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TENNESSEE VALLEY AUTHORITY

DRAFT

ENVIRONMENTAL STATEMENT SUPPLEMENTS AND ADDITIONS

BROWNS FERRY NUCLEAR PLANT UNITS 1, 2 and 3

VOLUME 3

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1.0 INTRODUCTION

This report supplements the Browns Ferry draft environmental statement dated July 14, 1971, which was circulated for agency comment on July 15, 1971. This supplement is in accordance with the requirements of the revision of Appendix D to 10 CFR Part 50 of the Atomic Energy Commission (AEC) regulations published in the Federal Register on September 9, 1971, and the following additions to the AEC Draft Guide to the Preparation of Environmental Reports for Nuclear Plants: (1) transportation of fuel elements to the plant as well as transportation of spent fuel elements to the reprocessing plant and packaged radioactive wastes from the plant to the low level waste burial grounds, (2) transmission lines from the Browns Ferry plant to the point at which they interconnect to the transmission system, and (3) environmental risks due to postulated accidents. The items discussed in this supplement will be subject to a 30-day review by Federal agencies, state and local officials, and interested persons after which this supplement, along with appropriate comments will become a part of the detailed environmental statement.

Since the date TVA submitted the Browns Ferry draft environmental statement for review, some additional delays in the operation of the plant have been encountered. Under the current schedule, TVA expects to be permitted to load the nuclear fuel for Unit 1 in May 1972. Full power operation is expected to be authorized in October 1972 for Unit 1, July 1973 for Unit 2, and February 1974 for Unit 3. This is a five-month delay on Unit 1, four-month delay on Unit 2, and a one-month delay on Unit 3.

This supplemental report is organized into two major sections. The first of these is the addition of a discussion of the environmental considerations of: (1) transportation of nuclear fuel and waste, (2) transmission facilities required to connect the plant to the transmission system and (3) the environmental risks due to postulated accidents. The second section of this supplement covers the matters described in sections A.1-4 of the revised Appendix D to 10 CFR Part 50 to the extent not previously discussed in the draft statement. The data and information presented in this section is intended to supplement those sections of the July 14, 1971, draft statement, and to the extent that these data are not consistent, the information contained in this supplement replaces that previously submitted.

2.0 ADDITIONS TO THE DRAFT ENVIRONMENTAL STATEMENT ISSUED JULY 14, 1971

2.1 Transportation of Nuclear Fuel and Radioactive Waste - About 200 tons of nuclear fuel in assemblies will be shipped annually to and from the plant, and packaged low level radioactive waste totaling about 300 tons annually will be shipped from the plant to AEC-licensed disposal areas. These radioactive materials will be subject to shipping procedures of applicable Federal and state regulations.

1. New fuel shipment - Fuel elements for the plant require an annual commitment of about 200 tons of natural uranium in the form of U_3O_8 for each reactor. However, some of this uranium may come from reprocessed spent fuel.

New fuel for the plant is made of slightly enriched uranium dioxide pellets which have been sintered and compacted to form very dense pellets having high strength and high melting points. The pellets are approximately 1/2 inch in diameter by 3/4 inch long and are stacked in zircaloy tubing with a space left at the end of the pellets to provide for collection of gas generated during the fission process. These tubes are welded shut at both ends and are subjected to rigorous quality control to ensure their integrity. Forty-nine rods are assembled into a 7 x 7 array to form a fuel assembly. Prior to shipment, plastic spacers are inserted between the rows of rods in the fuel assembly to provide protection for the fuel against the normal shock and vibration during transport and to assure that when the fuel is placed in the reactor, the proper spacing has been maintained between the fuel rods for heat transfer purposes.

A more detailed description of the fuel assemblies is given in the Browns Ferry Final Safety Analysis Report filed in support of the operating license application. TVA has applied for a special nuclear material license to provide for receipt, possession, and storage only of fuel elements before beginning shipment of the initial core of the reactor to the plant.

(1) <u>Container description and licensing</u> - The fuel assemblies are enclosed in a plastic bag and placed in a metal container which provides insulation for fire protection and which supports the fuel assembly along its entire length during the course of transportation. This metal container also provides necessary impact protection to meet the drop test requirements of the AEC regulations. The metal container is gasketed and bolted shut, then placed into an outer wooden box. The fuel properties and a description of the fuel shipping containers are given below.

<u>Fuel Properties</u>

No radioactive fission products

No radioactive gases

High melting point, insoluble solid

<u>Container Description</u>

Metal container in wooden box

Dimensions:

Metal container, 11½" x 18½" x 182" long

Wooden box, 33" x 32" x 207" long

Capacity - two BWR assemblies

Weights

Empty - 1400 pounds

Loaded - 2800 pounds

General Electric holds a Department of Transportation permit, No. 4986, and an AEC license for special nuclear material and fuel containers, SNM-54, Docket No. 70-1007, Amendment 71-16, in accordance with Section 71.7(b) of 10 CFR Part 71. General Electric's evaluation, done in support of the license application of the Model RA-3 new fuel shipping container which will be used for the Browns Ferry fuel, is documented in part in the following paragraphs.

There are no components of the package or its contents which are subject to chemical reaction in normal transportation environment. The package cannot be opened inadvertently, uses no coolant, and has no lifting devices or tiedown attachments. During normal transport conditions the containment integrity and nuclear safety are not significantly affected by ambient temperatures, $\pm 0.5\ lb_f/in^2$ pressure differentials and road vibration.

Accident evaluations of a free drop through 30 feet were conducted on the container, and the end of the outer box separated from the body, exposing the end of the inner container. The damaged end cap was in place and latched such that the fuel assemblies remained securely retained in the as-shipped condition. Actual thermal tests were not conducted since previous tests had demonstrated that melting or distortion of the outer surfaces would not be experienced.

Since the package is designed to remain subcritical assuming any degree of credible mode of water inleakage, it was unnecessary to subject the package to an immersion test.

(2) Method and frequency of shipment - The General Electric Company is responsible for shipment of the fuel assemblies from its fabrication plant at Wilmington, North Carolina, to the reactor site. This fuel will be shipped by truck in quantities of 16 shipping containers per load, each containing two fuel assemblies, thereby providing a maximum of 32 fuel assemblies per truck shipment. About 18 shipments will be received at the plant annually (about 24 shipments in the initial core for each unit).

(3) Environmental effects -

(a) Normal shipments - New fuel contains no radioactive gases and no significant radiation in itself. The radiation level at the surface of the containers ranges from 0.3 to 0.5 mrem/h. At the side of the roadway the dose rate would be less than 0.01 mrem/h. Therefore, it is concluded that there are no significant environmental risks from radiation associated with the normal shipment of new fuel.

(b) Accident occurrences - There would be no release of radioactive materials and no increase in radiation dose rates over those from normal shipment if the shipping container were involved in a transportation accident equivalent to that specified in 10 CFR Part 71. The damage would result from the physical damage of the impact and the interference associated with placing the containers on a substitute vehicle and continuing transportation back to the fuel fabricator to inspect the fuel to determine whether there had been damage of such significance that it would affect the subsequent operation of the fuel in the reactor. Thus, it is concluded that there would be no significant environmental risks from radiation resulting from an accident involving a shipment of new fuel.

2. Spent fuel shipment - Spent fuel removed from the three reactors during annual refuelings contains on a weight basis in excess of 99.99 percent of the fission products formed inside the fuel and is temporarily stored in the spent fuel pool at the plant. This spent fuel is covered by about 10 feet of water at all times which serves as a radiation shield and coolant while the short-lived fission products decay. At the end of this three- to four-month storage period, the spent fuel is loaded into ruggedly built lead-shielded steel containers for shipment to the fuel reprocessing plant where the spent fuel is chemically processed to recover its unused fuel content (uranium and plutonium) for future use. It is possible to ship spent fuel by rail, truck, or barge.

(1) Container description and licensing - The AEC and U.S. Department of Transportation (DOT) regulations specify both normal and accident conditions against which a package designer must evaluate any radioactive material packaging. These conditions are intended to assure that the package has requisite integrity to meet all conditions which may be encountered during the course of transportation. The normal shipping conditions require that the package be able to withstand conditions ranging from -40°F. to 130°F. and to withstand the normal vibrations, shocks, and wetting that would be

incident to normal transport. In addition, the packages are required to withstand specified accident conditions with the release of no radioactivity except for slightly contaminated coolant and up to 1,000 curies of radioactive noble gases. The accident conditions for which the package must be designed include, in sequence, a 30-foot free fall onto a completely unyielding surface, followed by a 40-inch drop onto a six-inch diameter pin, followed by 30 minutes in a 1475°F. fire, followed by eight hours immersion in three feet of water. The permissible radiation levels and releases under normal and accident shipping conditions are shown below.

CONTAINER DESIGN REQUIREMENTS

	Normal Conditions	Accident Conditions
External Radiation Levels		
Surface	200 mrem/hr	
3 ft. from surface		1000 mrem/hr
6 ft. from surface	10 mrem/hr	
Permitted Releases		
Noble gases	none	1000 Ci
Contaminated coolant	none	0.01 Ci alpha, 0.5 Ci mixed fission products 10 Ci iodine
Other	none	none
Contamination Levels		
Beta and gamma	2200 dpm/100 cm^2	
Alpha	220 dpm/100 cm^2	

These levels represent limits established by the regulations. In most cases, the containers will exhibit radiation levels and releases somewhat less than those permitted by the regulations. This is because the fuels and materials which will be handled will not be at the maximum activity levels for which the containers have been designed. Should the radiation criteria be changed, additional shielding materials can be provided and the packaging arranged or other steps taken to meet the criteria.

The GE-IF-300 cask has been designed in accordance with the criteria above and its license is pending (AEC Docket No. 70-1220, Amendment 71-3). The IF-300 cask body is a depleted uranium shielded and stainless steel clad, annular cylinder, closed at one end. Fuel is loaded through the top end and closure is accomplished using a bolted and gasketed head. The head shielding is similar to the cask body.

Fuel is held within the cask cavity by a removable copper basket. There are several basket configurations which may be used, depending on the specific fuel being shipped. There are also two heads which permit a variation in cask cavity length.

During normal operation, the cask cavity is water filled. Heat transmission from the fuel to the cavity walls is accomplished by natural circulation of the water. The cavity is protected from overpressure by a combination breaking pin rupture disk and pressure relief valve.

The cask outer surface has circumferential fins designed for both heat removal and impact protection.

The upper and lower ends of the cask are also equipped with sacrificial fins for impact protection. The cask surface is cooled by an air impingement technique. Four longitudinal ducts direct air from two diesel-driven blowers onto the cask surface. The cask, cask supports, and cooling system are all mounted on a steel skid. Exclusion from the cask and cooling system is provided by a wire mesh enclosure which is retractable for cask removal and locks in place during transport. The skid-mounted equipment forms a completely self-contained irradiated fuel shipping package.

The cask is specifically designed to meet the structural conditions of 10 CFR Sec. 71.32, 10 CFR Sec. 71.35 Appendix B, and 10 CFR Sec. 71.34. Safety factors are based on allowable loads, stresses, and deflections.

General Electric's accident analysis for the cask first considers the 30-foot drop. The cask utilizes circumferential body fins and radial-longitudinal head fins as energy absorbing members. These fins become plastic hinges on impact and limit the deceleration of the cask. The cask is analyzed in three dropping configurations--end, corner, and side. The end drop produced the maximum deceleration of 128 g's. The fuel assemblies are capable of withstanding the cask decelerations without failure. At no time does the outer shell sustain damage. There is also no redistribution of shielding material since the uranium metal structural properties are similar to those of mild steel. Under the worst drop condition (corner) for the closure, no yielding occurs in either the flanges or the studs.

The second phase of the accident analysis is the puncture test. Calculations show that the 1-1/2-inch cask outer shell, without taking credit for the fins, will puncture to a depth of only 1.27 inches. This analysis does not consider the uranium shielding which backs up the outer shell. The results are quite conservative from this aspect.

The third part of the accident analysis involved the fire-related effects. There are two principal items to be considered--thermal expansion of the shrink-fitted sections and cask cavity pressurization. These, even when combined, do not lead to stresses in excess of the allowable limits. The inner cavity has a working pressure of 400 lb_f/in^2 gauge at 815°F. and is designed in accordance with Section VIII of the ASME code for Unfired Pressure Vessels, although the maximum operating pressure is only 200 lb_f/in^2 gauge. The cavity is protected from overpressure by a burst disk and pressure relief valve. The cavity is sealed with a Conoseal metallic gasket which has a burst pressure of 600 lb_f/in^2, an operating temperature range from 32°F. to 1500°F., and a shock load resistance of 200 g's.

(2) Method and frequency of shipment - All the equipment and services for spent fuel transportation and reprocessing which may be required are the responsibility of the General Electric Company. General Electric will buy back the spent fuel from all three units of the Browns Ferry plant over the period of about the first 12 years of operation. Therefore, TVA will not have the responsibility of shipping spent fuel from Browns Ferry to a reprocessing plant until approximately 1985.

In accordance with the contract arrangements, General Electric will take title and custody of the spent fuel at the plant site and will be responsible for its shipment to a reprocessing plant. These shipments of spent fuel from Browns Ferry as presently scheduled go to GE's nuclear fuel reprocessing plant at Morris, Illinois (AEC Docket No. 50-268, pending). After loading the spent fuel into the cask, TVA will certify cask contents and assure that all tests are performed as required by 10 CFR Sec. 71.35(a)(4), 49 CFR Sec. 173.393(j) and 173.397(a). General Electric will notify the states involved as required by the states at the beginning of a series of shipments.

Due to the extreme weight involved in the shielding required for irradiated fuel, there is a considerable diversity of shipping methods proposed, ranging from truck shipments which will ship approximately 1/2 ton of uranium at a time to large rail casks which would ship more than five tons of uranium at a time. Water transportation has the potential to move five tons or more of uranium at a time and in special cases may be used as a link to the nearest available railroad.

Truck shipment of spent fuel from Browns Ferry would involve about 287 shipments over a period of about nine months annually, or about 82-144 shipments if a 90,000-pound limit is permitted.

Rail, which is the most probable mode of shipments, will originate from the TVA rail siding at Tanner, Alabama (about 7.5 miles from plant). The spent fuel in its special cask will be brought to the rail siding from the plant by a special multiwheeled tractor and trailer. This method has been used by TVA to move other heavy plant equipment, such as the generator stator, from this rail siding to the plant. About 32 shipments will be made annually. The shipments will be in the GE-IF-300 rail cask holding 18 fuel assemblies. Fuel assemblies which have identified clad perforations will be placed in a stainless steel container and sealed before being loaded into the spent fuel cask.

Prior to shipment, the fuel will be allowed to decay a minimum of about three to four months with the result that essentially all noble gases with the exception of krypton-85 will be gone and the iodine-131 will have decayed to very low levels. Further, the decay heat which has been generated by the fuel during reactor irradiation will have decreased to an insignificant level. This, coupled with the high melting point of the fuel pellets assures that during a shipping cask accident, there is very little potential for any radioactivity other than the noble gases being released into the cask cavity. Mechanical properties of the solid irradiated reactor fuel will act in a substantial way to mitigate the consequences of an accident by preventing the fission products from migrating to the outside of the basic fuel assembly.

There are several features which are typical of all shipping casks, such as heavy stainless steel shells on the inside and outside separated by dense shielding material, such as depleted uranium. Additionally, the cask has fins which serve as extended surface area for dissipation of decay heat and as an impact structure to absorb the energy of the 30-foot free fall and to limit the forces imposed on the cask and contents. The cask also contains a basket which is provided to support the fuel during transport.

These casks are mounted on a rail car for shipping. The cask is shipped in a horizontal position and is secured to withstand the normal impacts due to switching and other handling. Under normal shipping conditions, no release of any radioactive materials is permitted and under accident conditions the only releases permitted are slightly contaminated coolant and noble gases. Thus, the environmental effects of accidents involving waste shipments would result in a minor increase in radiation levels associated with the reduction of shielding. The exposure rates for both normal and accident conditions were evaluated in determining the projected population exposure resulting from transportation of radioactive materials. In both cases it was assumed that, under normal shipping conditions, a person would be a minimum of 100 feet away from the containers. It has been assumed that the transportation route covers 800 miles through a territory having an average population density of 334 persons per square mile. This is felt to be a very conservative assumption since, most probably, average shipping distances will be nearer to 500 miles and the average population density lower than that assumed.

It is felt that the simplifications and assumptions which have been made to provide greater ease in calculating population effects do not affect the credibility of results. These effects are presented as radiological results for normal shipments and those with postulated accident occurrences.

(3) Environmental effects -

(a) Normal shipment - Spent fuel shipments are planned, scheduled, and deliberate. The principal normal environmental risk from these shipments would be the direct radiation dose from the shipments as they move from the reactor to the reprocessing plant. In this regard, it has been assumed that the shipments are made at the maximum permitted level of 10 mrem/h at six feet from the nearest accessible surface. Based on this and with the nearest person assumed to be 100 feet from the centerline of the tracks (because of railroad right of way) it is estimated that the dose rate at that point would be 0.2 mrem/h. This would decrease to 0.01 mrem/h at 300 feet.

(b) Accident occurrences - A principal environmental risk to the public from an accident would be potential radiation exposure to the release of noble gases and some potential radiation exposure due to direct radiation; however, considering radiation attenuation with distance, it can be concluded that the potential exposure to the public from direct radiation would be negligible.

Calculations indicate that without a substantial quantity of decay heat in the shipping cask plus the addition of external heat, such as from a fire, there would be no release of the fission gases. However, this transportation accident is evaluated as per 10 CFR Part 71 criteria which considers that 1,000 curies of gaseous activity is released to the environment. On this basis and considering a population density of 334 people per square mile within a 50-mile radius of accident, the population exposure is less than 0.01 man-rem.

The cask design is such that the probability of rupturing the cask, given the accident, is believed to be low. The distance traveled is a variable depending on the location of the fuel reprocessing plant to which shipment is made. The effect of various other special precautions, such as routing speed limitations, much lower speeds in heavily populated cities, and expert driving, are factors that need to be considered.

Based on above information, during normal and under accident conditions, it is concluded that no undue hazard to the public or adverse environmental effects will result from the transportation of spent fuel from Browns Ferry to the fuel reprocessing plant.

3. Radioactive waste shipment - The solid wastes to be shipped offsite for disposal can be classified as demineralizer and filter aid sludges, low level compressible wastes, and irradiated or contaminated equipment components. Demineralizer and filter aid sludges comprise the bulk of the material to be shipped from the plant for offsite disposal. The volume of these wastes will be about 9,200 ft^3 a year for the three units. They will be shipped in the form of wet-solid waste. These two wastes are classified by radioactive content. The cleanup system sludge from the reactor cleanup system demineralizer has a radioactive content of about 8.7 Ci/ft^3 and a volume of about 450 ft^3 a year. The remainder is primarily

condensate demineralizer sludge with smaller quantities of waste demineralizer resin and various filter sludges which have a radioactive content of less than 0.5 Ci/ft^3 and a volume of about 8,750 ft^3 a year.

In addition to these, compressible wastes, consisting of contaminated paper, rags, gaskets, etc., will amount to about 4,500 ft^3 a year. Radioactive equipment components consist of such items as damaged zircaloy fuel channels, incore instruments, pipes, and valves. The volume is expected to be small and no shipments are expected during the first years of operation.

(1) <u>Container description and licensing</u> - The design of the packaging station permits the use of several different types of containers or packages. TVA has contracted ATCOR, Inc., to conduct an evaluation of various waste disposal packaging concepts for TVA use and perform a detailed design of the containers and provide assistance as necessary in obtaining AEC and Department of Transportation permits. The container for the higher level waste (about 8.7 Ci/ft^3) has been designed to hold 150 ft^3 of these wastes. An AEC license (SNM-1-13671-2) for this cask (LL-60-150) has been obtained. For the lower level waste (0.5 Ci/ft^3), an all steel cask holding about 183 ft^3 has also been designed and will be constructed by ATCOR, Inc.

The low activity compressible waste will be packaged for shipment in steel drums, fiberboard drums, and cardboard boxes as appropriate. Radioactive equipment components will be shipped by contract with a specialist in the field who would provide the necessary containers, such as modified spent fuel casks.

The LL-60-150 cask for the higher level solid waste is designed to meet or exceed the requirements established by the AEC and Department of Transportation for the shipment of large quantities of radioactive material. The evaluation made by ATCOR, Inc., in support of licensing for this cask considers both normal and accident conditions of transport. An analysis was performed to demonstrate that the cask provides adequate shielding to satisfy dose rate levels in the vicinity of the cask as required by 49 CFR Sec. 197.393(j)(3). A shielding analysis was also performed in order to assure that the cask meets the dose rate requirements after a shielding loss has occurred due to a hypothetical accident occurrence.

Calculations of the dose rate at six feet from the container during normal shipment was performed using the higher level solid waste source after a large number of fuel failures had occurred. The calculated value of the dose rate after correction for dose buildup factor is 4.02 mrem/h. Standard operating procedures will ensure that the dose rate limits are not exceeded when loading the cask. Final assurance of compliance with the regulations will be provided by actual measurement of the dose rate prior to shipment.

Accident analysis showed that the lead may slump towards the bottom of the cask as a result of the hypothetical 30-foot drop accident. The level of the lead falls 1.6 inches which will not remove the lead shielding from the top of the solid waste source. At three feet from the surface of the cask, the dose rate is estimated to be less than 500 mrem/h, which does not exceed the limit of 1000 mrem/h stated in 10 CFR Sec. 71.36(a)(1).

The analysis for puncture resistance was performed, and it was found that when considering any point along the 1-1/2-inch thick outer shell, failure in this mode will not occur and no release of radioactive material to the exterior or dose rates in excess of 10 CFR Sec. 71.36 limits will occur.

A complete fire test in support of this hypothetical accident occurrence was performed. There will be no melting of the lead with a temperature maximum of 470°F. and the cask is capable of holding the vapor pressure consistent with the elevated temperature.

Immersion of the cask in three feet of water for more than 24 hours will not cause any detrimental effect since the cask is established in the analysis to be leaktight following the preceding accident conditions.

(2) Method and frequency of shipment - Special TVA-owned high strength trailers will be designed to transport the LL-60-150 cask and the all steel container to offsite burial grounds. The casks will be decontaminated if necessary at the disposal area and returned to the plant. Because transportation is the largest single cost item in waste disposal, TVA's wastes will probably be buried at Morehead, Kentucky, or Barnwell, South Carolina. The burial sites are regulated by AEC and the states under AEC's agreement state procedure.

Demineralizer and filter aid sludges are collected in the plant and stored for decay of short-lived isotopes. After about 60 to 120 days' decay, the only significant radioactive isotopes present are long-lived corrosion products such as cobalt-60. The waste is then pumped into the shipping container and dewatered prior to shipment. There will be about three shipments of the higher level waste (about 8.7 Ci/ft^3) consisting of about 150 ft^3 each per year in a special steel-lead cask. There will be about 50 shipments of the lower level waste (<0.5 Ci/ft^3) consisting of about 183 ft^3 each year in a special all steel cask.

Drums of compressible wastes amounting to about 4,500 ft^3 per year will be placed on flatbed trucks with no additional shielding, since the dose rate is normally expected to be less than that allowed. Should drums of relatively high activity be ecnountered, they will be placed inside the steel containers which provide shielding. The large container packages will be shipped one per truck. After removal of the liner and the waste at the burial ground, the empty container will be returned to the plant for reuse.

The packaging scheme for shipment of radioactive equipment components has not been finalized. They will be stored in the spent fuel pit until a sufficient amount is accumulated for a shipment. They will be shipped by contract with a specialist in the field who would provide the necessary containers, such as modified spent fuel casks.

(3) Environmental effects -

(a) Normal shipment -

Shipment of solid waste containers between the reactor site and a disposal location will be done periodically. Regulations pertaining to such packaging and shipments and shipping safeguards given below will be adhered to in all cases. Because of the low dose rates as given in the Shipping Safeguards below (10 mrem/h at six feet from the container), the only exposure to people from routine shipments is for the brief period such a shipment is in direct view. A person standing alongside a roadway while a solid waste shipment passes would receive an insignificant radiation exposure. Persons further away from the roadway would receive even less exposure.

(b) Accident occurrences -

The only time any significant radiation exposure to the public could occur would be in case of an accident involving breakage of the solid waste containers. Usually the waste material is in the form of a very "stiff" or viscous slurry or it may be mixed with cement to form concrete. Because the containers must demonstrate the capability to withstand and meet the conditions for hypothetical accident conditions listed in the Shipping Safeguards below, any radiation exposure to people would be limited to those workers actually involved in cleanup and decontamination work following the accident. Radiation exposure to the general public from such accidents is judged to be insignificant.

4. Shipping safeguards -

(1) Administrative controls - The new fuel, spent fuel, and radioactive waste shipping containers must meet the following performance assessment criteria as applicable for normal conditions of transport in accordance with 10 CFR Sec. 71.35:

1. No release of radioactive material from the shipping container.
2. The effectiveness of the package will not be substantially reduced.
3. No mixture of gases or vapors which could, through any credible increase of pressure or explosion, reduce the effectiveness of the package.
4. Radioactive contamination of the coolant will not exceed limits.
5. No loss of coolant.
6. Subcriticality for fissile packages.

In addition, the containers must demonstrate the capability to withstand the hypothetical accident occurrences of free drop, puncture, thermal, and water immersion in transport and meet the following conditions in accordance with 10 CFR Sec. 71.36:

1. The reduction in shielding would not be sufficient to increase the external dose rate to more than 1000 mrem/hr at three feet.
2. No radioactivity released, other than 1000 curies of gases, and contaminated cooling not exceeding 0.1 percent

of the total radioactivity of the package contents nor 0.01 curie of Group I radionuclides, 0.5 curie of Group II radionuclides, and 10 curies of Group III radionuclides.

3. Subcriticality for fissile packages.

Transport vehicles will be placarded in accordance with Federal and state requirements, and all vehicles will be equipped with the necessary radiation monitoring instruments in order to perform the required monitoring as noted in Emergency plans below. The containers for spent fuel and radioactive waste material will be physically inspected to ensure integrity and monitored before shipment to ensure that radiation dose rates do not exceed the following values:

1. 1000 mrem/h at three feet from the external surface of the package.
2. 200 mrem/h at any point on the external surface face of the transport vehicle.
3. 10 mrem/h at six feet from the external surface of the transport vehicle.
4. 2 mrem/h in any normally occupied position in the vehicle.

In the event of an accident, every effort will be made to contain the contaminated material to prevent a radiation hazard to the public and the environment.

(2) Emergency plans - Emergency procedures regarding transportation of radioactive material will be described in the

TVA Radiological Emergency Plan.* Elements of the emergency procedures for handling transportation accidents for which TVA has responsibility will include, but will not be limited to, the following:

1. Vehicular accidents - General

   a. In the event of a vehicular accident involving radioactive material, a restricted area must be established [10 CFR Section 20.203(2)(b) and (c)].

   b. Use radiation survey meter to establish the perimeter of the restricted area.

   c. If survey meter is inoperable, calculate from experience and training a very conservative perimeter.

   d. If survey meter is operable and no radiation hazard exists, and the vehicle is in safe operating condition, the driver may continue on way if not detained by other accident related conditions.

   e. In any case, immediately after establishing a restricted area or before proceeding on way, TVA shall be notified.

2. Administrative control of transportation

   a. Certify container contents.

   b. Assure performance of all tests on loaded containers as required by 10 CFR Sec. 71.35(a)(4), 49 CFR Sec. 173.393(j) and 10 CFR Sec. 173.397(a).

   c. Insure that container and vehicle meet the requirements of applicable regulatory bodies for movement offsite.

* Being reviewed in draft inside TVA.

d. Qualified manpower and appropriate equipment to be available to make routine determinations as required by (b) above.

e. Driver reports en route each eight hours.

f. Estimated time of arrival (ETA) at destination.

g. Driver of vehicle will be responsible for control of shipments en route.

3. Notification and reports of incident to AEC

a. Appropriate TVA personnel receiving notice of a transportation accident shall notify the TVA load dispatcher who notifies the Central Emergency Control Center director.

b. The CECC director notifies as appropriate the AEC Operations Office, the State Department of Public Health, the state police, and the AEC Division of Compliance.

c. The Emergency Plan for Transportation Accidents in states involved will be followed by TVA and the states' procedures where desirable will be made a part of the TVA Radiological Emergency Plan.

TVA has consulted and will consult further with appropriate state agencies regarding the necessary emergency planning for shipments of radioactive material through the state and to seek the state's agreement with TVA's Radiological Emergency Plan. In addition, TVA will take into consideration the state's emergency plans. Training will also be initiated where necessary for handling of transportation accidents.

5. <u>Task force for analyzing radioactive material shipments</u> - TVA presently has nine nuclear units under construction or planned for operation between 1972 and 1978. Because of these commitments to the use of nuclear power for substantial portions of its generating capacity and the resultant necessity to ship radioactive materials associated with the operation of these and future nuclear plants, an interdisciplinary task force to evaluate the environmental implications, available technology, economics, and other factors related to the consequent shipment of radioactive material to and from these plants is to be established. The task force will investigate the various transportation modes, prevention of accidents, environmental risks and effects and develop criteria for establishing TVA's policies and procedures relative to the applicable regulations. The finding and recommendations of the task force will be used in formulating the detailed plans for shipment of all radioactive material to and from all of TVA's nuclear plants currently under construction or planned for the future.

6. <u>Conclusion</u> - Due to the integrity of the containers used for shipping new fuel elements, spent fuel elements, and low level radioactive wastes; the emergency plans for vehicular accidents; the administrative control exercised over transportation; and coordination with appropriate state agencies; it is concluded that no undue hazard to the public nor adverse environmental effects will result from the transportation of fuel elements from the fuel fabrication plant to the reactor, of spent fuel elements to the fuel reprocessing plant, and of low level waste to offsite disposal grounds.

2.2 Environmental Aspects of Transmission Lines - Construction of all transmission lines required for the Browns Ferry Nuclear Plant has been completed. The close proximity of the existing 500-kV transmission grid was a major consideration in siting the Browns Ferry Nuclear Plant. All new transmission line construction was within a 20-mile radius of the generating plant, as indicated schematically on figure 2.2-1. Approximately 70 miles of new construction was required to terminate the six 500-kV transmission lines.

Right of way for the existing West Point-Madison 500-kV transmission line was acquired in 1963. This line was looped into the new nuclear plant, creating the Browns Ferry-West Point and Browns Ferry-Madison No. 1 500-kV lines. This connection required the construction of two lines, each approximately one mile in length. The right of way for this construction was primarily on TVA reservation.

Similarly, the Browns Ferry-Madison No. 2 and the Browns Ferry-Davidson 500-kV transmission lines were connected to the existing grid by constructing two parallel lines, each approximately 23 miles in length, to the Davidson-Madison 500-kV transmission line. Right of way for this line was acquired in 1965. The use of parallel construction minimized the amount of right of way required.

The remaining two 500-kV lines were constructed to the Trinity 500-kV substation, a distance of approximately ten miles. These lines provide a heavy duty connection to supply the large industrial loads in the vicinity of Decatur, Alabama.

To provide construction and future station service power to the proposed nuclear plant, a 14.3-mile 161-kV line was constructed from the Athens, Alabama, 161-kV substation. A second 161-kV line, 10.7 miles long, was constructed from Trinity Substation into Browns Ferry to provide backup station service to the nuclear plant for emergency operation. The right of way for these lines was acquired in 1966 and 1967, respectively.

The two 500-kV lines and one 161-kV line constructed to Trinity cross the Tennessee River. The river crossings utilize double-circuit steel towers which allow space for one future line.

A total of 1,350 acres of land was involved for the transmission line connections to Browns Ferry Nuclear Plant. The 500-kV transmission line structures are self-supporting, waisted steel towers. The use of self-supported structures eliminates the need for guys, thereby reducing the impact on the land. The gray-colored insulators used are compatible with the galvanized steel used in these towers. The use of 500-kV transmission results in substantially smaller land commitments than are required when using lines of lower voltages. One 500-kV line can transmit as much electrical energy as ten to twelve 161-kV single-circuit transmission lines and requires only one-seventh as much land for right of way.

The 161-kV lines were constructed on single poles with epoxy fiberglass crossarms. The use of this type of crossarm minimizes the structure's silhouette and reduces the width of right of way by two-thirds of that which is normally required for 161-kV construction.

The transmission line routes were selected to minimize land-use impact. To reduce visual exposure, major highways and interstate routes were avoided where possible; however, when such crossings were necessary, they were made at approximately a 90-degree angle. Where possible, the transmission line routes parallel and adjoin existing transmission lines. In situations where paralleling was not practicable, the routes were selected to occupy low-density rural land where possible. Except in the vicinity of Decatur, Alabama, the routes selected primarily traverse sparsely settled rural land used for farming and pasturing. The landowners may continue to use their land for agricultural and other purposes which will not interfere with the operation and maintenance of the lines; however, the construction of buildings on the right of way will not be permitted. In the vicinity of Decatur, Alabama, a corridor of right of way was chosen to the west of town in order to avoid the highly developed industrial area to the east.

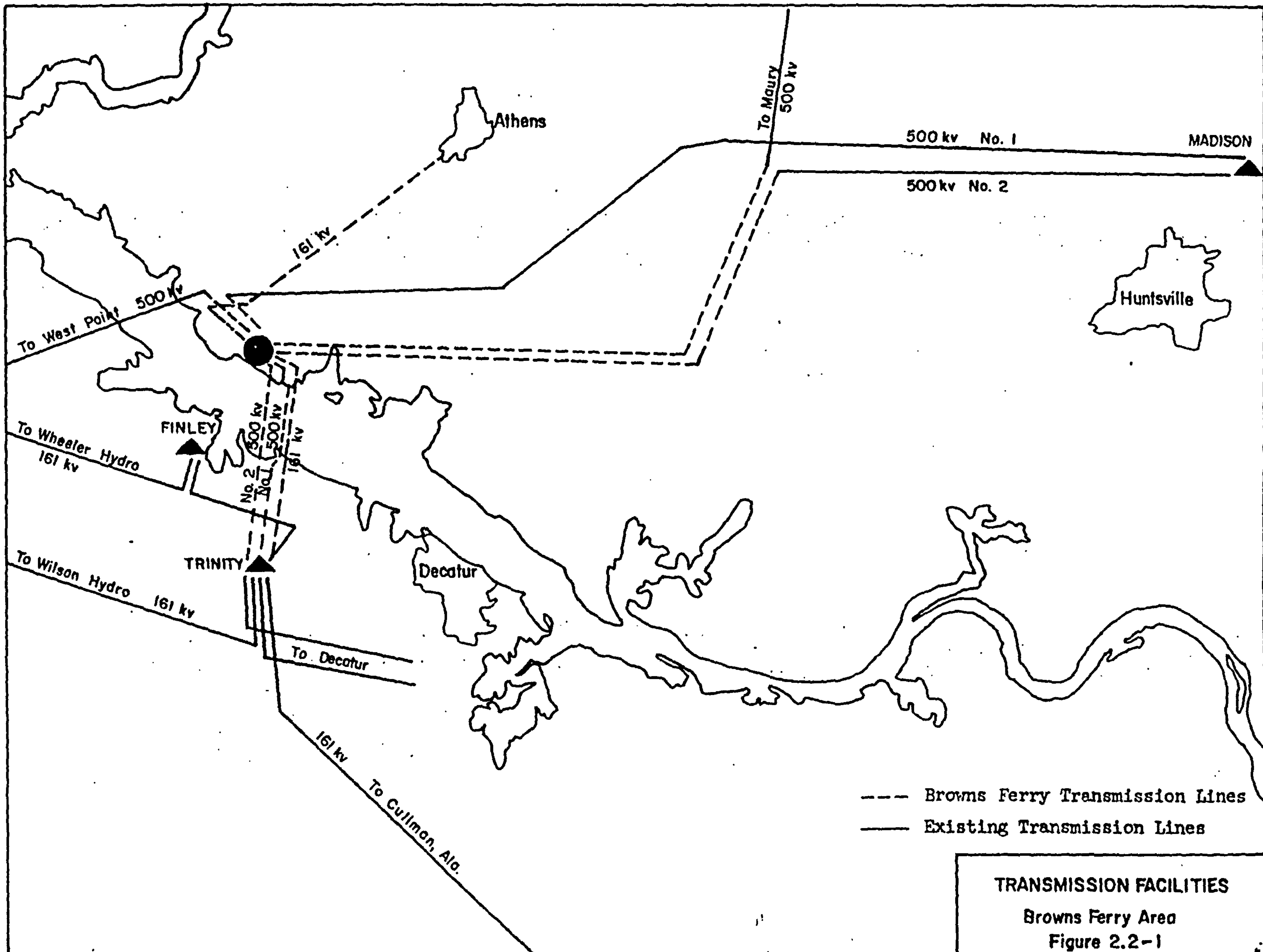
Construction of the transmission lines involved the use of heavy equipment for tower erection and conductor stringing. This equipment caused temporary rutting along the right of way, and the damage was repaired by TVA. TVA also paid for or repaired unavoidable damage to fences, gates, bridges, and other structures and reimbursed landowners for the value of crops damaged by construction activity.

During normal operations no adverse environmental impact is associated with either 161- or 500-kV transmission lines. Under some atmospheric conditions a light humming may be noticed directly under 500-kV lines, but this noise is rarely heard off the right of way. Transmission lines can, under certain conditions, cause mild static charges to develop on fence wires and other ungrounded objects under the lines. These charges are similar to the common static charges people experience when walking on certain types of indoor carpeting in dry weather.

Line maintenance operations will involve periodic repairs and selective cutting of vegetation along the rights of way to maintain electrical clearance between the conductors and the ground cover. These operations involve only minor environmental impacts.

Since the transmission lines for the plant are in service, any alternate which could be proposed would tend to create more environmental impact.

Except for the facilities required to construct the transmission lines and the right of way clearing associated with the construction, there are no irreversible and irretrievable commitments of resources for the transmission connections to the Browns Ferry Nuclear Plant.



TRANSMISSION FACILITIES

Browns Ferry Area

Figure 2.2-1

2.3 Radiological Effects of Accidents - To develop the overall balancing of environmental costs and benefits of the Browns Ferry Nuclear Plant, an assessment has been made of the consequences that could result from the occurrence of postulated accidents. A comparison of the consequences of the accidents analyzed in this section, using realistic assumptions with the same accidents analyzed in a safety analysis report (SAR), would show that the results of the realistic evaluation are far less severe than those predicted in the SAR where highly conservative assumptions are used. In the analysis of accidents described in this section, a description is given of the accident, the measures taken to prevent the accident, and the mitigation of its consequences.

The quantitative values given are necessarily preliminary, because of time limitations imposed by Appendix D to 10 CFR Part 50, but are considered sufficient to assess the accident effects on the environment. Furthermore, it is not possible at this time to quantify the probability, or frequency of occurrence, of any accident. This is principally due to the lack of statistically significant data available at this time on which to base the probability determinations. However, the impact of the accidents analyzed on the population around the plant is given and a comparison is made to the exposures resulting from natural background and the routine radioactive waste discharges from the plant.

In accordance with AEC requirements, TVA submitted with its applications for permits to construct units 1, 2, and 3 safety analysis reports which describe the technical features of the plant and the provisions for ensuring the health and safety of the public. The analyses presented in these reports demonstrate that even for postulated accidents of great severity and analyzed using highly conservative assumptions, the radiological consequences would be within the reference values of 10 CFR Part 100.

After extensive review of the applications, the AEC Regulatory Staff concluded in its Safety Evaluation reports that ". . . the issuance of permits for construction of the facilities will not be inimical to the . . . health and safety of the public." Independent reviews by the Advisory Committee on Reactor Safeguards resulted in similar conclusions, and after the mandatory public hearings required by AEC regulations, the Atomic Safety and Licensing Boards reached similar conclusions.

1. Minimizing the probability of occurrence - The probability of an accident occurring is minimized in a number of ways: (1) employment of conservative design criteria in selection and manufacture of system components, (2) incorporation of automatic protection systems, (3) quality assurance programs for design, construction, and operation, (4) administrative control of the conduct of operations, and (5) safety review.

These matters are covered in greater detail in the context of the 10 CFR Part 50 licensing procedures.

(1) Conservative design criteria - Conservative design criteria minimize the potential for occurrence of accidents. These design criteria assure that principal structures

and equipment which may serve either to prevent accidents or mitigate their consequences are designed, fabricated, and erected in accordance with applicable codes to withstand the most severe earthquakes, flooding conditions, windstorms, ice conditions, temperature, and other deleterious natural phenomena which could reasonably be expected to occur at the site during the lifetime of this plant. In addition, the criteria require fire and explosion protection for all equipment.

(2) System protection features - Protection features provided for various systems are illustrated below:

(a) Nuclear and radiation controls - maintain plant in a safe operational status.

(b) Reliability and testability of protection systems - assure fail-safe reactor protection functions of systems essential for the safe shutdown of the reactor and maintaining it in such a condition.

(c) Reactivity control - limits reactor core reactivity insertion and withdrawal rate.

(3) Quality assurance - A comprehensive quality assurance program is in effect. It defines the general methods, procedures, and organizational responsibilities for the design, construction, and operation of those structures, systems, and components that prevent or mitigate the consequences of postulated accidents.

(4) Conduct of operations - The Browns Ferry organization and responsibility follow the patterns developed

through experience and in use in all TVA steam generating plants. Training plays a vital part in the conduct of operations, ensuring that the technical specifications are not violated so that no significant adverse effects to the environment result from the operations. Key operations personnel will be licensed in accordance with the provisions of 10 CFR Part 55. Members of the plant maintenance and engineering support groups also receive training and specialized courses necessary to operate and maintain the plant. Operation will be conducted according to written procedures.

(5) Safety review - The Manager of Power provides overall management guidance for safe operation and maintenance of all TVA power plants, including the Browns Ferry Nuclear Plant.

A safety review board, consisting of members who have competence in various fields of nuclear technology and are familiar with safety problems and requirements has been established. This board reviews and advises on safety matters during the design, construction, and operation of TVA nuclear plants. In carrying out this function, the board reviews the plant design, safety analyses, licensing documents, and other sources of information bearing on plant safety and advises the Manager of Power of the results of its review.

2. Mitigating consequences of an accident - Several measures mitigate the consequences of an accident. These include: (1) multiple fission product barriers, (2) engineered safety features, and (3) emergency plan.

(1) Multiple fission product barriers - Fission product containment barriers are the basic features which minimize the release of radioactive materials. The design of Browns Ferry Nuclear Plant provides the following means of containing and/or mitigating the release of fission products: fuel barriers - high density ceramic UO_2 fuel sealed in zircaloy cladding; nuclear system process barrier - reactor vessel, pipes, pumps, tubes, and similar process components; steel primary containment vessel (drywell and suppression chamber) for each unit; reactor building - secondary containment surrounding the primary containment; standby gas treatment system - high efficiency and charcoal filters.

(2) Engineered safety features - The engineered safety features include those systems which are essential for the safe shutdown of the reactor and maintaining it in a safe shutdown condition. They are designed to provide high reliability and ready testability. Even if an improbable maloperation or equipment failure--including a double-ended circumferential rupture of any primary coolant pipe--allowed variables to exceed their operating limits, the nuclear safety systems and engineered safeguards limit the effects to values well below those which are of environmental concern.

(3) Emergency plan - The Browns Ferry Nuclear Plant Emergency Plans Manual will contain individual plans for coping with emergencies such as fire, air raid, tornado, and personnel injury. It will also include the radiological emergency plan which provides a description and action to be taken for events which could result in the release of significant amounts of radioactivity to the offsite environment. Procedures for operating the plant equipment under emergency or abnormal conditions are contained in emergency operating procedures.

3. Accident analysis - Those postulated accidents having the potential of uncontrolled release or radioactive material to the environment have been divided by AEC into nine classes, based on the systems involved and the type and potential severity of the release. These classes are shown in Table 2.3-1. Although in general several events have been analyzed in each class, only the most important from the standpoint of environmental risks are discussed. The accidents in each class whose potential for environmental effect is largest are analyzed in detail and man-rem doses are calculated for any which have a substantial radioactive material release. In most cases, results are given for the average meteorological conditions expected at the site, as well as the most adverse meteorological conditions. The former represents a more realistic picture of the potential for environmental effects. In the case of radioactive releases over a substantial period of time, average meteorological conditions are used. An evaluation of the environmental impact of postulated accidents follows the class nine

accident discussion. Where applicable, coolant activities are based on 0.2 percent failed fuel and a noble gas release rate of 70,000 μCi/s per unit (based on a 30-minute holdup time for decay).

(1) <u>Class one events</u> - These events are defined as trivial incidents including minor spills and pipe leaks that can release small quantities of radioactive material inside the containment. Although the probability of the occurrence of these types of accidents may be moderately high, their consequences by definition are trivial. Therefore, class one accidents present no risk to the environment and will not be considered further.

(2) <u>Class two events</u> - Events in this class include miscellaneous small spills and leaks of radioactive material that may occur outside of the primary containment during routine operation of the plant. Protection against the effects of such leaks is best accomplished by ensuring that:

(a) liquid spills and leaks are collected and routed to the liquid radwaste system for treatment, and

(b) leaks are detected so that plant personnel can take corrective action as required.

As far as class two accidents are concerned, the turbine building is the most important structure because it houses most of the primary coolant (steam) systems, such as the turbines and main steam piping, that contain primary coolant steam. The drainage system collects liquid spills, as well as equipment leakage, and routes it to the radioactive waste disposal system. Leakage may be detected by one or more of the following means:

(a) area radiation monitors,

(b) an abnormal increase in a sump level.

