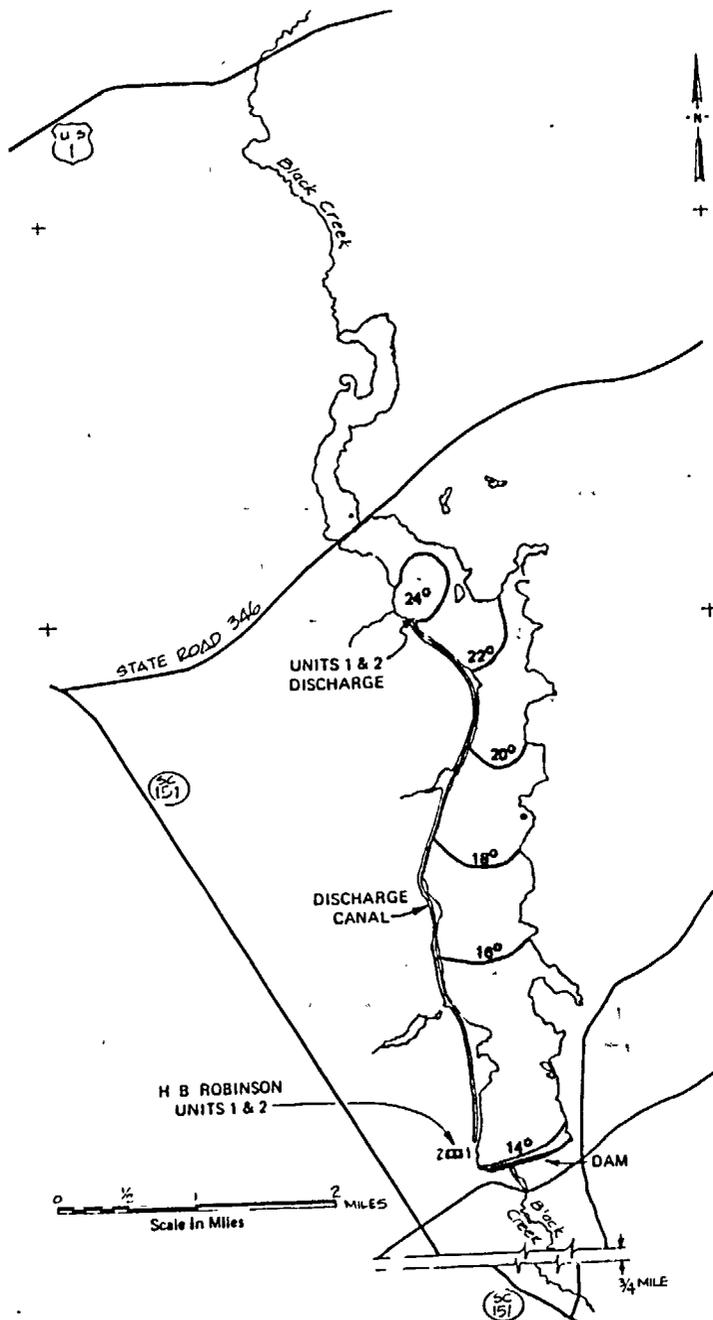


Figure 3.3.15 Robinson Impoundment predicted 2°C surface isotherms: typical winter and summer conditions

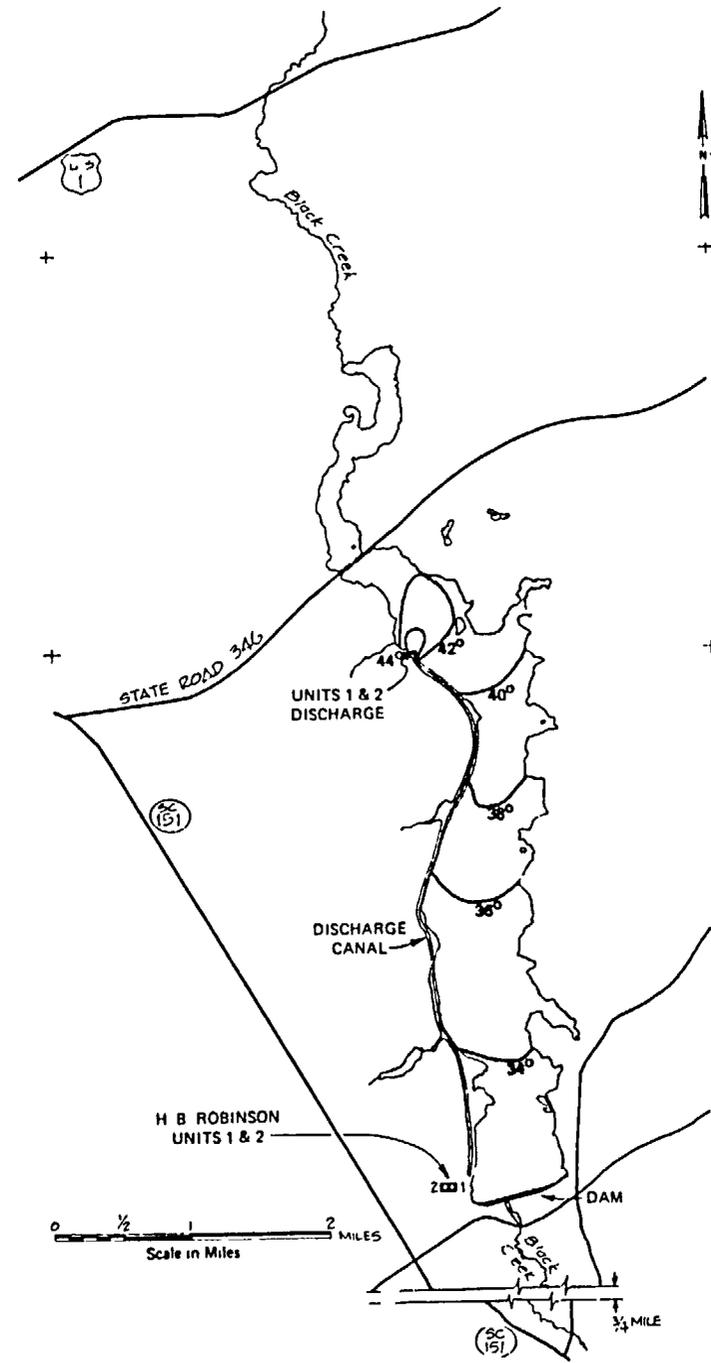
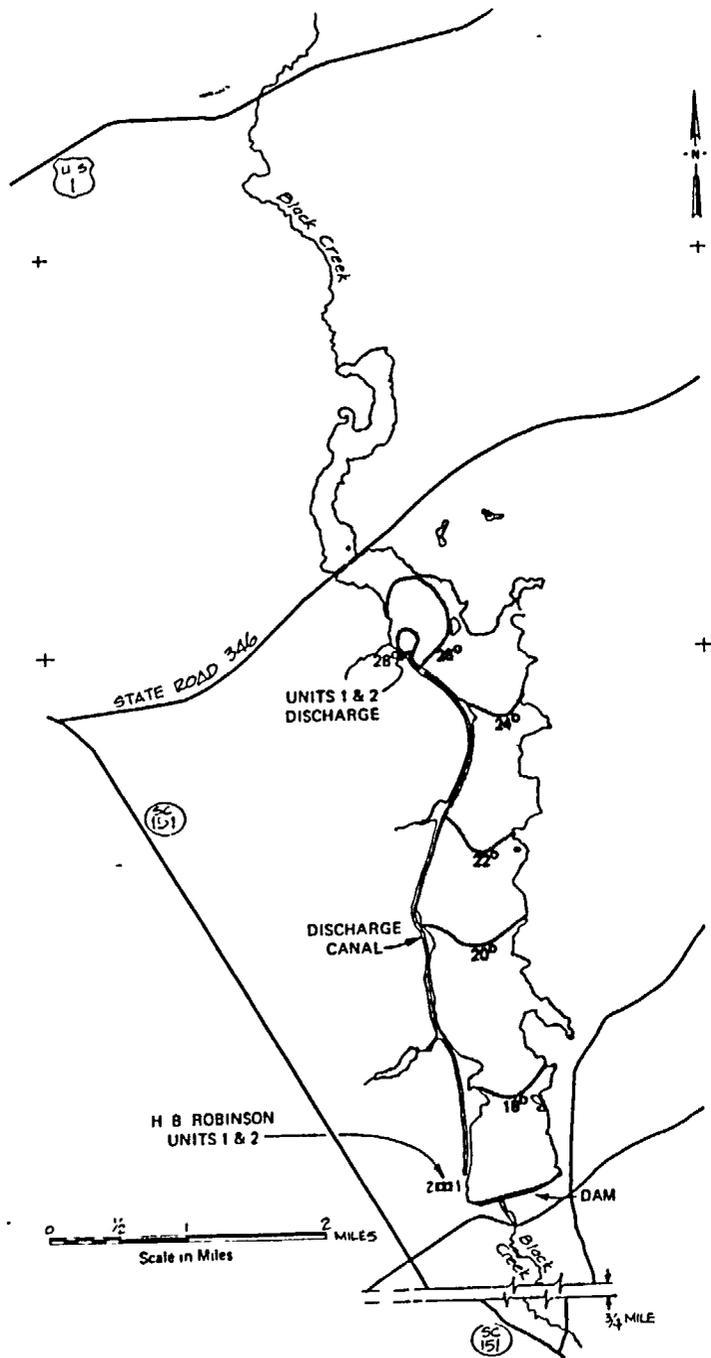