Due to the care taken in design, construction, and operation, postulation of a major failure in a system containing radioactive material is not considered reasonable. Several possible sources of leakage were considered and analyzed for this class of accidents. The most important potential source of leakage is considered to be a steam leak in the turbine building. The steam not only carries iodine to the condenser, but also contains the noble gases released from any fuel failures.

Any substantial leakage into the turbine building would be detected by either the area radiation monitoring system or the plant ventilation exhaust radiation monitoring system. Both systems actuate alarms in the control room upon sensing a high radiation level.

On the basis of experience in operating plants, 3500 pounds per hour of reactor steam per unit is assumed to be released continuously to the turbine building atmosphere. The activity contained in this leakage is transported to the environment by way of the turbine building ventilation system. This results in a release direct to the environment of about 0.01 percent of the noncondensable gases which are normally processed by the gaseous waste treatment system. The iodines contained in the steam are released to the building atmosphere where 50 percent is assumed to be removed by natural processes such as plateout. A leakage rate of 3500 pounds per hour results in a negligible noble gas release and an iodine release of 0.025 μCi/s per unit. The iodine release from the three-unit plant results in an annual average site boundary concentration of 3.3×10^{-14} μCi/ml.

(3) Class three accidents - Class three accidents include uncontrolled releases of radioactivity from the waste disposal systems as a result of an equipment malfunction or a single operator error. The waste disposal system has been designed to collect, monitor, treat, and discharge or package for disposal liquid, solid, and gaseous wastes (with all operations conducted in accordance with administrative procedures). For liquid and gaseous releases the rate of release is monitored.

(a) Solid radwaste - Because of the nature of solid radioactive wastes and the specialized procedures and equipment provided for packaging and handling these wastes, accidental releases of radioactivity with the potential to affect the environment adversely is considered extremely unlikely.

(b) Liquid radwaste - Liquid radwaste is collected in tanks, sampled and treated as required, resampled, then released under carefully controlled conditions to the condenser cooling water diffusers for dilution. The only postulated accident involving the liquid radwaste system with the potential for releasing a substantial amount of radioactivity in an uncontrolled manner is an inadvertent release from a waste sample tank.

The waste sample tank containing 0.2 curies is assumed inadvertently pumped to the discharge diffusers at the normal pumping rate of 80 gpm for 20 minutes, at which time the release would be alarmed and the situation corrected. This occurrence could arise through any of three single operator errors: (1) the operator commences pumping without taking a batch sample, a procedural error; (2) a batch sample is incorrectly analyzed or the results of the analysis are incorrectly communicated to the operator; or (3) the operator, having been notified of an acceptable batch sample, pumps the wrong tank by mistake. This accident has been selected as typical of its class principally on the basis of its probability of occurrence. Since radwaste equipment is manually operated, it is not typically subject to operational transients where malfunctions could lead to inadvertent release of system contents. This liquid radwaste accident would result in a concentration of less than 1.2×10^{-6} μCi/ml for a period of less than 20 minutes.

(c) Gaseous radwaste - All major components of the gaseous radwaste system are passive systems. Consequently, postulated equipment failures and malfunctions are restricted to leaks and ruptures from external sources. The greatest inventory of radioactive gases is in the gas holdup pipes and charcoal adsorbers, which delay the discharge of the gases in order to provide time for radioactive decay. The gas holdup pipes are underground and are designed to withstand internal explosions. Additionally, the hydrogen recombiners further reduce the potential for internal explosion.

Examination of the equipment contained in the offgas system, therefore, reveals that there are no realistic accidental sources of potential release, other than the normal effluent path from the system.

(4) Class four accidents - Class four accidents are events that release radioactivity into the primary system coolant (reactor water) including anomalous fuel failures during normal

operation, as well as fuel failure which might result from abnormal operating transients. Class four accidents result in increased gaseous releases to the environment and increased coolant activity, which increases the activity of the fluids processed by the radwaste system.

Each fuel rod consists of UO_2 fuel pellets stacked in a zircaloy-2 cladding tube which is evacuated, backfilled with inert gas (helium), and sealed by welding end plugs in each end. The cladding is strong enough to withstand the reactor coolant pressure without collapsing. Although most fission products are retained within the UO_2, a fraction of the gaseous products is released to the volume (plenum) inside the top of the rod. Any fuel damage would be characterized by perforation of the fuel rod cladding, which would release fission products to the reactor coolant. Mechanisms which could cause fuel damage are severe overheating or excessive pellet expansion. Fuel performance has been verified by analysis and experience. Reactor operation is limited by administrative procedures and automatic protection systems so that fuel damage limits are not exceeded. Nonetheless, the radwaste system has been designed to process the radioactive wastes generated by operation with failed fuel without limiting reactor operation.

An abnormal operational transient includes the events following a single equipment malfunction or a single operator error that are reasonably expected during the course of plant operations. Power failures, pump trips, and rod withdrawal errors are typical of the single malfunctions or errors initiating the events in this category. In considering the various abnormal operational transients, the full spectrum of conditions in which the reactor core may exist is considered.

Seven nuclear system parameter variations have been identified as potentia. threats to the fuel or primary coolant system. They are as follows:

1. High primary system pressure
2. Primary coolant temperature decrease
3. Positive reactivity insertion
4. Decreased inventory of primary coolant
5. Primary coolant flow decrease
6. Primary coolant flow increase
7. Increased inventory of primary coolant

The principal protective system for abnormal operational transients is the reactor protective system which limits the uncontrolled release of radioactive material from the fuel and nuclear system process barriers by terminating excessive temperature (which threaten to rupture the nuclear system process barrier). This system takes automatic protective action upon detection of an unsafe or abnormal condition.

No transients analyzed results in either fuel failures or any nuclear system stress in excess of that allowed by applicable industry codes. Anomalous failures of fuel rods (that is, perforation of fuel rod cladding in such a manner as to release fission products) may occur during normal operation. Expected levels of noble gas releases have been estimated on the basis of experience with operating plants. The radwaste system routine releases have been evaluated on the basis of a noble gas release of 172,000 μCi/s per unit (air ejector release after 30 minutes of decay) in the radioactive discharge section of this report. To analyze the effect of class four accidents, a release to the gaseous radwaste system of 344,000 μCi/s per unit from one unit, coincident with 172,000 μCi/s per unit from the remaining two units, has been analyzed on the basis of duration for 12 months. This results in the total release of 5.9×10^5 curies of noble gases to the environment with the extended treatment system.

(5) <u>Class five accidents</u> - Class five accidents are characterized by releases of radioactivity into the secondary water systems as a result of leaks. The Browns Ferry Nuclear Plant has several heat exchangers which could suffer such leaks including:

(a) Main condenser

(b) Residual heat removal system heat exchanger (RHRS)

(c) Drywell cooler heat exchanger

(d) Spent fuel storage heat exchanger

Item (a) would exhibit inleakage due to a lower pressure on the primary coolant side, and items (c) and (d) are cooled by closed cooling water loops which are monitored for activity.

The only source of primary system leakage directly into the secondary system for this plant is, therefore, via the RHR heat exchanger.

Since the primary system is at a higher pressure than the secondary side of the RHR heat exchanger, any leak between the two systems will result in primary coolant flow into the secondary system. The secondary system discharges directly to the discharge piping; therefore, the potential exists for an additional environmental effect from this source. However, radiation monitors located on the secondary system discharge line alarm when the discharge concentration reaches approximately 2×10^{-6} µCi/ml.

Consideration of the operating mode of the RHR-HX would indicate that the greatest potential for a primary coolant leak would be during the shutdown-depressurization mode. Under this condition, it is expected that the primary system would be at a higher pressure for approximately three hours after which time the two systems would be at the same pressure or with the service water at possibly a higher pressure.

This accident results in concentration of less than 2×10^{-7} µCi/ml in the discharge diffuser piping to Wheeler Reservoir.

(6) Class six accidents - Class six accidents are refueling accidents which might occur inside the secondary containment, such as a dropped fuel element, a heavy object dropped on the reactor core or spent fuel in the fuel storage pool, or a mechanical malfunction. Dropping of a fully loaded shipping cask has also been postulated.

Detailed refueling procedures will be used to ensure a safe and orderly refueling. When fuel is being inserted, removed, or rearranged in the reactor core, or when control rods are being installed, removed, or manipulated, licensed operators will be in the control room and on the refueling floor supervising the operations. In addition to these administrative safeguards, refueling interlocks are provided in the plant instrumentation and control systems which back up procedural controls to preclude an inadvertent criticality during refueling operations.

Specially designed and constructed equipment will be used to carry out refueling operations. One refueling platform is provided for each unit and is the principle means of transporting fuel assemblies between the reactor well and the fuel storage pool. This platform travels on tracks and supports the refueling grapple and auxiliary hoists. A single operator can control all the equipment necessary to handle the fuel assemblies during refueling. Interlocks on the grapple and hoists prevent the operator from improperly operating the equipment.

A spent fuel storage pool for each unit provides underwater storage space of spent fuel assemblies removed from the reactor. Each pool is designed so that no single failure of structures or equipment will cause inability (1) to maintain the irradiated fuel submerged in water, (2) to reestablish normal pool water level, or (3) to safely remove fuel from the plant. To limit the possibility of pool leakage, each pool is lined with stainless steel. Inlet or outlet lines are designed so that their failure would not result in loss of water from the pool. The design of the storage racks provides for subcritical storage for any anticipated condition. The fuel pool cooling and cleanup system is designed to remove the decay heat released from spent fuel assemblies to the pool water. The system also maintains the pool water within specified temperature, purity, water clarity, and water level limits. This minimizes the concentration of any fission products in the water which could be released from the pool to the reactor building atmosphere. The flow rate is greater than two complete changes per day of the spent fuel pool water.

During refueling operations, the drywell closure head and the reactor vessel head are removed. This eliminates the primary coolant system and the primary containment as barriers to fission product release. All refueling operations are conducted within the secondary containment. Fuel assemblies are handled only under water to minimize plant personnel exposures and to ensure adequate cooling. If a fuel failure does occur during refueling operations, fission products will be released from the gap between the fuel pellet and the clad to either the reactor vessel water or the spent fuel pool water. Gaseous fission products would be released rapidly into the reactor building atmosphere. However, nonvolatile fission products would be retained by the water and would ultimately be either routed to the liquid radwaste system for processing or removed by the pool cleanup system. Fission product iodine would be slowly released to the secondary containment atmosphere until an equilibrium condition is established. The ratio of the concentration in the water to that in the air is shown by experimental evidence to be approximately 10^4 for conditions such as would exist during refueling.

The standby gas treatment system (SGTS) would process the exhaust from the refueling area in the event of a refueling accident. This system consists of filters which remove particulates and activated charcoal which removes iodine. Tests on iodine filter systems have shown iodine removal efficiencies greater than 99.9 percent even in environments approaching 100 percent relative humidity. The initial acceptance tests and annual tests of the SGTS filters will require an iodine removal efficiency of at least 99.9 percent and 99.0 percent, respectively. These annual tests are conducted before the refueling of any reactor in order to verify that the system performance has not been degraded. Therefore, the standby gas treatment system would remove at least 99 percent of all iodines released during a fuel handling accident.

Releases from the standby gas treatment system are routed out the plant stack to obtain maximum dispersion and to minimize doses at the site boundary. The standby gas treatment system would be started automatically by a high radiation signal in the refueling area.

The possible events which would lead to fuel assembly damage during refueling include dropping a fuel assembly due to mechanical failure of fuel handling equipment or dropping of a heavy object onto either the reactor core or the spent fuel stored in the spent fuel pool.

The analysis has been performed on the basis that all of the fuel rods in one fuel assembly (49) suffer cladding failures. The fuel assembly is assumed to have cooled for four days before the accident, and the iodine release is decreased by a factor of 4 to account for plateout effects in the containment. This accident results in a release to the environment of 1600 curies of noble gases and 62 curies of iodine via the plant stack.

The fuel cask is transferred from the reactor fuel pool to a vehicle by means of the reactor building crane. The crane lifts the loaded cask from the reactor building fuel pool and after decontamination lowers it through a hatch to the vehicle 99 feet below. All transfer components are tested under weighted conditions just prior to the actual transfer. An average of about ten cask transfers are performed each year for each unit at the site.

In order for the postulated accident to occur, the hoist brake, cable crane hook, lifting yoke, cask trunnion, or support ring must fail while the cask is suspended from the maximum height and the cask must rupture when it impacts upon the relatively yielding vehicle below. The probability that a drop could occur from any height after such careful planning and testing of equipment is expected to be low. The cask design is such that even in the event of a drop rupture is not likely. A fully loaded spent fuel cask is assumed dropped while being lowered.

This event is chosen to represent its category because it has the potential for dropping the fuel cask from the maximum height and because the fuel could lose its containment if the cask integrity is lost.

The reactor, if operating, is shut down by the operator. The cask is considered as dropping from a height of $\leq$ 99 feet to a yielding surface resulting in a release within the limits of 10 CFR Part 71.

The radiological consequences of the cask drop accident are based on the following considerations:

(a) The vehicle for transportation will be in position under the cask being lowered, thus providing a yielding type of impact surface. (The 30-foot cask drop design criteria is on a nonyielding impact surface.)

(b) The cask will be loaded with a maximum of 18 fuel elements which have been out of the reactor for a period of three to four months.

(c) The fuel is designed to withstand an impact of 500G and the cask 270G.

(d) The maximum deceleration of the cask after falling 99 feet is 148G.

(e) Upon impact with the yielding surface the cask closure head will remain intact thus preventing the spilling of fuel.

(f) Based on the cask design and fuel capability no fuel damage will result as a consequence of this event.

While it is expected that no release of fission products will occur as a result of the accident the assumption is made that 1000 curies of noble gas activity and some contaminated coolant are released to the environment via the plant stack (10 CFR Part 71 criteria).

(7) Class seven accidents - This class applies to the movement of a spent fuel cask from the time it leaves the reactor building until it reaches the site boundary. Spent fuel movement outside containment is always done with the fuel inside the cask. The engineering and procedural cautions pertaining to the movement of spent fuel on site essentially preclude the possibility of the cask dropping onsite due to instability, or improper attachment to the vehicle; further, even if such a drop were to occur, it would be from such a height that the shipping cask would easily sustain it. The cask could conceivably be damaged by fire; but the site arrangement precludes movement of the cask in areas of appreciable fire hazard.

Thus exposure to the public due to onsite movement of spent fuel outside the containment is not expected.

(8) Class eight accidents - These events are as described in section 14 of the SAR and are briefly detailed in the following paragraphs. These include the inside containment loss-of-coolant accident (recirculation pipe break), the outside containment loss-of-coolant accident (steam line break), and the reactivity excursion accident (control rod drop). The design basis refueling accident is discussed in class six.

(a) Loss-of-coolant accident (LOCA) - A sudden circumferential break is assumed to occur in a recirculation line, permitting the discharge of coolant into the primary containment from both sides of the break. Concurrent with this failure, the worst single active component failure is assumed to occur, i.e., failure of the LPCI injection valve in the unaffected recirculation loop to open.

The calculation of core heatup following the double-ended recirculation line break was predicted on a realistic basis by applying the results of parametric studies to the standard core heatup models currently in use. Peak clad temperatures were calculated for a spectrum of leak sizes and percent perforations were calculated from the resulting temperatures.

The realistic analysis shows no heatup of fuel into the perforation range except for the double-ended recirculation pipe break. Perforation even in this case will be limited to 2.5 percent or less. The resultant radiological effects are a function of the quantity and type of activity released, natural fission product removal effects, containment leak rate, etc.

Those values assumed applicable for the above parameters of concern are identified as follows:

1. Fuel rods damaged - 2.5 percent core
2. Primary containment leak rate - 0.5 percent per day initial with average 30-day release rate of 0.2 percent per day
3. Plateout plus condensation effects - 10 for iodines
4. Partition factor in the suppression pool - 10^4 for iodines
5. Mixing in the secondary containment - 100 percent
6. Standby gas treatment system efficiency - 99.0 percent iodines plus 0 percent for noble gases
7. Breathing rate - 232 cc/sec
8. Release height - 183 meters

The resulting releases are predicted to be 710 curies of noble gases and 1.8 curies of iodine from the plant stack.

(b) <u>Steam line break accident (SLBA)</u> - The postulated accident is a sudden, complete severance of one main steam line outside the drywell with subsequent release of steam and water containing products to the pipe tunnel and the turbine building. Since this accident does not result in any fuel damage, the environmental effects are limited to those radiological doses which may be received as a consequence of exposure to the activity associated with the primary coolant.

The mass of coolant (steam and liquid) released during the four-second isolation valve closure time is 79,000 pounds. As a consequence of depressurization approximately 30 percent of the released liquid will be flashed to steam. Due to the affinity of iodine for water, it is not expected that any additional iodine will be released from the remaining coolant. Therefore, the iodine released to the turbine building, as a consequence of the accident, will be proportional to that quantity of water flashed to steam. Due to the condensation, plateout will occur on surfaces which the steam will come in contact with before release to the general environment through special panels in the turbine building roof. It is assumed that an iodine removal factor of two is applicable to these effects.

Due to the type of activity released, the primary dose effect from this accident is inhalation thyroid exposure. This accident results in the release of 3.2 curies of iodine and 1.1 curies of noble gases over a short period of time.

(c) Control rod drop accident (CRDA) - The postulated accident is a reactivity excursion caused by accidental removal of a control rod from the core at a rate more rapid than can be achieved by the use of the control rod drive mechanism. In the CRDA, a fully inserted control rod is assumed to fall out of the core after becoming disconnected from its drive and after the drive has been removed to the fully withdrawn position. The design of the control rod velocity limiter limits the free fall velocity to three ft/s. Based on this velocity and assuming the reactor is at full power, the maximum rod worth is approximately one percent, resulting in the perforation of less than ten fuel rods, but with a high probability that none will actually fail.

In order for a rod to drop from the core, it must first become detached from the drive, remain lodged in position while the drive is withdrawn from the core, and then, while the drive is still withdrawn, become dislodged and fall freely. This is a complex series of events, there being many possible actions (or inactions) that are interrelated, but this is offset by the indications and procedures that are designed to avoid such an event.

In addition to the assumed failure of ten fuel rods, the radiological effects are also based on rated steam and recirculation flow, an iodine carryover fraction of one percent, and a main steam line isolation valve closure time of four seconds.

In addition to isolating the main steam line (MSL), the MSL radiation monitors also isolate the normal offgas system thereby bottling the activity between the MSL isolation valves and the offgas isolation valves. The primary source of leakage from the system will therefore be via the turbine gland seals and will be due to changes in environmental pressure with respect to the turbine condenser.

The activity airborne in the condenser is a function of the partition factor, volume of air and water, and chemical species of the fission product activity. The values associated with these parameters are: a partition factor of 10^4 for iodine, a condenser plus turbine free volume of 2.1×10^5 ft^3 and a condensate volume of 1.3×10^4 ft^3. The resulting total release to the environment would be 11 curies of noble gases and 1.3×10^{-5} curies of iodine.

(9) <u>Class nine accidents</u> - Class nine accidents are described as hypothetical sequences of successive failures which are more severe than those postulated as design-basis accidents whose results are summarized in the safety analysis reports by applicants requesting construction permits and operating licenses from the AEC for nuclear power plants. Although the consequences of class nine accidents could be severe, the probability of their occurrence is made so small that their environmental risk is extremely low.

It is emphasized that although the consequences of class nine accidents could be severe, the occurrence of such an accident is considered incredible. These accidents would require the occurrence of multiple failures of the plants engineered safety features with each failure even more severe than the postulated design-basis accidents which are analyzed using extremely conservative assumptions, and which, themselves, have extremely low probabilities of occurrence.

Conservative design; diverse and redundant physical barriers, protection systems, and engineered safety features; extensive quality assurance; and control of operations dictate such a probability of occurrence that the environmental risk associated with class nine accidents is negligible as compared to that of the other classes of accidents. For this reason, class nine accidents will not be considered further.

4. Evaluation of environmental impact of postulated accidents - The principle effect of accidents on the environment is the increased exposure to man which might result from the release of radioactive material. This exposure is summarized in Table 3.2-2 for the principle accidents analyzed. The analysis of this information shows that no accident or class of accidents results in an undue risk to the health and safety of the public.

The duration of exposure used in the analysis for events which occur during a short period of time is taken as the maximum duration of the offsite release, usually less than 30 days. Conditions which by their very nature do not halt operation are assumed to prevail for what is considered to be a reasonable length of time. They may, in fact, prevail for longer or shorter periods. Using this duration, the total release for the period has been calculated. Where applicable, the plant design lifetime of 40 years has been used.

Two types of meteorology have been used. The average annual meteorological conditions have been used to evaluate the average result of an accident. While this gives little information as to the maximum severity of the accident, it does provide a realistic measure of consequence.

Adverse meteorology is used in the analysis only to provide an estimate of the maximum reasonable effect of an accident. This does not provide a realistic measure of the consequence due to a postulated accident. This meteorology is generally used in safety evaluations and demonstrates that even under very unfavorable conditions, the accidents do not lead to unacceptable results.

Atmospheric release of tritium from this plant is extremely low. Even if some mechanism existed whereby all the tritium which is released to the primary coolant could be continuously released to the atmosphere, the resulting dose rate at the site boundary would be less than 1×10^{-4} mrem per year.

Total population exposure is the principle measure of the environmental effect of postulated accidents. The routine releases from this plant are estimated to result in an increase in the total population exposure within 50 miles of the plant of less than 0.1 percent above the exposure due to natural background. Table 3.2-2 demonstrates that no single accident analyzed using either average annual meteorological or adverse meteorological conditions will result in an increase in total population exposure of more than 0.004 percent of natural background.

A second measure is the dose at the site boundary with average annual meteorological conditions. Any accidental release which, added to the releases from routine operation averaged over one year, does not result in exceeding the levels proposed in Appendix I to 10 CFR Part 50 is not considered further in this analysis because of its trivial consequences. This includes the accidents analyzed in classes one, four, six, and seven. The whole body doses from the accidents postulated in classes two, three, five, and eight would also be less than these levels.

The steam line break accident, which is potentially most severe, would result in a dose at the site boundary under average meteorological conditions of 1.7 mrem to the thyroid. When averaged over the 40-year design lifetime of the plant, this would increase the total exposure of a person by less than 0.04 percent above natural background and therefore should have no significant effect. It should be noted that to receive that dose a person would have to stay at the site boundary for the entire 30-day duration of such a release.

Although the probability of any accident occurring has not been quantified, it is possible to speak qualitatively concerning their occurrence. Accidents in class one may occur relatively frequently, while accidents in classes two, three, four, and five are expected to occur very infrequently, if at all. Accidents in classes six, seven, and eight are not expected to occur.

It should be noted that the release of iodines due to leakage of steam from the primary system at the rate of 3500 pounds per hour results in an average annual site boundary concentration which is in excess of the proposed Appendix I to 10 CFR Part 50. TVA has under study provision of equipment for minimizing this release. The design of this equipment will be based on meeting the requirements of Appendix I to 10 CFR Part 50, as finally adopted.

On the basis of this analysis, TVA concludes that there is no reasonable possibility that the occurrence of these accidents will lead to any undue risk to the health and safety of the public.

TABLE 2.3-1

CLASSIFICATION OF POSTULATED ACCIDENTS AND OCCURRENCES

Number of Class	Description	Example(s)
1	Trivial incidents	Small spills Small leaks inside containment
2	Miscellaneous small releases outside containment	Spills Leaks and pipe breaks
3	Radwaste system failures	Equipment failure Serious malfunction or human error
4	Events that release radioactivity into the primary system	Fuel failures during normal operation. Transients outside expected ranges of variables.
5	Events that release radioactivity into secondary system	Class 4 & Heat Exchanger Leak
6	Refueling accidents inside containment	Drop fuel element Drop heavy object onto fuel. Mechanical malfunction or loss of cooling in transfer tube.
7	Accidents to spent fuel outside containment	Drop fuel element Drop heavy object onto fuel. Drop shielding cask--loss of cooling to cask. Transportation incident on site.
8	Accident initiation events considered in design-basis evaluation in the Safety Analysis Report	Reactivity transient Rupture of primary piping Flow decrease - Steamline break
9	Hypothetical sequences of failures more severe than Class 8	Successive failures of multiple barriers normally provided and maintained.

Table 2.3-2

RADIOLOGICAL EFFECTS OF POSTULATED ACCIDENTS

Class	Event	Time Period of Exposure	DOSE AT SITE BOUNDARY-REM: Annual Average Meteorology	DOSE AT SITE BOUNDARY-REM: Adverse Meteorology	POPULATION EXPOSURE-MAN-REM: Annual Average Meteorology	POPULATION EXPOSURE-MAN-REM: Adverse Meteorology
0	Naturally Occurring Background Radiation	40 Years	4.48 WB	4.48 WB	2,800,000	2,800,000
0	Routine Radioactive Discharge 0.5 Percent Failed Fuel	40 Years	0.233 WB	0.233 WB	2,518	2,518
1	Trivial Releases	40 Years	NIL	NIL	NIL	NIL
2	Primary Coolant Steam Leakage 3500 lb/h Into Turbine Bldg.	40 Years	<0.00001 WB .033 TH	<0.00001 WB .033 TH	99	99
3	Inadvertant Discharges of a Waste Sample Tank	20 Minutes	0.0013 WB	0.0013 WB	0.2	0.2
4	Operation With One Percent Failed Fuel in One Unit and 0.5 Percent Failed Fuel in the Other Two Units	1 Year	0.0037 WB	0.0037 WB	55	55
5	Leak in RHR Heat Exchange During Shutdown	3 Hours	0.0003 WB	0.0003 WB	0.03	0.03

WB - Whole Body
TH - Thyroid

Table 2.3-2 (Continued)

RADIOLOGICAL EFFECTS OF POSUTLATED ACCIDENTS

Class	Event	Time Period of Exposure	DOSE AT SITE BOUNDARY-REM Annual Average Meteorology	DOSE AT SITE BOUNDARY-REM Adverse Meteorology	POPULATION EXPOSURE-MAN-REM Annual Average Meteorology	POPULATION EXPOSURE-MAN-REM Adverse Meteorology
6	Spent Fuel Cask Drop Accident	2 Hours	<0.00001 WB	0.00006 WB	0.02	0.02
6	Fuel Handling Accident Inside Containment	30 Days	<0.00001 WB 0.00095 TH	0.00003 WB 0.0071 TH	13.1	20.1
7	Fuel Handling Accident Outside Containment	N.A.	NIL	NIL	NIL	NIL
8	Control Rod Drop Accident	30 Days	<0.00001 WB <0.00001 TH	<0.00001 WB <0.00001 TH	0.01	0.01
8	Loss-of-Coolant Accident	30 Days	<0.00001 WB 0.00002 TH	<0.00001 WB 0.00014 TH	0.39	0.64
8	Main Steam Line Break Accident	2 Hours	<0.00001 WB 0.0017 TH	0.00001 WB 0.014 TH	0.26	1.6

WB - Whole Body
TH - Thyroid

3.0 SUPPLEMENTS TO THE JULY 14, 1971, DRAFT ENVIRONMENTAL STATEMENT

3.1 Radioactive Discharges - TVA has studied the expected releases from Browns Ferry Nuclear Plant and investigated the alternatives available for keeping the radioactivity in effluents to unrestricted areas as low as practicable. AEC provided qualitative guidance for this in its proposed amendment to 10 CFR Part 50 on December 3, 1970. However, no definitive numerical guidance was given for determining when either design objectives or operating levels meet requirements until the proposed Appendix I to 10 CFR Part 50 was issued on June 9, 1971. In the meantime, TVA independently decided to make additional improvements in the radwaste treatment system at the Browns Ferry Nuclear Plant by providing extended treatment of the radioactive gaseous and liquid wastes.

Although the annual whole body doses to any individual from either liquids or gases with the planned extended treatment are already much less than those permitted by the proposed Appendix I, there are alternative ways of obtaining further reductions. These have been considered so as not to foreclose prematurely any options which might further reduce releases to the environment. In order to assess the adequacy of the planned extended treatment systems when compared to the alternatives, each system will be evaluated in terms of its cost, feasibility, adaptability to the Browns Ferry plant and environmental benefits. These systems will be compared to the original radioactive waste treatment systems.

1. Gaseous radwaste system -

(1) Existing gaseous radwaste system - The system originally designed for treatment of the gases that are formed inside the fuel elements and in the cooling medium during reactor operation included 30-minute holdup and elevated stack release. These gases, some of which are radioactive, are carried in a direct cycle boiling water reactor with the steam from the reactor through the turbine into the condenser.

The gases mix with inleaking air in the condenser and this gas-air mixture is continuously removed from the condensers by the air ejector offgas system to maintain vacuum. In this way, radioactive gases are removed continuously from the reactor coolant system. A period of decay is needed to reduce the radioactivity content of the gas-air mixture prior to release to the environment. This decay period is provided by a long length of large diameter pipe buried in the ground which effectively holds up the gas for 30 minutes. (Figure 3.1-1)

The gland seal offgas subsystem uses a large diameter pipe which provides a 1.75-minute holdup time to allow decay of short-lived radioactive N-16 and O-19 isotopes from the gland seal exhauster and mechanical vacuum pumps. These gases have a very low activity level and require no further treatment. (Figure 3.1-1)

(2) Alternative treatment of gaseous radwaste - Four alternative ways to reduce these radioactive gaseous discharges at the Browns Ferry Nuclear Plant have been evaluated. The expected releases with the alternative systems were investigated and

the resultant doses compared with the proposed Appendix I to 10 CFR Part 50 which provides numerical guidance for keeping radioactive effluents to unrestricted areas as low as practicable. A summary description of each alternative system considered, the timing of the installation, its cost, and its environmental benefit is discussed below.

(a) Hydrogen recombiners - The short-lived radioactive isotopes contained in the gas-air mixture removed from the condensers by the air ejector offgas system will, with sufficient holdup time, decay to very low activity levels prior to being discharged through the stack. Addition of hydrogen recombiners to the original 30-minute holdup piping effectively increases the time for decay of short-lived isotopes by recombining the radiolytic hydrogen and oxygen into water using a catalyst bed. Removal of this radiolytic hydrogen and oxygen reduces the gas volume in the offgas system by about 90 percent, which makes any subsequent holdup system more effective. A factor of approximately six dose reduction to an individual at the site boundary is achieved by the addition of hydrogen recombiners alone.

The hydrogen recombiner systems would be installed downstream of the condenser offgas ejector. The recombiners would exhaust to the holdup pipe for each unit. This system is shown schematically in figure 3.1-2. This system has been used in similar applications at other nuclear plants and is of proven design. The investment cost of this system is estimated to be $6,000,000 for the three-unit plant.

(b) Charcoal adsorber system - The hydrogen recombiners system can be augmented by the installation of charcoal adsorbers. The charcoal adsorber system would be installed at the downstream end of the 30-minute holdup pipe and would consist of filters, cooler-condensers, moisture separators, preheaters, and vessels containing the charcoal adsorber material. This system is shown schematically in figure 3.1-3.

The charcoal adsorber system increases the effective holdup time for xenon and kyrpton and thus further reduces the amount of radioactivity which is released from the stack. TVA studies indicate that the addition of six charcoal beds to the hydrogen recombiner system would result in a dose reduction factor of approximately 17. The addition of six more charcoal beds (total of 12) would result in an additional dose reduction of approx- mately five. Thus, the total dose reduction for the recombiner and six-charcoal bed system is approximately 100 and for the recombiner and twelve-charcoal bed system is approximately 500.

The six-charcoal bed system is estimated to cost $3,000,000, and the cost of the twelve-bed system is estimated to be $4,500,000. The total cost of the hydrogen recombiner-charcoal adsorption system is $9,000,000 for the six-bed alternative and $10,500,000 for the twelve-bed scheme.

Charcoal beds have been used in similar applications for nuclear power plants and in other plants in the nuclear industry. Their design performance and reliability have been demonstrated for the type of service that would be required at Browns Ferry. The following items represent a summary of advantages for the charcoal adsorption system:

i) demonstrated performance on other reactors

ii) delays short-lived isotopes until activity is minimal

iii) delays xenon and krypton for long periods

iv) cleans gas by filtration

v) adsorbed gas released slowly in event of housing rupture

vi) passive system

(c) <u>Absorption by solvent (ORGDP System)</u> - This system shows promise for removing krypton and xenons from a gas stream by selective absorption in a fluorocarbon solvent. Its main advantages when compared to the charcoal adsorption system are:

i) compactness

ii) efficiency better than 99.9 percent for removal of noble gas radioisotopes

iii) relatively inexpensive for equipment probably in the order of 1/4 million dollars

The performance and reliability of this type system has not been proven in nuclear plant service. The only experience to date with the absorption by solvent system has been with bench and pilot plant size systems. While this system shows promise for future application to nuclear plants, it was decided that further development would have to be done before it could become an acceptable alternative for large-scale applications such as Browns Ferry.

(d) <u>Cryogenic distillation</u> - This system works by liquifying radioactive gases at low temperatures and storing them while their radioactivity decays. It would be installed downstream of the 30-minute holdup pipe. This scheme is shown schematically in figure 3.1-4. Its main advantages when compared to the charcoal adsorption system are:

i) very high radioactivity reduction factors achievable (>1000)

ii) system relatively insensitive to flow change

iii) no stack normally needed

Cryogenic systems for producing industrial oxygen were developed 30 to 40 years ago. However, the application of a cryogenic system to a nuclear plant could have performance problems unrelated to those encountered in other industries. Additional costs related to providing clean steam to the seals and packing must also be taken into account, as well as the problems associated with krypton-85 storage onsite and its eventual disposal.

In the cryogenic extended radwaste treatment system, krypton-85 and other noble gases are continuously removed from the condenser offgases and stored in tanks. The holdup of krypton-85 would increase the potential dose to station personnel, would present the potential for the accidental release of the concentrated waste to the environment, and would require long-term storage and ultimate disposal of gaseous radioactive waste. The use of charcoal adsorption does not involve these problems.

While the future potential of the cryogenic system may offer advantages, it has not been used for the treatment of radioactive gaseous wastes in large commercial nuclear power plants. As compared to charcoal adsorption systems, the cryogenic system is a rather complicated mechanical system utilizing pumps, compressors, refrigeration systems, piping, and tanks. TVA has concluded that, because of the lack of experience with this type of equipment in this type of service and the complex mechanical systems utilized, the reliability of the cryogenic system would not be as high as that of the charcoal adsorption system which is essentially a passive system and has been used in radioactive gas treatment for nuclear plants similar in design to Browns Ferry. The cryogenic system would result in an additional operating cost of $60,000 per year when compared to the charcoal adsorption system. The present value of this difference in operation and maintenance cost is approximately $700,000. The estimated investment cost and relative operating cost are shown in Table 3.1-1 below.

(e) Other alternatives - In addition to the alternatives described, pressurized tanks were also considered. However, the relatively low dose reduction factors obtainable and the high quantities of gas to be handled with compressors precluded favorable consideration of these systems.

(3) Schedule for installation - It is estimated that the cryogenic system for Unit 1 could be placed in operation at the time of the first refueling outage which is presently scheduled for May 1974. A similar situation exists for Unit 2 which is scheduled for its first refueling outage during February 1975. The cryogenic system for Unit 3 could be in service by the time that unit is placed in commercial operation (February 1974). Based on the present schedule and assuming the cryogenic alternative, Unit 1 would be operating for nine months, Units 1 and 2 would be operating for ten months, and Unit 2 would be operating for nine months with the originally designed 30-minute holdup system.

With the charcoal bed alternative, the system could be installed by September 1973 for Unit 1, November 1973 for Unit 2, and by the time of commercial operation for Unit 3. This would result in Unit 1 operating for nine months, Units 1 and 2 operating for two months, and Unit 2 operating for only two months without the extended treatment for gaseous radwaste. Thus, with the charcoal bed alternative there would be 23 unit-months less of operation without extended treatment when compared to the cryogenic alternative.

Table 3.1-5 indicates the radioactive releases, resultant doses, and population exposures for two-unit and one-unit operation with the original 30-minute holdup system, assuming a conservative estimate of 0.5 percent fuel failure. All analyses of the routine releases from Browns Ferry have been based on an average of 172,000 μCi/s of noble gas released from the condenser air ejector of each unit (after 30 minutes of decay). This corresponds to operation with an 80 percent capacity factor and approximately 0.5 percent of the fuel rods experiencing clad perforations. TVA believes that this is a conservative basis and, in fact, reflects poorer fuel performance than expected with the extensive fuel quality assurance program undertaken by TVA and the General Electric Company. Examination of available data from operating plants indicates that this level will probably not be exceeded during the lifetime of Browns Ferry Nuclear Plant.

(4) Summary and conclusion - The calculated radiation doses for the alternative extended treatment systems are summarized below assuming that the three units could operate with as much as 0.5 percent fuel defects.

TABLE 3.1-1

	Annual External Dose to Any Individual at the Site Boundary (mrem) Three-Unit Plant	Cost Three Units
1. 30-minute holdup	290	base
2. Recombiners only	50.0	$ 6,000,000
3. Recombiners and 6 charcoal beds	2.8	$ 9,000,000
4. Recombiners and 12 charcoal beds	0.6	$10,500,000
5. ORGDP System	less than 0.1	not estimated
6. Cryogenic System	less than 0.1 1/	$ 9,700,000 2/

1/ Dose due to gland seal leakage exceeds 5 and 6 and may exceed 4.

2/ Includes $700,000 of additional operating cost.

The gaseous radwaste system as originally designed with 30-minute holdup and elevated point of release incorporated all of those components of proven reliability and performance which were commercially available for large power reactors at the time the equipment was purchased. Other equipment components and alternative system concepts for radioactive waste processing are now available. TVA has evaluated the alternatives available in terms of their cost, feasibility and adaptability to the Browns Ferry plant, and their capability to reduce the environmental impact of radioactive gaseous releases from the Browns Ferry plant. The following table summarizes the benefits in terms of reduction in dose to any individual and the economic cost of each alternative.

TABLE 3.1-2

	Reduction in Annual External Dose (mrem)1/	Cost	Dollars per mrem Reduction	Incremental Cost of mrem Reduction $ per mrem
1. Recombiners only	240	$ 6,000,000	$25,000	$ 25,000
2. Recombiners and 6 charcoal beds	287.2	9,000,000	31,300	63,600 2/
3. Recombiners and 12 charcoal beds	289.4	10,500,000	36,300	682,000 3/
4. Cryogenic system	290	9,700,000	33,500	250,000 3/

1/ Three-unit plant - 0.5 percent failed fuel.

2/ Incremental cost over recombiners only.

3/ Incremental cost over recombiners and six charcoal beds.

TVA has concluded that the recombiner and six-charcoal bed alternative represents the best balance of economic cost, reduction in environmental impact, and feasibility. This results in a reduction of the hypothetical "fence post dose," assuming 0.5 percent failed fuel, to about 2.8 mrem. This very low "fence post dose" is 0.56 percent of 10 CFR Part 20 limits and 28 percent of the numerical guidance provided by the proposed Appendix I. It also represents a very small percentage (about three percent) of the naturally occurring background dose. TVA believes the benefits to be gained by further reducing the radioactive gaseous releases are not commensurate with the cost associated with the reduction. To implement this conclusion, TVA is proceeding with the design and procurement for the hydrogen recombiner and six-charcoal bed alternative. TVA is attempting to expedite the delivery of equipment and installation in order to minimize the time any of the units would be operating without extended treatment of gaseous radwaste.

2. <u>Liquid radwaste system</u> - A single system is designed to handle the radioactive liquid wastes from all three units of the plant. The following radioactive liquids are processed: high purity wastes, low purity wastes, chemical wastes, detergent wastes, and fuel cask decontamination wastes.

Tritium amounting to an estimated 51 curies per year is to be released, of which between 60-90 percent is released as liquid waste. The annual average concentration before dilution in Wheeler Reservoir is approximately $1.4 \times 10^{-8}\ \mu Ci/ml$.

(1) <u>Alternative treatment of liquid radwaste</u> - The liquid radwaste system as originally designed would have resulted in releases of approximately 40 curies per year of radioactivity (exclusive of tritium) into Wheeler Reservoir. Two alternatives were considered for reducing these releases.

(a) <u>Demineralization</u> - Modify the operation of the liquid radwaste treatment system to demineralize low conductivity liquid from the floor drains. This would result in a reduction factor of approximately eight in the radioactivity discharged. The annual operating cost of this alternative is approximately $490,000.

(b) Evaporator - Install an evaporator to treat the liquid radwaste. This alternative would result in an additional reduction factor over the demineralization of floor drain alternative above. The investment cost of this alternative would be about $1,000,000 with annual operating costs of approximately $85,000. The total annual cost (including fixed cost) of this alternative is estimated to be $175,000.

(2) Summary and conclusion - The following table summarizes the costs and benefits of these alternatives.

TABLE 3.1-3

	Liquid Effluents Annual Total Curies1/	Annual Total Internal Dose to Any Individual (mrem)	Annual Operating Cost, Including Amortization of New Equipment
1. Additional Processing by Demineralizer	5	1.0	$490,000
2. Evaporator	0.4	0.08	175,000

1/ Except tritium.

In addition to the economic justification, the installation of an evaporator will further reduce the estimated radioactive liquid releases with the existing system even with the proposed additional processing of floor drains by demineralizers, from about five curies per year to about 0.4 curie per year (except tritium).

The amount of tritium expected to be released is so small as to be inconsequential in terms of population dose.

Based on the above analyses, TVA has concluded that an evaporator along with its associated buildings and equipment should be installed at the Browns Ferry Nuclear Plant. It is estimated that approximately 30 months will be required to design, procure, and install the necessary equipment. Thus, the evaporator should be ready for service at approximately the same time as Unit 3 is placed in commercial operation. In the interim, floor drain wastes will be processed by demineralization to achieve lower release levels. The flexibility will also be retained after installation of the evaporator to process the liquids from the floor drains through the demineralizers should it be needed. Estimated liquid releases are given by isotope in Table 3.1-4. The liquid radwaste treatment system including the evaporator is shown in figure 3.1-5. There are no other feasible alternatives which would further reduce the liquid radioactive discharges. The system chosen for treatment of radioactive liquids yields a very low (0.08 mrem) annual internal dose to any individual which is less than two percent of the numerical guidance values provided by the proposed Appendix I to 10 CFR Part 50.

3. <u>Estimated increase in annual environmental radioactivity levels and potential annual radiation dose from principal radionuclides</u> - With extended treatment for gaseous and liquid radwaste, the releases of radioactivity to unrestricted areas from the Browns Ferry Nuclear Plant will be so low as to be unmeasurable with present measurement techniques. However, TVA has calculated the

expected increase in radioactivity levels and potential radiation doses to the population as a result of these low level releases.

(1) <u>Interim operation</u> - TVA has also calculated potential radiation doses to the population resulting from releases prior to the completion of the installation of the extended gaseous treatment system.

The following cases were considered for dose calculations.

Case 1 - Extended gaseous and liquid treatment system (recombiner, six charcoal beds, and evaporator); three units

Case 2 - Before completion of extended treatment systems

These calculations were based on the following conservative assumptions:

(1) Each reactor operates at annual average of 80 percent of full power. Results are shown for 0.5 percent fuel defects for case one and for 0.5 percent fuel defects for case two.

(2) For estimation of individual doses, the hypothetical individual is assumed to be located at the highest dose point on the site boundary 24 hours a day, 365 days per year, and this individual is assumed to drink water having the same radioactivity concentration as that in the plant effluent, before dilution. It is also assumed that this individual eats 45 pounds of fish per year taken from the Wheeler Reservoir.

(3) The external dose from gaseous effluents is the sum of the beta and gamma doses.

(4) For estimation of the population dose from drinking water, the plant effluent is assumed to be mixed with 65 percent of the average streamflow in Wheeler Reservoir downstream from the site to Wheeler Dam and to be mixed with 100 percent of the average streamflow after passing Wheeler Dam. It is assumed that all radioactivity released to the reservoir remains in solution and is not removed by being deposited in bottom sediment. Radioactive decay is considered to the point of water intake, but is not further considered between the time of intake and the time of consumption. It is assumed that all water consumed by the population groups served by surface water supplies within 50 miles downstream of the plant contains the same concentration of radioactivity as in the drinking water intake.

(5) For estimation of the population dose from eating fish it is assumed that all sport fish taken from Wheeler, Wilson, and Pickwick Reservoirs and all edible commercial fish harvested from Wheeler and Wilson Reservoirs and the Alabama portion of Pickwick Reservoir are consumed within the 50-mile radius surrounding Browns Ferry Nuclear Plant. It is assumed that all fish are continuously exposed to the average radioactivity concentration that is present in the river channel of Wheeler Reservoir downstream from Browns Ferry Nuclear Plant and that no reduction in radioactivity due to radioactive decay occurs between the time a fish is removed from the water and the time of consumption.

Based on these conservative assumptions, estimated quantities and concentrations of radioactivity released to the environment and calculated radiation doses to the population are summarized in Tables 3.1-5 and 3.1-6.

(2) <u>Conclusion</u> - The annual natural background radiation dose at the Browns Ferry Nuclear Plant site has been measured to be 115 mrem. The annual population dose from this background radiation to the 608,750 persons within 50 miles of the plant is estimated to be 70,000 man-rems.