Figure 3.3.16 Robinson Impoundment predicted 2°C surface isotherms: predicted winter and summer maxima

4.0 Fisheries

4.1 Introduction

Preliminary studies of fish populations in Robinson Impoundment were begun in 1972 and 1973 and served to identify the methodology necessary to conduct a comprehensive study of the fishery and to begin compilation of a species list. During 1974 the studies were redesigned to meet the Nuclear Regulatory Commission regulations requiring fish population data and in view of the Company's decision to proceed with a 316 demonstration for the Environmental Protection Agency. Studies were further revised (added) during 1975 to strengthen weaknesses in the programs as they were identified.

The physical and chemical characteristics of Robinson Impoundment have been described in detail in Section 3 of this report. Other factors affecting fish populations such as vegetation and substrate are also described (Sections 6, 7) and should be kept in mind when examining the various characteristics of the fish population.

4.2 Fish Distributions in Robinson Impoundment

4.2.1 Introduction

Distribution of fishes is governed by environmental requirements that may vary with species or size. Certain species or sizes of fish exhibit preferences for particular water depths, temperatures, substrates, or cover types as well as being limited to certain ranges of these and other environmental parameters.

The objectives of the fish distribution study included determining the species present in the impoundment, examining variations in numbers and species among locations, and evaluating the numbers and species of fish present in the vicinity of the discharge with respect to other areas of the impoundment.

4.2.2 Methods and Materials

Gill netting, wire trapping, seining, and electrofishing were used to collect fishes from the various areas of the impoundment. The efficiency of these gear types varies with species and size of fish; therefore, results will be evaluated separately. In the quarterly sampling programs, quarters were defined as winter, January through March; spring, April through June; summer, July through September; and fall, October through December. An attempt was made to collect samples near the middle of the quarter.

Standard 30.5 m (100 ft) experimental gill nets, 2.4 m (8 ft) deep, (equal panels of 25 mm, 51 mm, 76 mm, and 102 mm (1 in, 2 in, 3 in, and 4 in) stretch mesh) were set at stations 1 and 3 of transects A, C, E, and G (Figure 4.2.1) for two consecutive days each quarter from summer 1974 through fall 1975. Nets were set off-bottom perpendicular to the shoreline at depths varying from 2 m (6.5 ft) to approximately 12.2 m (40 ft). The nets were checked and catch examined after approximately 24 and 48 hours.

Single funnel poultry wire traps approximately 1.2 m (4 ft) in length and .6 m (2 ft) in diameter were also set at stations 1 and 3 of transects A, C, E, and G for two consecutive days each quarter from spring 1974 through fall 1975. Traps were usually set in water 1 meter deep and were checked after approximately 24 and 48 hours.

Seining was conducted quarterly with a 15.2 m (50 ft) bag seine (6 mm (1/4 in) mesh) from summer 1974 through fall 1975. One seine haul was made at stations 1 and 3 of transects A, C, E, and G. Each haul consisted of extending the seine along the shoreline and sweeping an arc of 180° and radius the length of the seine (when possible). Water depth or bottom conditions at times prevented the full extension of the seine.

Electrofishing was conducted for 0.5 hour at stations 1 and 3 of transects A, E, and G monthly from April, 1975 through March, 1976. A Smith-Root type VI control unit and 3500 watt generator were used operating at 600 volts (AC). Current was generally within the range of 1-3 amps. Fishes

that were incapacitated were collected with a dip net and were held in a tub of water until the end of the collection period. The dark color of the water and low conductivity created some difficulty in collecting electrofishing samples. These conditions were generally uniform throughout the impoundment so comparison of data among stations can be made. Extreme caution should be used, however, in comparing these data with electrofishing samples collected in other bodies of water and different environmental conditions.

Numbers, lengths, and weights were recorded for all fish collected. Sex and maturity were recorded when possible. Scales, stomachs, and gonads were removed from largemouth bass, bluegill, warmouth, and chain pickerel when needed for age-growth, food habit, and fecundity studies. Larger fish which were not sacrificed and were in good physical condition were tagged with Floy anchor tags and released.

Catch rates have been adjusted to numbers and weights per 24-hour set for gill nets and wire traps, to number per haul for seine catches, and to number per hour for electrofishing to facilitate direct comparisons.

4.2.3 Results and Discussion

Species Composition

Thirty-one species of fish were collected from Robinson Impoundment during 1974 and 1975 (Table 4.2.1). Thirteen of these were centrarchids, indicating the importance of sunfish in the impoundment. The most common species collected were bluegill and warmouth, although species abundance varied with area. Three species, flier, white crappie, and black crappie were collected only from the H. B. Robinson Plant intake screens during studies of fish impingement (Section 4.9) or during creel surveys (two black crappie). Several additional species were collected from Black Creek and probably occur in the impoundment.

All of these are typical of the piedmont-coastal plain region and many are generally associated with "black water" systems. Table 4.2.2 compares the fish species collected from Robinson Impoundment and Black Creek with other

similar bodies of water in North and South Carolina. All of these, with the exception of Par Pond are characterized by darkly stained water. Par Pond, located in southeastern South Carolina, receives heated effluent from a nuclear reactor. The table illustrates that the fish species typically found in this area are well represented in Robinson Impoundment and that the species composition of Robinson Impoundment is not unlike that of other similar bodies of water in the area. (See Table 3.4.1)