For operation of the Browns Ferry Nuclear Plant with 0.5 percent fuel defects prior to the completion of extended treatment systems the maximum dose from plant operation to an hypothetical individual at the site boundary is calculated to be 112 mrem per year which is slightly less than the annual dose that an individual receives from natural background radiation. For the hypothetical individual to receive the calculated dose he would have to remain in the highest dose point on the site boundary 24 hours a day, 365 days per year, and drink water having the same radioactivity concentration as that in the plant effluent before dilution. The actual dose to a real individual will be much less than the calculated dose to the hypothetical individual. The dose during the second year of operation to the hypothetical individual at the site boundary is only ten percent of the annual dose to an individual from natural backgound radiation. Thereafter the annual dose to the hypothetical individual is calculated to be only three percent of the natural background radiation dose.

The total calculated radiation dose from plant operation to the population within 50 miles of the Browns Ferry Nuclear Plant for the first year, second year, and following years of operation is only 1.2 percent, 0.14 percent, and 0.06 percent, respectively.

of the dose from natural background radiation. This dose is only a very small fraction of the natural background radiation dose and is, in fact, much less than the variations in natural background radiation doses which result from changes in altitude or in the type of housing in which a person lives or from various other causes. Therefore, the radiation dose resulting from operation of the Browns Ferry Nuclear Plant will result in no undue risk to the health and safety of the public.

The only alternative to the operation without extended treatment of radwaste is to delay the startup of the Browns Ferry plant. The need for power and consequences of delays are discussed in section 3.7 Electric Power Supply and Demand. TVA has weighed the benefits derived from the operation of the plant between the startup of Unit 1 and the completion of installation of the extended radwaste facilities and the environmental risks associated with this operation. TVA has concluded that the operation of the plant during the interim period is justified on the basis of its insignificant environmental impact vis-a-vis the need for electric power from Browns Ferry at the earliest possible moment.

Table 3.1-4

EXPECTED ANNUAL RADIOACTIVITY RELEASE[1] IN LIQUID EFFLUENTS EXCLUDING TRITIUM

Discharge Rates for Three-Unit Plant

Isotope[2]	Half-Life	Release Rate (Ci/yr[4]) System as Designed	With Demineralizer	With Evaporator
Sr-89[3]	50.6d	2.9×10^{-1}	3.6×10^{-2}	2.9×10^{-3}
Sr-90[3]	28y	7.8×10^{-2}	9.8×10^{-3}	7.8×10^{-4}
Sr-91[3]	9.7h	3.6	4.5×10^{-1}	3.6×10^{-2}
Mo-99[3]	66h	7.7	9.6×10^{-1}	7.7×10^{-2}
I-131	8.05d	3.6	4.5×10^{-1}	3.6×10^{-2}
I-133	20.8h	6.0	7.5×10^{-1}	6.0×10^{-2}
I-135	6.7h	2.7	3.4×10^{-1}	2.7×10^{-2}
Cs-134	2.1y	3.9×10^{-2}	4.9×10^{-3}	3.9×10^{-4}
Cs-137	30y	7.8×10^{-2}	9.8×10^{-3}	7.8×10^{-4}
Ba-140[3]	12.8d	7.7	9.6×10^{-1}	7.7×10^{-2}
Ce-144[3]	284d	1.0×10^{-2}	1.2×10^{-3}	1.0×10^{-4}
Np-239	2.35d	7.8	9.8×10^{-1}	7.8×10^{-2}
Co-58	70d	4.2×10^{-1}	5.2×10^{-2}	4.2×10^{-3}
Co-60	5y	4.2×10^{-2}	5.2×10^{-3}	$4.2\times10^{\cancel{-3}-4}$
	TOTAL	40 Ci/yr	5 Ci/yr	0.4 Ci/yr

1/ Tritium releases are expected to approach about 51 Ci/yr from the plant. The distribution between gaseous and liquid wastes will depend upon the actual amount of water leaving by each route.

2/ Isotopes having a half-life less than 2.3 hours were excluded because the holdup in the plant would generally be sufficient to result in negligible concentrations in released wastes. Other isotopes of the elements listed were considered. The radionuclides Zr-95, Nb-95, Ru-103, Ru-100, Te-129m, Te-132, Nd-147, Na-24, S-35, P-32, Cr-51, Mn-54, Mn-56, Fe-55, Fe-59, Cu-64, Ni-65, Zn-65, Zn-69m, Ag-110m, Ta-182, and W-187 were also considered. These radionuclides may be present, but if present will be negligible or in trace concentrations relative to those isotopes listed and were omitted from the table.

3/ Daughter isotopes, Yttrium, Technetium, Lanthanum, and Praseodynium, may be observed in waste samples in equilibrium with or approaching equilibrium with their parent depending upon sample and analysis timing and procedure.

4/ Although two significant numbers are used in expressing the release rates as a convenience for making further calculations, only one significant figure is warranted by the source data.

Table 3.1-5

Case 1

ESTIMATED QUANTITIES AND CONCENTRATIONS OF RADIOACTIVITY RELEASES AND CALCULATED RADIATION DOSES WITH EXTENDED TREATMENT FOR LIQUIDS AND GASEOUS RADWASTE

Browns Ferry Nuclear Plant - Three-Unit Operation

	0.5% Fuel Defects	Proposed 10 CFR 50 Appendix I Limit
A. Liquid Effluents		
1. Annual total quantity (except tritium)	0.4 Ci	15 Ci
2. Annual average concentration (before dilution in Wheeler Reservoir)	1.1×10^{-10} µCi/ml	2×10^{-8} µCi/ml
3. Annual average concentration of tritium (before dilution in Wheeler Reservoir)	1.4×10^{-8} µCi/ml	5×10^{-6} µCi/ml
4. Annual internal dose to any individual (based on specific isotope identification)		
a. Drinking water	0.082 mrem*	
b. Eating fish	0.012 mrem	
c. Total	0.094 mrem	5 mrem
B. Gaseous Effluents		
1. Annual external dose to any individual	2.8 mrem	10 mrem
C. Total annual dose to any individual	2.9 mrem	---
D. Total estimated population dose within 50-mile radius		
a. External	41.0 man-rems	
b. Drinking water	0.075 man-rems	
c. Eating fish	1.0 man-rems	
d. Total	42.1 man-rems	---

* Dose is 0.01 mrem if dilution in reservoir is assumed.

Table 3.1-6

Case 2
ESTIMATED QUANTITIES AND CONCENTRATIONS OF
RADIOACTIVITY RELEASES AND CALCULATED RADIATION DOSES*
BEFORE COMPLETION OF EXTENDED TREATMENT SYSTEMS

Browns Ferry Nuclear Plant

	First Year Operation	Second Year Operation	Proposed 10 CFR 50 Appendix I Limit
A. Liquid Effluents			
1. Annual total quantity (except tritium)	2.1 Ci	1.4 Ci	10 Ci***
2. Annual average concentration (before dilution in Wheeler Reservoir)	1.3×10^{-9} µCi/ml	4.2×10^{-10} µCi/ml	2×10^{-8} µCi/ml
3. Annual average concentration of tritium (before dilution in Wheeler Reservoir)	1.4×10^{-8} µCi/ml	1.4×10^{-8} µCi/ml	5×10^{-6} µCi/ml
4. Annual internal dose to any individual (based on specific isotope identification)			
a. Drinking water	1.0 mrem**	0.32 mrem**	
b. Eating fish	0.06 mrem	0.04 mrem	
c. Total	1.06 mrem	0.36 mrem	5 mrem
B. Gaseous Effluents			
1. Annual external dose to any individual	111 mrem	10.3 mrem	10 mrem
C. Total annual dose to any individual	112 mrem	10.7 mrem	---
D. Total estimated population dose within 50-mile radius			
a. External	815.0 man-rems	94.0 man-rems	
b. Drinking water	0.4 man-rems	0.3 man-rems	
c. Eating fish	5.0 man-rems	3.3 man-rems	
d. Total	820.4 man-rems	97.6 man-rems	

* Based on 0.5% fuel defects.
** Dose is 0.05 mrem for first year and 0.03 mrem for second year if dilution in reservoir assumed.
*** Limit for two units.

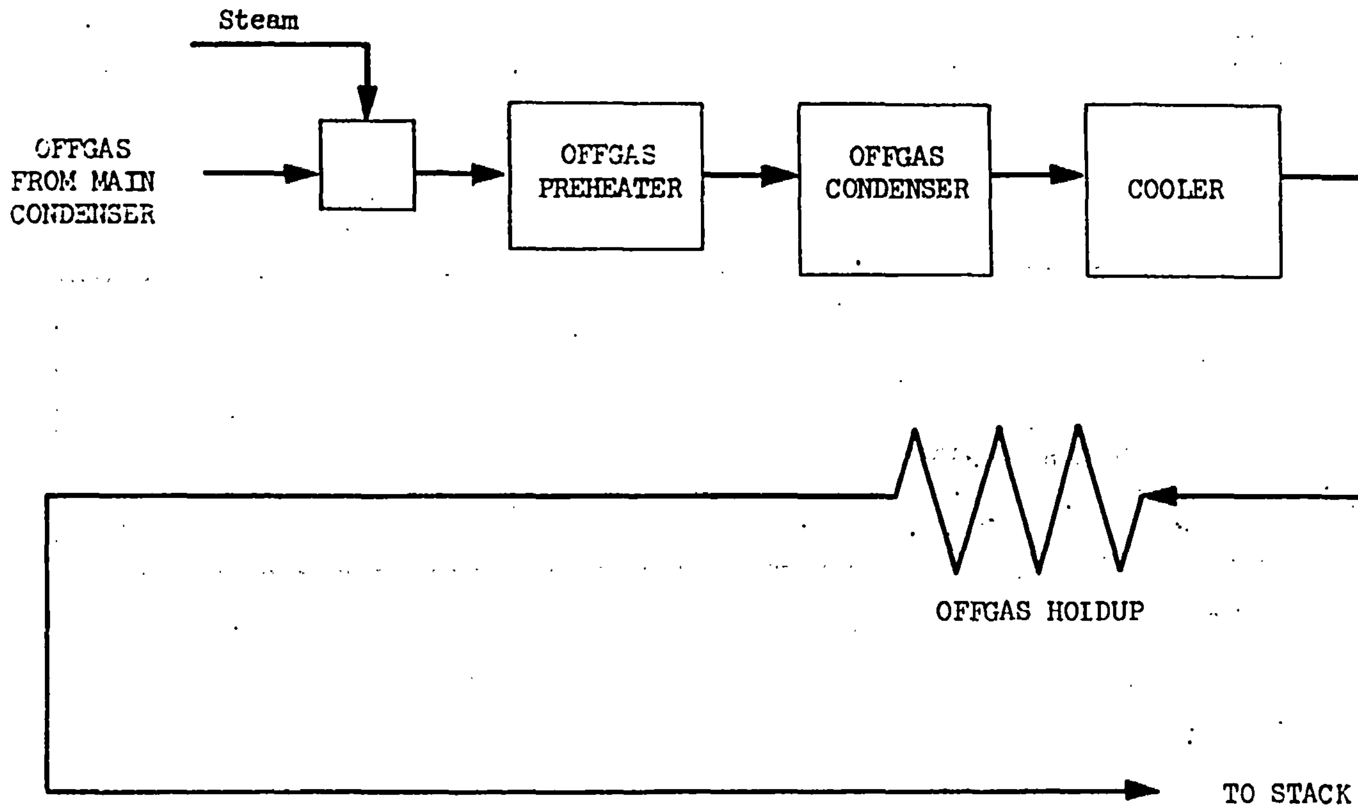


Figure 3.1-1

CONDENSER OFFGAS SYSTEM
AS ORIGINALLY DESIGNED

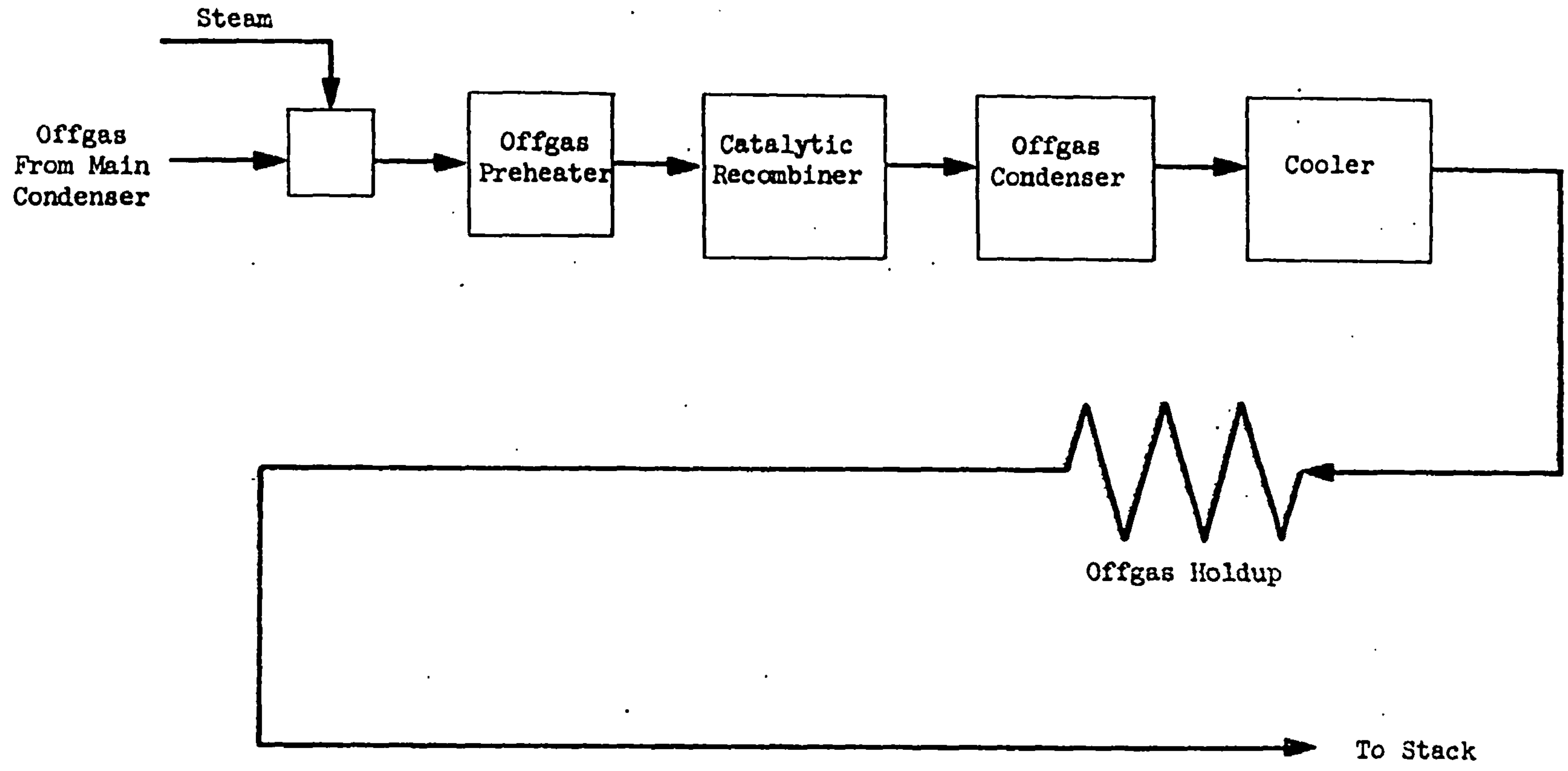


Figure 3.1-2

CONDENSER OFFGAS SYSTEM
WITH HYDROGEN RECOMBINERS

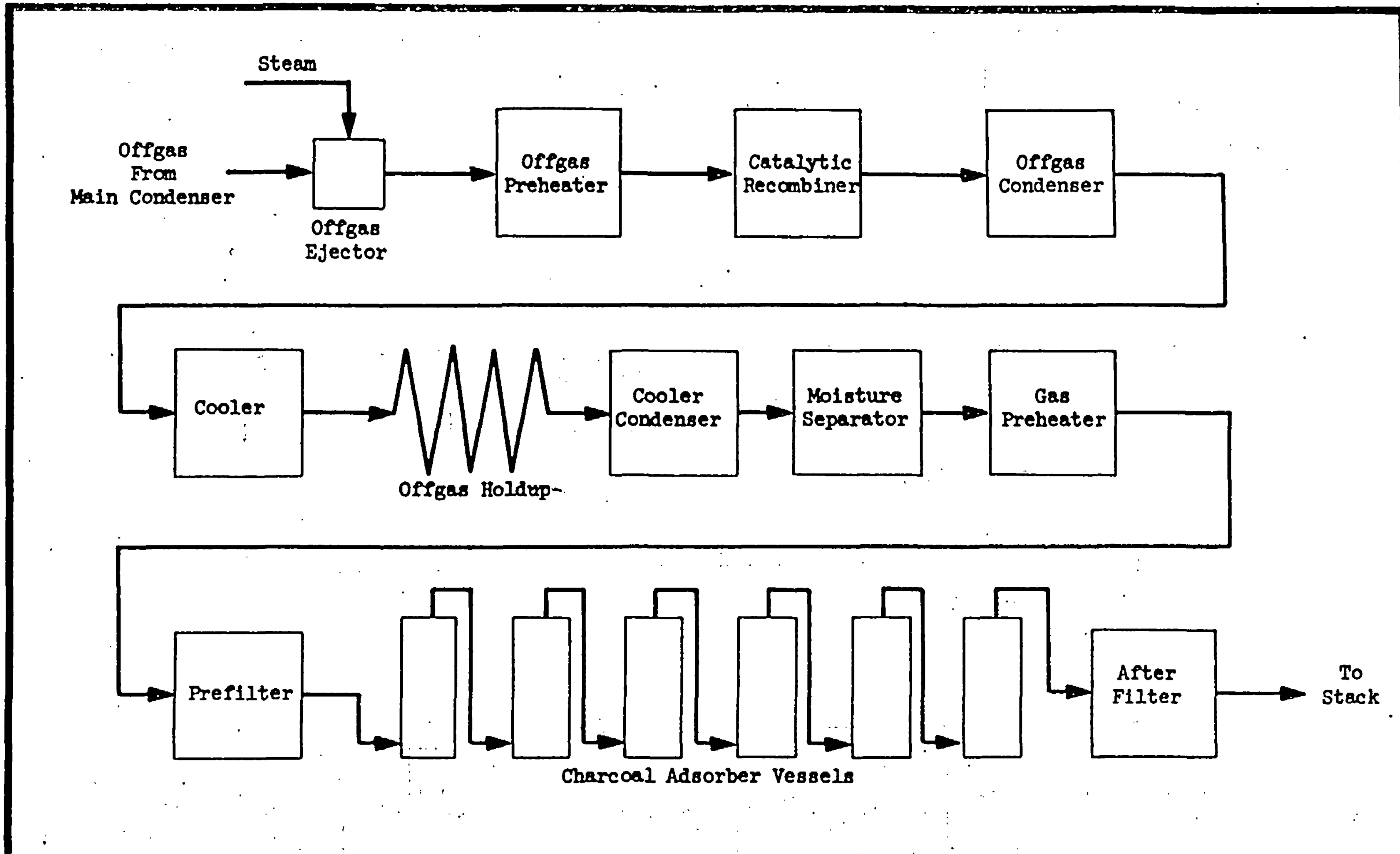


Figure 3.1-3

CONDENSER OFFGAS SYSTEM
CHARCOAL ADSORBERS

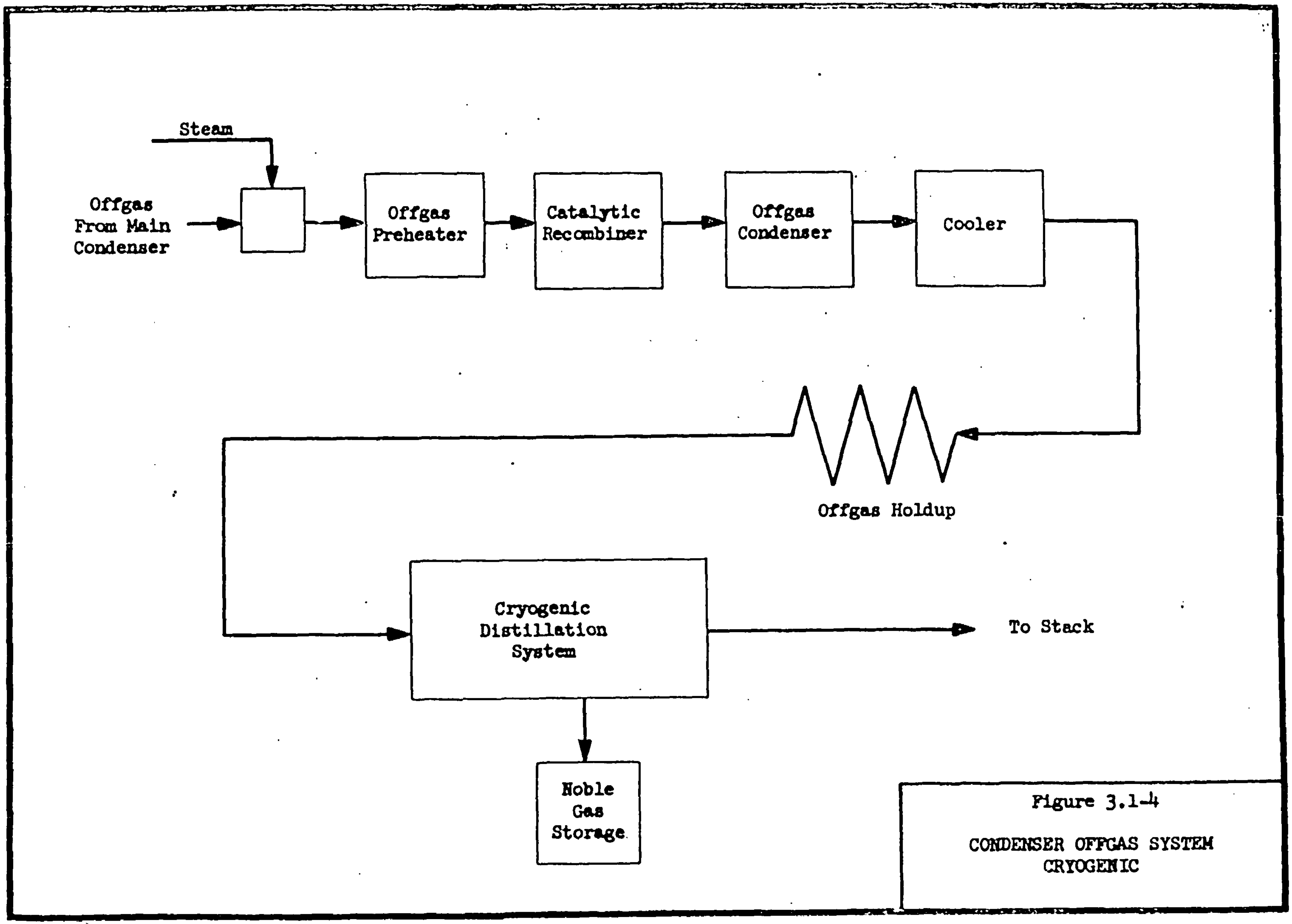


Figure 3.1-4

CONDENSER OFFGAS SYSTEM
CRYOGENIC

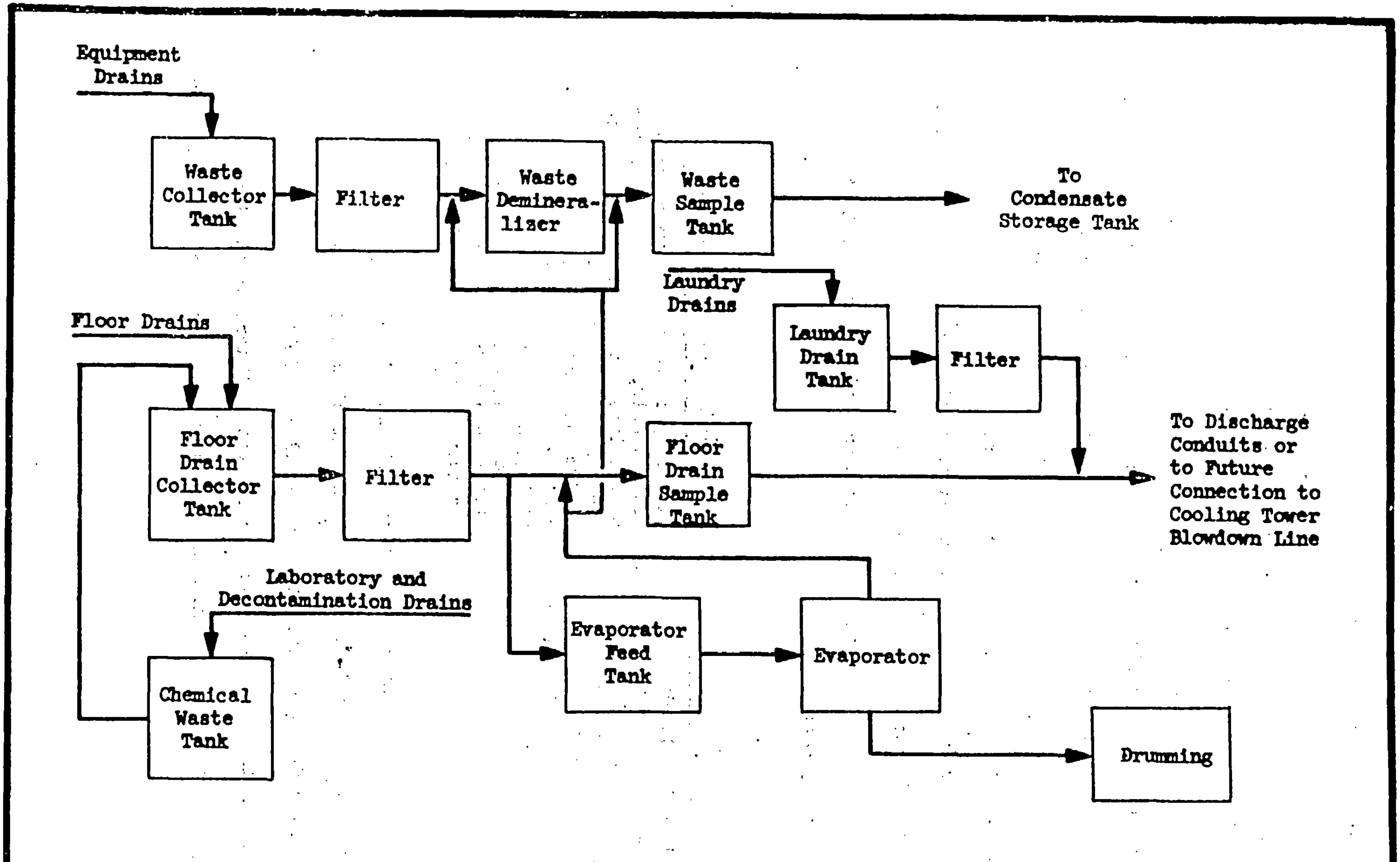


Figure 3.1-5

LIQUID RADWASTE SYSTEM WITH EVAPORATOR

3.2 Heat Dissipation -

1. Water temperature control - objectives and standards - As discussed on pages 5-6 of the 7/14/71 draft of TVA's environmental statement for Browns Ferry, facilities for dispersing the warmed condenser water into Wheeler Reservoir have been planned and constructed by TVA to adequately protect the waters of Wheeler Reservoir for the following uses: public water supply, swimming and other whole body water-contact sports, fish and wildlife, and agricultural and industrial water supply. Of these uses, the propagation of warmwater fish and other aquatic life was judged to be the one requiring the highest degree of protection from thermal effects.

The proposed temperature criteria of the State of Alabama are as follows:

Water Use	Temperature Specifications
Public water Supply Swimming and Other Whole Body Water-Contact Sports Shellfish Harvesting Fish and Wildlife Agricultural and Industrial Water Supply	With respect to cooling water discharges only, the ambient temperature of receiving waters shall not be increased by more than 10°F. by the discharge of such cooling waters, after reasonable mixing; nor shall the discharge of such cooling waters, after reasonable mixing, cause the temperature of the receiving waters to exceed 93°F.

These proposed criteria have been excepted from approval by the Federal Water Pollution Control Administration (now the Water Quality Office of the EPA). On April 5-7, 1971, a Water Quality Standards-Setting Conference for the Interstate Waters of the State of Alabama was held by EPA in Montgomery, Alabama. One of the recommendations made by EPA at this conference was that the State of Alabama adopt temperature standards for streams and reservoirs supporting smallmouth bass, sauger, and walleye that would limit the maximum temperature rise of a stream by the addition of heat to not more than 5°F. with a maximum allowable water temperature not to exceed 86°F. This maximum allowable temperature was to apply to those streams and reservoirs designated by the Alabama Department of Conservation as smallmouth bass, sauger, and walleye fisheries. Wheeler Reservoir has been designated as this type fishery. The State of Alabama has not officially adopted this recommended temperature standard. EPA has previously approved temperature standards for Coastal and Piedmont zone streams in both Virginia and North Carolina that would allow a 5°F. rise and a maximum temperature of 90°F.

2. Existing heat dispersal facilities - It was recognized early in the plant design stages that the condenser water should not be discharged directly into the surface strata of Wheeler Reservoir. Instead, it was decided that, by means of a diffuser, the condenser water should be mixed as quickly as possible with as much unheated river water as possible. By this procedure, no excessively warm surface strata will exist and the mixing zone will be restricted to a relatively very small area.

Based on extensive TVA studies (discussed in section 5.6 of the statement) and the experience of others at the time Browns Ferry was designed, it was concluded that aquatic life would be protected if outside the mixing zone: (1) the average temperature over any cross section should be limited to not more than 93°F. and should not exceed 95°F. at any point at any time, and (2) the rise in temperature of the mixed stream should be limited to not more than 10°F. above natural water temperature at any time. These temperature limits are in agreement with those proposed by the Alabama Water Improvement Commission and were used in design of the Browns Ferry plant beginning in 1965.

The mixing zone will not be permitted to exceed 75 percent of the total cross section of the reservoir. Based on model studies by Massachusetts Institute of Technology and TVA laboratories, the mixing due to the diffusers will not extend more than 200 feet downstream from the outfall.

As presently planned, heat from this plant will be wasted to the adjacent reservoir waters from which it will then be transferred to the atmosphere. The following section describes the thermohydrodynamics of this disposal.

Each unit will have its own distinct flow system consisting of an intake, pumps capable of producing a flow of 1450 cubic feet per second, pipes leading to a turbine condenser, a 25°F. rise turbine condenser, and a discharge pipe leading to an underwater diffuser in Wheeler Reservoir.

All units use a short, common intake channel located on the right bank (plant side), 1200 feet upstream from the diffuser pipes. The intake structure consists of 18 bays each having a traveling screen. The intake is designed such that water is withdrawn from the reservoir over the full depth.

The main channel, where the diffusers are located and mixing takes place, occupies about one-third of the width of the reservoir but carries about 65 percent of the total river flow. The reservoir outside the main channel at this location is approximately one mile wide and three to ten feet deep at minimum pool level. The perforated, corrugated, galvanized steel diffuser pipes are laid side-by-side across the bottom of the 1800-foot wide channel. The channel is approximately 30 feet deep. The pipes are 17 feet, 19 feet and 20 feet 6 inches in diameter and of different lengths. Each has the last 600 feet perforated on the downstream side with more than 7,000 holes two inches in diameter spaced six inches on centers in both directions. These pipes will distribute the three-unit, 4350 cubic feet per second of cooling water evenly near the bottom of the river channel and mix it with the overflowing cooler water.

The diffuser for Unit 1 occupies the central portion of the main river channel while Unit 2 occupies the lefthand (far) third, and Unit 3 the righthand third. The arrangement and design of the diffuser system is shown in figures 3.2-1 and 3.2-2.

3. Reservoir thermohydrodynamics for existing design - For convenience the following discussion has been separated into three sections: (1) the initial jet mixing in the immediate vicinity of the diffusers, (2) an intermediate region covering a 4-6 mile reach upstream and downstream from the plant, and (3) the far field or extended downstream reach where the heat is dissipated into the atmosphere. Furthermore, the discussion first centers on three-unit operation and then moves on to the differences expected when only Unit 1 or Units 1 and 2 are operated.

(1) Three-unit operation -

(a) Initial jet mixing - The heated water is discharged through the two-inch diameter ports at a velocity of about 9 feet per second. Initial mixing of the jets with that portion of the flow passing over the diffusers occurs rapidly. Mixing is complete within about 50 feet. Figure 3.2-3 shows the temperature distribution obtained from model tests in the immediate vicinity of the diffusers for a total steady reservoir flow of 30,000 cubic feet per second. Within a matter of a few feet from the diffuser, the mixed temperature rise is about 13°F. The maximum temperature rise at the reservoir bottom is about 7-8°F. over an area extending a distance of about 30 feet from the diffuser. At distances greater than about 50 feet, the observed temperature rise of 5°F. agrees well with the theoretical rise of 5.5°F. Figure 3.2-4 shows additional temperature distributions for flows of 10,000, 20,000 and 40,000 cubic feet per second.

The steady-state temperature rise of the mixture can be computed from

$$\Delta T_R = \frac{Q_c \Delta T_c}{PQ_R} \qquad (1)$$

where ΔT_R is the temperature rise in the mixture, Q_c is the condenser flow (1450 ft^3s per unit), ΔT_c is the temperature rise in the condenser (25°F.), and P is the portion of the total reservoir flow, Q_R, passing over the active diffusers. Field studies have shown that about 65 percent of the total reservoir flow occurs in the main navigation channel, and results from a three-dimensional model have shown that the flow is uniformly distributed over the length of the diffusers. Thus, the efflux from each diffuser is mixed with one-third of the flow in the main navigation channel.

The temperature of the mixed flow after initial jet mixing can be determined from

$$T_M = T_R + \Delta T_R \tag{2}$$

Where T_M is the mixed temperature and T_R is the ambient river temperature.

It is emphasized that equation (1) predicts steady-state temperatures that are approached asymptotically after any change in flow conditions. At flows above approximately 10,000 cubic feet per second the steady-state temperature rise is approached rapidly; however, at lower flows several hours may be required for the temperature rise to reach its steady-state value. The significance of this is that equation (1) will predict a temperature rise that is too high for the first few hours after the flow is decreased to less than 10,000 cubic feet per second. Figure 3.2-5 shows the steady-state temperature rise as a function of total river flow, not just channel flow. The minimum total river flow required to meet an allowable temperature rise of 10°F. and 5°F. in the warmed surface layers of the channel flow are about 17,000 cubic feet per second and 33,000 cubic feet per second, respectively.

(b) <u>Intermediate region</u> - The behavior of the initial mixed flow at temperature T_M is considerably affected in this region by the fact that T_M is always greater than the upstream natural reservoir temperature and thus stratification may occur.

As the mixed flow (at temperature T_M) leaves the jet mixing region it immediately flows adjacent to that portion of the reservoir flow which did not pass through the jet mixing zone. For three-unit operation, the unaffected reservoir flow is primarily over the shallow portion of the reservoir along the left bank. The density difference between the mixed and natural flows will promote the formation of stratification in which the cooler water will flow from the shallow area into the main river channel downstream from the diffusers while the warmer mixed flow (of temperature T_M) will move laterally over the shallow area and, under certain conditions, upstream against the reservoir flow. The larger the flow in the reservoir, the weaker the stratification will be; for sufficiently large streamflows no upstream wedge will form and the flow leaving the jet mixing zone may form an unstratified flow downstream at a temperature less than the initial mixed temperature, T_M.

A complete quantitative evaluation of the thermal regime on the intermediate region is not yet available; the results of tests on the three-dimensional thermal model, which is now in operation at TVA's Engineering Laboratory, will increase the understanding of the areal distribution but not the depth of the upper strata. It is possible, however, to predict the conditions under which the mixed flow at temperature T_M may move upstream from the diffusers. Model tests show that a reservoir flow of 40,000 cubic feet per second is sufficient to prevent any upstream movement of heated water.

The possible thermal regimes in the intermediate region are qualitatively illustrated in figures 3.2-6, 3.2-7, and 3.2-8. First, figure 3.2-6 shows the case of a reservoir flow less than 40,000 cubic feet per second in which an upstream arrested wedge has formed and in which a two-layer stratification exists with a surface layer of temperature, T_M. The stratification extends over the shallow portion of the reservoir and in the main river channel. Figure 3.2-7 shows a reservoir flow larger than 40,000 cubic feet per second such that no heated water extends upstream from the diffusers but in which the downstream stratification persists. In figure 3.2-8 an even greater reservoir flow has provided sufficient turbulence to destroy the downstream stratification. In this case the highest temperatures are less than T_M since additional mixing has occured. It should be noted that the shallow portion of the reservoir will always experience some temperature rise (but no greater than T_M) either by the formation of a stratified system or by lateral turbulent mixing.

(c) <u>Downstream surface heat loss region</u> - As described in the previous section, a portion of the mixed flow (at temperature T_M) does not immediately spread upstream of the diffusers or laterally into the shallow area adjacent to the diffusers but instead flows downstream with the reservoir current. Initially just below the diffusers, this downstream heated flow is limited to the deep river channel, but within a few miles of the diffusers it spreads over the full width of the reservoir as a heated surface layer. As previously discussed, the degree of vertical stratification is dependent upon the magnitude of the reservoir flow. However, the downstream surface layer loses heat to the atmosphere at a rate which is independent of the depth of the layer.

(d) Downstream surface layer temperature calculations - Temperature studies based on dissipation of heat from the surface to the atmosphere for the flowing water were made for the months of April, July and September for 1954, a relatively warm year; and for 1970, a relatively normal year. Assumptions used in the temperature computations were: the heated water moving downstream would spread laterally over the entire reservoir surface area within a distance of about three miles; that no mixing subsequent to the initial jet mixing would occur; and that no heat would be lost by flow over the local shallow left bank area or due to upstream movement. The spreading assumption is consistent with preliminary observations of the three-dimensional model. The no-mixing assumption will give slightly higher temperatures at high reservoir flow rates; the no-heat loss assumption will give slightly higher temperatures at all discharges.

It is emphasized that temperatures higher than standards will not be permitted to develop as a result of plant operation. Use of temperatures greater than 93°F. in the calculations was for illustrative purposes only.

Environmental heat exchange coefficients and equilibrium temperatures were computed for each of these months based upon monthly average meteorological data. The environmental heat exchange coefficient governs, in part, the rate of heat exchange. The equilibrium temperature is the temperature at which there is no net heat exchange with the environment. If the temperature of the water body is below equilibrium it will gain heat; if its temperature is above equilibrium, it will lose heat.

Observed water temperature data were used as initial reservoir temperatures for 1970; however, no temperature data are available for 1954, and it was assumed that the reservoir temperature was at equilibrium.

Results of this analysis are shown on figures 3.2-9 through 3.2-14 for a range of total river flows from 10,000 to 100,000 cubic feet per second. It is emphasized that these predictions represent average conditions for the specified times.

(2) Two-unit operation -

(a) Initial jet mixing - Results of tests on the three-dimensional model have shown that the reservoir flow is distributed uniformly across the main channel in which the diffusers are located, even if only one or two of the diffuser sections are active. Thus, a two-unit operation will intercept about 44 percent of the total reservoir flow ($P = 0.44$ in equation 2). Since the condenser flow for two units Q_c is also reduced to two-thirds the three-unit value, the mixed temperature, T_M, will be the same and figure 3.2-5 may be used to determine T_M for a given reservoir flow. The jet mixing region will be identical to that described for three units, figures 3.2-3 and 3.2-4, except that the mixing region will occupy only that portion of the river channel intercepted by the active diffuser.

(b) Intermediate region - As discussed above, two-unit operation will result in the same mixed temperature, T_M, for a given reservoir flow. Thus, the temperature of the upper layer in the intermediate region will be the same for two-unit operation as for three units. The flow necessary to prevent an upstream wedge will still be 40,000 cubic feet per second. It is expected that the general thermal regime for two-unit operation will be similar to that described for three units (see figures 3.2-6, 3.2-7, and 3.2-8), except in the immediate vicinity of the diffusers. In this region the reservoir flow passing over the inactive diffuser section (Unit 3) does not mix with the condenser discharge but instead flows downstream of the diffuser to become a part of the lower layer in the intermediate region. The exact configuration of the upper layer (at temperature T_M) is not presently known but will be determined by tests in the three-dimensional thermal model. However, model tests to date have shown clearly that the mixing action of the diffuser does not block the downstream flow of natural water over the inactive diffuser sections.

(c) <u>Downstream surface heat loss region</u> - The downstream flow of heated water (at temperature T_M) for two-unit operation is initially (near the diffusers) only as wide as the active diffuser sections but, as in the three-unit case, the heated surface layer spreads over the full width of the reservoir within a few miles downstream. The initial temperature of the intermediate region (T_M) will be the same for two units as for three but the rate of temperature decrease due to surface heat loss will be greater because of the lesser heat addition.

(d) <u>Downstream surface layer temperature calculations</u> - Temperature studies made for two-unit operation for the same months as for the three-unit operation are shown in figures 3.2-15 through 3.2-20. As explained in the preceding section, the initial mixed temperature downstream from the active diffusers for two-unit operation will be the same as for the three-unit operation.

It was assumed, based on model observations, that the heated water will spread over the entire reservoir width in about three miles.

(3) <u>One-unit operation</u> -

(a) <u>Initial jet mixing</u> - The jet mixing region for one unit will be identical to that described for three units except that the mixing region will occupy only that portion of the river channel intercepted by the active diffuser; thus, only about 22 percent of the total reservoir flow will be mixed with the discharge. The temperature distribution, including the mixed temperature, T_M, is the same as for three-unit operation (see figures 3.2-3, 3.2-4 and 3.2-5).

(b) <u>Intermediate region</u> - As in the case of two-and three-unit operation, the flow necessary to prevent an upstream wedge will be 40,000 cubic feet per second. The thermal regime on the intermediate region (figures 3.2-6, 3.2-7 and 3.2-8) will be similar to that described for three- and two-unit operation with the exception of the region very near the diffuser. Since the diffuser for Unit 1 is located in the center of the channel, reservoir flow will pass unaffected on both sides of the single-unit mixing region and flow downstream to become a part of the intermediate region lower layer.

(c) <u>Downstream surface heat loss region</u> - The downstream flow of heated water (at temperature T_M) for one-unit operation will initially be only as wide as the Unit 1 diffuser section. As with the three- and two-unit cases, the heated flow spreads over the full width of the reservoir within a few miles downstream.

(d) Downstream surface layer temperature calculations - Temperature studies for one-unit operations are shown on figures 3.2-21 through 3.2-26. Again, the mixed temperature downstream from the active diffuser is the same as for the three-unit operation. It was assumed that the entire width of the reservoir was covered in about three miles. Heat will be dissipated from the upper layer most rapidly for the one-unit operation since the total quantity of heat added is lowest.

4. Intake channel and structure - A trapezoidal intake channel leads from the reservoir to the intake structure. For full three-unit operation, the maximum average velocity at the entrance to the intake channel, during the period April-September, when biotic entrainment is of interest will be about 0.7 foot per second. The flow will accelerate to an average velocity of about 1.3 feet per second midway between the entrance and the structure. The intake structure consists of 18 bays that have net openings of 8 feet 8 inches by 20 feet; thus the average velocity will be about 1.4 feet per second during three-unit operation and is independent of the reservoir elevation. The maximum average velocity through the traveling screens which have net openings 3/8" x 3/8" will be about 1.8 feet per second during the April-September period. Intake channel velocities will be reduced to one-third for one-unit operation and to two-third for two-unit operation. Bay and screen velocities will remain the same regardless of the number of units operating.

5. Impact of thermal discharges on observed streamflows - As previously discussed, the operation of the Browns Ferry Nuclear Plant with the present diffuser system will produce stratified conditions in

Wheeler Reservoir under certain flow conditions. However, to obtain an appreciation of what the increases in reservoir temperatures would be if the diffusers were used to disperse the heated water from the plant across the channel width near the bottom, regardless of the number of units operating, a detailed study was made to determine the thermal rise that would have occurred at the Browns Ferry site during the period from 1966 to 1970 for each of the one-unit, two-unit, and three-unit levels of operation. In this study the mean daily releases and weekly tailrace temperatures that actually existed at Wheeler Dam during this period were used to represent conditions at the plant site. It was further assumed that the indicated number of units were in continuous operation and that all condenser flows were mixed with two-thirds of the streamflow. It is realized that modifications of the present diffuser system would be required to achieve complete mixing across the full width of the main channel for one-unit and two-unit operation. However, for three-unit operation, complete mixing with the main channel flow will be achieved without diffuser modification. This study demonstrates that, even without allowance for unit outages which might coincide with periods of low flow and high temperature, special flow regulation would be required for only a small percentage of the time to keep water temperatures in the reservoir below the design control temperatures. The results of this study are shown on Table 3.2-1. During those periods when special controls might be applied, the thermal limits would be met by (1) regulating streamflows at the Browns Ferry site, or (2) decreasing power production, or (3) a combination of both.

The decision as to which approach will be used during these periods will be made only after careful consideration of the potential effects of the special operation on all other uses of the TVA reservoir system.

Mean annual streamflows for the years 1966 through 1970 were 37,550; 57,550; 40,000; 40,460; and 43,760 cubic feet per second, respectively. The long term mean flow is 49,000 cubic feet per second.