Gill Netting

Gill net catches in Robinson Impoundment were generally small and varied both in number and species. Mean total catch per day (Table 4.2.3) was compared between stations on each transect as a possible basis for combination, using a paired Student's t-Test (Snedecor and Cochran, 1967). Significant differences ($P = .05$) were found between stations so overall variance in total catch (number per set) was evaluated using a 2-way Analysis of Variance and F Test, with sampling station and sampling date the classes of interest. Differences between sampling dates were not significant ($P = .05$), while differences between stations were highly significant ($P = .01$) (Table 4.2.4). Mean total catches by sampling station were then subjected to Duncan's five percent level New Multiple Range Test (Steele and Torrie, 1960). Three groupings of means were apparent (Table 4.2.5) indicating values which were not significantly different from each other. Catches at station G-3 were significantly higher than at the other sampling stations. The catch at the other upper impoundment sampling station (G-1) was next in numerical rank; however, no significant difference was indicated between the catches at stations G-1, E-3, E-1, A-1, and C-1. The catches at stations A-3 and C-3 were significantly lower than catches at G-1 but were not significantly different from catches at E-3, E-1, A-1, or C-1. These station differences indicate there is no difference in catch rate in the lower and middle reaches of the impoundment (including the discharge area), but these rates are lower than catches in the upper impoundment (G). In addition, catches from the discharge area and the east side of lower and mid-impoundment transects were not different from catches from the east side of the upper impoundment.

An alternative analysis was suggested by Dr. Charles H. Proctor of the North Carolina State University, Department of Statistics as being more appropriate. This analysis is presented in Exhibit 3. Discussion and conclusions were essentially the same following either procedure.

In examining species composition of catches at particular stations by season, no differences are readily apparent. There are, however, notable differences between stations. Gill nets at transects A and C generally caught a higher proportion of bluegills and chain pickerel than were taken on transects E and G. Suckers and golden shiners were generally collected in greater proportions from transects G and E than from transects C and A. Although warmouth and yellow bullheads were collected from most sampling stations, warmouth were taken in greater proportions from transects E, C, and A than from transect G, while yellow bullheads were taken in greater proportions from transects G and E than from transects A and C.

Wire Trapping

Wire trapping in Robinson Impoundment was generally inefficient with only centrarchids, primarily bluegill and warmouth, collected. Although the data were not subjected to statistical testing, mean catches by station appear to be grouped (Table 4.2.6). Largest catches were made at Station A-1 (average 3.2 fish per set), and were several times greater than catches at any other location. Mean total catches from Stations C-3, E-1, and G-1 ranged from 0.6 to 0.8 fish per set. A third grouping of Stations A-3, C-1, and E-3 (0.2 - 0.3 fish per set) was discernible. No fish were collected with wire traps at Station G-3.

In evaluating catches by year and season, more fish were taken in wire traps during 1974 than during 1975, and more fish were taken in the spring and summer than in the fall and winter. This seasonal variation is expected as lower fall and winter temperatures generally correspond to reduced activity of fishes and a decrease in trapping efficiency.

Seining

Much larger catches were made by seining in Robinson Impoundment during the spring and summer than in the fall and winter. During the cooler water periods, fish generally move from the shoreline areas to deeper water and are less susceptible to capture by seining.

Considering mean catches across all sampling periods, largest catches were taken at stations G-1, C-1, and A-1 (Table 4.2.7), ranging from 14.2 to 29.5. The low catches at stations A-3 and C-3 (1.1 and 1.2) are probably due primarily to the bottom type and topography. Both of these stations are located on washed sand shorelines which drop off rapidly preventing full extension of the seine and efficient sample collection. Collections at G were often hampered by bottom obstructions; the much larger mean catch at station G-1 due primarily to one haul which took 99 bluegills.

Bluegill was the most numerous species collected by seining at all stations and was the only species taken at station E-1. Chain pickerel and largemouth bass were also collected at most stations. The diversity of fishes collected by seining was higher at transect G than at other sampling locations. Seine catches at G included golden shiners, spotted suckers, creek chubsuckers, pirate perch, lined topminnow, black-banded sunfish, bluespotted sunfish, and dollar sunfish which were not taken at other sampling locations. Mosquitofish and redbreast sunfish were collected in the lower impoundment, but were not taken in the transect G seine hauls.

Much of the observed difference can be attributed to habitat and cover type. Low catches and diversity on transect E are probably due to the combination of high summer temperatures, cover type (algal mat over soft mud substrate), and inefficiency in seining due to roots protruding from the bottom. The smaller fishes which are susceptible to seining often are associated with aquatic vegetation, and seining at transect G included vegetated areas more frequently than seining at the other locations (Section 7).

Electrofishing

Although there was some difficulty collecting electrofishing samples from Robinson Impoundment due to the low conductivity and visibility, electrofishing was the most efficient sampling method employed. A variety of fishes was collected from each sampling location (Table 4.2.8) during most of the year and the number of species collected generally increased from the lower impoundment to the upper impoundment. This trend is best illustrated in the plot of the Shannon-Weaver diversity index (Weber, 1973) (Figure 4.2.2). The indices calculated for Stations A-1 and A-3 were generally lower than for other stations except during April, May, June, and July when the catch of bluegill declined which raised the proportion of other species in the catch, thus raising the indices. Indices calculated from catches at Stations E-1 and E-3 were generally higher than Transect A but exhibited a decline through the early summer reaching a minimum in July (August data not available), then increasing to levels comparable to early spring. Transect G indices were high and relatively stable with the exception of Station G-1 during May when no fish were collected.

Electrofishing catches were also examined by performing analysis of variance on the log transformation of bluegill, largemouth bass, warmouth, chain pickerel, and total catches per hour with sampling month and sampling location the variables of interest. Highly significant differences were evident in all of the groups considered with respect to sampling location while largemouth bass and total catch exhibited highly significant ($P=.01$) differences and bluegill and warmouth exhibited significant ($P=.05$) differences among sampling months (Table 4.2.9).

When significant differences were indicated, variation was examined further using Duncan's 5 percent level New Multiple Range Test (log transformation of catch per hour).

In this analysis, ranked means which are not significantly different from each other are grouped; any two means not included in a single group are significantly different from each other. Groups exhibiting significant differences in catches by sampling month are presented in Table 4.2.10. Differences

in sampling location for the various groups examined are presented in Table 4.2.11. Total catches at Transect A were significantly larger than from any other location. No significant differences were found between catches from E-1, E-3, G-1, and G-3. The large catches from Transect A were due primarily to the large number of bluegills collected during most sampling periods. The Duncan's test of bluegill electroshocker catches also supports this with Stations A-1 and A-3 exhibiting significantly larger catches than other sampling locations. No significant difference was evident between catches from Stations E-1, G-1, and G-3 or between catches from E-1 and E-3 but catches from G-1 and G-3 were significantly smaller than the E-3 catches. The concentration of bluegills on Transect A probably results from their utilization of the rock rip-rap along the dam for cover. Electroshocker catches of largemouth bass were significantly larger at Stations E-3, E-1, and A-1 than at Stations G-3, A-3, and G-1 with the station nearest the discharge (E-3) exhibiting the largest mean catch. Station A-1 largemouth bass catches, however, were not significantly larger than G-3 catches. Warmouth electrofishing catches from Stations A-1, G-3, and A-3 were not significantly different and were larger than catches at the other stations. Warmouth catches at stations E-1, G-1, A-3, and G-3 were not significantly different. Station E-3 catches were significantly lower than catches at the other stations. Electroshocker catches of chain pickerel were not significantly different between sampling stations. The pattern of larger bluegill and warmouth catches from the lower impoundment is probably a reflection of habitat preference, with these species occupying the rock rip-rap areas.

An alternative analysis was suggested by Dr. Charles H. Proctor of the North Carolina State University Department of Statistics as being more appropriate. This analysis is presented in Exhibit 3. Discussion and conclusions were essentially the same following either procedure.

These fish distribution data suggest that most species are distributed primarily as a function of habitat type. The area around Transect G contains many stumps, logs, and rooted aquatic vegetation. These sources of fish cover were much less abundant in the vicinity of Transect E and still less abundant at Transect A. Distributions may change seasonally as a result of environmental variable avoidance such as summer discharge temperatures (Shannon-Weaver index) but when yearly mean values were considered, the distributions appear to be based primarily on habitat. A depression in the fish population was not evident in the discharge area when mean values were considered.