The study referred to above also includes an estimate of the number of days during 1966-1970 and the percent of days on which the EPA-recommended temperature standards (5°F. rise with 86°F. maximum) and the EPA-approved temperature standards for North Carolina and Virginia (5°F. rise with 90°F. maximum) would have been equaled or exceeded had streamflows been the same and no additional flow carried out. This latter temperature standard has been included in the study as an intermediate standard for illustrative purposes. It is realized that these estimates are valid only if uniform streamflow were maintained during each day. These results are also shown in Table 3.2-1.

The computed temperature rises for each mode of operation and for each year of the period 1966 to 1970 are shown graphically in figures 3.2-27, 3.2-28, and 3.2-29. For reference, dashed lines representing 5°F. and 10°F. rises above natural temperature, and solid lines representing maximum temperatures of 93°F., 90°F., and 86°F. have been added to the figures. It should be noted that the natural temperature of the river equaled or exceeded 86°F. on 96 or 5.3 percent of the days during the five-year period.

(1) <u>Operating level 1 - One unit at full load</u> - The continuous operation of one unit at full load during the period from 1966 to 1970 would have equaled or exceeded the original

design thermal criteria (which are consistent with the present Alabama temperature standards) on only four days. Similarly, the EPA-recommended standards (5°F. rise with 86°F. maximum) and the alternative standards (5°F. rise and 90°F. maximum) would have been equaled on 228 and 63 days, respectively.

As would be expected, the maximum allowable temperature most frequently controls during the months of July and August when natural temperatures are at their highest.

(2) Operating level 2 - Two units at full load - With continuous operation of two units at full load, the three temperature standards evaluated would have been equaled or exceeded on 58 or 3.2 percent; 490 or 26.8 percent; and 305 or 16.7 percent, respectively, of the days during the five-year period.

(3) Operating level 3 - Three units at full load - The continuous operation of three units would have resulted in equaling or exceeding the three temperature standards evaluated on 165 or 9.0 percent; 886 or 48.5 percent; and 786 or 43.0 percent, respectively, of the days during the period studied. With three units, a 5°F. rise would have been equaled or exceeded on 731 days (40 percent of the days) regardless of the allowable maximum temperature.

LIST OF FIGURES

3.2 Heat Dissipation

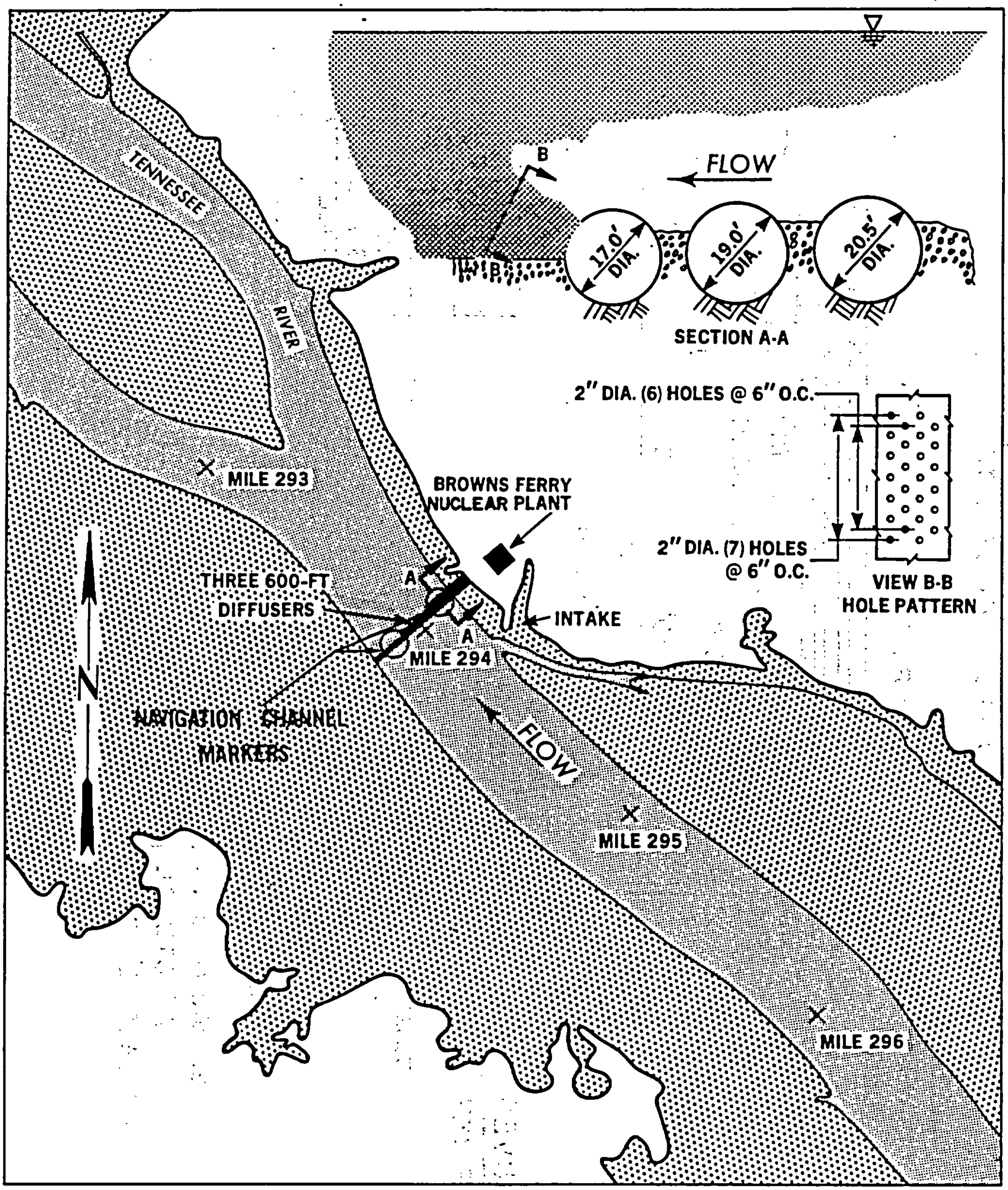


Figure 3.2-1
Diffuser System and Channel Markings

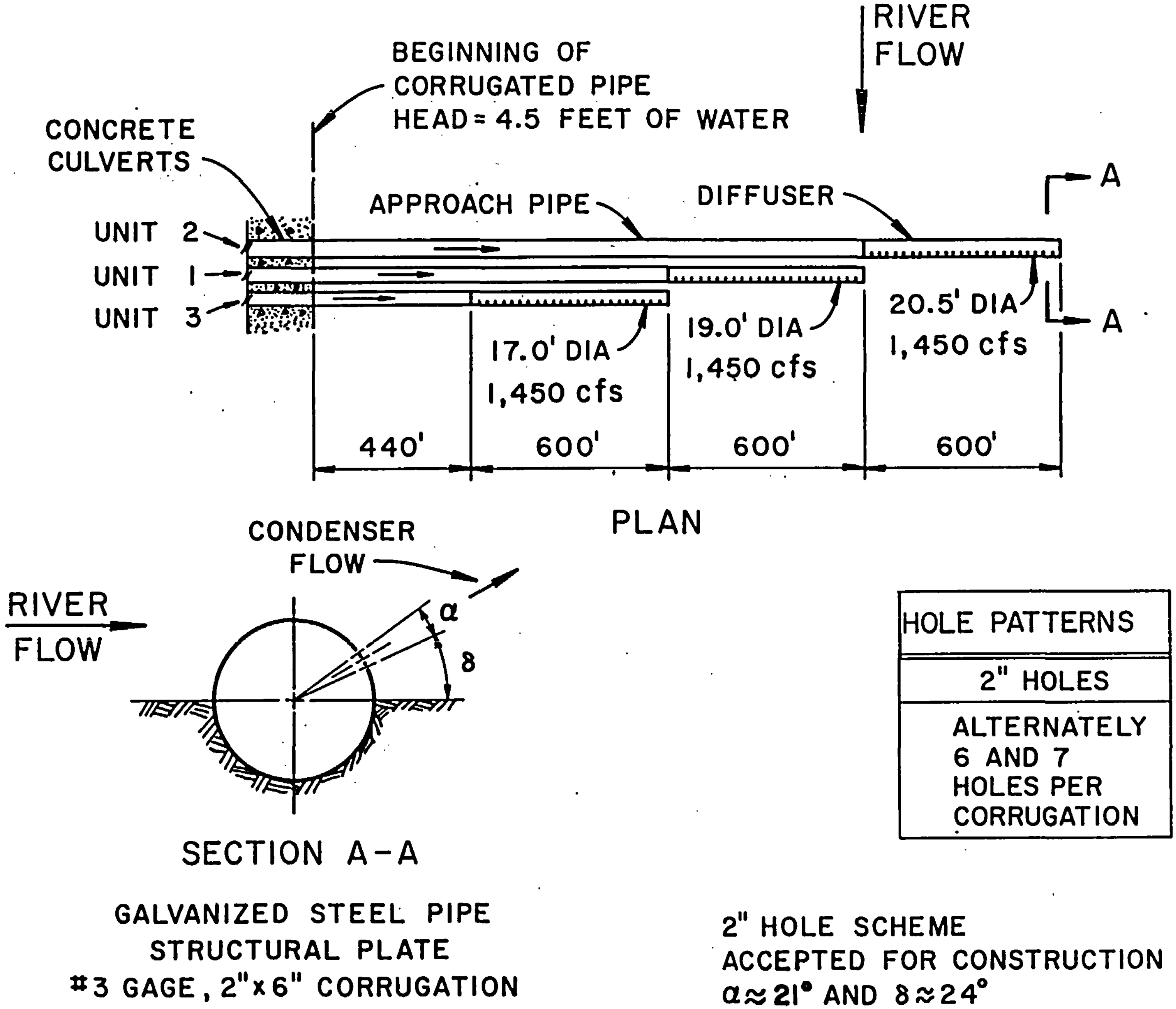


Figure 3.2-2
Diffuser System Design

TABLE 3.2-1

NUMBER AND PERCENT OF THE DAYS DURING THE FIVE YEAR PERIOD 1966-1970 THAT THREE TEMPERATURE CRITERIA WOULD HAVE BEEN EQUALED OR EXCEEDED FOR EACH OF THREE MODES OF OPERATION AT THE BROWNS FERRY NUCLEAR PLANT

Mode of Operation	Present Standards[1/] 10° F. Rise With 93° F. Maximum Days Equaled or Exceeded						Recommended Standards[2/] 5° F. Rise With a 86° F. Maximum Days Equaled or Exceeded						Alternative Standard[3/] 5° F. Rise With a 90° F. Maximum Days Equaled or Exceeded					
	10° F. Rise		93° F. Max.		10° F. Rise Or 93° F. Max.		5° F. Rise		86° F. Max.		5° F. Rise Or 86° F. Max.		5° F. Rise		90° F. Max.		5° F. Rise Or 90° F. Max.	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
One Unit - Full Load																		
1966	0	0	0	0	0	0	16	4.4	42	11.5	57	15.6	16	4.4	1	0.3	16	4.4
1967	1	0.3	0	0	1	0.3	20	5.5	0	0	20	5.5	20	5.5	0	0	20	5.5
1968	2	0.5	0	0	2	0.5	12	3.3	38	10.4	46	12.6	12	3.3	2	0.5	13	3.6
1969	1	0.3	0	0	1	0.3	2	0.5	48	13.2	48	13.2	2	0.5	10	2.7	11	3.0
1970	0	0	0	0	0	0	3	0.8	55	15.1	57	15.6	3	0.8	0	0	3	0.8
TOTALS	4	0.2	0	0	4	0.2	53	2.9	183	10.0	228	12.5	53	2.9	13	0.7	63	3.5
Two Units - Full Load																		
1966	16	4.4	2	0.5	17	4.7	71	19.5	63	17.3	111	30.4	71	19.5	14	3.8	81	22.2
1967	20	5.5	0	0	20	5.5	37	10.1	2	0.5	37	10.1	37	10.1	0	0	37	10.1
1968	12	3.3	4	1.1	13	3.6	75	20.5	71	19.4	125	34.2	75	20.5	17	4.6	79	21.6
1969	2	0.5	3	0.8	4	1.1	45	12.3	80	21.9	107	29.3	45	12.3	31	8.5	62	17.0
1970	3	0.8	1	0.3	4	1.1	41	11.2	88	24.1	110	30.1	41	11.2	12	3.3	46	12.6
TOTALS	53	2.9	10	0.5	58	3.2	269	14.7	304	16.6	490	26.8	269	14.7	74	4.1	305	16.7
Three Units - Full Load																		
1966	44	12.1	15	4.1	50	13.7	172	47.1	89	24.4	205	56.2	172	47.1	44	12.1	180	49.3
1967	25	6.8	3	0.8	25	6.8	55	15.1	15	4.1	55	15.1	55	15.1	7	1.9	55	15.1
1968	44	12.0	15	4.1	46	12.6	176	48.2	104	28.4	221	60.4	176	48.2	40	10.9	189	51.6
1969	11	3.0	20	5.5	26	7.1	177	48.5	95	26.0	208	57.0	177	48.5	49	13.4	190	52.1
1970	13	3.6	10	2.7	18	4.9	151	41.4	104	28.4	197	54.0	151	41.4	48	13.2	172	47.1
TOTALS	137	7.5	63	3.5	165	9.0	731	40.0	407	22.3	886	48.5	731	40.0	188	10.3	786	43.0

1. Present temperature standards of the State of Alabama.
2. Temperature standards recommended to the State of Alabama by EPA.
3. Temperature standards that EPA has approved in North Carolina and Virginia.

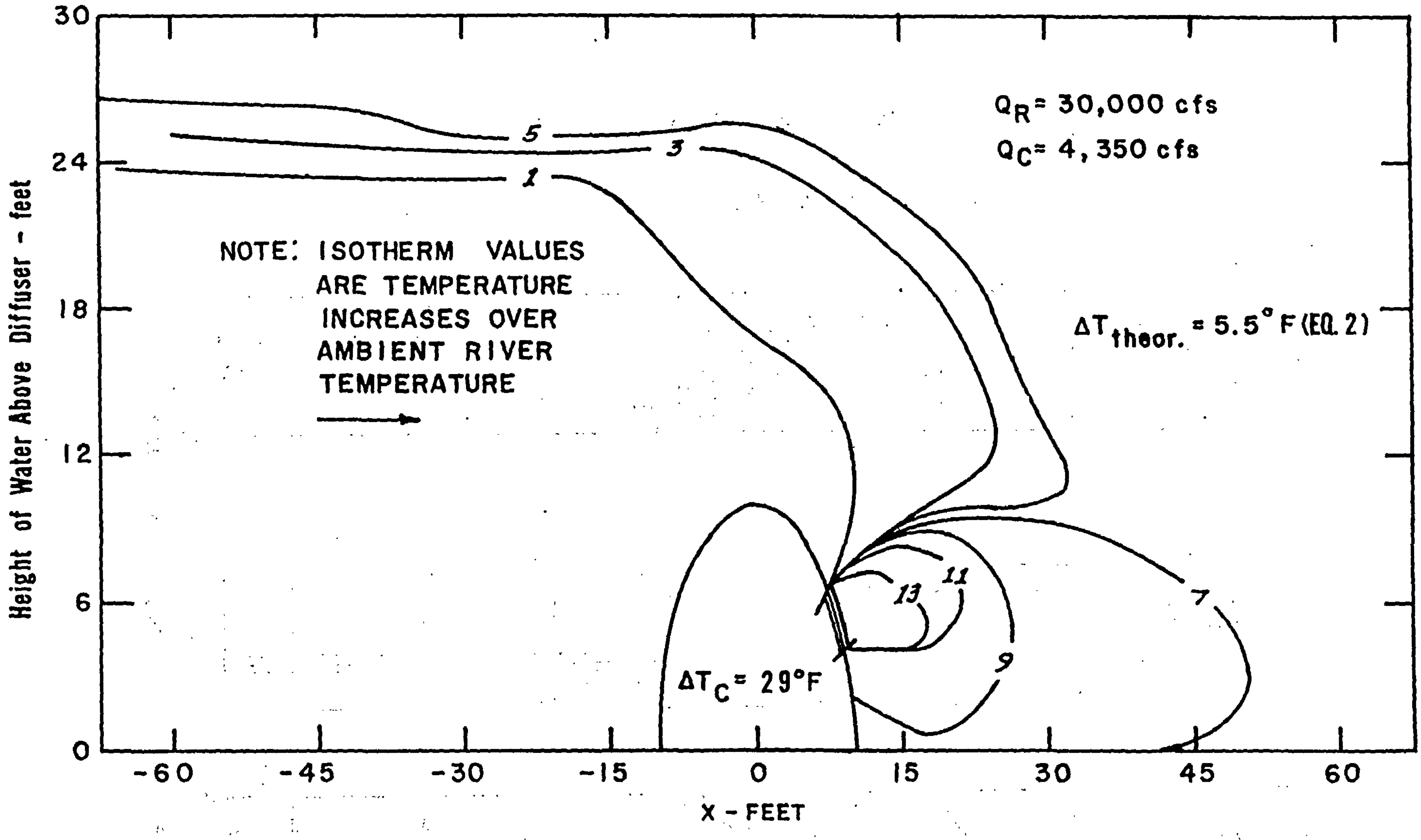


FIGURE 3.2-3 TEMPERATURE SURVEY IN VICINITY OF JET PORTS WITH ΔT_c OF 29° F (ΔT_c FOR BROWNS FERRY IS 25°F)

NOTE: ISOTHERM VALUES ARE TEMPERATURE INCREASES OVER AMBIENT RIVER TEMPERATURE

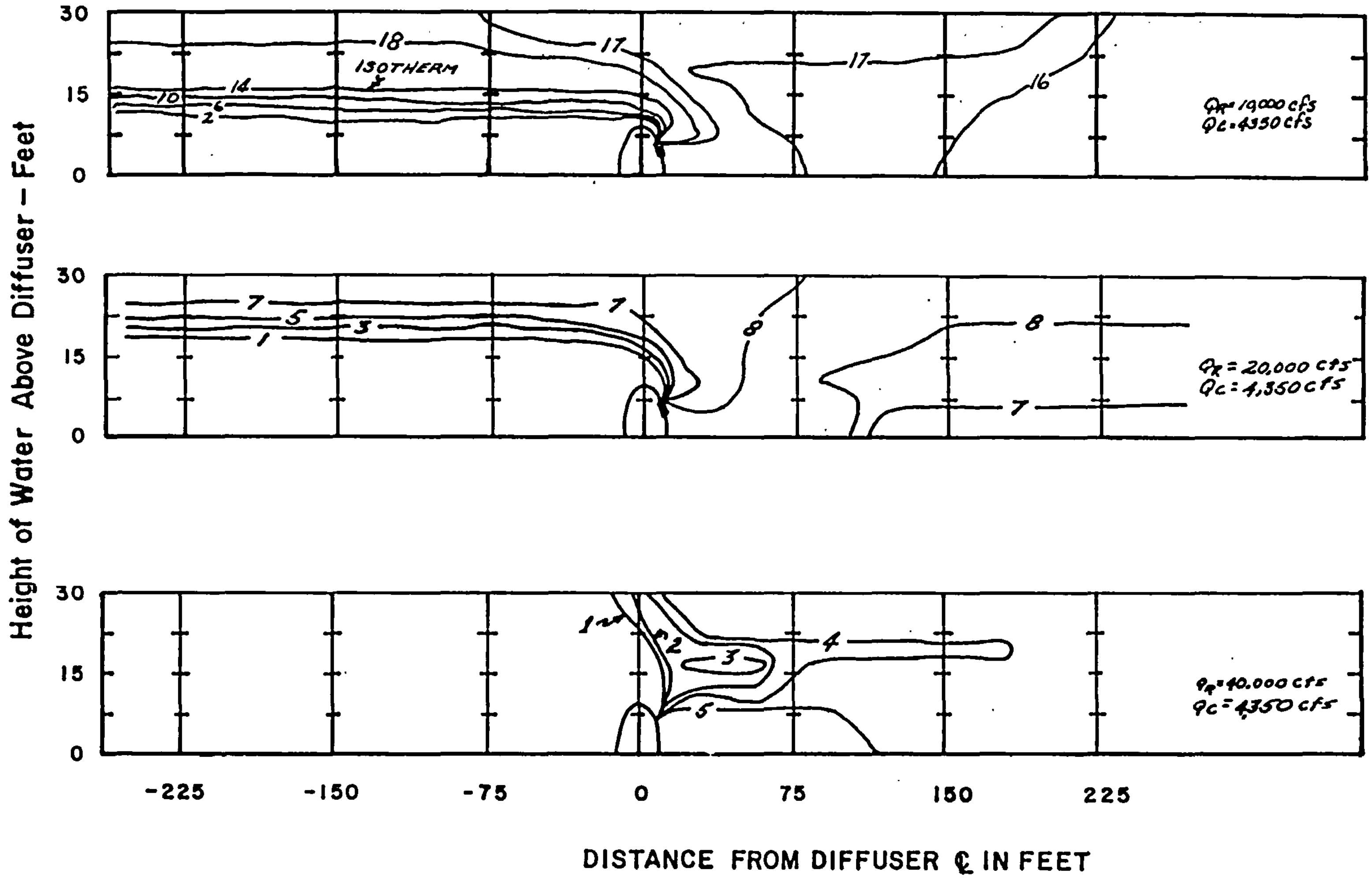


FIGURE 3.2-4 ISOTHERMS FOR STEADY STATE RIVER FLOWS

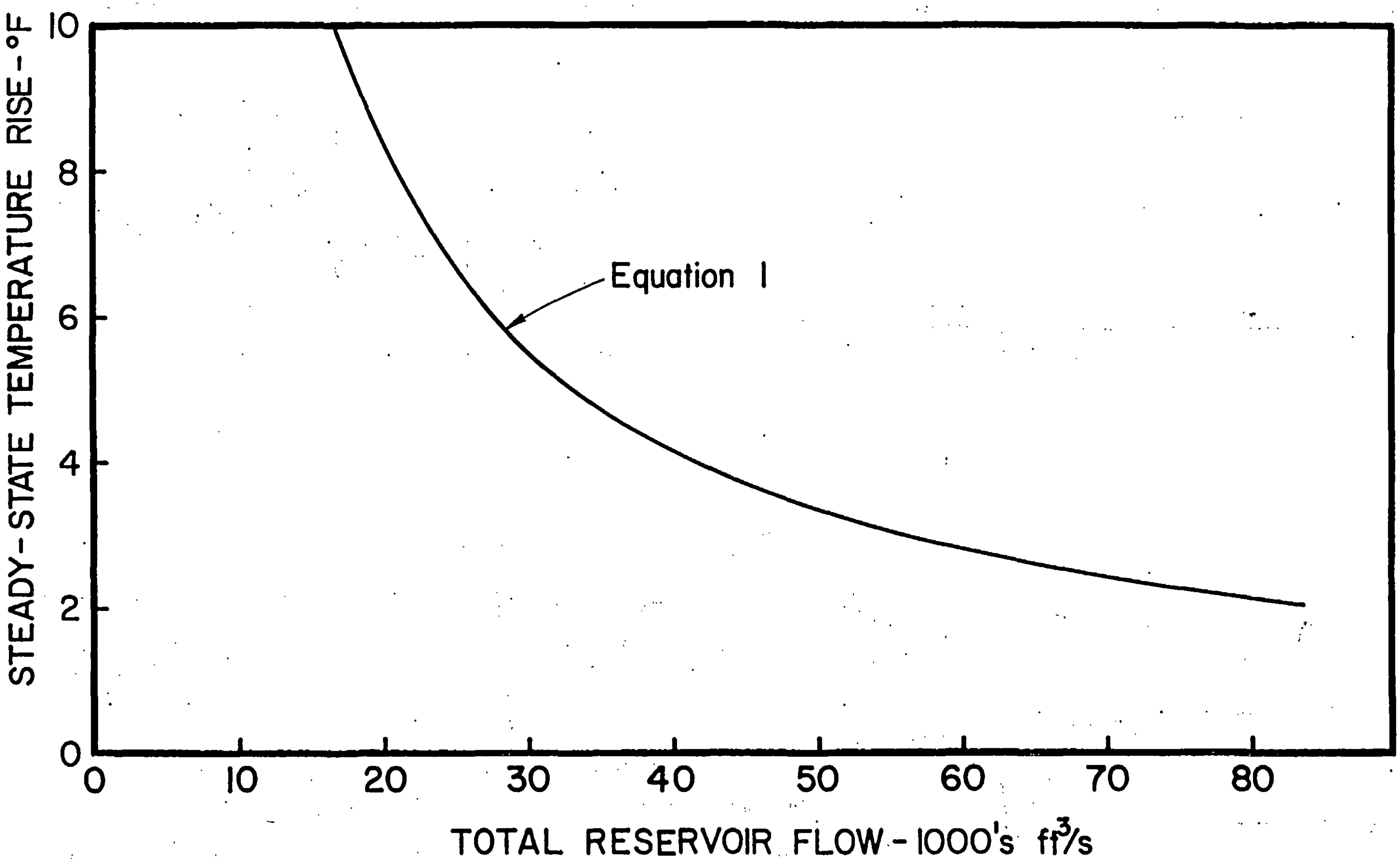


Figure 3.2-5
BFNP
3 UNIT OPERATION

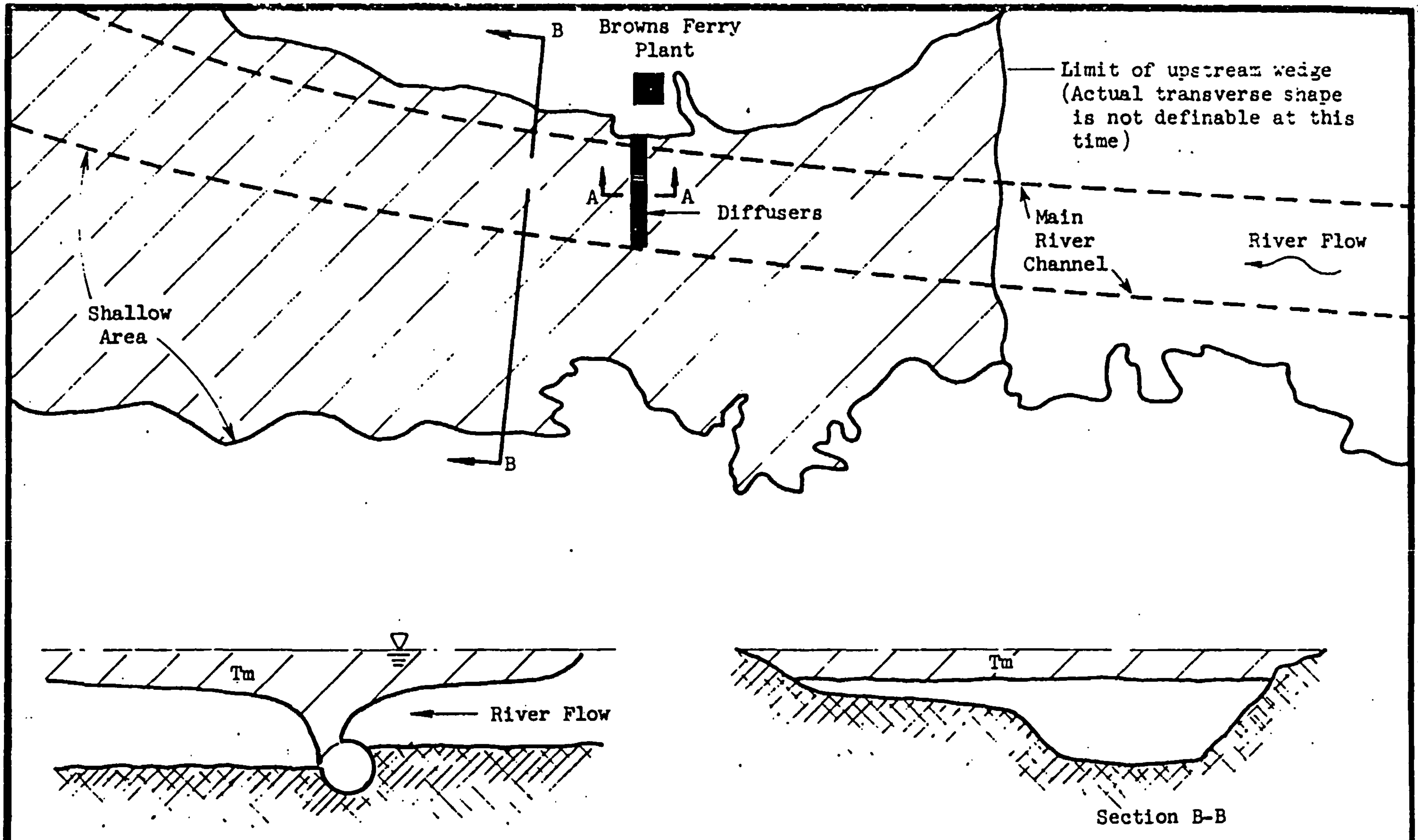


Figure 3.2-6
TEMPERATURE REGIME
FOR Q_R < 40,000

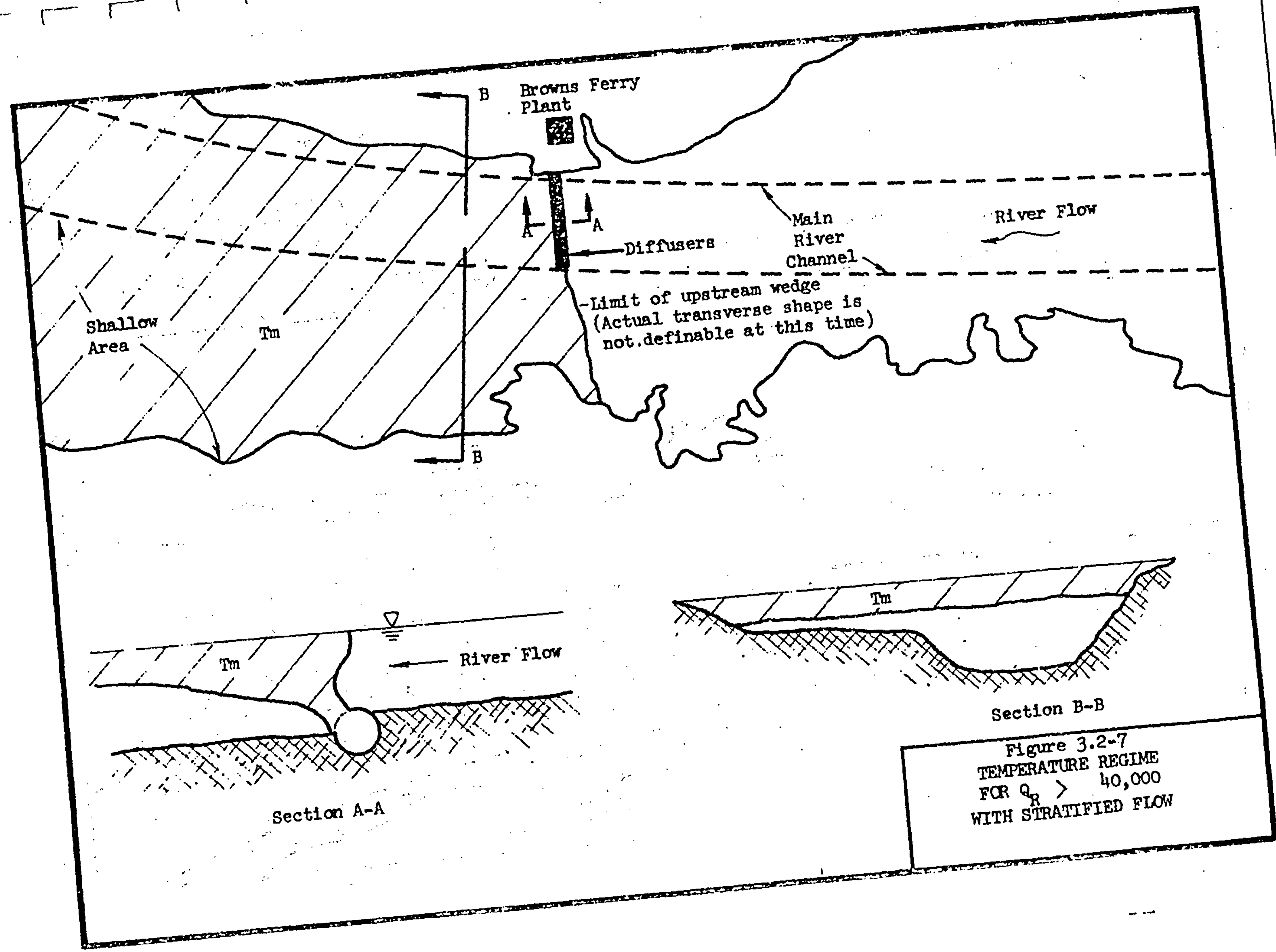


Figure 3.2-7
TEMPERATURE REGIME
FOR Q_R > 40,000
WITH STRATIFIED FLOW

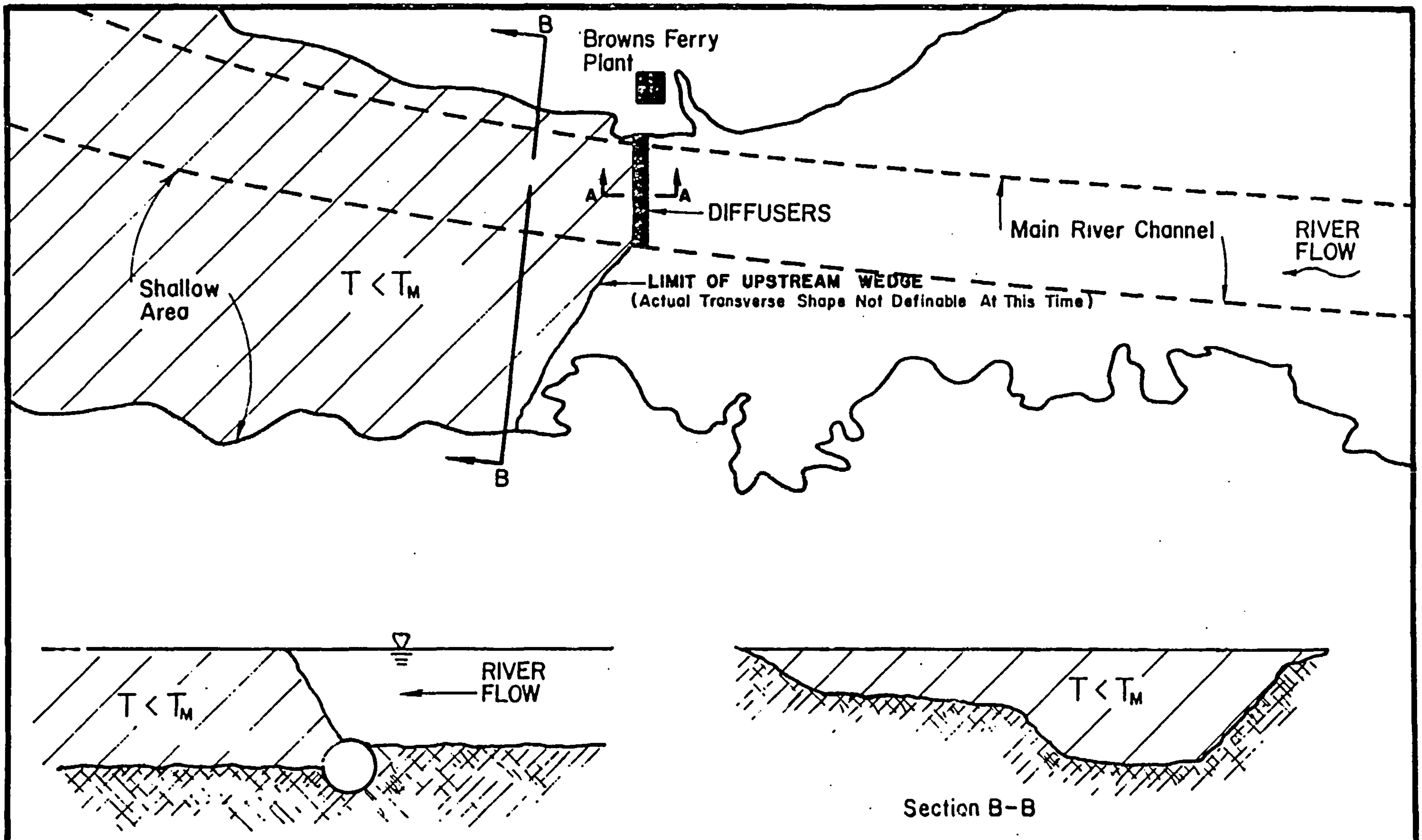


Figure 3.2-8
TEMPERATURE REGIME
FOR $Q_R \gg 40,000$
NO STRATIFICATION

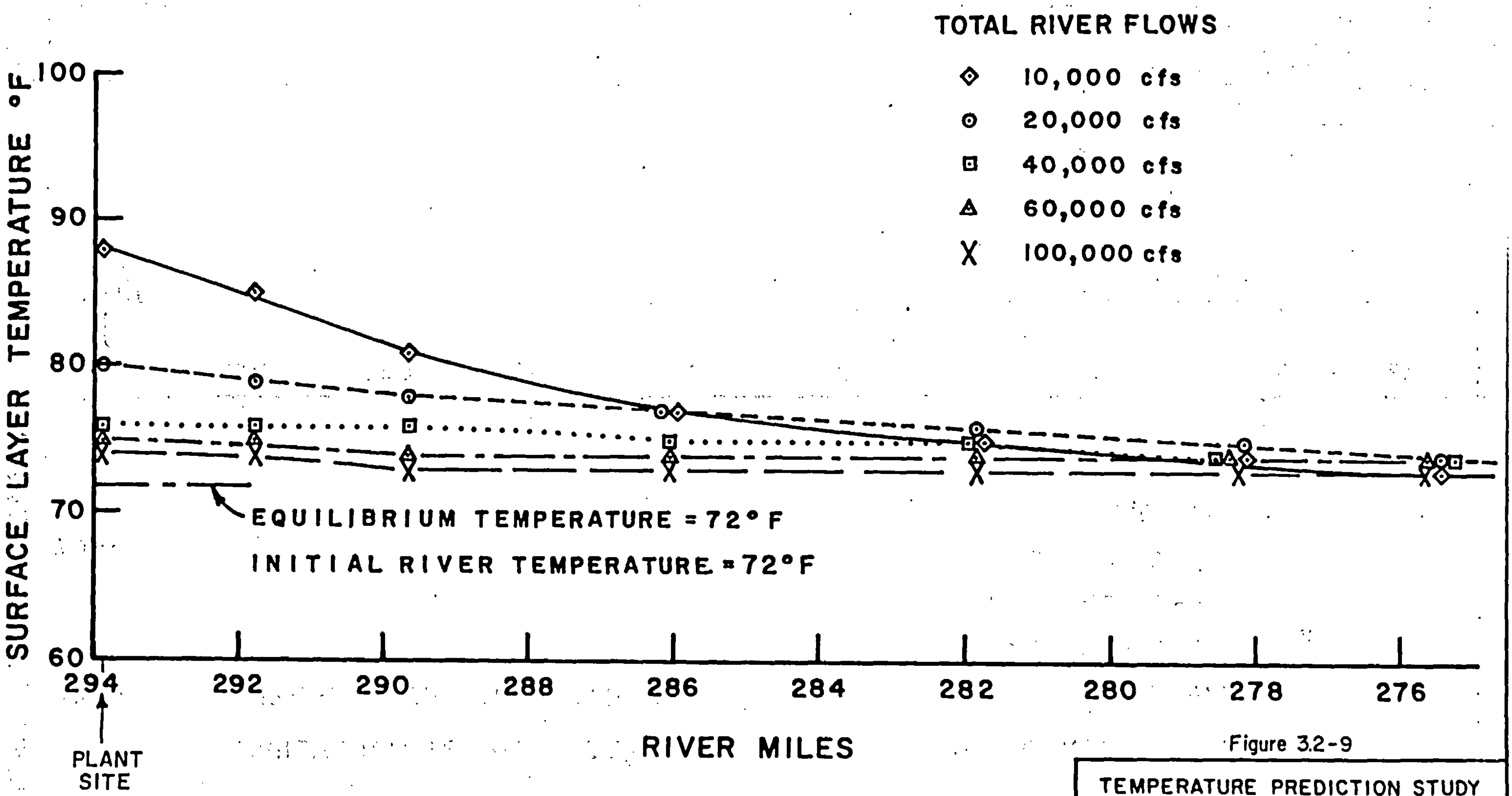


Figure 3.2-9

TEMPERATURE PREDICTION STUDY

RIVER TEMPERATURE DATA
3 UNITS — 1800' DIFFUSER
APRIL, 1954

BROWNS FERRY NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY

DRAWN	ENGINEER
ELT	
CHECKED	APPROVED

NORRIS	9-17-71	67	EL	920	A-

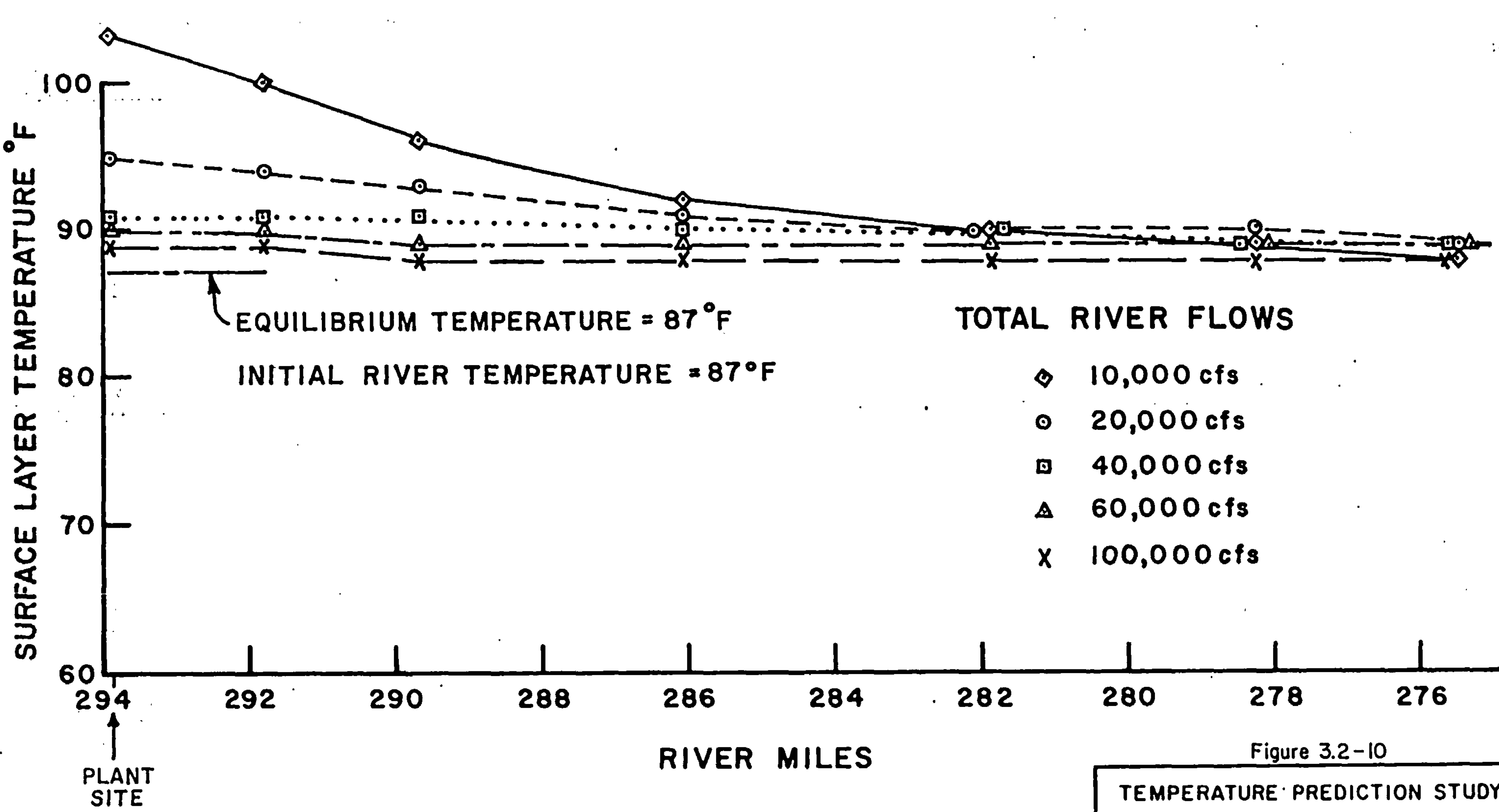


Figure 3.2-10

TEMPERATURE PREDICTION STUDY

RIVER TEMPERATURE DATA
3 UNITS – 1800' DIFFUSER
JULY, 1954

BROWNS FERRY NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY

DRAWN	ENGINEER
ELT	
CHECKED	APPROVED

NORRIS	9-17-71	67	EL	920	A-

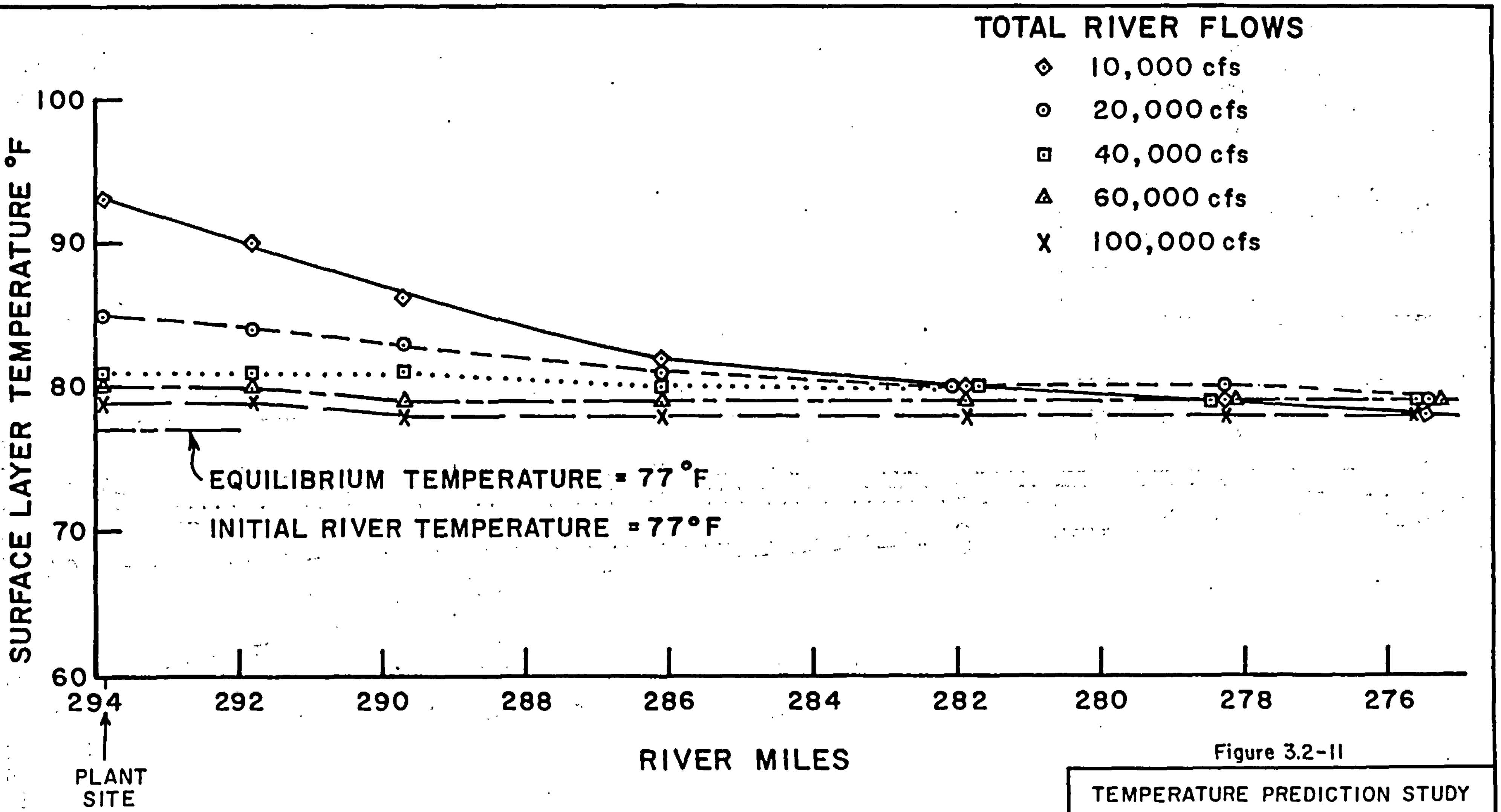


Figure 3.2-11

TEMPERATURE PREDICTION STUDY

RIVER TEMPERATURE DATA
3 UNITS – 1800' DIFFUSER
SEPTEMBER, 1954

BROWNS FERRY NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY

NORRIS	9-17-71	67	EL	920	A-

DRAWN	ENGINEER
ELT	
CHECKED	APPROVED

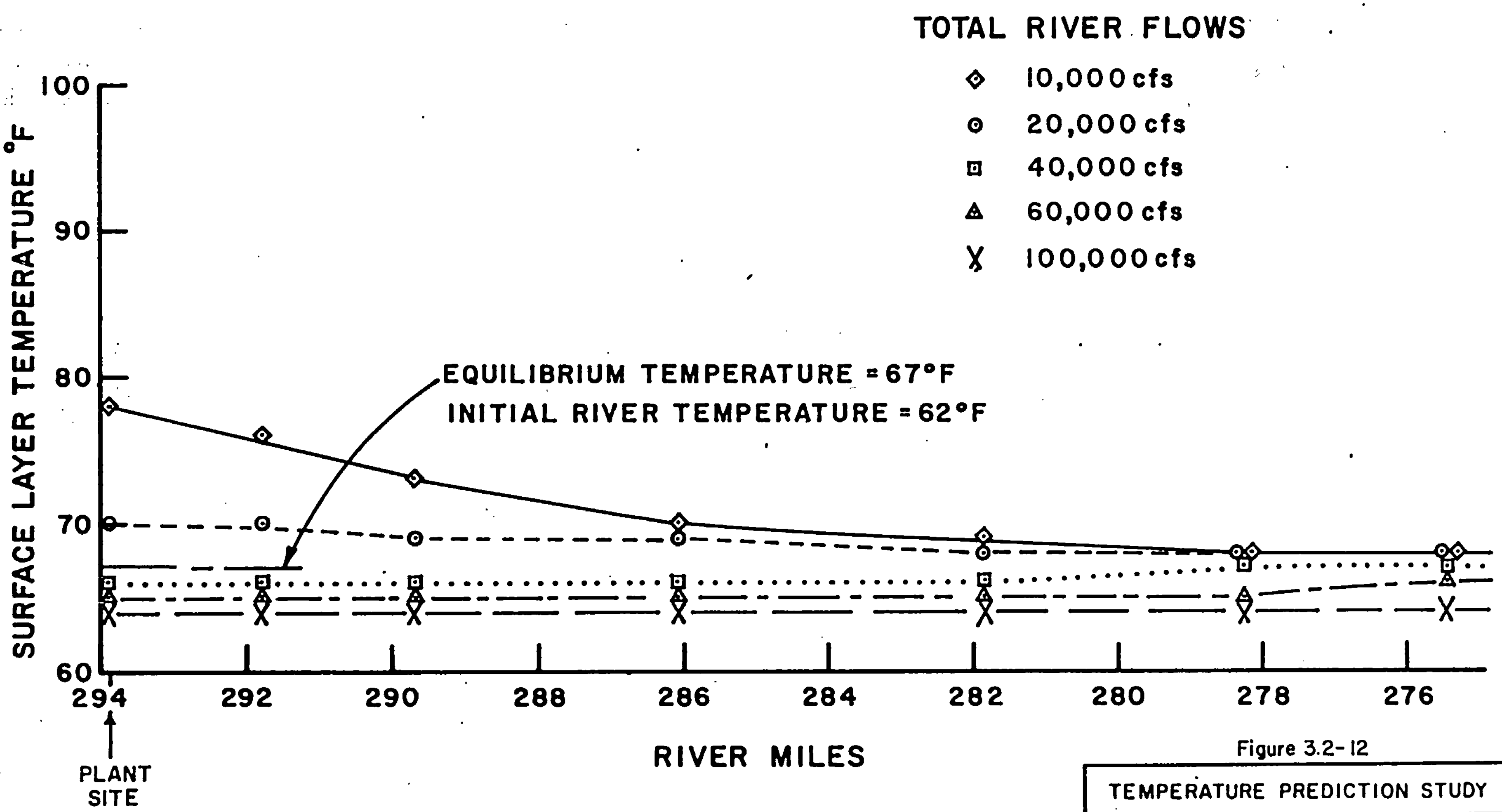


Figure 3.2-12

TEMPERATURE PREDICTION STUDY

RIVER TEMPERATURE DATA
3 UNITS—1800' DIFFUSER
APRIL, 1970

BROWNS FERRY NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY

NORRIS	9-17-71	67	EL	920	A-

DRAWN ELT	ENGINEER
CHECKED	APPROVED

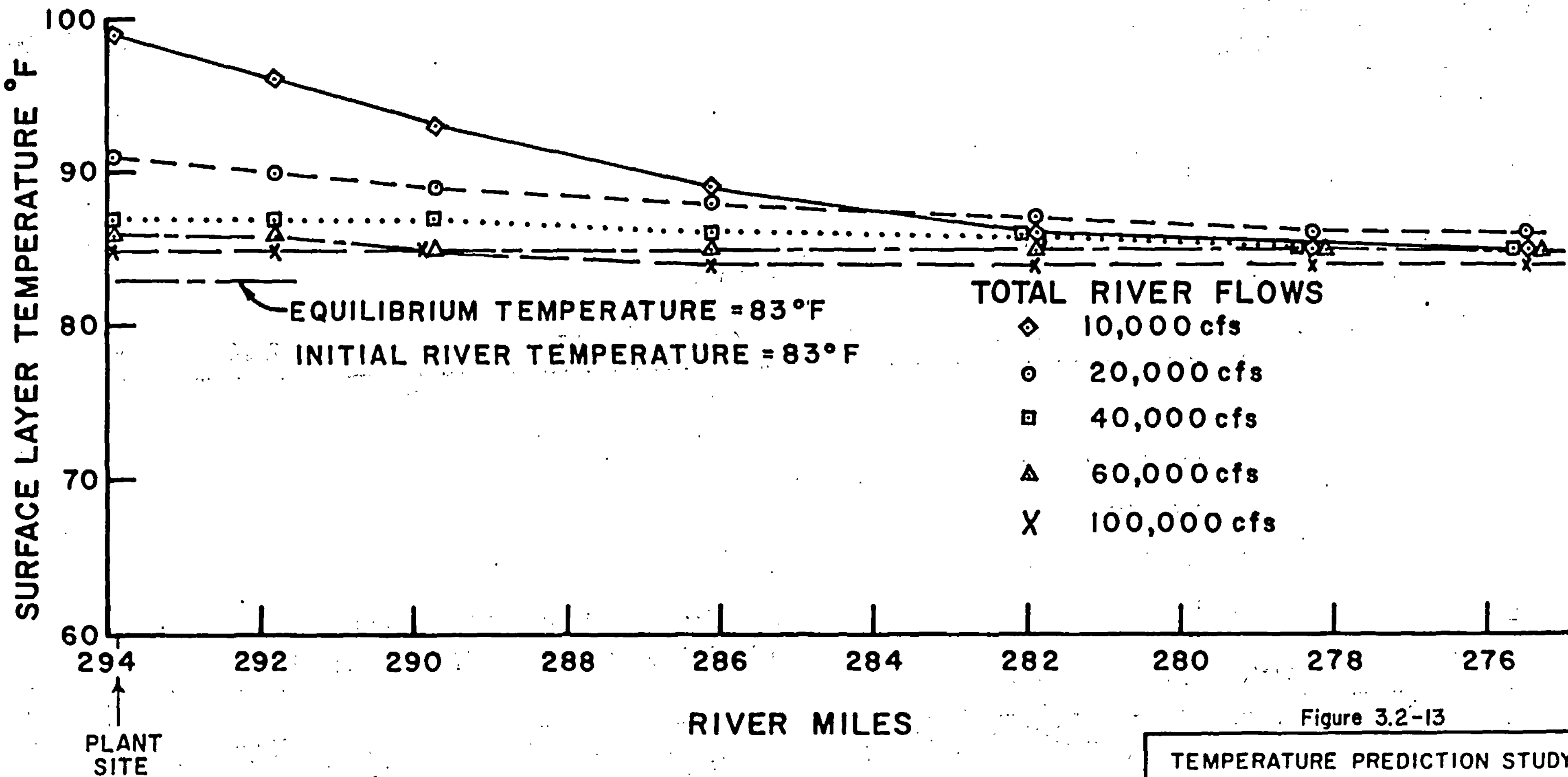


Figure 3.2-13

TEMPERATURE PREDICTION STUDY

RIVER TEMPERATURE DATA
3 UNITS—1800' DIFFUSER
JULY, 1970

BROWNS FERRY NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY

NORRIS	9-17-71	67	EL	920	A-

DRAWN ELT	ENGINEER
CHECKED	APPROVED

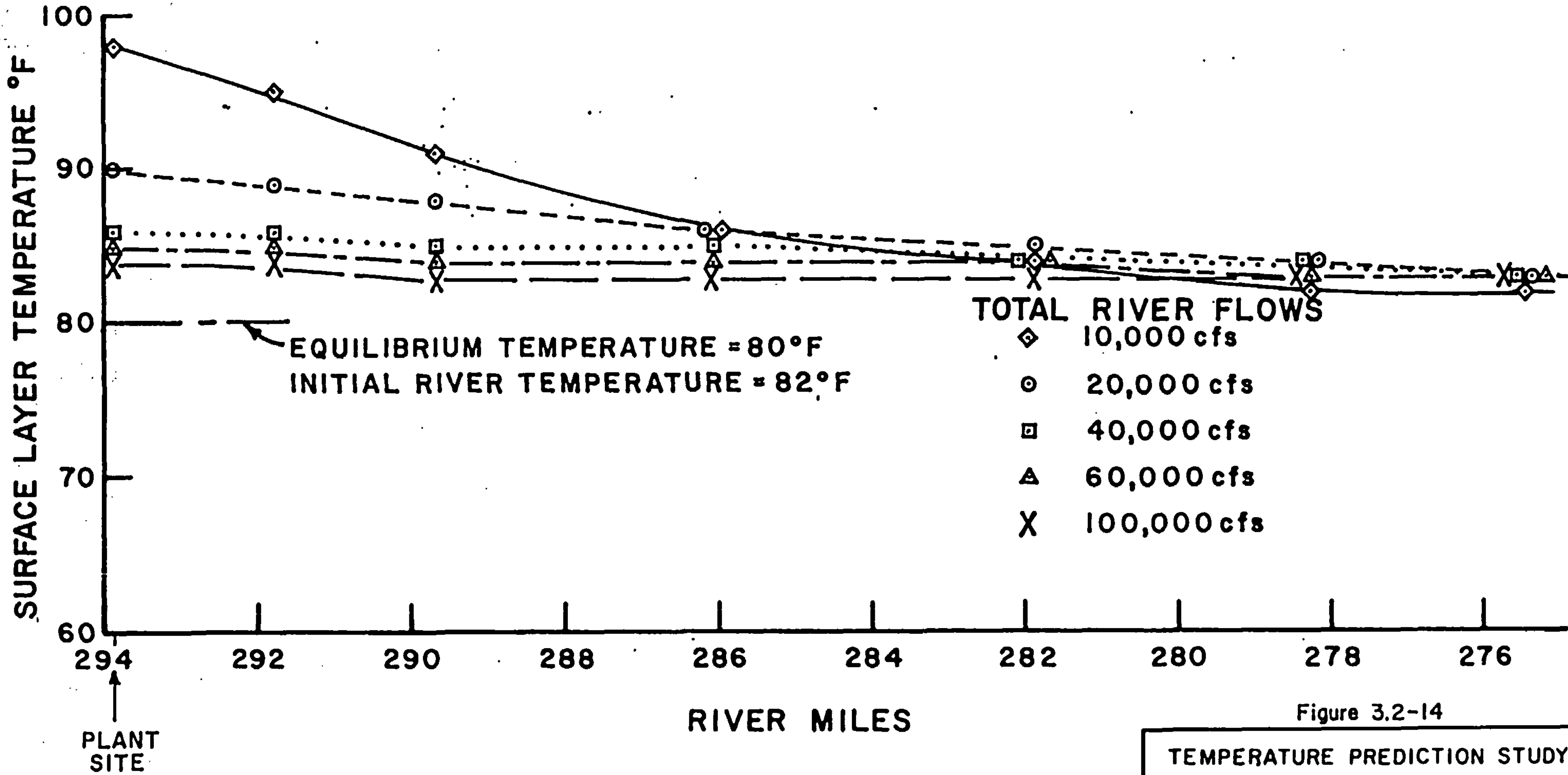


Figure 3.2-14

TEMPERATURE PREDICTION STUDY

RIVER TEMPERATURE DATA
3 UNITS—1800' DIFFUSER
SEPTEMBER, 1970

BROWNS FERRY NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY

DRAWN ELT	ENGINEER
CHECKED	APPROVED

NORRIS	9-17-71	67	EL	920	A-

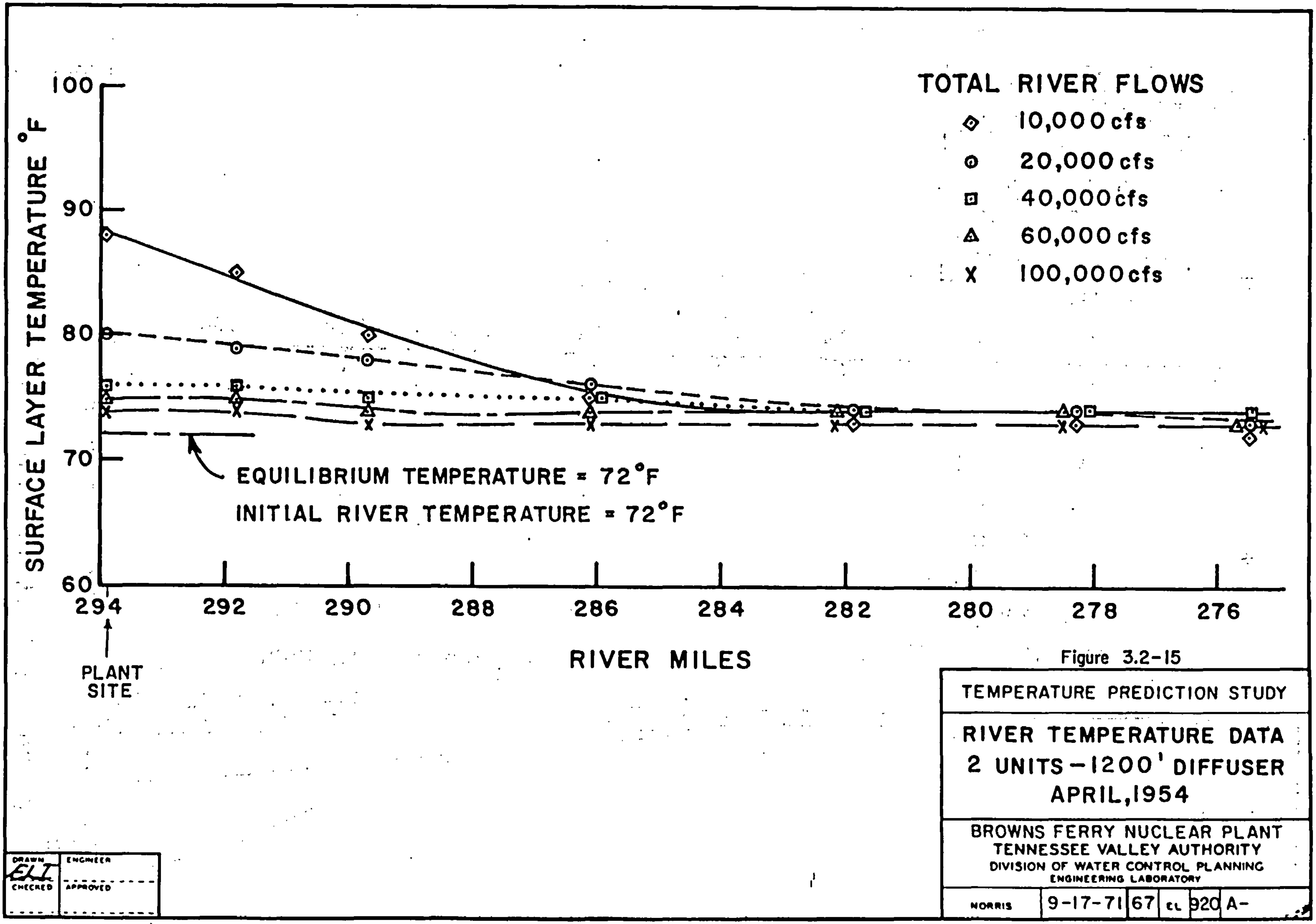


Figure 3.2-15

TEMPERATURE PREDICTION STUDY

RIVER TEMPERATURE DATA
2 UNITS – 1200' DIFFUSER
APRIL, 1954

BROWNS FERRY NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY

NORRIS 9-17-71 67 EL 920 A-

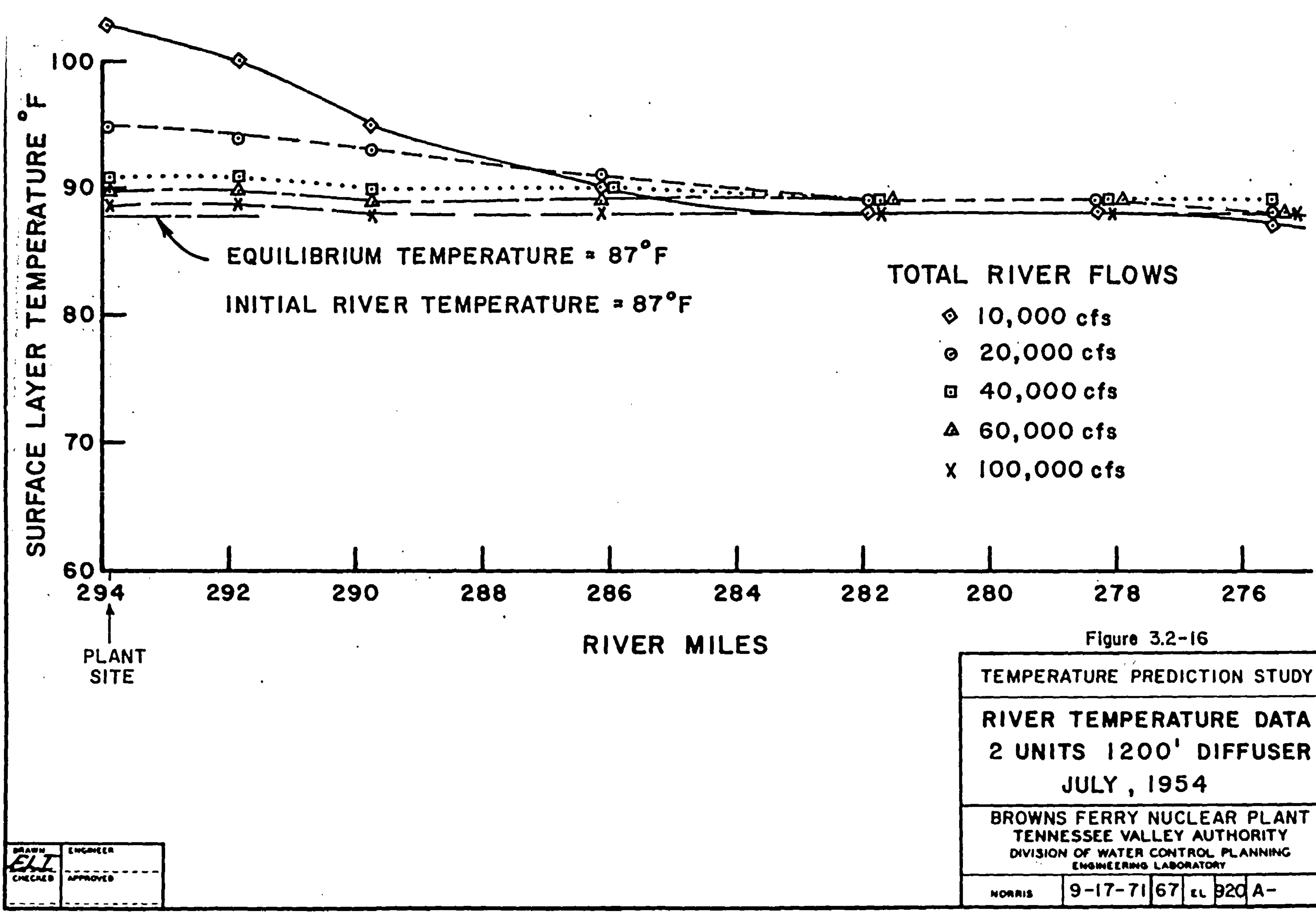


Figure 3.2-16

TEMPERATURE PREDICTION STUDY
RIVER TEMPERATURE DATA 2 UNITS 1200' DIFFUSER JULY, 1954
BROWNS FERRY NUCLEAR PLANT TENNESSEE VALLEY AUTHORITY DIVISION OF WATER CONTROL PLANNING ENGINEERING LABORATORY
NORRIS 9-17-71 67 EL 920 A-

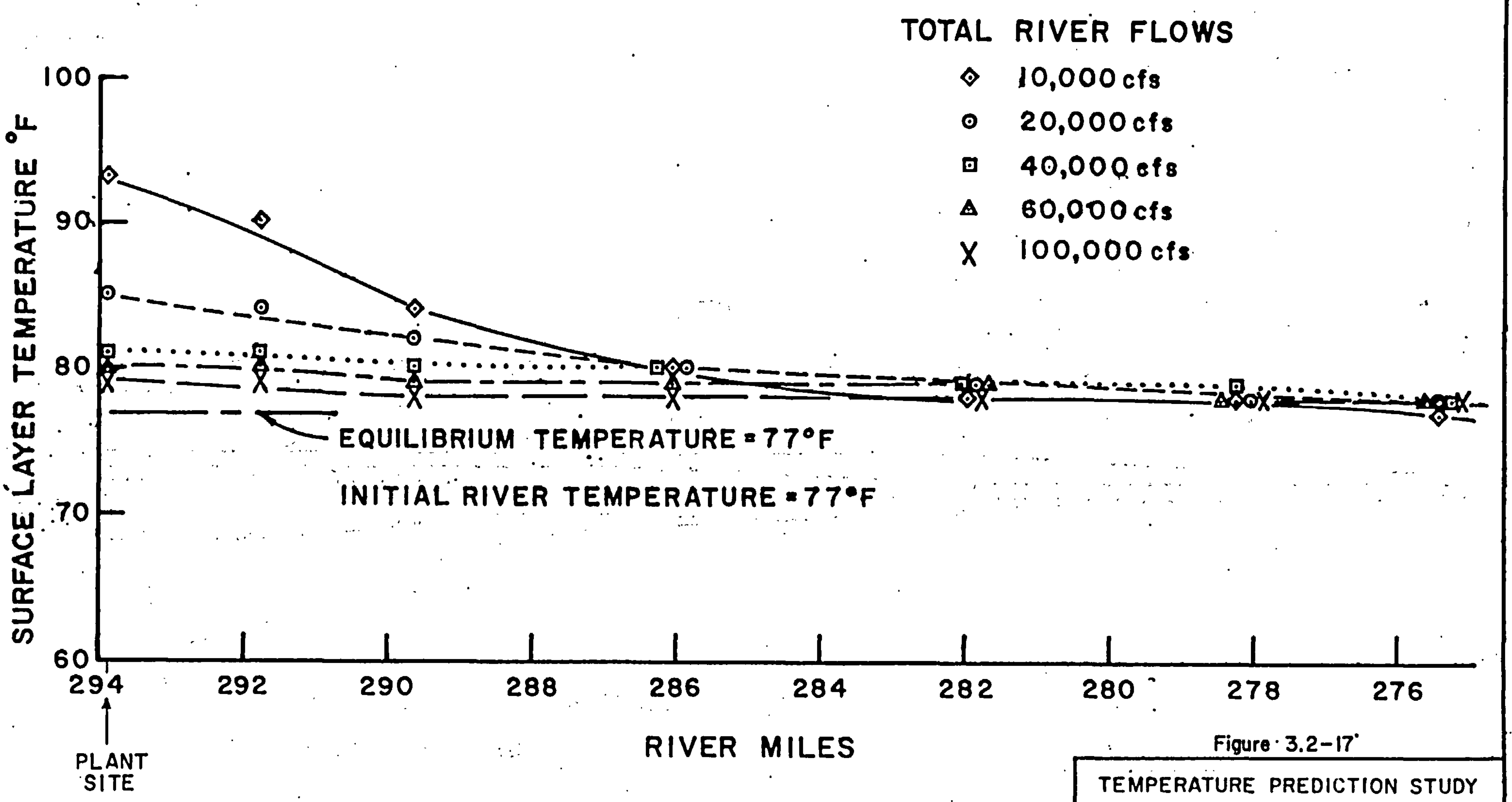


Figure 3.2-17

TEMPERATURE PREDICTION STUDY

RIVER TEMPERATURE DATA
2 UNITS—1200' DIFFUSER
SEPTEMBER, 1954

BROWNS FERRY NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY

NORRIS | 9-17-71 | 67 | EL | 920 | A-

DRAWN ELT | ENGINEER
CHECKED | APPROVED

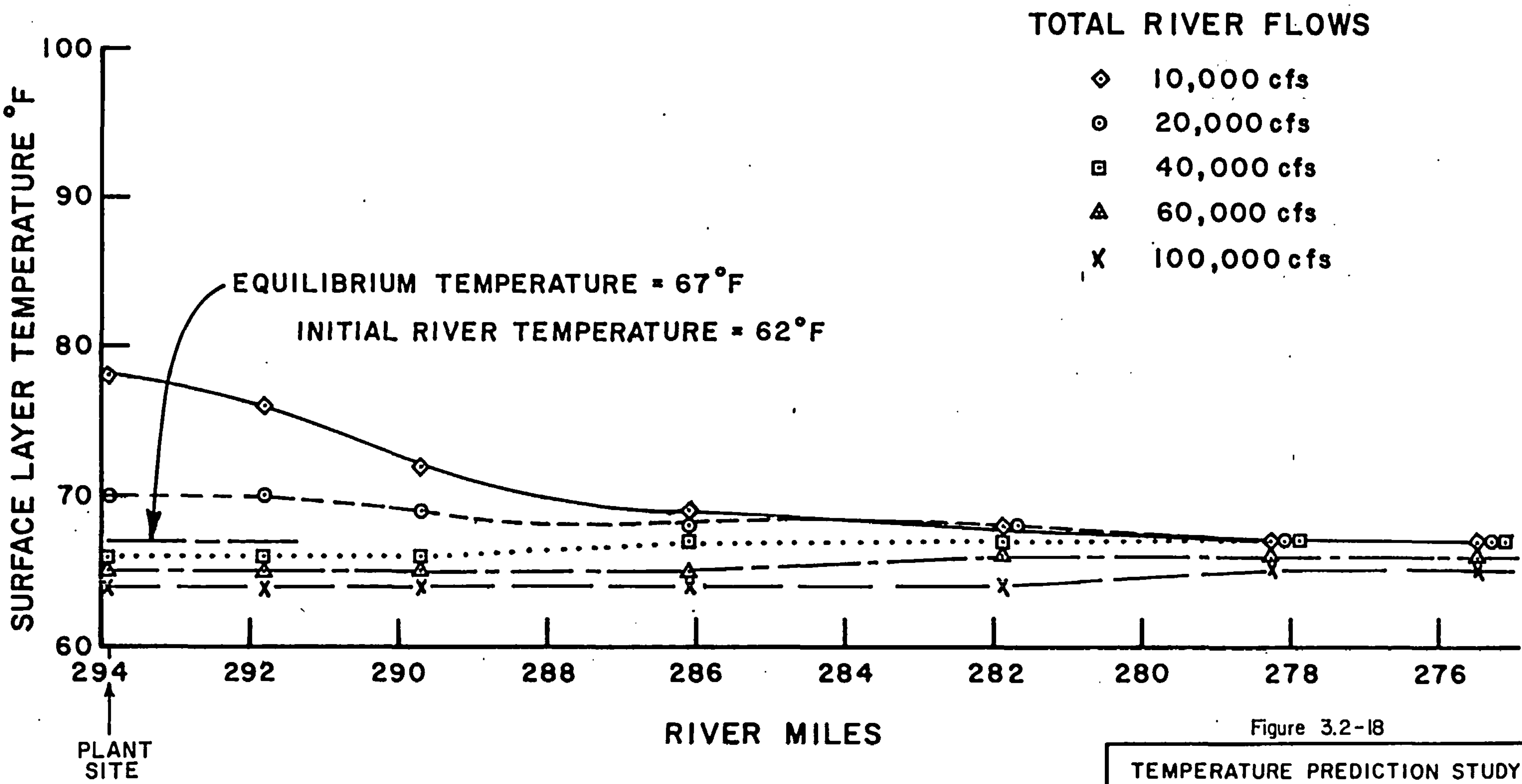


Figure 3.2-18

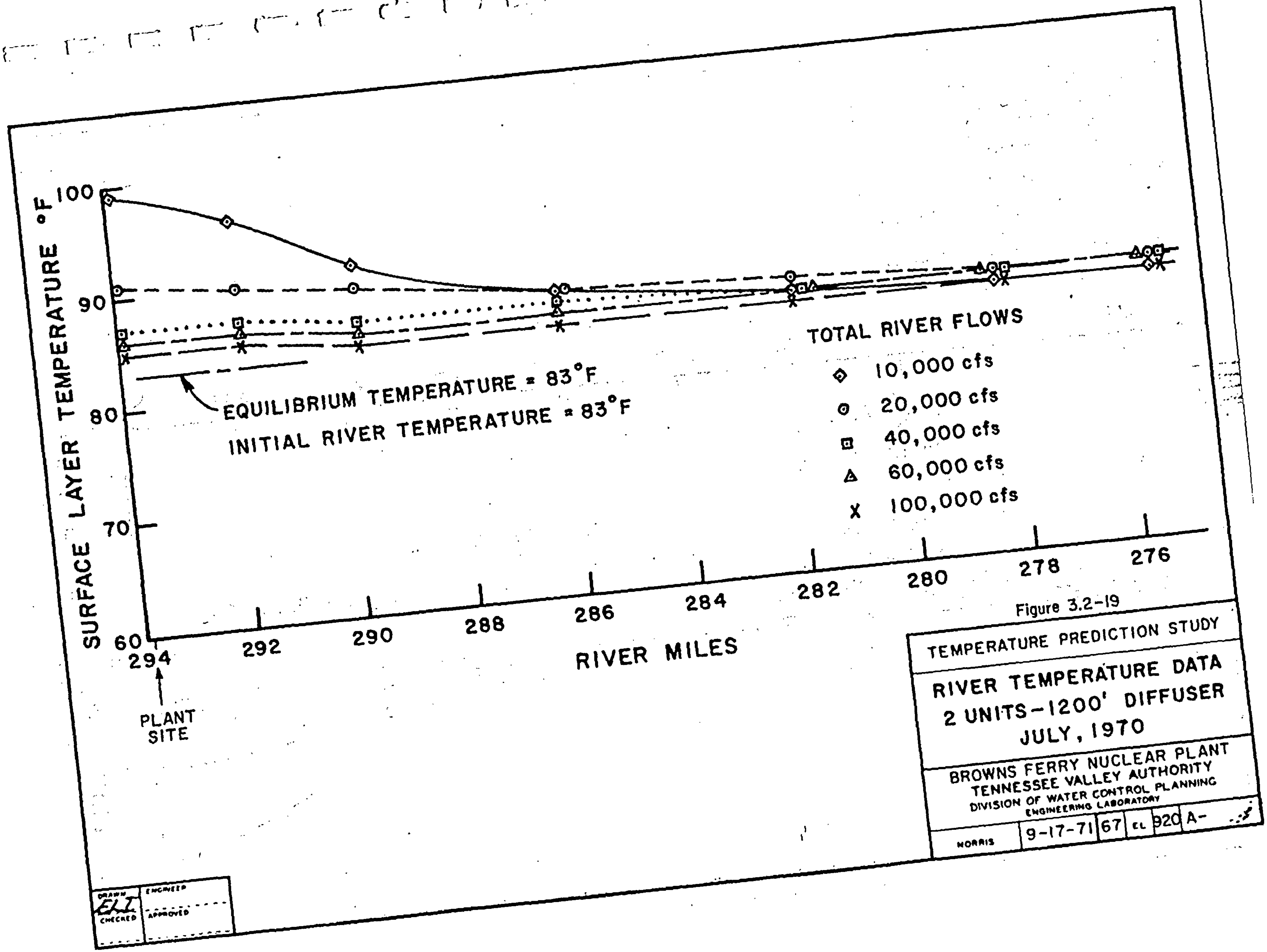
TEMPERATURE PREDICTION STUDY

RIVER TEMPERATURE DATA
2 UNITS - 1200' DIFFUSER
APRIL, 1970

BROWNS FERRY NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY

NORRIS	9-17-71	67	EL	920	A-

DRAWN ELT	ENGINEER
CHECKED	APPROVED


SURFACE LAYER TEMPERATURE °F
100
90
80
70
60
294
292
290
288
286
284
282
280
278
276
RIVER MILES
PLANT SITE
EQUILIBRIUM TEMPERATURE = 83°F
INITIAL RIVER TEMPERATURE = 83°F
TOTAL RIVER FLOWS
10,000 cfs
20,000 cfs
40,000 cfs
60,000 cfs
100,000 cfs
TEMPERATURE PREDICTION STUDY
RIVER TEMPERATURE DATA
2 UNITS-1200' DIFFUSER
JULY, 1970
BROWNS FERRY NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY
NORRIS
9-17-71
67
EL
920
A-
DRAWN
ENGINEER
CHECKED
APPROVED
Figure 3.2-19

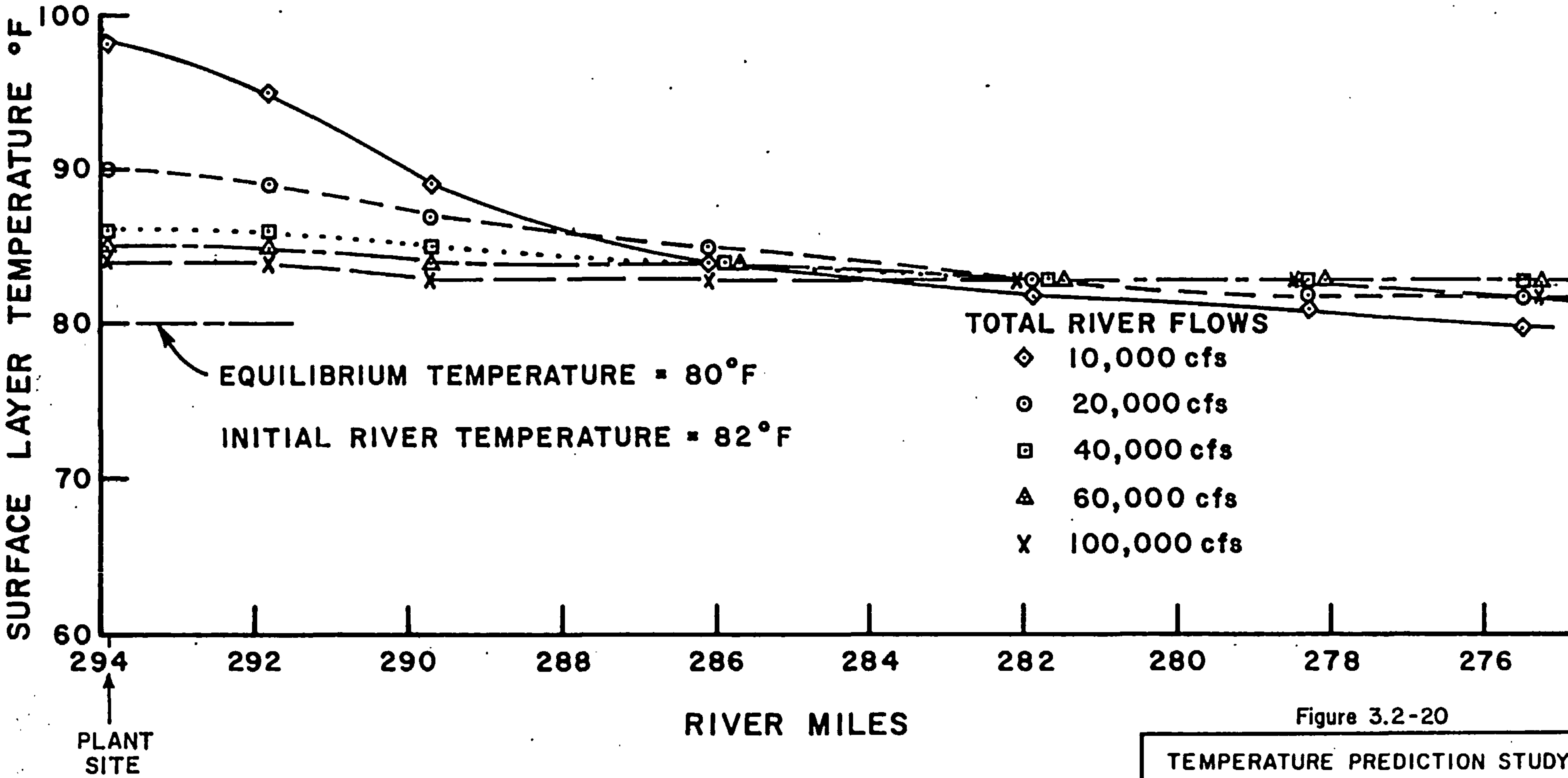


Figure 3.2-20

TEMPERATURE PREDICTION STUDY

RIVER TEMPERATURE DATA
2 UNITS 1200' DIFFUSER
SEPTEMBER, 1970

BROWNS FERRY NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY

NORRIS | 9-17-71 | 67 | EL | 920 | A-

DRAWN ELT | ENGINEER
CHECKED | APPROVED

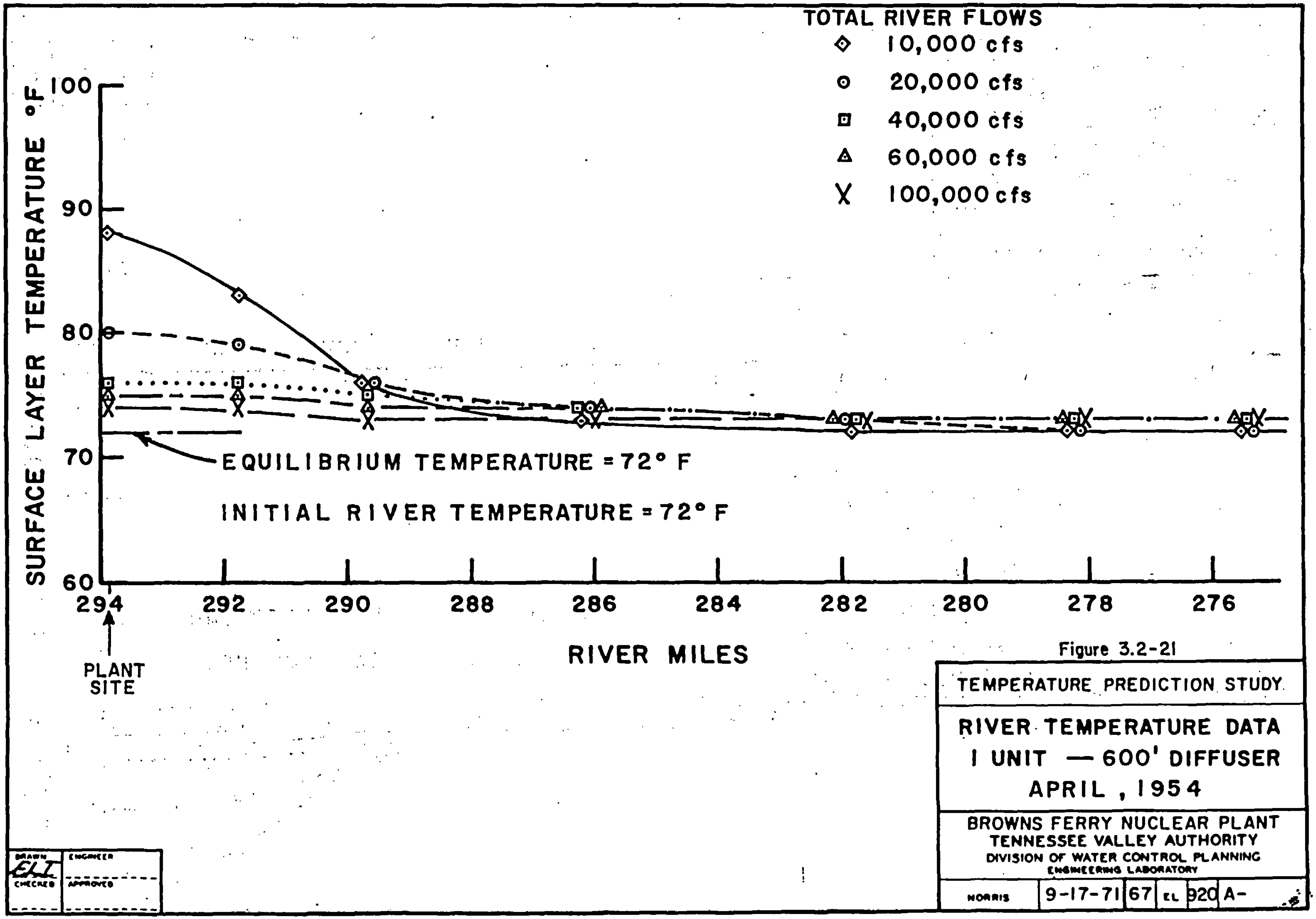


Figure 3.2-21

TEMPERATURE PREDICTION STUDY

RIVER TEMPERATURE DATA
1 UNIT — 600' DIFFUSER
APRIL, 1954

BROWNS FERRY NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY

NORRIS 9-17-71 67 EL 920 A-

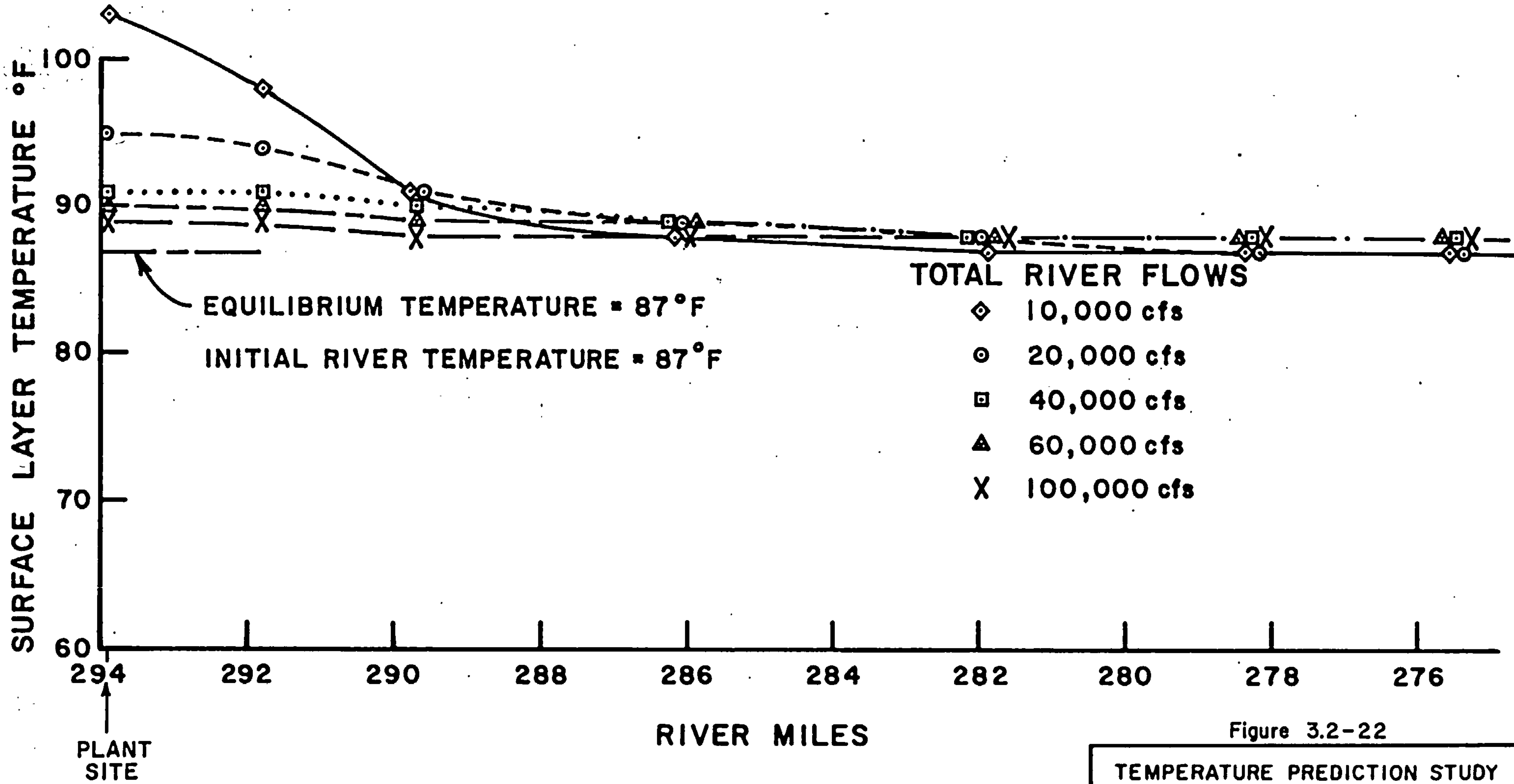


Figure 3.2-22

TEMPERATURE PREDICTION STUDY

RIVER TEMPERATURE DATA
1 UNIT – 600' DIFFUSER
JULY, 1954

BROWNS FERRY NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY

NORRIS	9-17-71	67	EL	920	A-

DRAWN	ENGINEER
ELT	
CHECKED	APPROVED

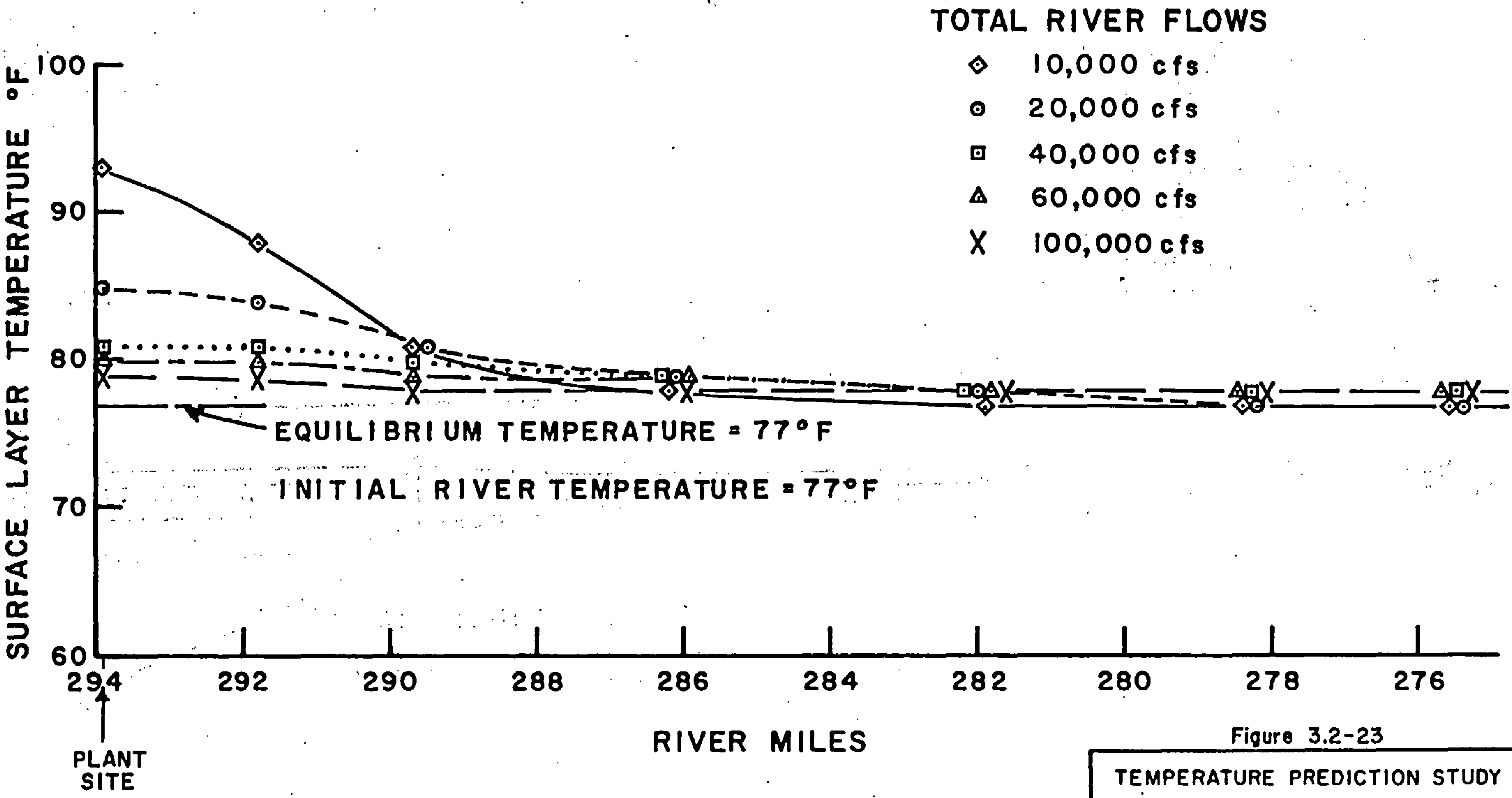


Figure 3.2-23

TEMPERATURE PREDICTION STUDY

RIVER TEMPERATURE DATA
1 UNIT — 600' DIFFUSER
SEPTEMBER, 1954

BROWNS FERRY NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY

NORRIS 9-17-71 67 EL 920 A-

DRAWN ELT ENGINEER
CHECKED APPROVED

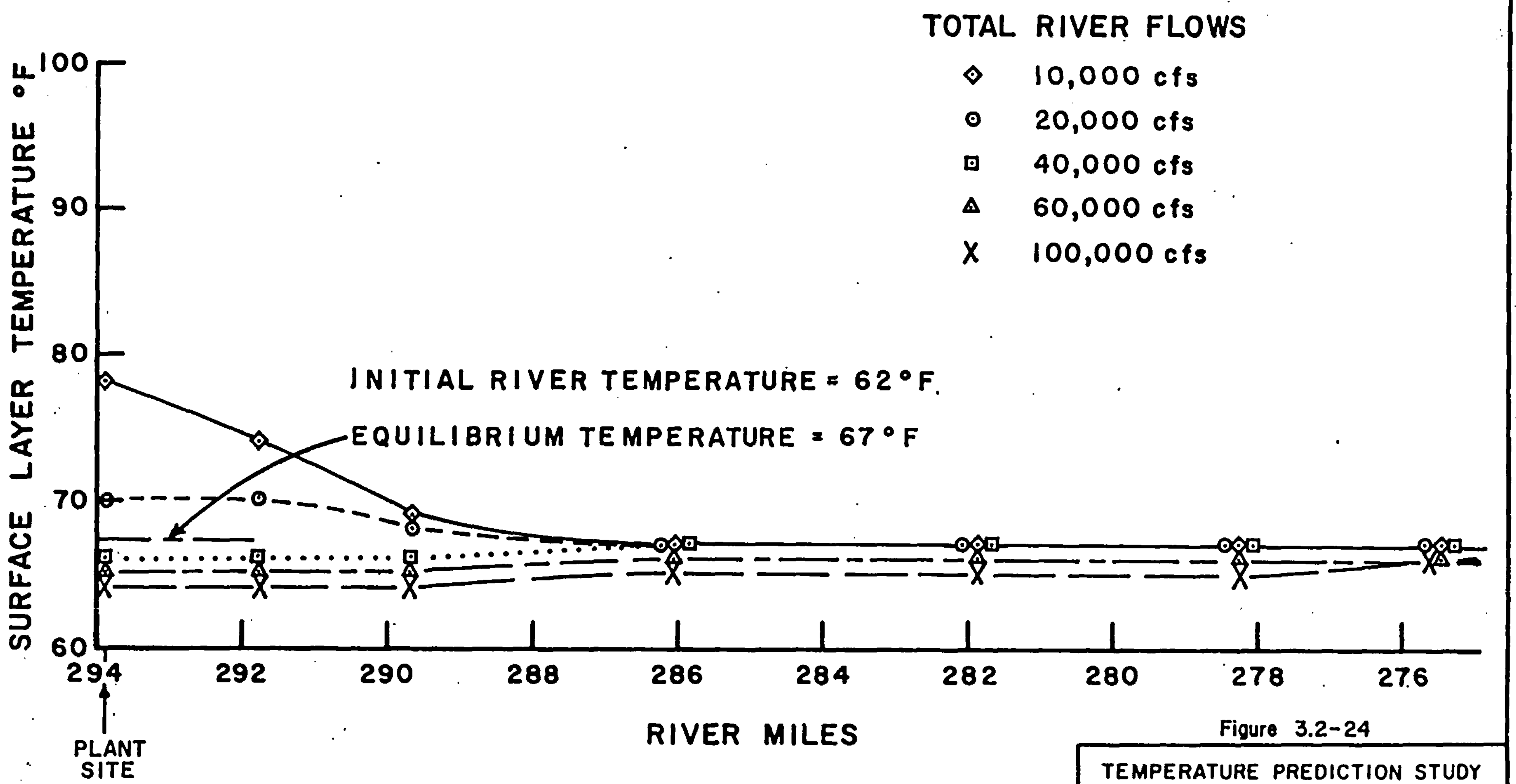


Figure 3.2-24

TEMPERATURE PREDICTION STUDY

RIVER TEMPERATURE DATA
1 UNIT — 600' DIFFUSER
APRIL, 1970

BROWNS FERRY NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY

NORRIS	9-17-71	67	EL	920	A-

DRAWN ELT	ENGINEER
CHECKED	APPROVED

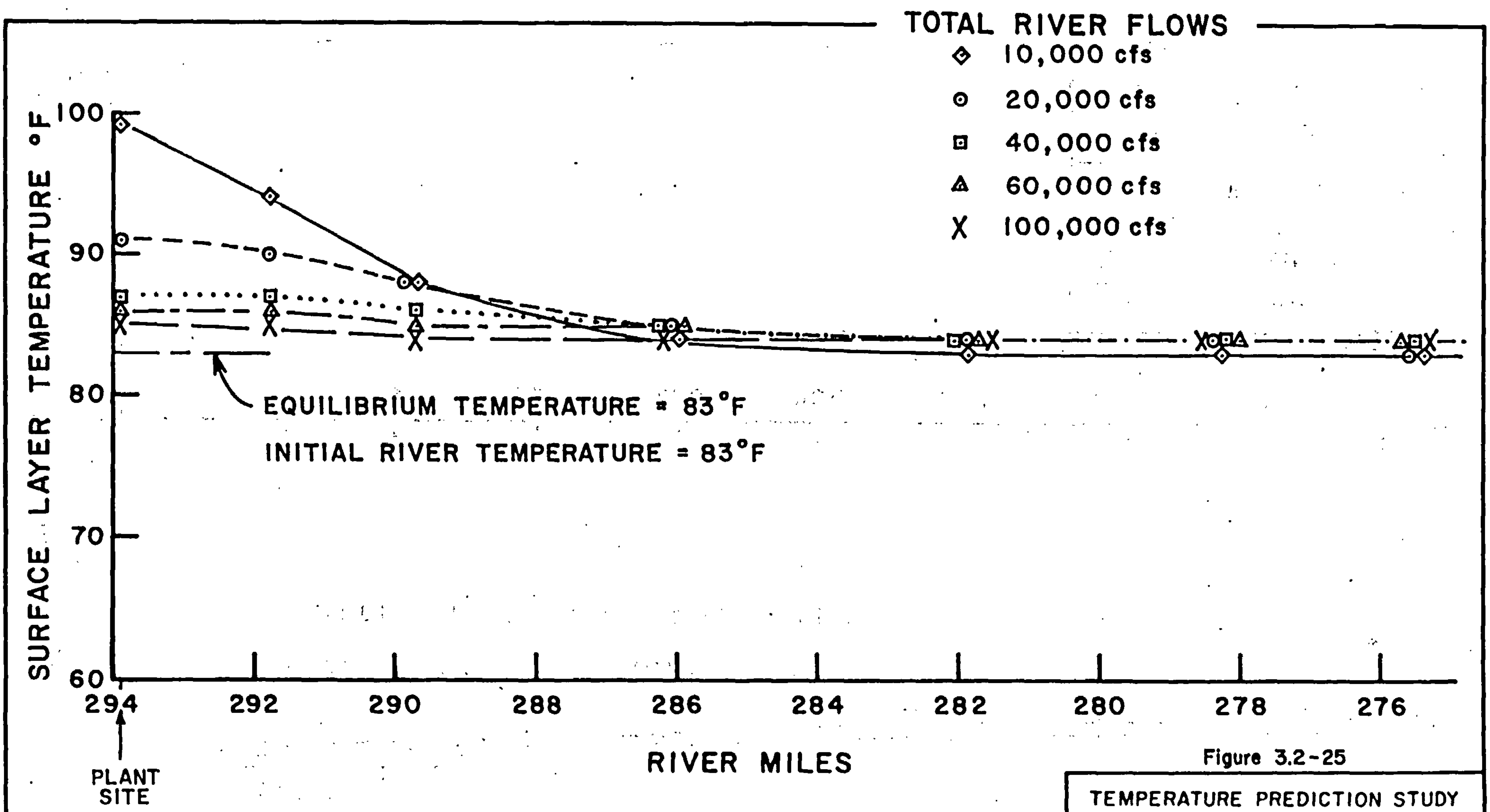


Figure 3.2-25

TEMPERATURE PREDICTION STUDY

RIVER TEMPERATURE DATA
1 UNIT – 600' DIFFUSER
JULY, 1970

BROWNS FERRY NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY

NORRIS 9-17-71 67 EL 920 A-

DRAWN ELT ENGINEER
CHECKED APPROVED

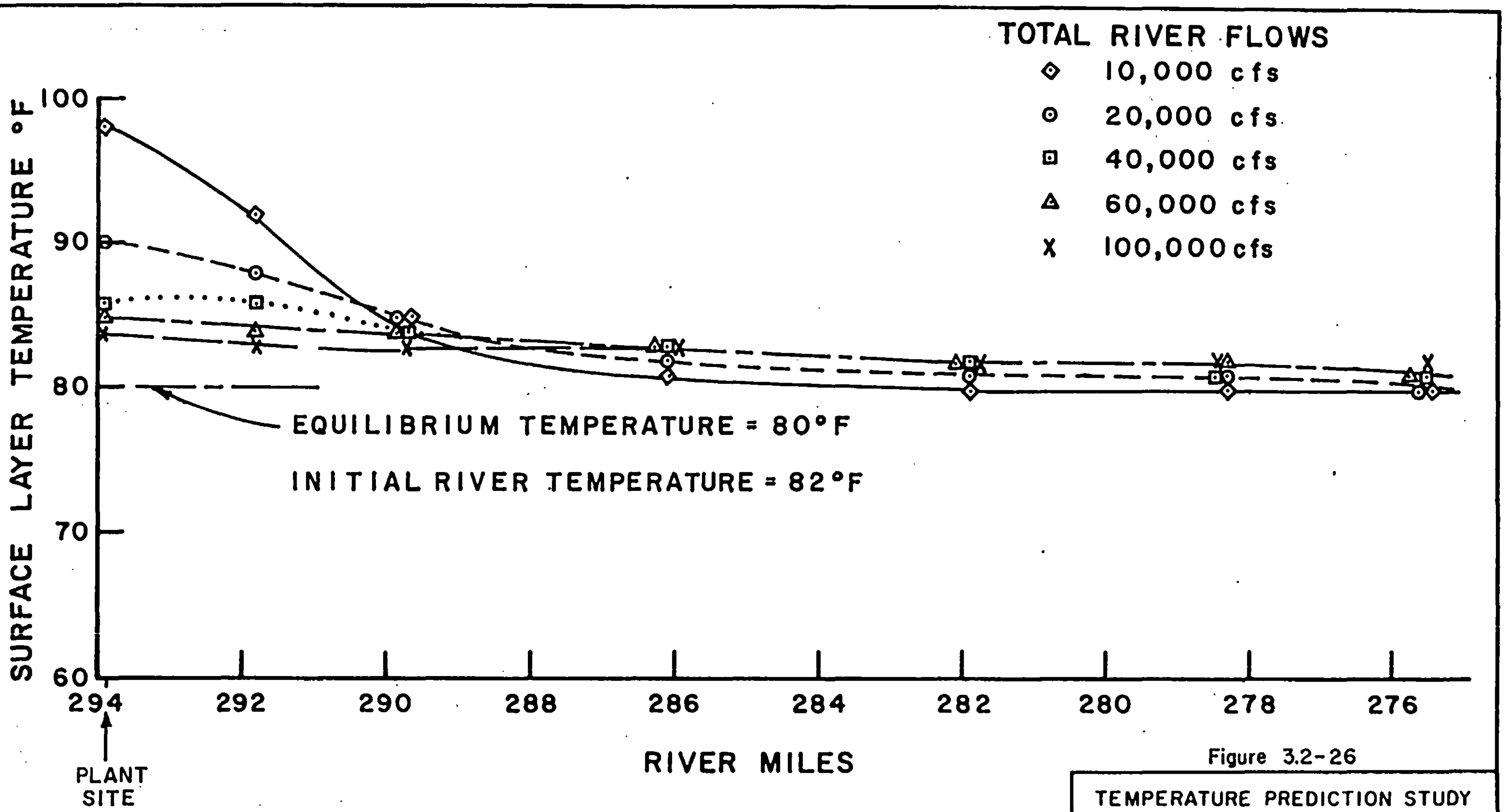


Figure 3.2-26

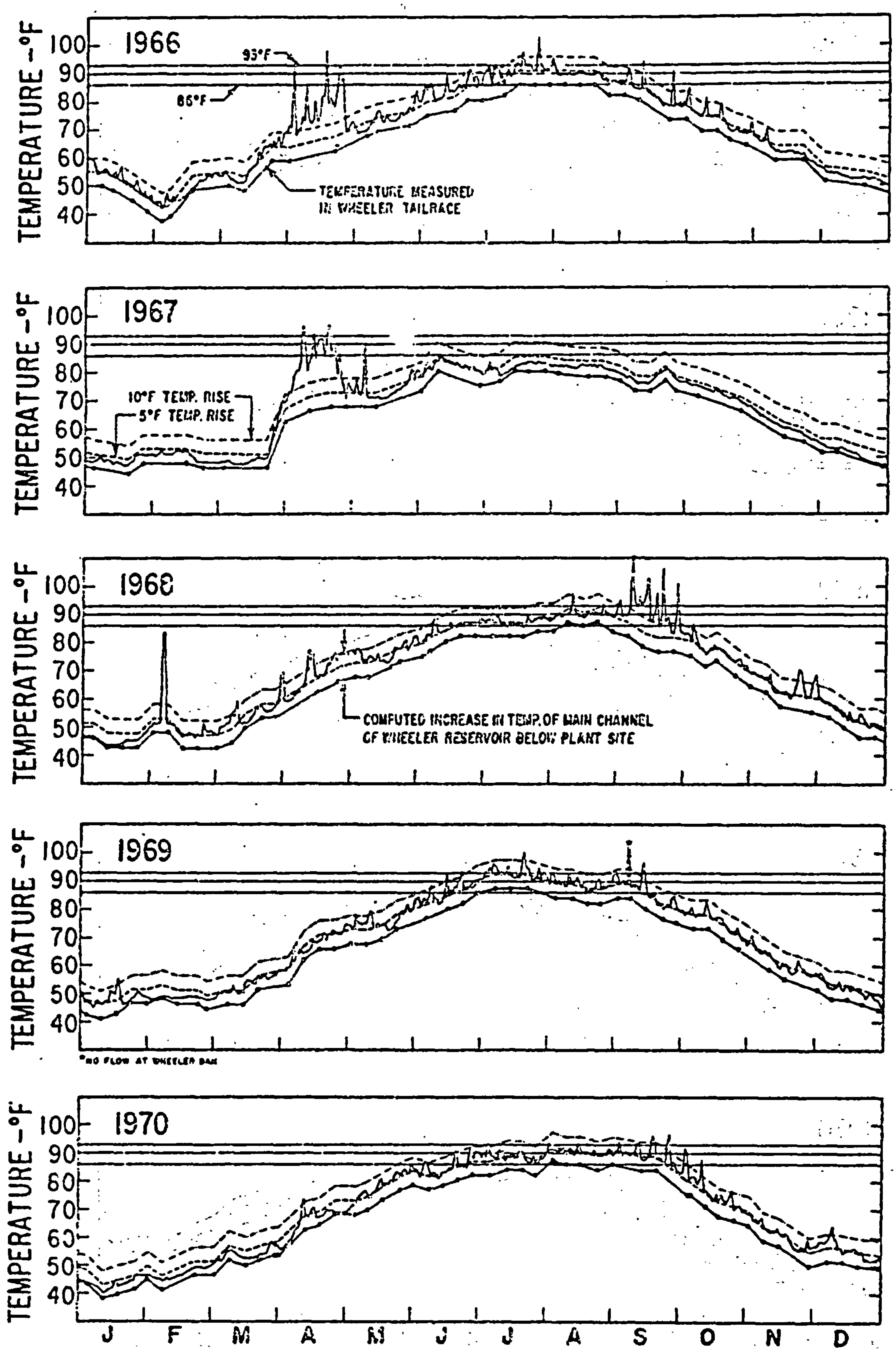
TEMPERATURE PREDICTION STUDY

RIVER TEMPERATURE DATA
1 UNIT — 600' DIFFUSER
SEPTEMBER, 1970

BROWNS FERRY NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY

DRAWN	ENGINEER
ELT	
CHECKED	APPROVED

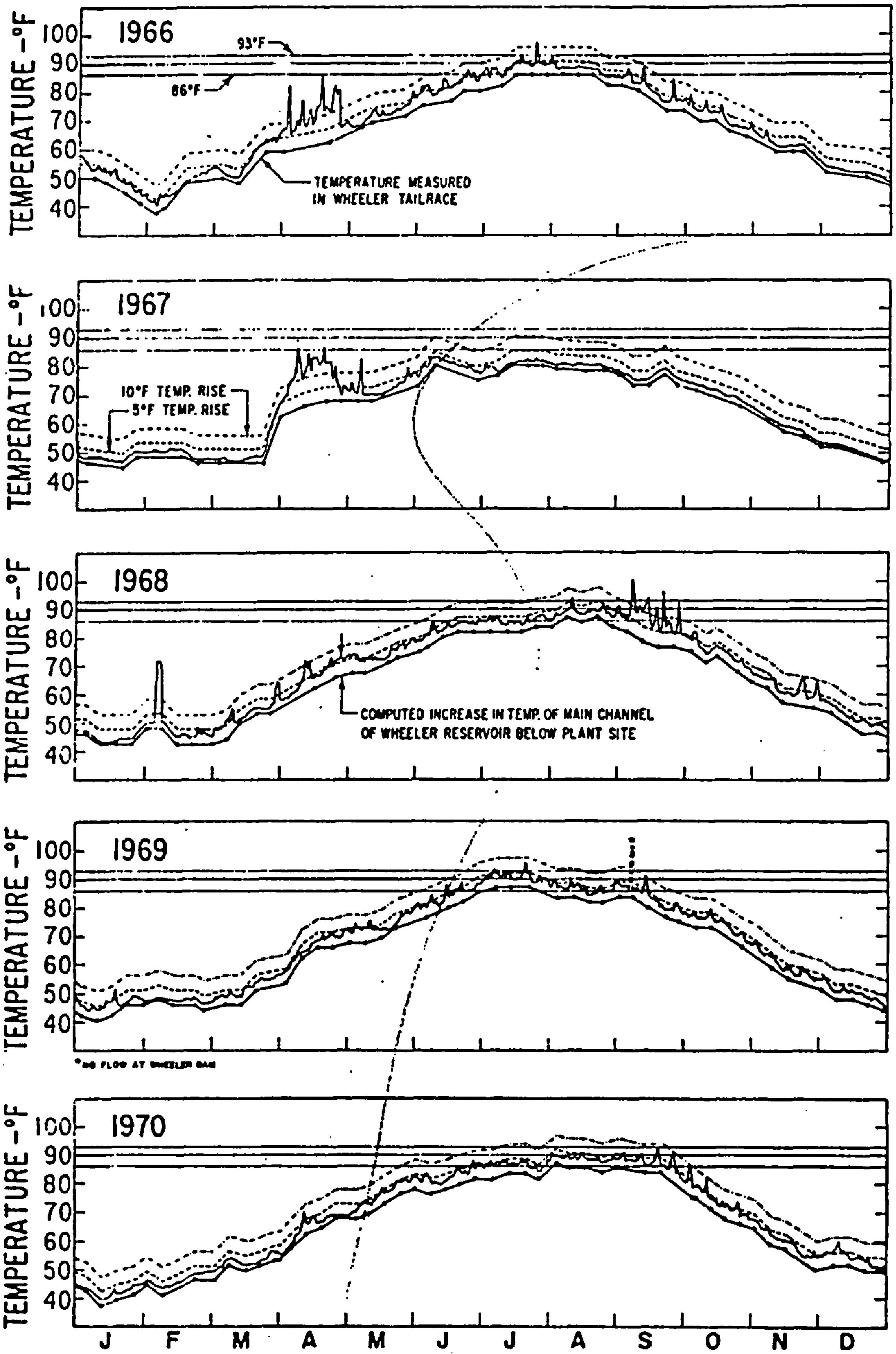
NORRIS	9-17-71	67	EL	920	A-



COMPUTED INCREASE IN WATER TEMPERATURE IN WHEELER RESERVOIR

ASSUMING THREE UNITS AT BROWNS FERRY NUCLEAR PLANT IN FULL OPERATION AND COMPLETE MIXING OF WARM CONDENSER DISCHARGE WITH THE MAIN CHANNEL FLOW OF THE RIVER

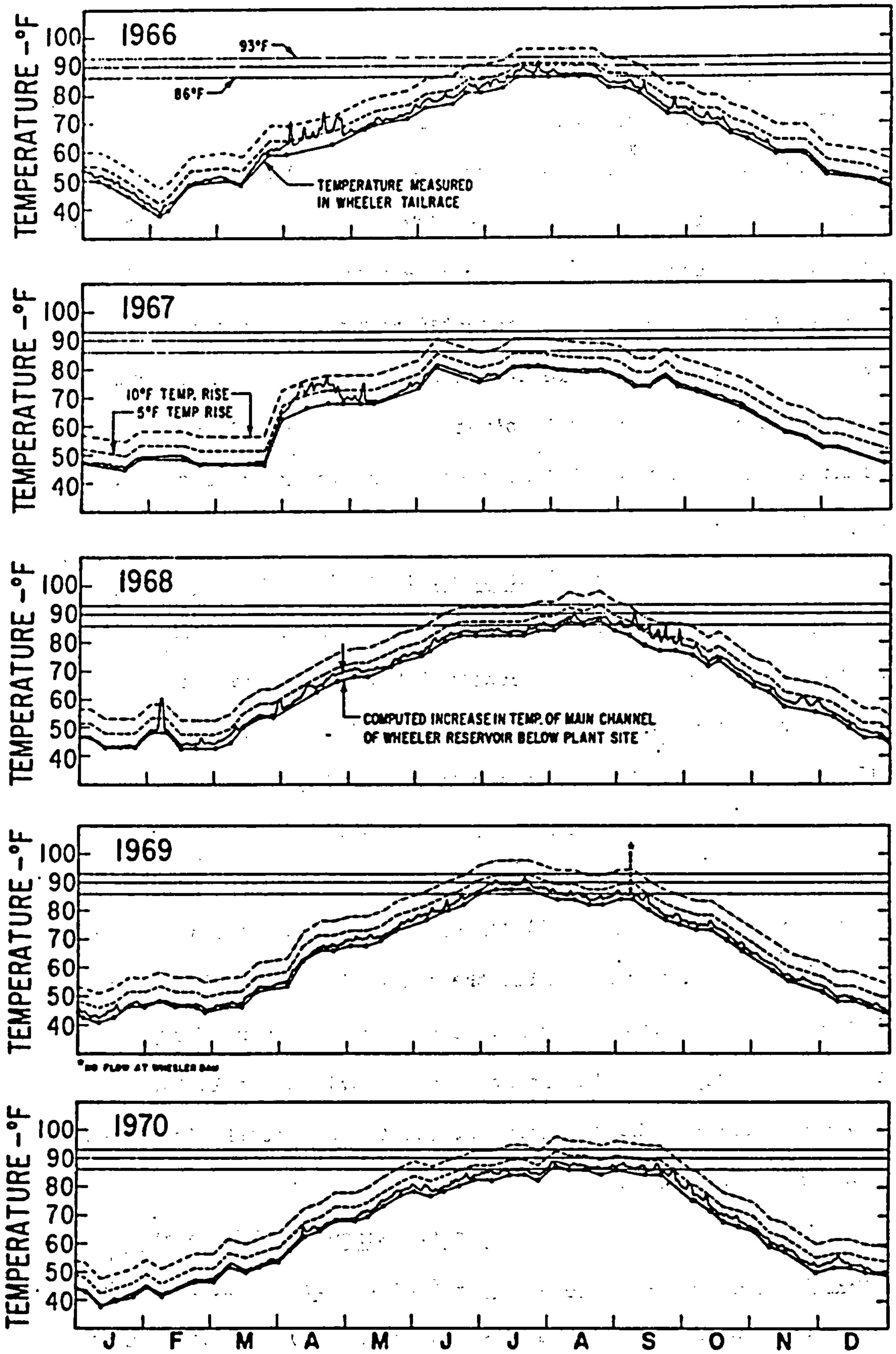
Figure 3.2-27



COMPUTED INCREASE IN WATER TEMPERATURE IN WHEELER RESERVOIR

ASSUMING TWO UNITS AT BROWNS FERRY NUCLEAR PLANT IN FULL OPERATION AND COMPLETE MIXING OF WARM CONDENSER DISCHARGE WITH THE MAIN CHANNEL FLOW OF THE RIVER

Figure 3.2-28



COMPUTED INCREASE IN WATER TEMPERATURE IN WHEELER RESERVOIR

ASSUMING ONE UNIT AT BROWNS FERRY NUCLEAR PLANT IN FULL OPERATION AND COMPLETE MIXING OF WARM CONDENSER DISCHARGE WITH THE MAIN CHANNEL FLOW OF THE RIVER

Figure 3.2-29

3.3 Effects on Aquatic Life - TVA has developed comprehensive ecological studies and monitoring programs to document environmental characteristics prior to construction and operation of Browns Ferry nuclear power plant in order that the effects on the environment can be determined. These studies also provide a basis for identifying measures that will minimize any projected adverse effects on the environment. Some of these are currently under way, while others are planned to commence prior to plant startup and continue after the plant is in operation. All of these programs are discussed at various points below.

1. Ecological studies and analyses performed - Subsection (1) lists some of the results of the fish monitoring investigations. Subsection (2) discusses TVA's experience with heated water effects on aquatic life at its various steam plants. Subsection (3) discusses effects of construction activity and subsection (4) discusses the possible effects of heated water on aquatic life. Subsection (5) discusses the implications of withdrawal and return of cooling water. Subsection (6) discusses measures taken to assure adequate ecological studies. While the extent to which all of the possible effects of heated water may be present at Browns Ferry is not yet fully known, it is important from an environmental standpoint to recognize all the possible effects to objectively judge the actual impact of the plant.

(1) Identification of fish species important to sport and commercial use - Fish monitoring investigations have been conducted quarterly since the winter of 1968. These

investigations have shown the following fish to be important to sport use: largemouth bass, smallmouth bass, spotted bass, white bass, crappie, bluegill, and sauger. Important commercial fish are: bigmouth buffalo, smallmouth buffalo, channel catfish, flathead catfish, blue catfish, carp, drum, and paddlefish. While Table 3.3-1 is not a complete species list for the reasons given in the draft statement, it does identify all important sport and commercial populations in Wheeler Reservoir. Although the striped bass occasionally appears in Wheeler Reservoir and its tailwaters, the species is not included since it is judged that it has neither established resident populations nor does it occur in significant numbers. Important seasonal sport fisheries exist for all game fish noted with the exception of yellow bass, longear, and green sunfish. Important commercial species include the two species of buffalo and the three species of catfish. Drum, carp, and paddlefish are of lesser commercial importance. Forage fish are poorly represented here. Conventional sampling techniques employed in monitoring and population-inventory studies do not sample small forage fish efficiently. Smith-Vaniz reports more than 24 species of minnows, including 16 species of <u>Notropis</u>, in the Alabama sections of the Tennessee River system, as well as 18 species of darters. These totals do not include rare species reported from only one location.

It is difficult and in some cases perhaps invalid to assign given species to tropic levels, since many species will undergo ontogenetic changes in regard to tropic levels or will assume a very broad trophic character as adults. However, some generalizations are possible: the basses and gars can be considered as true piscivores as adults; forage fish and some rough fish species can be considered planktivorous; the remainder are essentially omnivorous.

(a) <u>Importance of area for fish larvae and spawning</u> - The Browns Ferry plant is located directly downstream from an extensive area of shallow water, including the mouths of several creeks. Two additional extensive areas of shallow overbank habitat are located on the opposite side of the channel, directly across from the plant and about 2 miles downstream. Limited areas of shallow habitat occur directly downstream from the plant site. Areas of this type usually serve as spawning and nursery sites for most important fish species, as well as being areas of high production of fish food organisms.

(b) <u>Importance of area for bottom fauna fish food chain organisms</u> - The Browns Ferry Nuclear Plant is located in the transition zone between riverine and impoundment habitats. The river channel and fields along the old river bank between TRM 308 and TRM 288 are inundated, providing two major habitats for bottom fauna.

Major bottom fauna in the plant site area are adapted to specific substrates, water depths, and food sources. Soft sediments on the overbank opposite the plant are generally 10 cm or more in depth adjacent to the river channel and 2 to 5 cm and shallower toward the shore above Mallard Creek embayment. Various substrates on the overbank above the plant site include soft sediment, granular clay, and gravel. Gravel is dominant near the channel and wave-washed shore. Substrate in the river channel is predominantly soft sediment over gravel and on the right bank is soft sediment.

Bottom fauna species diversity is limited in the plant site area. Bottom fauna inhabiting the channel, listed in order of abundance, are Asiatic clams (Corbicula) and oligochaetes in soft sediments containing organic materials, sponges on rocks and old tree branches, a few mussels, and mayflies of the genus Hexagenia in the soft sediments. Hexagenia (mayflies) are relatively abundant in those habitats which are suitable for their colonization. Chaoborus (phantom midge larvae) frequent the bottom of the river channel during the day but spend most of their life at some intermediate point in the water column. All of these bottom fauna species are important food for game and commercial fish species.

The bottom fauna on the overbank includes several species of mussels, Asiatic clams, mayflies (Hexagenia, Caenis), midges, snails, sponges, bryozoans, and a few crayfish. Crayfish and snails occur among scattered aggregations of rocks with some snails on clay ridges or other substrates suitable for algal growth on which they feed.

(2) TVA experience on effects of heated water - Since 1955, TVA has been observing the distribution in streams and in reservoirs of heated waters discharged from TVA's thermal-electric power plants. The first plants were relatively small compared to the sizes of receiving streams. Over the years

the sizes of individual units, power plants, and the amount of heat discharged to the environment have increased. To ensure that aquatic life in receiving streams is not being adversely affected by thermal discharges, biological surveys have been made at all of TVA's plants. Table 3.3-2 lists characteristics of these plants.

Typical of these surveys are the detailed temperature and biological studies made in August and September of 1967 at the Widows Creek power plant on Guntersville Reservoir. Heated water there is discharged into the edge of the reservoir, where it "floats" into the main channel and rapidly mixes with streamflow. Temperature and biological data were collected along cross sections of the reservoir above and below the plant. Temperature of the discharge water was between 84°F. and 86°F., about 10°F. higher than temperature in the river above the plant. The warm water plume spread diagonally across the river in less than the upper ten feet of water, or less than half the river depth. Bottom fauna and periphyton growth were sampled and analyzed.

Results of these studies showed that: (1) the horizontal area of the reservoir covered by the zone of elevated temperatures is small; (2) the maximum temperatures observed in the mixing zone were in the top two feet of water; (3) the maximum increase in temperature in the mixing zone was 10.3°F. on August 30, and 6.1°F. on August 31; (4) the temperature increase in the Tennessee River water after complete mixing was less than 1°F.; (5) the diversity and abundance of bottom fauna above and below the steam plant discharge were similar, and slight differences are attributed to variability of substrate rather than to temperature effects; (6) the observed periphyton growth was not consistent with the proximity of the observation stations to the discharge; consequently, the differences in growth are not considered to be due to the steam plant discharges; and (7) the discharge from the Widows Creek Steam Plant has not produced significant effects on aquatic life in the Tennessee River.

Although temperature rise in condensers of TVA's fossil-fueled plants typically varies from 10°F. to 18°F., results of similar temperature and biological surveys show that the thermal discharges from the various plants produce no significant adverse effects on aquatic life in the receiving waters--except at the Paradise plant. It is interesting to note that fishing in the warm water during the winter months is very popular at most TVA steam plants.

Initial operation of the Paradise Steam Plant on the Green River in Kentucky did produce significant adverse effects on aquatic life. In the first five miles below the plant, adverse effects were observed on bottom and suspended aquatic organisms. For some 20 miles below the plant, a decrease in fish populations was also observed. However, these effects were detected by environmental monitoring conducted by TVA and outside consultants. As a result of the findings of the biological studies, lower thermal criteria were established by TVA and cooling towers were installed. Studies to assess cause and effect relations in the river are continuing.

While observations during the first two years after plant operation suggest adverse effects on fish, subsequent findings on fish are inconclusive. Preliminary results also indicate that the adverse effects on other biota are not permanent. Appendix III of the July 14, 1971, draft environmental statement provides a description of the Green River studies.

Some insight into the effects of a specific thermal regime is provided by observations at the Paradise plant. Based on continuous recordings of water temperature throughout the first two years of plant operation at a monitoring station downstream from the plant, water temperatures from surface to bottom were raised 10°F. or more during 18 percent of the time. On several occasions temperatures reached 93°F. At this same monitoring station expert consulting biologists found, at the end of this two-year period, no deleterious effects on bottom or suspended aquatics assignable to plant-added heat.

TVA's experience demonstrates that in some situations warm condenser water can be discharged into surface streams without significant adverse effects on aquatic life. The Paradise experience, although somewhat atypical due to the nature and small size of the Green River, demonstrates the value of comprehensive monitoring programs in detecting adverse effects of thermal discharges at an early stage in plant operation.

(3) <u>Effect of construction activities on shoreline habitat</u> - Construction activities have resulted in

alteration and loss of a large portion of the shoreline habitat at the plant site. Additional deposition of spoil material has occurred recently in the shallow area downstream from the plant, increasing emergent area and representing loss of fish habitat. Since construction operations have not ceased in this regard, it is difficult to estimate the ultimate extent of construction effects. It is judged, however, that this loss of shallow water habitat will approximate only 60 acres which constitute a small but definitive percentage of the total.

(4) Possible impact of heated water on aquatic life - Appendix III of the July 14, 1971, draft environmental statement outlines studies conducted by TVA and others on the effects of heated water on aquatic life. Appendix II of that statement describes some preliminary results of the type of monitoring being undertaken in order to fully assess the effects of heated water on aquatic life.

Aquatic life that will be most directly affected by operation of the Browns Ferry Nuclear Plant will be the floating and drifting (entrained) assemblage of planktonic organisms. Phytoplankton and zooplankton are the food of many forage fish species, including the gizzard shad. This fish is an important item in the diet of largemouth bass and other game fish. The plankton also includes the larvae of many fish species.

Phytoplankton samples collected on a seasonal basis in a cross section at Browns Ferry average 350,000 to 2,200,000 cells per liter. This assemblage is composed of diatoms (50 to 85 percent), green algae (10 to 40 percent), and blue-green algae (less than 15 percent). Spring floods reduce the phytoplankton population density and productivity through dilution and the adverse effects of turbidity and flocculation. As the water clears and wind action decreases, three- to ten-day periods of bright sunny weather may result in phytoplankton blooms.

Aquatic life in Wheeler Reservoir is subject to ambient temperatures which may exceed 87°F. at the surface in the open reservoir for parts of each day during most of the summer. Surface temperatures may occasionally exceed 92°F. On the inundated overbanks and in embayed areas or among emergent and floating aquatic macrophytes, higher temperatures are encountered for more extended periods each day; yet a greater diversity of aquatic life occurs in these areas. It has been found that the dominant bottom fauna listed earlier can maintain relatively high population levels at temperatures up to 95°F. in steam plant basins and discharge canals.

(a) <u>Effects on biota passing through condensers</u> - Intake velocities are estimated to range from 0.7 ft/sec at the mouth of the intake canal to 1.4 ft/sec at the intake forebay--at a reservoir elevation of 553 feet which is the lowest normal elevation for the April-September period. Velocities through the 3/8-inch-square mesh traveling screens will be 1.8 ft/sec at the same elevation. Intake velocities will increase when the reservoir level is low, and will range from 1.0 ft/sec at the mouth to 2.0 ft/sec at the forebay. At these velocities most larval fish, zooplankton, and phytoplankton in the vicinity will be entrained because they cannot withstand velocities much above 0.2 ft/sec. Large concentrations of larval and young fish occur in the vicinity of the plant and population densities are greatest near the surface of inshore waters of ten feet depth or less. During the period from April through August the extent of entrainment of young fish will be variable and will depend on several factors including size, species and physical condition, and the spatial and temporal pattern of current velocities in the intake canal.

It appears from the technical literature that investigations of entrainment effects on planktonic larval fish and fish eggs have been largely inconclusive. However, water temperatures which exceed 80°F. in the condensers and which may occur from April through mid-November will be detrimental to entrained eggs of several fish species including the shads, drum, possibly mooneye, and any other species specifically selecting the intake area as a spawning site. Water temperatures which exceed 95°F. in the condensers, which may occur May through September, would be detrimental if not immediately lethal to larvae of most fish species. No data are available for estimating synergistic effects involving temperature and other factors such as pressure and small amounts of chemical waste.

The addition of 25°F. in the plant condenser to the ambient river temperature will be lethal to most plankton when calefaction plus ambient temperature exceeds 96°F. Experimental work and evaluation of plankton passing through TVA steam plant condensers indicate the carbon fixation potential of phytoplankton is impaired. Studies at Paradise Steam Plant in particular and secondarily at other TVA steam plants indicate a minor destruction of plankton cells when passed through the condensers during the fall, winter, and spring. Plankton killed by passage through a steam plant condenser may still provide food for fish, bottom fauna, and zooplankton. Observations at the Paradise Steam Plant indicate that algal losses in summer and fall due to heat kill are replaced by rapid growth in the downstream heated plume.

The percent of plankton organisms that will be entrained cannot be accurately estimated. At full load the condenser circulating water flow is approximately 10 percent of the mean annual flow and approximately 25 percent of the mean April flow. The extent to which the number of organisms entrained is correlated with the volume of flow is not known but during periods of low flow it is assumed that about 25 percent of the plankton organisms flowing past the plant will be entrained. Entrained organisms may be subjected to several stresses; among these are thermal shock, pressure changes, abrasion, and exposure to small amounts of chemical wastes.

<u>Three-unit operation</u> - The amount of entrained plankton will be small relative to the amount contained in total flows, in all seasons. Greatest impact will be in summer and early fall. For example, for an early April total river flow of 20,000 ft^3/s withdrawal will be 33 percent of channel flow or 22 percent of river flow. Increased flows later or earlier in the year would reduce the percent of flow affected. The impact on plankton would not be detrimental until combined ambient and condenser rise temperature exceeds $96^{\circ}F.$, which might occur for at least part of each day from May through September. At times during the summer most organisms passing

through the condensers would be killed, the total number is dependent upon population densities, percent of flow passed through the condensers, and timing of the withdrawals.

Two-unit operation - Full load withdrawals for two-unit operation will require 22 percent of the channel flow or 14 percent of the river flow at an assumed 20,000 ft^3/s flow. At higher flows, say 40,000 ft^3/s, entrainment will amount to only about 7 percent of river flow.

One-unit operation - A proportional decrease in the number of plankton and larval fish passed through the condensers will be expected because at a river flow of 20,000 ft^3/s, the withdrawal will decrease to 7 percent of river flow or 11 percent of channel flow. Withdrawal from a river flow of 40,000 ft^3/s will affect the planktonic organisms in only 3.5 percent of river flow.

(b) Effects on receiving waters - Some of the heaviest fishing in the Tennessee Valley takes place in the discharge channels and basins that receive warm water from the condensers of TVA steam plants. Many fish species prefer the conditions in steam plant basins, particularly in winter. Since 1957, TVA Public Safety Service Officers have been counting fishermen at four TVA steam plants: Kingston, Widows Creek, Colbert, and Johnsonville. Fishing trips average 70,000 per year or about 760 trips per acre per year - some of the heaviest fishing in the Valley.

Figures 3.2-9 through 3.2-26 in section 3.2, Heat Dissipation, show temperature distributions predicted by the model studies that would occur near the diffuser for flows of 10,000, 20,000, 40,000, 60,000, and 100,000 ft^3/s for periods when 1, 2, or 3 units are operating. The maximum temperature rise at the reservoir bottom is relatively small and extends over only a small area. Downstream where the warm water spreads over the overbank areas the reservoir will be stratified and the warm water should contact neither the channel benthos nor most of the overbank benthos. Only the benthos near the shoreline will be affected.

Large spawning areas exist along the shoreline above and below the plant site. Based on preliminary analyses of field observations it appears that nursery grounds are not unique to the plant vicinity but are located throughout most of the shoreline area of the reservoir and its principal tributary, Elk River. Littoral areas are utilized as spawning habitats by several species and it is suspected that the large embayments of Mud, Mallard, and Fox Creeks, located within a three-mile radius of the plant site, may be significant spawning areas. However, due to a paucity of information, the impact of the warm water on spawning habitats cannot be accurately assessed at the present.

The zone of heated water below the diffusers will probably attract some fish species and repel others. Young fish of a species are more likely to inhabit the warmer areas than are adults. Attracted species will probably be mostly commercial species which have high thermal tolerances such as catfish, carp, gar, and buffalo. Some species, including redhorse, sauger, smallmouth bass, some sunfish, and crappie are likely to avoid the warmer areas and locate either upstream or downstream from the diffusers where the temperature rise is 2^{o}F. to 4^{o}F. above ambient river temperature. Largemouth bass may be attracted to the warmer area by a combination of warm temperatures and abundance of forage fish.

Some species, such as white bass and carpsucker, and perhaps some of the species listed above may be thermally neutral and avoid only the warmest areas or areas of steepest thermal gradients. A small region no more than 10 feet above the bottom and extending probably no more than 30 feet downstream of an active diffuser may be entirely devoid of fish because of increased temperatures and steep thermal gradients.

The thermal discharge may have some effects on fish movements and reproduction. The presence of increased water temperatures may cause some thermally intolerant species to avoid this zone in their daily and seasonal nonreproductive movements. This is not judged to have a significant impact on the fishery resources of the reservoir, although localized changes in distribution and abundance may occur. The zone of heated water may attract some species which may remain in the zone and spawn there. Fish may spawn earlier than normal, eggs may develop and hatch more rapidly, and larval fish may enter the reservoir system in advance of normal timing, depending on the time spent in the warm water zone and on the relative importance of water temperatures in the reproductive cycle of a species. These phenomena have been noted in studies of cooling basins and discharge canals. In view of the expected dynamic nature of the mixing zone (as a result of the interaction of flow rates, current patterns, and seasonal temperatures) and because fish will have complete freedom of movement into or out of the zone, it is judged that early spawning by significant numbers of fish is unlikely.

Wheeler Reservoir is a reasonably mature aquatic system and has probably reached an equilibrium in terms of total biomass. Biomass within given trophic levels may also have reached equilibrium although species biomass may fluctuate widely. Thermal enrichment, within certain limits, may increase total biomass. The extent to which an increase in biomass is desirable will depend on the species affected.

It is not likely that the warm water will form a thermal barrier such that fish cannot, or will not, traverse itor move around or under it to swim upstream or downstream. The warm water will extend across the entire reservoir and except at high river flows some degree of stratification will exist. If a barrier is established it is most likely to affect those species which make extended upstream or downstream spawning migrations. Of the important species in Wheeler Reservoir the sauger will be most likely to be adversely affected in their upstream migration to the tailwaters of Guntersville Dam. If sauger are prevented from completing their spawning migration, one of two possible results will occur: (1) the fish may spawn in the river below the barrier, or in tributary streams, probably with reduced reproductive success, and (2) no spawning may occur, gametes would be resorbed, and failure of a year class would occur.

Three-unit operation - over the diffusers movement upstream and downstream of all fish in the river channel will be through water heated to the mixed temperature. As discussed in the July 14, 1971, draft environmental statement, further downstream and upstream from the diffusers the warm water will be limited to a layer on the reservoir surface. Organisms along the shoreline will be exposed to the mixed temperature which might stimulate metabolism and food consumption but the effects will not be lethal.

Passage through the heated water could be either beneficial or adverse but will not be lethal. The larval fish passing downstream in the river channel will experience first heating and a zone of fewer living food organisms, and then an abundance of food organisms. It is concluded that operating the plant in compliance with a 10°F. rise and a 93°F. maximum would not result in any significant adverse effects on the reservoir ecology except for possible effects resulting from death of entrained organisms.

Two-unit operation - The heated water discharged by Unit 2 will flow along the submerged left bank of the river channel adjacent to the heated water discharge of Unit 1. Less warm water will be present to act as an attractant or repellent of fish than will be present with three units operating; thus, distributional changes in fish population densities may be of somewhat lesser magnitude. Effects on daily and seasonal nonreproductive movements will probably be less than effects with a three-unit operation owing to the smaller warm water zone and the existence of a zone of cool water in the channel along the right bank. It is judged that the probability of establishing a thermal barrier is not significant.

Organisms along the shoreline will be exposed to the mixed temperature T_M which might stimulate metabolism and food consumption of bottom fauna and young fish, but which will not be lethal. It is concluded that operation of the plant in compliance with a 10°F. rise and a 93°F. maximum will not result in any significant adverse effects on the reservoir ecology except for possible effects resulting from death of entrained organisms.

<u>One-unit operation</u> - As stated above for two-unit operation the operation of Unit 1 will not result in any significant adverse effects on reservoir ecology except for possible effects resulting from death of the entrained organisms.

The preceding sections have dealt with a range of potential thermal effects of varying probability, most of which have not been specifically studied or observed in an aquatic ecosystem of the size of Wheeler Reservoir. The zone of potential adverse influence of the Browns Ferry Nuclear Plant is only a small fraction of the total reservoir. For these reasons, the conclusion is reached that discharge into Wheeler Reservoir of the quantities of heat under consideration should not have a significant adverse effect on the environment. Furthermore, the adverse effects of the quantities of heat to be added are judged to be relatively minor and subject also to amelioration if necessary by additional facilities for condenser water cooling.

(5) <u>Implications of withdrawal and return of cooling water</u> - The three units and auxiliaries at Browns Ferry require the withdrawal and return of approximately 1,980,000 gallons of water per minute. This constitutes about ten percent of the water passing the site at mean annual flow. Operation of two units requires withdrawal and return of approximately seven percent of the water passing the site at mean annual flow and operation of one unit requires withdrawal of approximately three percent.

(a) <u>Nutrient circulation</u> - Plankton may be destroyed by passage through the condensers. Destruction of plankton in the condensers will release nutrients that could result in the growth of heterotrophic slimes. This possible effect will be detected by monitoring programs, but no significant adverse effects on important species populations are anticipated.

(b) Reduction of DO concentrations in the condensers - Since warm water can hold less oxygen in solution than cooler water, the theoretical effects of elevation of water temperatures some 25°F. in passing through the condensers has been considered. For example, the oxygen saturation concentration in water at 80°F. is 7.7 milligrams per liter, whereas at 100°F. the saturation concentration is 6.3 milligrams per liter.

Observations of DO concentrations in Wheeler Reservoir above and below the Browns Ferry site indicate that in the summer months DO concentrations are not at saturation but in the range of 75-80 percent of saturation. Thus, instead of 7.7 mg/l of DO in water at 85°F. the actual concentration is observed to be approximately 6 mg/l. Thus, during the warmer months of the year, even after the temperature is elevated 25°F. in passing through the condenser, saturation concentrations are not apt to be exceeded. Consequently, as regards elevation of water temperatures no significant reduction in oxygen concentrations should occur.

Another factor tending to lower DO concentrations in water passing through a condenser is the partial vacuum existing at the discharge end of the condenser. This partial vacuum results from the fact that the discharge end of the condenser lies above the hydraulic gradient. This situation is common to all TVA steam plants. While vacuum pumps are installed to remove any accumulated air, experience has shown that very little air accumulates and needs to be removed from the system. Consequently, no significant quantity of oxygen should be lost at Browns Ferry due to this hydraulic situation.

These conclusions are consistent with findings above and below TVA's Paradise power plant where the temperature elevation in water passing through the condensers is approximately the same as at Browns Ferry, and a significant negative pressure exists at the downstream ends of the condenser.

No significant adverse effects on important species populations are anticipated due to the reduction of DO concentrations in the condensers, since no significant quantity of oxygen will be driven off.

(c) <u>Effect of elevated temperatures on biochemical oxygen demand</u> - To provide an estimate of the quantitative effect on oxygen consumption of organic wastes in the waters of Wheeler Reservoir, an organic load of 25,000 pounds per day of five-day BOD was assumed to be discharged into the reservoir immediately downstream from the plant.

Based on a low total streamflow of 21,000 ft^3/s, an increase in temperature from 85°F. to 93°F., and applicable Streeter-Phelp equations, calculations show that the increase in temperature would result in an increased DO depression of less than 0.1 mg/l. The effects will be less with only one or two units operating. It is not anticipated that this small DO depression will have any adverse implications on important aquatic populations.

(6) Measures taken to assure adequate ecological studies - TVA has consulted with the Fish and Wildlife Service, U.S. Department of the Interior, and the Alabama Department of Conservation in developing plans for environmental monitoring for the Browns Ferry plant. A quality control program for radioactive monitoring has been established with the Alabama Department of Public Health Radiological Laboratory and the Eastern Environmental Laboratory - EPA, in Montgomery, Alabama. In addition, TVA has discussed environmental monitoring plans with the Alabama State Health Department, the Alabama Water Improvement Commission, the Bureau of Sport Fisheries and Wildlife, and the Bureau of Commercial Fisheries of the U.S. Fish and Wildlife Service.

2. Studies to be continued - There are no ecological studies to be completed prior to operation of the plant which will affect plant design. The three-dimensional model studies on the diffuser systems will be continued after the plant begins operation.

3. Monitoring programs - The monitoring programs for this plant are discussed in detail in the July 14, 1971, draft environmental statement.

4. Potential hazards to fish of cooling water intake and discharge - Small meshed traveling screens are provided on the circulating water pump intakes so that larger fish forms will not be entrapped or pass through the condensers. The traveling screen consists of a number of screen sections, fastened top to bottom, to form an endless belt of screens. The screens move continually through

the cooling water intake to remove trash and other debris. This debris, along with any entrained fish, is washed off the screens in their upward pass and returned to the reservoir.

TVA has not encountered problems with fish entrapment at any of its large coal-fired steam plants, all of which are equipped with similar screens.

5. Damage to life systems - Fish larvae will be entrained in the cooling water and most entrained larvae may be killed in passing through the condensers when ambient stream temperature is high. Studies are under way to determine the population densities of fish larvae passing the intake channel and as operating experience is gained steps will be developed which could prevent or reduce the intake of fish larvae. Most plankton present in the condenser cooling water will be killed when subjected to temperatures in excess of 96°F. However, during the season when damage to the plankton and fish larvae is most likely, less than 25 percent of the total river flow passes through the condensers. Based on TVA's experience with other large thermal plants, rapid reseeding of plankton populations downstream of the condenser outfall would be expected. To the extent that this plankton serves as a food source for other aquatic life its destruction is not an adverse effect.

There may be some loss of existing river bottom fauna and habitat in the immediate vicinity of the diffuser pipes which cannot be avoided. Since these effects are very local, no significant damage is expected. Extensive studies to be conducted will forewarn of developing adverse effects.

Table 3.3-1 Common and scientific names* of fishes of Wheeler Reservoir

Game

Largemouth bass - Micropterus salmoides
Smallmouth bass - Micropterus dolomieui
Spotted bass - Micropterus punctulatus
White bass - Morone chrysops
Yellow bass - Morone mississippiensis
White crappie - Pomoxis annularis
Black crappie - Pomoxis nigromaculatus
Bluegill - Lepomis macrochirus
Warmouth - Lepomis gulosus
Longear sunfish - Lepomis megalotis
Green sunfish - Lepomis cyanellus
Redear sunfish - Lepomis microlophus
Rock bass - Ambloplites rupestris
Sauger - Stizostedion canadense

Rough

Longnose gar - Lepisosteus osseus
Shortnose gar - Lepisosteus platostomus
Spotted gar - Lepisosteus oculatus
Skipjack herring - Alosa chrysochloris
Mooneye - Hiodon tergisus
Bigmouth buffalo - Ictiobus cyprinellus
Smallmouth buffalo - Ictiobus bubalus
Channel catfish - Ictalurus punctatus
Flathead catfish - Pylodictis olivaris
Carp - Cyprinus carpio
Drum - Aplodinotus grunniens
Spotted sucker - Minytrema melanops
Hog sucker - Hypentelium nigricans
Golden redhorse - Moxostoma erythrurum
Black redhorse - Moxostoma duquesnei
River redhorse - Moxostoma carinatum
Blue catfish - Ictalurus furcatus
Paddlefish - Polyodon spathula

Forage

Threadfin shad - Dorosoma petenense
Gizzard shad - Dorosoma cepedianum
Orange spotted sunfish - Lepomis humilis
Logperch - Percina caprodes
Brook silversides - Labidesthes sicculus
Golden shiner - Notemigonum crysoleucas
Emerald shiner - Notropis atherinoides
Bluntnose minnow - Pimephales notatus
Fantail darter - Etheostoma flabellare
Blackstripe topminnow - Fundulus notatus

*According to American Fisheries Society Special Publication No. 6, 1970.

TABLE 3.3-2

TVA-BUILT THERMAL-ELECTRIC POWER PLANTS

Plant	Unit Number	Normal Full Load, per Unit	First Year of Commercial Operation		Total Plant			Mean Flow of Receiving Stream
			First Unit	Last Unit	Thermal Rise in Condensers	Condenser Flow	Heat to Stream (Btu)	
		megawatts			°F.	gal/min	billions per hr	ft³/s
Browns Ferry	1-3	1,150	'72	'74	25	1,800,000	22.2	49,000
Bull Run	1	900	'67		18	397,900	3.6	4,310
Colbert	1-4	200	'55	'55				50,500
	5	500	'65		13	865,500	5.8	
Cumberland	1,2	1,300	'72	'73	12	1,616,000	9.3	24,000
Gallatin	1,2	250	'56	'57	16	592,400	4.7	18,000
	3,4	275	'59	'59				
John Sevier	1-4	200	'55	'57	15	454,000	3.5	3,540
Johnsonville	1-6	125	'51	'53				61,000
	7-10	150	'58	'59	13	1,029,000	6.5	
Kingston	1-4	150	'54					6,300
	5-9	200		'55	14	967,000	6.9	
Paradise	1,2	690	'63	'63	26	452,400	5.8	8,370
Shawnee	1-10	150	'53	'56	12	1,076,000	6.5	255,400
Watts Bar	1-4	60	'42	'45	10	280,000	1.5	26,400
Widows Creek	1-4	135	'52					35,200
	5,6	130		'54				
	7	525	'61		15	1,092,400	8.2	
	8	525	'65					

3.4 Alternative Heat Dissipation Methods - The present design for dissipating the waste heat from the Browns Ferry Nuclear Plant is described in section 3.2. TVA is investigating the following alternative heat dissipation methods: mechanical draft cooling towers, natural draft cooling towers, spray canal system, and cooling lake.

Analyses were performed for the various alternatives using the following factors as a basis: feasibility, land requirements, environmental considerations, economic considerations, and construction schedule. In order not to preclude any of the alternative heat dissipation methods, provisions are being made in the design and construction of the diffuser cooling system to enable installation of these alternatives with a minimum loss of plant operation.

1. Alternative modes of operation - Two operating modes for each of the four alternative cooling methods are possible:

(1) Closed cycle systems - The alternative cooling methods can be operated so that the only water discharged to Wheeler Reservoir would be the required blowdown from the cooling system. This operation would prohibit the use of Wheeler Reservoir for heat dissipation and would result in the reduction of plant efficiency and net electrical output.

(2) Combined cycle systems - The cooling towers can be used in combined cycle systems, that is, in the closed, open, or helper mode. In the open mode, the diffusers alone would be utilized, bypassing the alternative system. In the helper mode, condenser cooling water passes through the alternative system and then

through the diffusers. Figure 3.4-1 shows the schematic arrangement and operation of the gates in the cooling water circuit necessary to accomplish combined cycle operation. These schemes provide flexibility for using the Wheeler Reservoir for heat dissipation according to temperature requirements.

The spray canal system could also be operated in the closed, open, or partially closed modes. While it is technically possible to operate a cooling lake in more than one mode, the required location of a cooling lake being some distance from the plant would make such a design very difficult and expensive.

(3) <u>Percent of time on various modes</u> - Calculations indicate that maximum temperature of water returned to Wheeler Reservoir would not exceed 90°F. for the cooling tower schemes, based on average monthly inlet water temperatures. To meet a potential 5°F. temperature rise requirement, river flow would be required for mixing at the diffuser outlet with discharge water with the plant on the open cycle mode or helper cycle mode. An analysis of the percent of time each mode of operation would be required to meet an assumed 5°F. temperature rise follows:

Alternative Heat Dissipation Method	System	Percent of Year		
		Open	Combined	Closed
Mechanical Draft	Combined	58.5	30.5	11.0
Natural Draft	Combined	58.5	29.0	12.5
Spray Canal	Combined	58.5	24.6	16.9
Cooling Lake	Combined	58.5	--	41.5

This is based upon operating all three units in the same mode at all times and river flow based on ten-year flow duration records (1959-1968). A reduction in the percentage of time on combined and closed cycle operation could be achieved by controlling releases from upstream dams and dividing the different modes of operation between units.

2. Mechanical draft cooling towers - Mechanical draft cooling towers would require six towers, each 73' wide by 60' high by 480' long, to operate when on either closed or helper cycle.

The water would be broken into drops by falling through fill. Heat from the drops is transferred to the air, which is induced by large fans. The water returning from the towers would flow by gravity back to either the discharge conduit for return to the reservoir through the diffusers or to the intake structure where the existing circulating pumps would then transport it through the plant condensers.

(1) Feasibility - Mechanical draft cooling towers are suitable for application to the Browns Ferry Nuclear Plant. Figure 3.4-2 shows a possible location and arrangement of the six mechanical draft towers on the plant site. Within TVA owned property, an access road, parking facilities, a boat harbor, and a sewage treatment plant would have to be moved from present or planned locations. The present intake and discharge systems would be modified to permit the use of towers, with makeup and blowdown provisions. A new booster pumping station would be used to lift the circulating water to the towers.

(2) Land requirements - The use of mechanical draft towers as an alternative means of cooling would not require the purchase of additional land beyond that already owned. It would, however, require building a permanent dike 5000 feet long about 200 feet (300 feet at the powerhouse only) from the present shoreline into the reservoir.

(3) Environmental considerations -

(a) Physical and chemical characteristics of tower effluent - The water required for continuous operation of the plant will be obtained from the Tennessee River at the plant site. The quantity of water required (makeup) will be dependent upon the following items: (1) amount of blowdown necessary to maintain the total dissolved solids below standards applicable to the Tennessee River, (2) the amount of evaporation from the tower, and (3) drift losses. With a blowdown concentration factor of 2, the total makeup required would be approximately six percent of the circulating flow, or 220 ft^3/s.

A certain portion of the water in any closed cycle system must be removed. This blowdown prevents the concentration of impurities in the water which would otherwise interfere with operation. The amount of blowdown is estimated to be about 110 ft^3/s and will be dependent on the amount of evaporation, the dissolved solids presently contained in the source river water, and the applicable effluent or stream quality standards. The dissolved solids in the river for 1964-1965 averaged approximately 107 mg/l with a peak of 137 mg/l. With a concentration factor of 2, the dissolved solids in the blowdown should not exceed acceptable levels. Slightly increasing the quantity of blowdown would further reduce the dissolved solids concentration. The temperature of this blowdown water will be approximately 57°F. under average winter conditions, 75°F. under average fall and spring conditions, and 86°F. under average summer conditions. Peak summer conditions can produce temperatures near 94°F. However, blowdown can be withheld under peak temperature conditions provided they do not last more than about two days. A mixing device will be required to meet present thermal standards for this small quantity of water.

Drift, which is water blown out of the tower, has been estimated by cooling tower manufacturers to involve quantities from 0.03 percent to 0.2 percent of the circulating water flow, or 1.1 to 7.3 ft^3/s. Careful placement of the towers should minimize the localized effect of drift.

(b) Local fogging and icing -

General - The range of environmental effects of cooling tower operation at power plants may include modification of the local environment to some degree by more frequent formation of fog, increased fog density, reducing visibility, by increased precipitation, alteration of humidity, and icing on nearby surfaces caused by contact of supercooled vapor plumes with objects at or below freezing temperatures.

Local atmospheric conditions indicate that dense, naturally occurring fogs (visibility less than 1,000 feet) can be expected about 25 days per year in the vicinity of the Browns Ferry Nuclear Plant. This compares to 5 to

10 days for the Central Great Plains region, 30 days for areas along the New England coastline, and 60 days for some of the valley areas in the Central Appalachians.

Fogs occurring in the Browns Ferry area result mainly from nocturnal cooling and subsequent saturation of air near the surface. These fogs normally occur during the late night and early morning hours when low winds and strong cooling conditions prevail. On a seasonal basis, dense natural fogs occur with highest frequency from late fall through the winter and with lowest frequency during late spring and early summer.

Evaluations of the environmental effects of the proposed cooling towers were based partly on observations over 365 days (August 11, 1970, through July 31, 1971) at TVA's Paradise Steam Plant in Kentucky. During this period, one or more of the three hyperbolic natural draft cooling towers were in operation 105 days between 0730 and 0900 hours local time. The observation days included all seasons. Plume observations by the resident meteorologist, data from TVA's Paradise meteorological station, and extrapolated Nashville rawinsonde data were reduced for analysis.

Since the length of visible cooling tower plumes depends primarily on the moisture content of the atmosphere, observed plumes at TVA's Paradise Steam Plant were correlated to absolute humidity deficit--the amount of moisture a parcel of air can contain at saturation for a specific dry-bulb temperature, less the actual amount of moisture present.

Observed plume lengths and humidity deficits for Paradise were fitted by least squares. Expected plume lengths were estimated with the resulting equation using early morning Nashville rawinsonde data for one year extrapolated to the Browns Ferry area. The rawinsonde data were tabulated for two layers (0-1,000 feet and 500-3,000 feet) for mean meteorological conditions applicable for the lower mechanical draft cooling towers (60 feet) and the higher (500 feet) natural draft towers. Also, a correctional factor was applied for the larger water emission rate at Browns Ferry.

This information was used to construct radial graphs illustrating the directional frequency of expected plume lengths. Two graphs were prepared for each type of proposed cooling tower--one for all temperatures and one for below freezing. Radial distances on each graph represent plume lengths from 0 to 5 miles, and plotted contours represent percentages of occurrence of plumes equal to or greater than an indicated length.

Impact - In some cases the visible plumes from these towers are expected to move downwind at near ground level. Of particular interest would be the intensifying effects of these low level plumes during natural fog conditions. Such natural fogging conditions would likely occur on about 25 days per year with optimum fogging conditions occurring between 3 and 8 a.m.

Most fogging would probably occur to the north of the plant, the direction of the highest frequency of plume occurrence. Figure 3.4-3 shows that 16 percent

(54 days) of the total days the plumes would be transported north of the plant under humidity conditions associated with plumes more than 0.7 mile in length. As these plumes could aggravate natural fogging conditions, the frequency of fog immediately north of the plant could be approximately doubled. Also, the one percentile contour indicates that the plume fogging could extend to five miles or more on about three to four days per year.

Periods of potential icing conditions, when the ambient temperature is below freezing, could increase traffic hazards in the local area. The data indicate that cooling tower induced icing could occur on 55 days (about 275 hours) per year during the five-month period, November-March, with the highest expected frequency in January and February. Duration of heaviest icing would depend upon the persistency of the below freezing temperatures with the period most favorable to freezing being from midnight to 7 a.m.

Figure 3.4-4 shows the directions with the maximum frequency of plume travel during icing conditions are south and southeast over the Tennessee River. These conditions will extend to more than four miles less than two percent of the time. On these occasions some light-to-moderate icing could be encountered by river traffic.

A second direction of potential light-to-moderate icing is north-northeast of the plant out to 3-1/2 miles or more. Such icing might occur up to five days per year with a possible hazard to road traffic on the Browns Ferry-Huntsville and the Browns Ferry-Athens secondary roads and the plant access road. Some icing on structures in the immediate plant area and on adjacent transmission towers and lines might also be expected.

(c) Construction effects - Construction of the 5,000-foot long dike will require approximately 470,000 cubic yards of reservoir fill and will disturb approximately 16 acres of reservoir habitat adjacent to the plant. Some temporary turbidity and sediment deposition downstream and out into the reservoir can be expected from this construction activity. The dike construction will result in an irretrievable loss in the sections of the existing shoreline and littoral areas impounded by or covered by the earthen dikes.

Preoperational monitoring surveys have shown this area to support a rich fish fauna during all seasons of the year. The area directly downstream from the plant, which would be destroyed by the mechanical tower installation, supports at present large concentrations of larval and young fish during the May-September period, and also appears to provide suitable habitat for several species of macroinvertebrates, including Hexagenia. To what extent the new shoreline will become repopulated and tend to mitigate the effects of disturbing the existing shoreline is unknown.

(d) Aesthetics - The materials of mechanical towers are not compatible with the architecture of the powerhouse; therefore, design features will be incorporated to achieve architectural compatibility with the main plant. The relatively low profile (60 feet high) of the mechanical draft towers would not present a very large vertical barrier or landmark on the terrain. While the towers viewed from their end permit intermittent horizontal views of the landscape, when viewed from their side they present a horizontal barrier exceeding a thousand feet. The physical characteristics of the site and the existing plant arrangement require that the towers be located linearly along the shoreline. This will require special site treatment to relate the towers to the main plant area and prevent destroying the natural characteristics of the shoreline.

(e) Noise - The use of mechanical draft cooling towers will increase noise levels at the plant site by a small increment. This increase will be due to (1) the fans, and (2) the falling water. Predicted sound pressure levels from one major manufacturer of cooling towers are 76 dB at 250 Hz, 63 dB at 2000 Hz, and 59 dB at 8000 Hz--all 50' from the louvered face (re 0.0002 microbar).

(4) Economic considerations -

(a) Initial investment - The additional initial investment required to install this alternative is estimated to be 35.0 and 36.0 million dollars for the closed and combined systems, respectively.

(b) Capability - Any substitution of a cooling tower system produces a system less efficient than the original diffuser type cooling system design due to the higher back pressures plus the fan and pumping power required. This efficiency loss reduces the output of the plant and makes it necessary to replace this loss with additional capacity in order to assure TVA customers the same reliability of power supply they would have had with the original diffuser system. The effect is as follows:

System Type	Closed	Combined
Capacity Loss, kW	29,380	9,525
Replacement Cost, 1971 Dollars	5,463,000	1,772,000

(c) Operation and maintenance - The use of cooling towers would increase operating costs over those of the original diffuser system due to the lower efficiency plus added fan and pumping costs, and also add the cost of maintenance of the towers to the overall plant operating costs. An economic evaluation of the present worth of these costs in terms of 1971 dollars is shown below:

System Type	Closed	Combined
Heat Rate Increase, Percent	0.90	0.29
Heat Rate Increase, Btu/kW	92	30
Efficiency Loss, Dollars	3,597,000	1,186,000
Fan & Pump, Power Cost, Dollars	11,388,000	3,111,000
Total Operation Cost, Dollars	14,985,000	4,297,000
Maintenance Cost, Dollars	3,700,000	1,536,000
Total Operation & Maintenance Cost, Dollars	18,685,000	5,833,000

(d) Total cost - The total estimated cost of the above items would then be 59.1 and 43.6 million dollars for the closed and combined systems, respectively.

(5) Construction schedule - It is expected that the design, construction, and placement into operation of mechanical draft cooling towers would take approximately 24 to 28 months.

3. Natural draft cooling towers - The use of natural draft cooling towers as an alternate cooling method would require three cooling towers about 400 feet in diameter and about 500 feet high. Makeup and blowdown requirements would be handled by other facilities. A new booster pumping station would be built to lift the circulating water to the towers.

The water would be broken into drops by falling through fill. Heat from the drops is transferred to the air. The air flow is created by the tall hyperbolic shells. The water returning from the towers, depending on the mode of operation, would flow back by gravity to either the discharge conduit or to the intake structure where the existing circulating water pumps would then transport it through the plant condensers.

(1) Feasibility - Natural draft cooling towers have been used for many years. The first unit in the United States, Big Sandy, was built and put into operation in 1962. The largest tower in operation, to our knowledge, is 320 feet in diameter and 452 feet high. The following counterflow towers are under construction with none being in operation:

Ohio Power - Amos Plant - 400' diameter x 492' high

Portland General Electric - Trojan Plant - 385' diameter x 492' high

Toledo Edison - Davis Besse Plant - 411' diameter x 492' high

Toledo Edison - Zimmer Plant - 383' diameter x 479' high

Figure 3.4-5 shows a possible location and arrangement of the three natural draft towers on the plant site.

(2) <u>Land requirements</u> - The land requirements and contemplated movement of facilities required by the use of the natural draft tower schemes will be similar to and not in excess of those required by the mechanical draft schemes. The dike required would be about 2500 feet long and would extend into the reservoir about 200 feet (300 feet at the powerhouse).

(3) <u>Environmental considerations</u> -

(a) <u>Physical and chemical characteristics of tower effluent</u> - The amount of makeup required for continuous operation with natural draft cooling towers is estimated to be the same as the estimate for the mechanical draft towers, i.e., approximately six percent of the circulating water flow, or 220 ft^3/s.

The amount of blowdown and its dissolved solids concentration required for continuous operation with natural draft cooling towers is estimated to be approximately the same as for the mechanical draft towers, i.e., three percent of the circulating water flow. The temperature of this blowdown water will be approximately 60°F. under average winter conditions, 78°F. under average fall and spring conditions, and 89°F. under average summer conditions. A peak summer condition might produce temperatures near 97°F. However, blowdown can be withheld during peak temperature conditions provided they do not last more than about two days.

The drift, or water blown from the tower, is expected to involve from 0.03 to 0.2 percent of the flow or 1.1 to 7.3 ft^3/s, although actual amounts within this range will be somewhat less than for mechanical draft towers.

(b) Local fogging and icing -

General - The general discussion of the local atmospheric conditions and method of analysis described under the section 3.4.2(2) of the mechanical draft cooling towers is applicable to natural draft towers.

Impact - No significant environmental effects are anticipated with the plume discharge from the natural draft cooling towers at Browns Ferry. With average initial plume rise ranging from 500 to 1,000 feet above the 500-foot cooling towers, the visible portion of the elevated plume would seldom, if ever, reach ground and cause localized ground fogging. This behavior is confirmed from the observations of the cooling tower plumes at TVA's Paradise Steam Plant.

During general (or coning) dispersion conditions with neutral stability, moderate wind and cloudy skies, only segments of the bottom portion of the plume would conceivably reach ground level at distances beyond two to three miles. However, experience indicates that such conditions rarely occur.

In contrast to the combined effects of natural fog and plumes from the lower mechanical draft cooling towers, no increased density or frequency of surface fog from the elevated plumes of the natural draft towers are to be expected in this relatively flat terrain. During periods of dense natural fog the air within the lower 1,500 feet, including the cooling tower plumes, would be moderately stable; and there would be no downwind mixing of the plume to ground level with resulting intensification of the lower fog layer. During subsequent inversion breakup or limited mixing dispersion conditions, the visible plume would not normally be found at ground level since the cooling tower plume condensate would normally evaporate well before reaching ground.

Another environmental aspect of natural draft cooling tower plumes involves aesthetics. Frequently, these elevated plumes will have large dimensions, particularly if the plume movement is perpendicular to the alignment of the towers. In such cases the width of the combined plumes from three towers would be estimated to be 0.5, 0.6, 0.7, 0.9, and 1.2 miles at respective distances of 1, 2, 3, 5, and

10 miles from the plant. However, plume extensions beyond five miles are expected to occur less than one percent of the time.

Based on the study period covered in figure 3.4-6, and assuming continuous cooling tower operation, the visible plumes should move northeastward 14 percent of the annual days with lengths equal to or greater than 0.5 mile during the early morning hours. The plume will extend to 4.5 miles or more one percent of the time about four days per year.

The data suggest that a light icing potential does exist on 50 or 60 days (250 to 300 hours) per year during the five-month period, November-March, when freezing temperatures would normally be expected. As indicated by figure 3.4-7, the majority of these potential icing conditions will occur within about five miles of the plant, primarily in the southeast through south directions.

Observations at the Paradise Steam Plant during the winter seasons of 1969 and 1970 indicated no occurrence of significant icing attributable to the operation of the three natural draft cooling towers, although fallout of ice crystals from the plume was observed on one occasion. At this latitude, about 180 miles north of the Browns Ferry site, the general icing potential would likely be greater. It follows, then, that the icing potential at the Browns Ferry site should not be significant.

Because of the elevated height of the proposed natural draft cooling towers, direct-contact icing, if any, should be limited to elevated surfaces such as the top of the 600-foot stack. Light fallout of freezing precipitation from the bottom of the plume should occur only rarely.

(c) Construction effects - Construction of the 2500-foot long dike will require approximately 450,000 cubic yards of reservoir fill and will disturb approximately 12 acres of reservoir habitat.

The installation of natural draft towers would not remove as much shoreline and littoral habitat and would be concentrated in an area already disturbed by construction activities.

(d) Aesthetics - The hyperbolic form and concrete materials are compatible with the architecture of the main plant and would not require any special aesthetic treatment.

The natural draft cooling towers which are about 500 feet high would most certainly become a landmark on the surrounding terrain. The extensive plumes would increase this effect.

(e) Noise - Based on TVA's experience with the three natural draft towers installed at its Paradise Steam Plant, only slight increases in noise levels at the site boundary are expected if natural draft towers are installed.

(4) Economic considerations -

(a) Initial investment - The additional initial investment required to install this alternative is estimated to be 48.0 and 49.0 million dollars for the closed and combined systems, respectively.

(b) Capability - With natural draft cooling tower systems, as in the case of mechanical draft cooling systems, the plant net electrical output is reduced. The effect on plant capacity is as follows:

System type	Closed	Combined
Capacity loss, kW	45,800	11,811
Replacement cost, 1971 dollars	8,526,000	2,196,000

(c) Operation and maintenance - Operating and maintenance costs would be greater for natural draft tower systems than for the original diffuser system. An economic evaluation of the present worth of these costs in terms of 1971 dollars is shown below:

System type	Closed	Combined
Increase in Heat Rate, Percent	1.39	0.39
Increase in Heat Rate, Btu/kWh	142	37
Increase in Heat Rate, Dollars	5,613,000	1,464,000
Fan and Pump Power Cost, Dollars	4,500,000	1,140,000
Total Operational Cost, Dollars	10,113,000	2,604,000
Maintenance Cost, Dollars	1,000,000	415,000
Total O&M, Dollars	11,113,000	3,019,000

(d) Total cost - The total estimated cost of the above items would then be 67.6 and 54.2 million dollars for the closed and combined systems, respectively.

(5) Construction schedule - It is expected that the design, construction, and placement into operation of natural draft cooling towers would take approximately 45 to 51 months.

4. Spray canal system - The use of a spray canal system as an alternate cooling method would require a cooling canal approximately five miles in total length and 200 feet wide with 700 power spray modules spaces four abreast in 175 rows.

Preliminary investigation indicates that the canal should probably extend about a mile each way from the powerhouse along the shoreline and be connected by a three-mile long channel cut into the land. The two-mile section extending along the shoreline would be separated from the reservoir by a dike located about 200 feet from the shoreline except at the powerhouse area where it would be about 300 feet from the shoreline.

The water returning from the canal would flow by gravity back to the intake structure where the existing circulating water pumps would then transport it through the plant condensers.

Figure 3.4-8 shows a possible location of a spray canal system at the plant site.

(1) Feasibility - The use of a spray canal for power plant cooling is a relatively new concept and only in recent months has a large unit been put into operation. Typical among units in operation are:

User	Location	Millions-Btu/h	Purpose
Commonwealth Edison	Dresden	5466	Temporary startup Units 2 & 3
Gulf States Utilities	Beaumont, Texas	-	Salt water test
Detroit Edison	Fermi	261	Testing
Virginia Elec & Power	Chesterfield	2067	Topping
Public Service of N.H.	Merrimack	429	Topping

The largest unit, Dresden, has been in operation a few months and is for the purpose of starting up units of 809 MW capacity. By comparison the heat rejected from the Browns Ferry plant is 22,200 million Btu/h. Later these modules will be combined with a cooling lake.

If it is assumed that the necessary conditions exist, it is possible to operate a spray canal system at the Browns Ferry plant site as either a totally closed system which, other than for makeup and blowdown provisions, would be isolated from the reservoir, or as an open system. It could also be operated as a partially closed system in which a part of the inlet flow to the plant would be taken from the reservoir and part would be taken from the spray canal. At the same time, a flow would be returned to the river, immediately after passing through the condensers, equal to the inlet flow taken from the reservoir. Since the layout of the canal is such that it terminates upstream from the intake structure, it is not practical to operate the system in helper mode inasmuch as the cooled discharge from the canal would have to bypass the inlet structure to reach the discharge diffusers.

The combined cycle system can be operated in the following modes:

a. Open cycle mode
b. Two-thirds open cycle, one-third closed cycle
c. One-third open cycle, two-thirds closed cycle
d. Closed cycle

There are no immediately available data on the sealing characteristics of the soil in the canal area. Further, there is presently no installation of major size that relies wholly on a spray canal.

(2) <u>Land requirements</u> - Based on a preliminary investigation of site conditions, it is estimated that a spray canal system would require the purchase of about 350 acres of additional land in the general form of a strip approximately 1/3 mile wide by approximately 1-1/2 miles long.

(3) <u>Environmental considerations</u> -

(a) <u>Physical and chemical characteristics of canal effluents</u> - Water necessary for continuous operation of the cycle will be obtained from the Tennessee River at the plant site. This quantity of makeup will be dependent upon the following items: (1) amount of blowdown necessary to maintain the total dissolved solids at acceptable levels in the Tennessee River; (2) desirable amount of blowdown necessary to maintain the water quality in the system such that corrosion or scaling control chemicals will not have to be added; (3) the amount of evaporation from the canal; and (4) drift losses. With a blowdown concentration factor of 2, the total makeup required would be approximately six percent of the circulating flow or 220 ft^3/s.

The amount of blowdown and its dissolved solids concentration required for continuous operation with spray canal is estimated to be approximately the same as for cooling towers, i.e., three percent of the circulating water flow of 110 ft^3/s. Assuming three-unit operation and no effect of solar radiation, the temperature of this blowdown water will be approximately 65°F. under average winter conditions, 83°F. under average fall and spring conditions and 94°F. under average summer conditions. A peak summer condition might produce temperature near 98°F. However, blowdown can be withheld during peak temperature conditions for several days. The dissolved solids in the river for 1964-1965 approximately averaged 107 mg/l with a peak of 137 mg/l. With a concentration factor of 2, the dissolved solids in the blowdown should not exceed acceptable levels.

Drift is the water blown from the spray canal by wind. Although the water is sprayed into the air by the spraying modules and is subject to being carried away, the droplets are large and should be carried only a short distance. Furthermore, the channel edge would be approximately 20 feet from the side spray modules and the edge would be sloped back to the channel so that a large percentage of water which may be blown by the wind would return back to the canal.

(b) Local fogging and icing - Environmental effects from the use of a spray canal system at the Browns Ferry Nuclear Plant would include some fogging and icing. These effects are largely dependent on the evaporation rate of the canals and absolute humidity deficit of the atmosphere. Also, the expected plume lengths are longer than those estimated for the cooling towers. Because of the water sprayed upward at a low level (15 to 20 feet) as compared to a plume release height of 60 feet and 500 feet for the mechanical- and natural-draft towers, respectively, more significant local effects are expected.

Drift from a spray canal system may present some problem in the immediate vicinity of the canal, especially during periods of moderate wind speeds. Mean wind speeds of 12 miles per hour or more were considered to lead to drift entrainment. Data from the Browns Ferry meteorological station for August 1970 to July 1971 indicated 105 days per year when this wind speed is equalled or exceeded. Of these 105 days, there were approximately 20 days when the temperature was below freezing. During these conditions localized icing downwind could be expected. The affected area downwind would depend on the wind speed and the direction of the wind with respect to the alignment of the spray canal. The wind rose for the 105 days, figure 3.4-9, indicates the direction from which a wind with a speed equal to or greater than 12 mi/h originates and the frequency at which it occurs. Therefore the maximum frequency of drift occurances would be south of the canal (drift direction is opposite the wind direction).

In many cases, visible plumes generated by the spray canals will move downwind near ground level with intensifying effects on natural fogging. Such conditions should occur about 25 days per year with most fogging between 3 a.m. and 8 a.m. Most fogging will probably occur north of the plant--the highest frequency of plume occurrence. Figure 3.4-10 shows that on 12 percent of the total days the plumes could be about two miles in length in this sector.

Periods of potential canal-induced icing when the ambient temperature is below freezing are expected on 56 days per year during the five-month period, November-March, with the highest frequency in January and February. Duration of heaviest icing would depend upon the persistency of the below-freezing temperatures. Most severe conditions are expected between midnight and 7 a.m. As shown in figure 3.4-11, the directions with the maximum frequency of plume travel during icing conditions are south and south-southeast.

(c) Aesthetics - The use of a spray canal might be attractive except when fogging and plume extension occur.

(d) Noise - The use of a spray canal will increase noise levels at the plant site by a small amount. This increase will be due to motor noise plus the falling water. A test, conducted on a 17-module test system against a background of 62-64 dB(A), indicated 76 dB(A) at 100 feet.

(4) Economic considerations - Since the extent of design and construction problems which may exist at this time are not known at this time, the cost estimates of spray canal cooling systems cannot be accurately estimated.

(5) Construction schedule - No estimate of the time required to construct a spray canal system is available at this time.

5. Cooling lake system - The use of a cooling lake system would require approximately 5,000 acres of exposed water surface based on a rule of thumb of 1.5 acres per MW of nuclear capacity. The exact lake size and the corresponding expected thermal performance cannot be determined without an extensive investigation of the shape and depth of the lake, the location of the inlet and outlet to the lake, and the climatic history of the area. By inspection of the topography in the vicinity of the plant site it has been determined that in order to impound a reservoir of the anticipated size the normal water level would have to be 50-100 feet above the existing reservoir, and that the construction of the reservoir would require many miles of canals and high dikes.

(1) Feasibility - The use of cooling lakes is an old and well established concept of heat rejection which, if the plant site is favorably located, results in not only efficient, economical cooling but also fringe benefits in improved recreational facilities. The Browns Ferry site, however, is not conducive to this form of cooling for reasons previously mentioned.

If the assumption is made that all engineering problems associated with the construction of a cooling lake were surmountable, it would be possible to operate the system as either a totally closed system which, other than for makeup and blowdown provisions, would be isolated from the reservoir or as an open system. Since the level of the cooling lake would be much higher than the level of the reservoir and since the cooling lake would be physically located upstream from the intake structure, it would be possible but not economically attractive to operate the system in a helper mode. The system might possibly be operated as a partially closed system in which one or more of the units may be operated on closed cycle while the other units are operated on open cycle.

The combined cycle system can be operated in the following modes:

a. Open cycle mode
b. Two-thirds open cycle, one-third closed cycle
c. One-third open cycle, two-thirds closed cycle
d. Closed cycle

There are no immediately available data on the sealing characteristics of the soil in the lake area.

The above considerations indicate that this method of cooling would not be practical for the Browns Ferry site.

(2) <u>Land requirements</u> - Based on a preliminary investigation of site conditions, it is estimated that a cooling lake system would require the purchase of over 10,000 acres of additional land.

(3) Environmental considerations -

(a) Physical and chemical characteristics of pond effluents - Water necessary for continuous operation of the cycle will be obtained from the Tennessee River at the plant site. This quantity of makeup will be dependent upon the following items: (1) amount of blowdown necessary to maintain the total dissolved solids at acceptable levels in the Tennessee River; (2) desirable amount of blowdown necessary to maintain the water quality in the system such that corrosion or scaling control chemicals will not have to be added; and (3) the amount of evaporation from the lake. With a blowdown concentration factor of 2, the total makeup required would be approximately three percent of the circulating water flow or 110 ft^3/s.

The amount of blowdown and its dissolved solids concentration required for continuous operation with a cooling pond is estimated to be about half that as for cooling towers or spray canals, i.e., one and one-half percent of the circulating flow or 55 ft^3/s. Since the optimum temperatures or water flows have not yet been determined for the cooling pond, the exact blowdown flows or temperatures cannot be predicted.

It is not anticipated that any water droplets will be carried from a cooling pond by the wind in the form of drift.

(b) Fogging and icing - Evaluations of the environmental effects of cooling ponds are very limited to date. A review of the literature and discussions with other investigators* indicate that if the cooling pond is of adequate size for the thermal discharge, the environmental effects of cooling ponds are limited to within 1/4 mile from the pond border. "Adequate size" is determined using a rule-of-thumb estimation as 1-1/2 acres of cooling pond for one megawatt plant size rating for nuclear power plants.

Local atmospheric conditions indicate that dense, naturally occurring fogs (visibility less than 1,000 feet) can be expected about 25 days per year in the vicinity of the Browns Ferry Nuclear Plant. The use of a cooling pond is expected to increase only the density and not the frequency of these fogs over the pond and out to within 1/4 mile downwind from the pond edge at the end where the warm water enters.

The affected peripheral area is indicated by the annual wind direction frequency distribution in the plant area. Frequencies were obtained from mean values of wind direction from surface to 75 feet for a year of data from TVA's Browns Ferry meteorological station. As indicated in figure 3.4-12, the areas most affected will be north and west-northwest of the cooling pond (plume direction is opposite to wind direction).

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* Personal communications, James E. Carson, Argonne National Laboratories, 10/1/71, and Donald Portman, University of Michigan, 9/29/71.

In the absence of natural fogs, particularly in the winter months, "steam fogs" will occasionally develop over the pond, but this type of fog is usually very thin and dissipates quickly. However, if the air is very cold, these steam fogs may drift over structures and through vegetation causing rime icing up to 1/4 mile downwind of the pond. Based on wind direction frequency distribution during freezing temperatures, figure 3.4-13, the local sectors affected most frequently are south-southeast and south-southwest of the cooling point.

(c) Aesthetics - The cooling lake would have to be located several miles from the plant site and would probably not be aesthetically associated with the plant. As a policy, however, the natural features of the locale would be retained as far as possible.

(d) Noise - This system should not contribute any measurable noise to the environment.

(4) Economic considerations - Since the extent of design and construction problems which may exist are not known at this time, cost estimates of the cooling lake system cannot be accurately estimated.

(5) Construction schedule - No estimate of the time required to construct a cooling lake system is available at this time.

6. Effect of alternative cooling facilities on existing plant design - If auxiliary cooling facilities are required at the Browns Ferry Nuclear Plant, the installation of certain alternatives may require that some of the present facilities be modified. These include the facilities by which chemical and radioactive materials are discharged from the plant.

(1) Chemical discharges - The quantities of chemicals discharged from the plant are discussed in section 5.4 of the draft environmental statement, and section 3.8 of this supplement discusses the treatment of these discharges. The concentrations of these chemicals will be unaffected by operation on the helper system. When operating on the closed cooling system, the chemical wastes will be discharged into the condenser circulating water system at the circulating water intake channel. The chemicals will be dispersed in the circulating water system. At two concentrations of solids in the cooling water system as a closed cooling tower circuit the maximum solids concentration from the chemical discharges are as follows:

Alum	.04 mg/l
Chlorine	.001 mg/l
Polymer	Nil
SO_4^{--}	3.3 mg/l
Na^+	1.9 mg/l

These will be the maximum concentrations of these chemicals in the blowdown from the cooling towers. For spray canal or cooling pond systems, dilution will be greater and concentrations will be less than two, so chemical discharge concentrations will be less than these listed.

(2) Radioactive discharges -

(a) Liquid - When operating on the helper system, the radioactive wastes will be discharged into the condenser circulating water system between the return of the cooling water from the towers and the diffuser system. Concentrations will be the same as those given in section 3.1.

When operating on the closed cycle system, the radioactive waste discharges will be injected into the suction of the blowdown pump. The blowdown pump would discharge to one of the existing diffusers. The annual average flow of blowdown will be about 50,000 gal/min. Based upon this rate of 50,000 gal/min, the annual average concentration of radioactivity, except tritium, will be about 4 picocuries per liter. The annual average tritium concentration will be about 470 picocuries per liter. Discharge from the radioactive waste facilities will be electrically interlocked against opening if the blowdown pump is not operating. All effluents will be monitored for radioactivity.

(b) Gaseous - Because of the large size of the natural draft cooling towers, their installation may substantially interfere with dispersion of radioactive gaseous effluents from the 600-foot stack. The towers may create a wake--occurring up to an altitude of two tower heights and a length of three tower diameters--and may lead to downwash of the plant radioactive gaseous effluents. This effect has been evaluated and preliminary indications are that the annual whole body dose to a hypothetical individual at the plant boundary may increase by a factor of about

2-1/2 times. This dose is within the guidelines of the proposed Appendix I to 10 CFR Part 50.

Because of their low height, the mechanical draft towers would have no effect on the ability of the 600-foot stack to disperse the radioactive gaseous effluents.

7. Evaluation of alternative heat dissipation methods - Based upon the information available at the time of this analysis, TVA has concluded that the installation of the spray canal or the cooling lake alternatives would not offer substantial benefits over the other available alternatives. This conclusion is based on an analysis of the following items:

1. Feasibility - While the concept of cooling lakes is well established, the use of spray canals is a relatively new concept and has not been applied to a plant as large as Browns Ferry. Examination of the terrain indicates that a cooling lake installation is not readily adaptable due to the lack of low lying areas of the size required in close proximity to the plant. Also, the necessary sealing characteristic of the soil is not known at this time for either spray canals or cooling lakes. An extensive investigation would be required to ascertain the feasibility of either of these alternatives at the Browns Ferry plant.
2. Environmental impact - While the potential for fogging with a spray canal or cooling lake is less than that to be expected with towers, the land requirements are

substantially higher--350 additional acres required for spray canals and up to 10,000 additional acres required for a cooling lake.

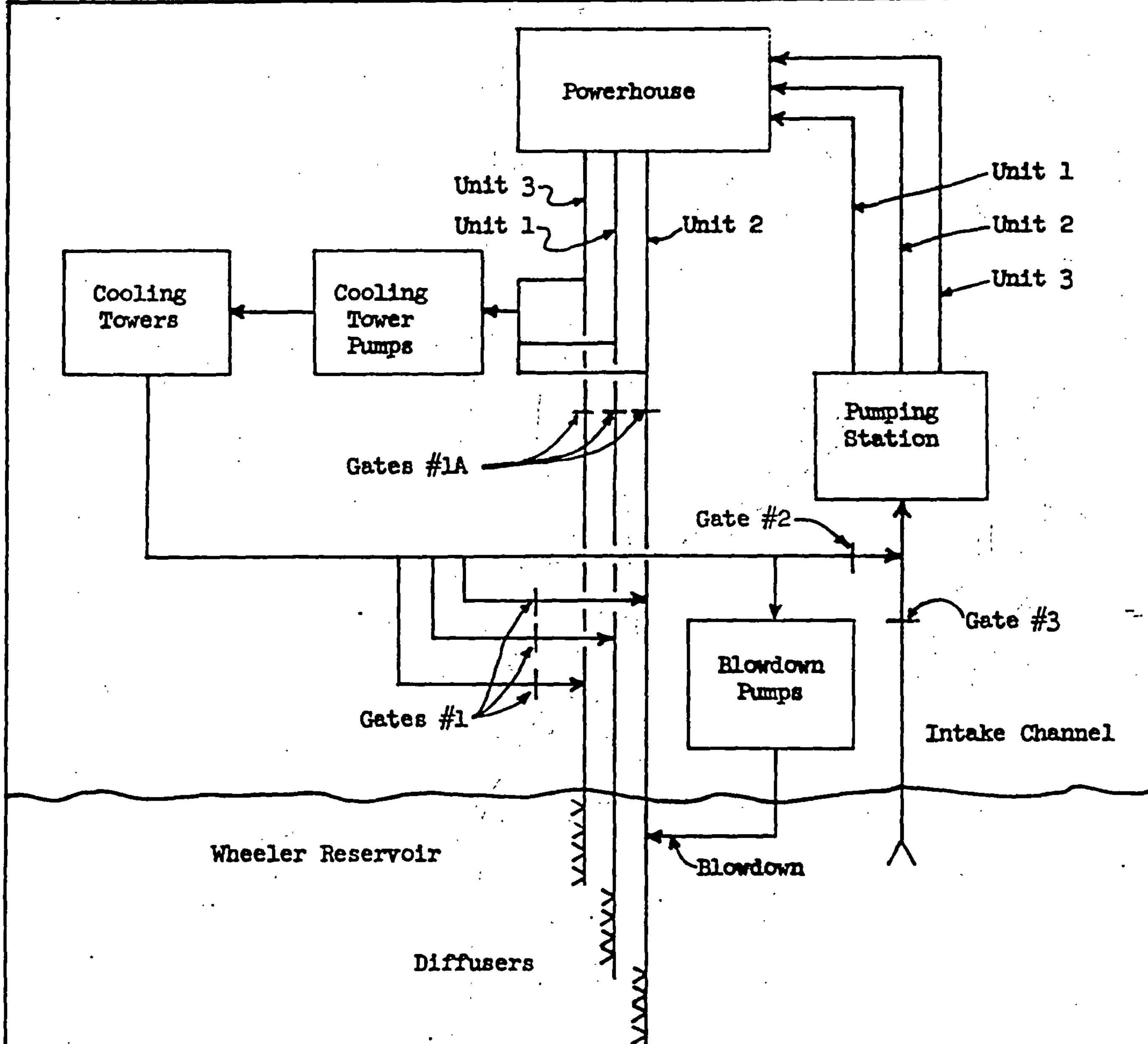
The following table summarizes a present worth cost comparison (1971 dollars) of the remaining two alternatives for both the closed system and the combined system:

System Type	Closed	Combination 1/	Closed	Combination 1/
Tower Type	Mechanical Draft	Mechanical Draft	Natural Draft	Natural Draft
Average Annual Net Turbine Heat Rate Btu/kWh	10358	10296	10409	10303
Cooling Tower Operation	100%	41.5%	100%	41.5%
Facilities Cost	35,000,000	36,000,000	48,000,000	49,000,000
Operating Cost	15,000,000	4,300,000	10,100,000	2,600,000
Capability Cost	5,500,000	1,800,000	8,500,000	2,200,000
Maintenance Cost	3,700,000	1,500,000	1,000,000	400,000
Total	59,200,000	43,600,000	67,600,000	54,200,000

1/ Makes use of existing diffuser system on which present cost is estimated at 4.9 million dollars, the cost of which is not included.

The economic advantages of the mechanical tower are $8.4 million for the closed system and $10.6 million for the combined system. This does not include the cost of modifying the gaseous radwaste system which may be required for a natural draft cooling towers installation at Browns Ferry.

In addition to the economic benefits of mechanical draft towers, their installation can be completed approximately two years earlier than a natural draft tower installation and thereby would be the more expeditious installation to comply with more stringent thermal standards, if adopted. Except for slightly higher noise levels and a greater potential for fogging and icing with mechanical towers, the environmental impacts of the two alternatives are generally comparable. Thus TVA has concluded that in the absence of definitive standards the mechanical draft tower alternative probably represents the most attractive alternative heat dissipation method for Browns Ferry should auxiliary facilities be required at some later time.



GATE NO.	1	1A	2	3
River Cooling	C	O	C	O
Helper Cooling	O	C	C	O
Closed Cooling	C	C	O	C
*Combined Cooling	C Unit 1 O Units 2&3	O Unit 1 C Units 2&3	C C	O O

*Shown for Unit 1 on river and Units 2 and 3 on helper cooling.

Figure 3.4-1

DIAGRAM SHOWING GATE ARRANGEMENTS FOR VARIOUS MODES OF OPERATION OF ONCE-THROUGH AND SUPPLEMENTAL COOLING WATER FACILITIES

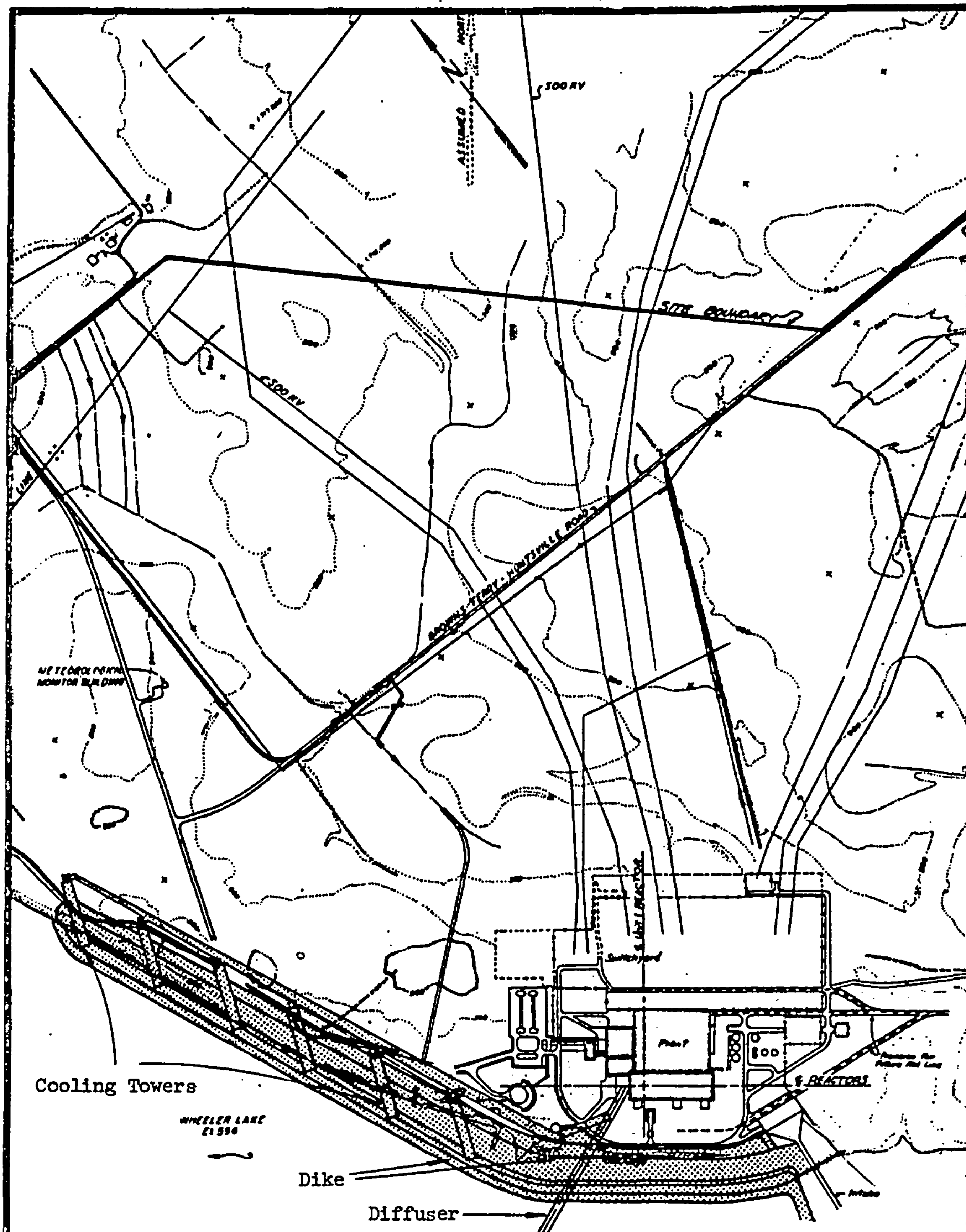
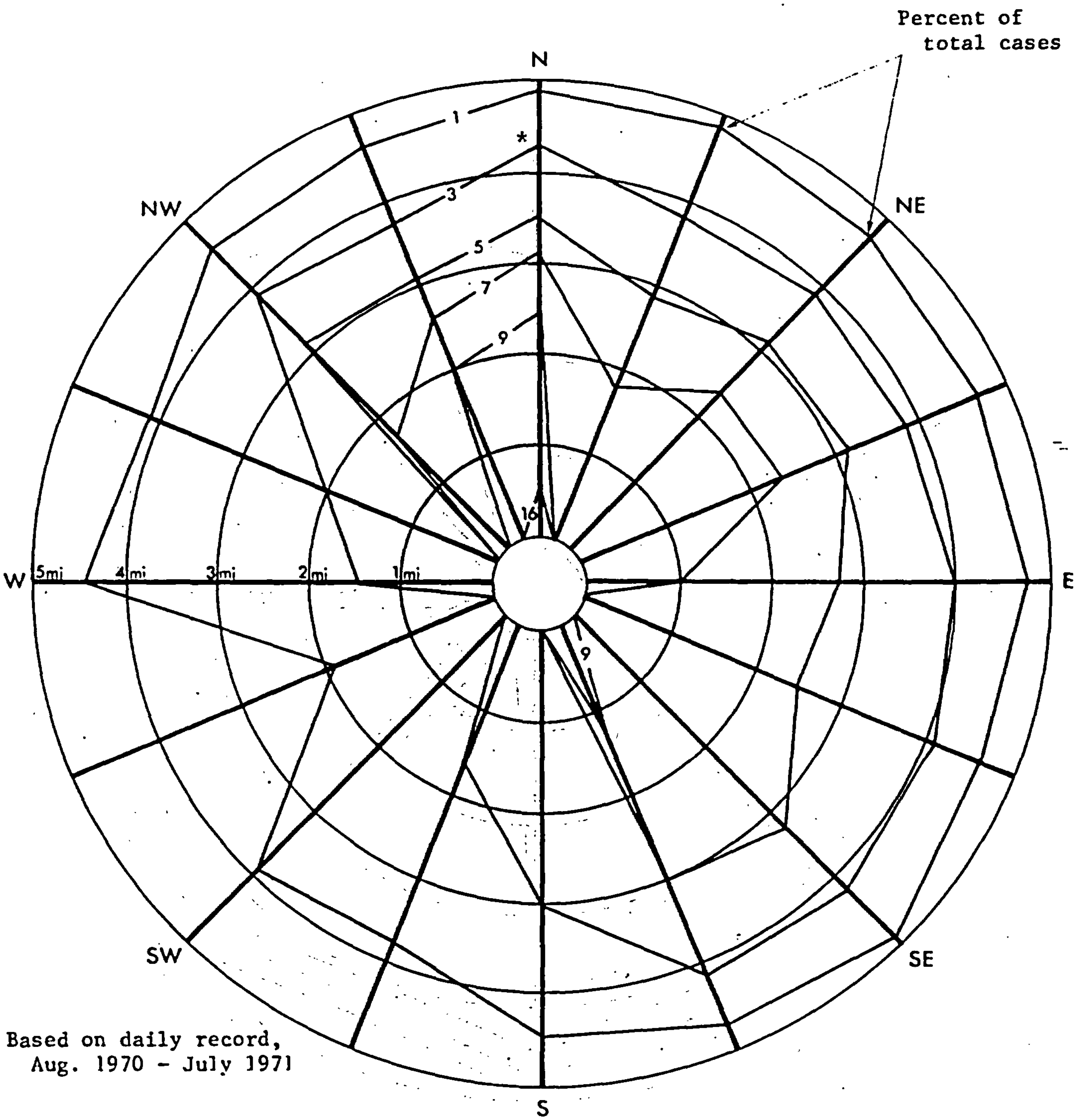


Figure 3.4-2

Arrangement of Mechanical Draft Cooling Towers

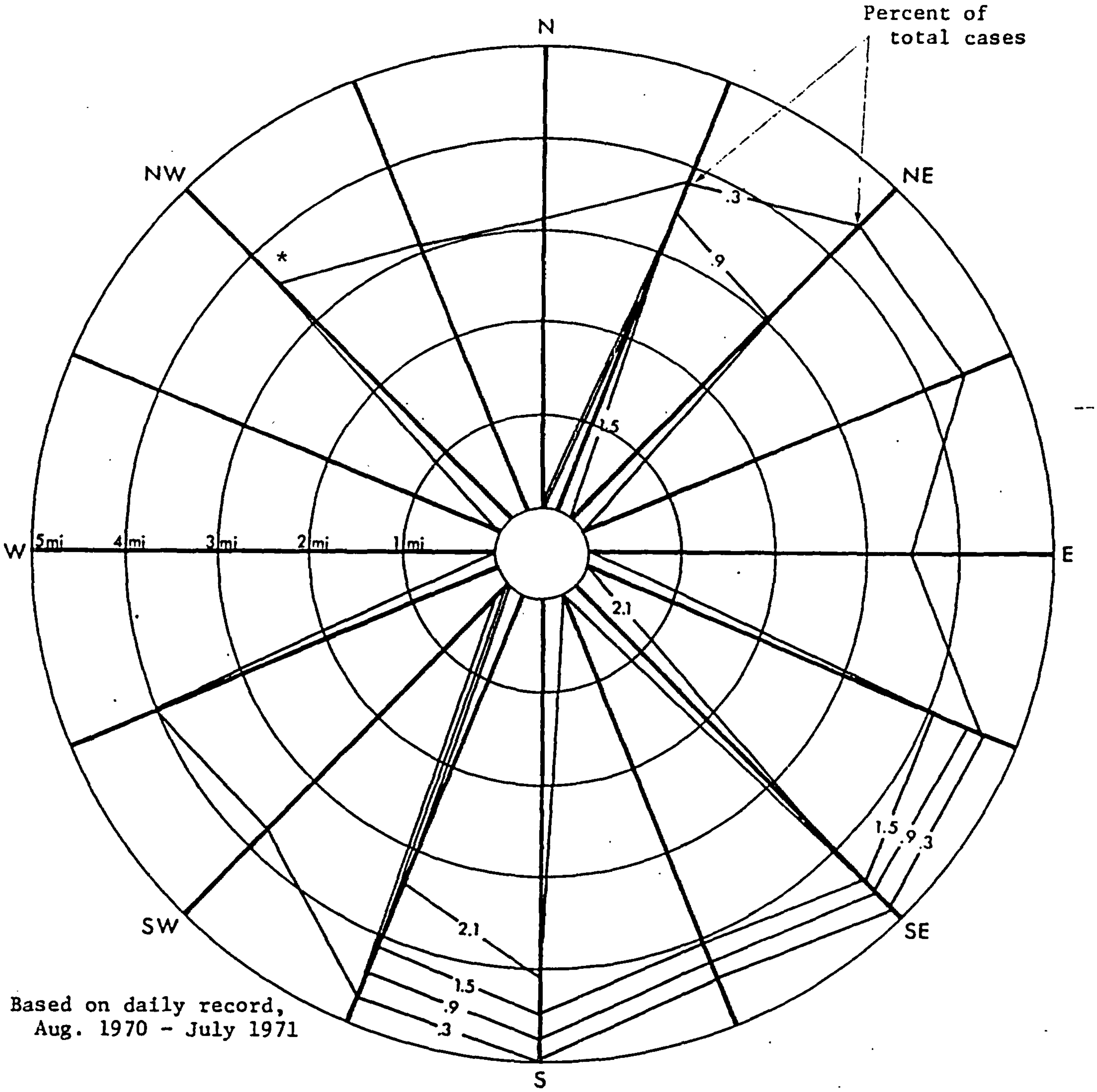
*Example: 3% of total cases occur in the 22-1/2° sector north of the plant with plume length ≥ 4.2 mi.



Based on daily record,
Aug. 1970 - July 1971

Figure 3.4-3 PREDICTED PLUME LENGTH AND FREQUENCY OF OCCURRENCE
FOR 16 COMPASS POINT SECTORS
MECHANICAL DRAFT COOLING TOWERS
BROWNS FERRY NUCLEAR PLANT

*Example. 0.3% of total cases occur in the 22-1/2° sector northwest of the plant with plume length ≥ 3.5 mi.



Based on daily record, Aug. 1970 - July 1971

Figure 3.4-4 PREDICTED PLUME LENGTH AND FREQUENCY OF OCCURRENCE FOR 16 COMPASS POINT DIRECTIONS (AMBIENT TEMPERATURE BELOW FREEZING) MECHANICAL DRAFT COOLING TOWERS BROWNS FERRY NUCLEAR PLANT

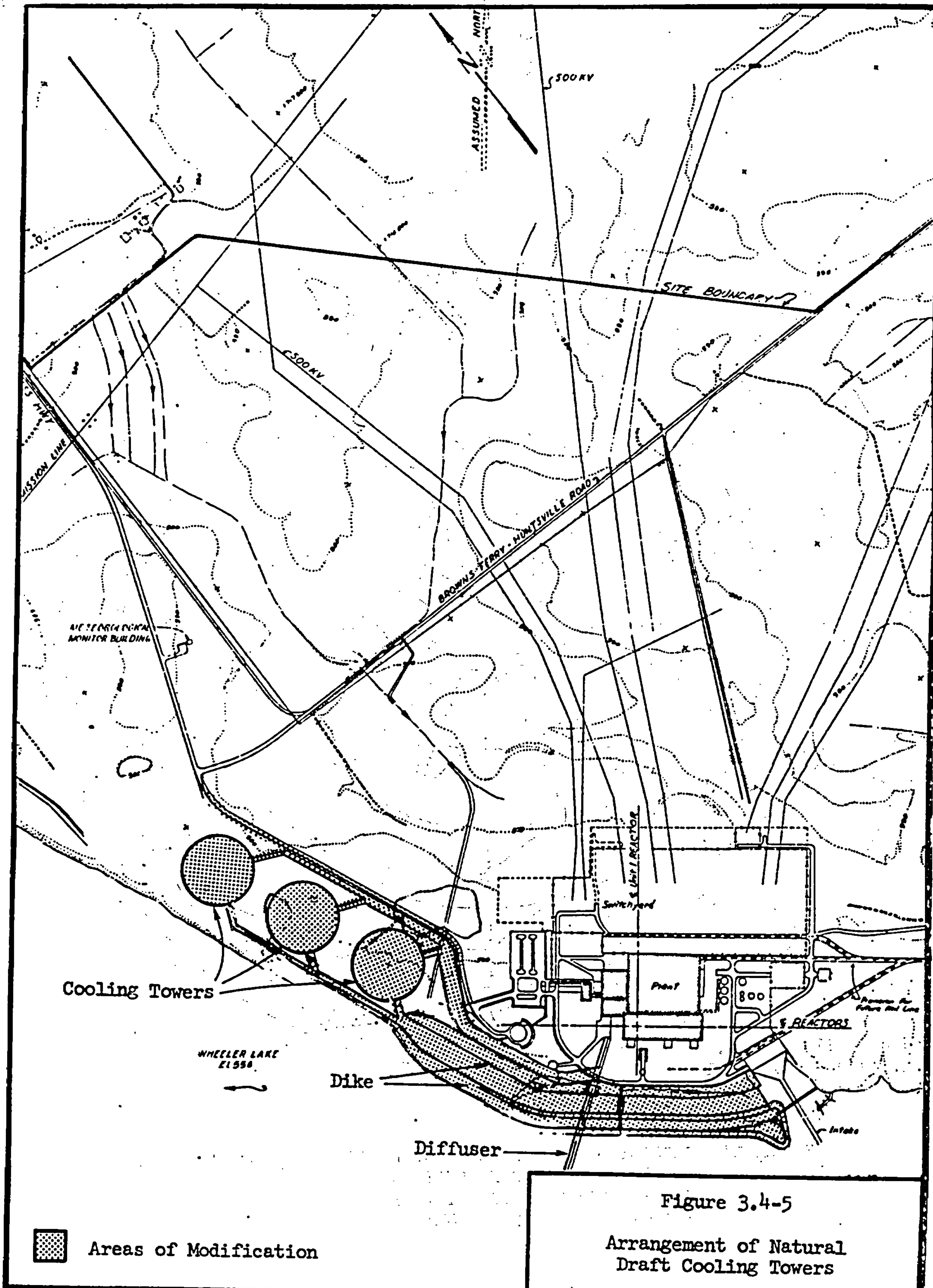
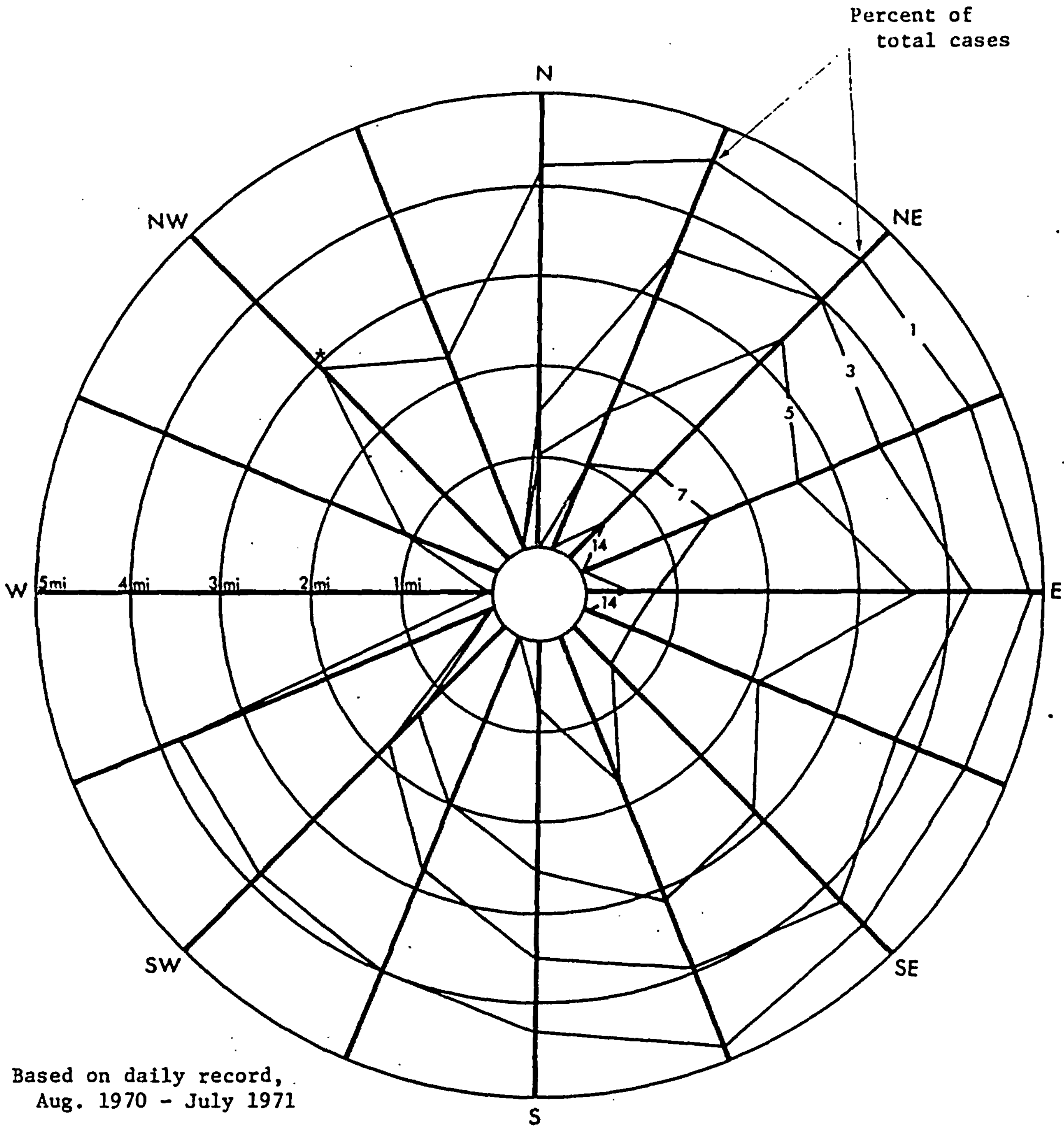


Figure 3.4-5

Arrangement of Natural Draft Cooling Towers

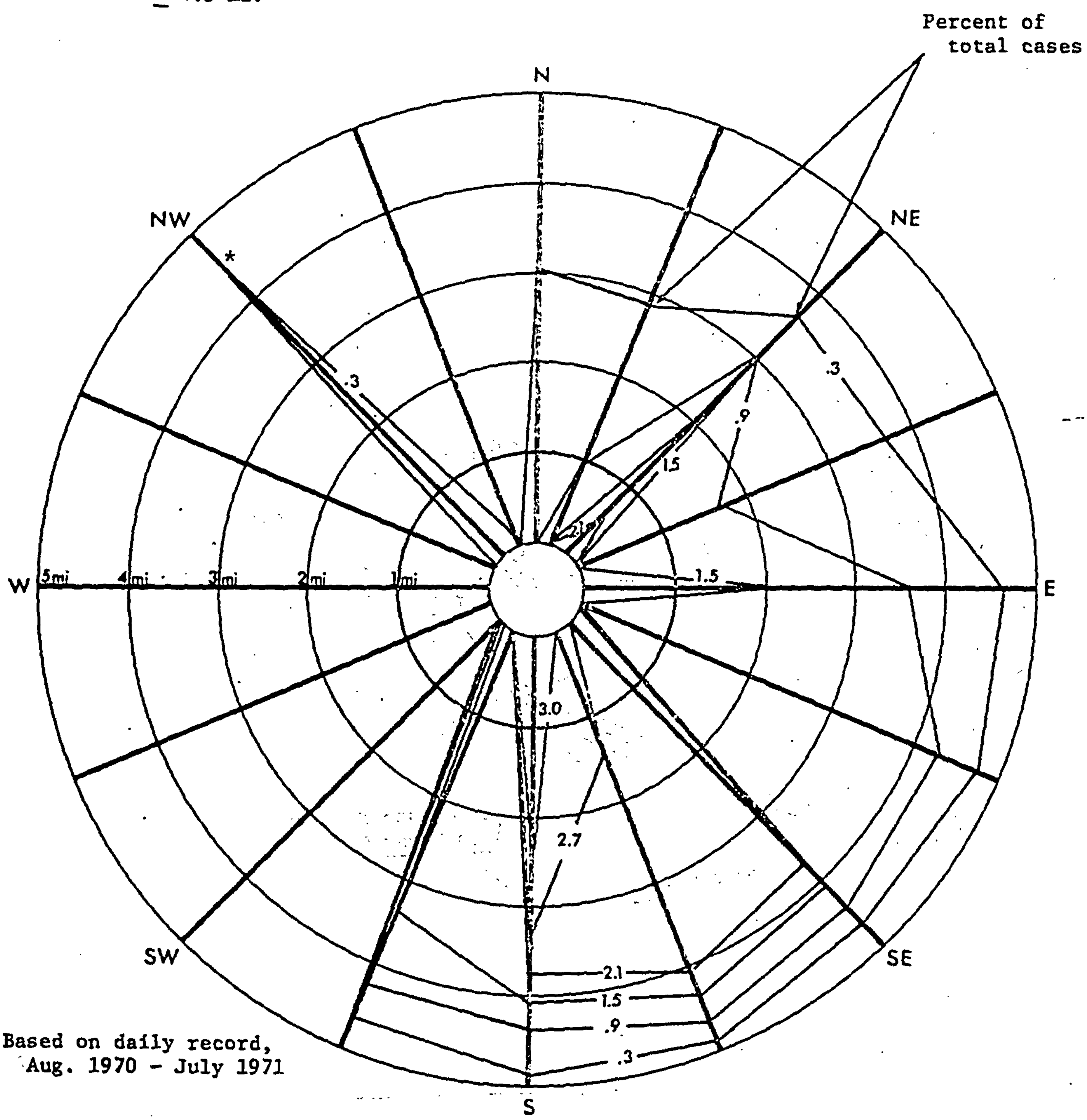
*Example: 1 percent of total cases occur in the 22-1/2° sector northwest of plant with plume length ≥ 2.8 mi.



Based on daily record, Aug. 1970 - July 1971

Figure 3.4-6 PREDICTED PLUME LENGTH AND FREQUENCY OF OCCURRENCE FOR 16 COMPASS POINT SECTORS NATURAL DRAFT COOLING TOWERS BROWNS FERRY NUCLEAR PLANT

*Example: 0.3% of total cases occur in the 22-1/2° sector northwest of plant with plume length ≥ 4.5 mi.



Based on daily record, Aug. 1970 - July 1971

Figure 3.4-7 PREDICTED PLUME LENGTH AND FREQUENCY OF OCCURRENCE FOR 16 COMPASS POINT DIRECTIONS (AMBIENT TEMPERATURE BELOW FREEZING) NATURAL DRAFT COOLING TOWERS BROWNS FERRY NUCLEAR PLANT

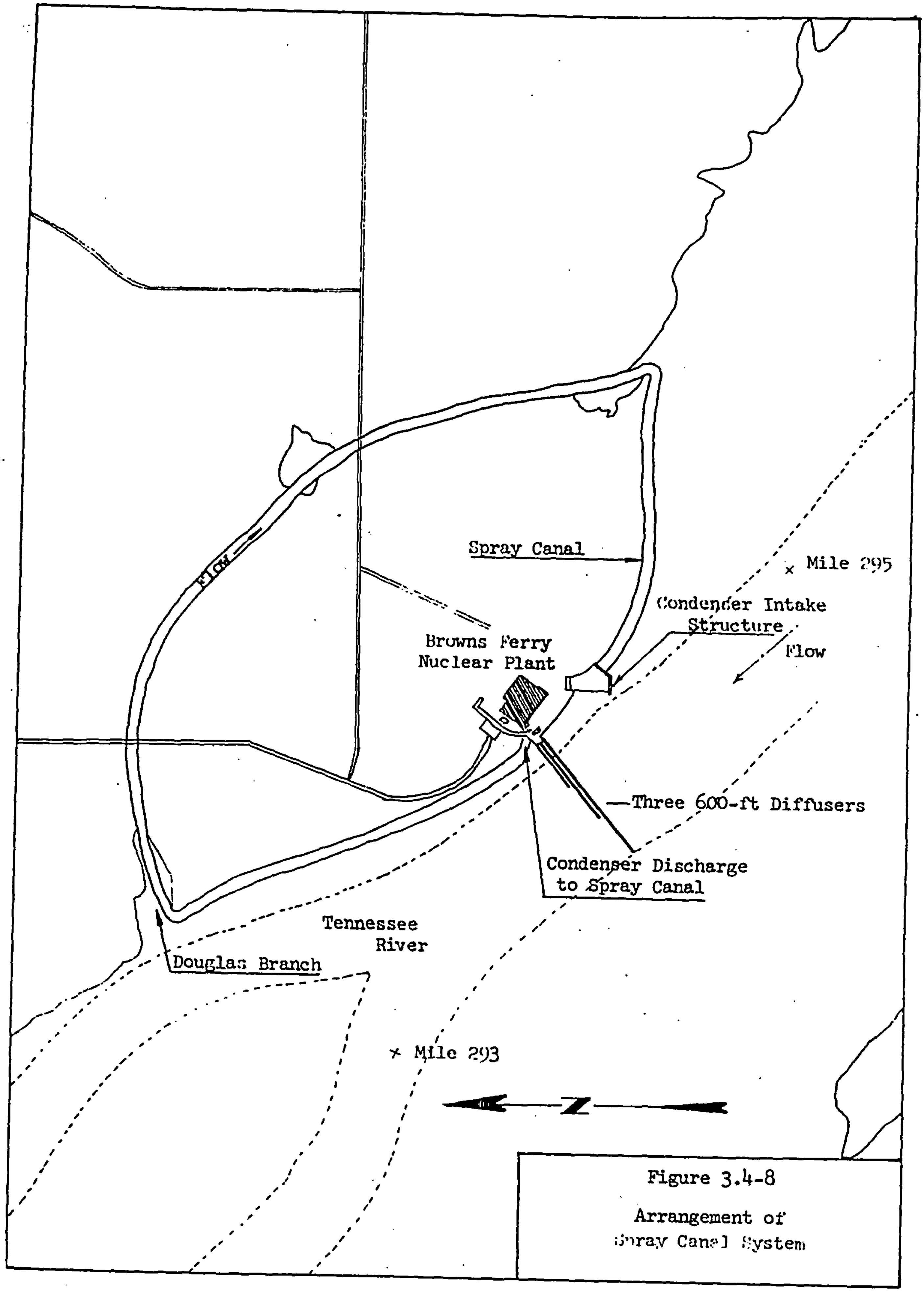


Figure 3.4-8

Arrangement of Spray Canal System

STATION LOCATED 0.12 MILE NNW OF BROWNS FERRY SITE;
ELEVATION 600 FEET MSL; INSTRUMENT MOUNTED
75 FEET ABOVE GROUND

August 1970 - July 1971
(Annual - 105 Days)

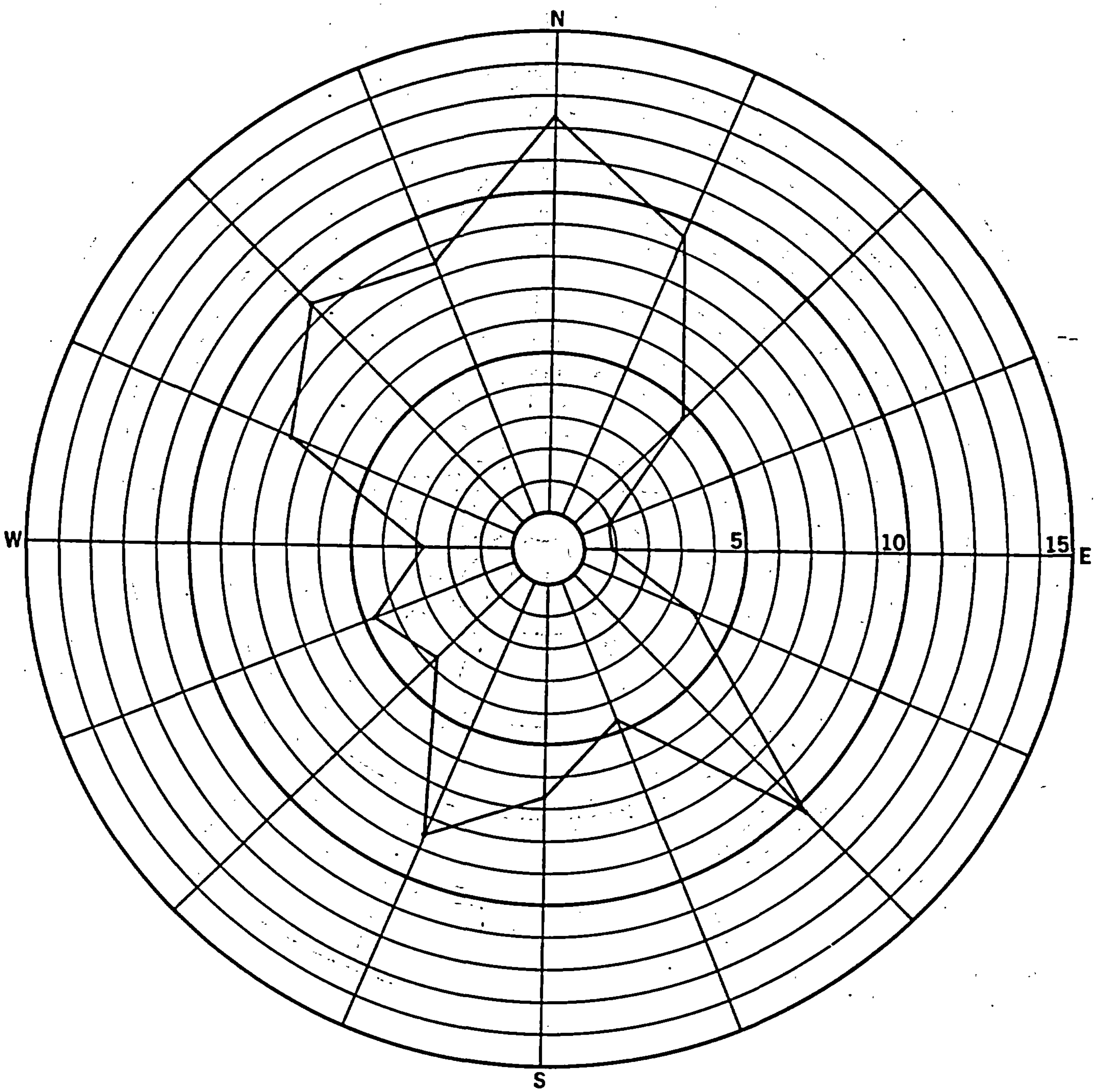
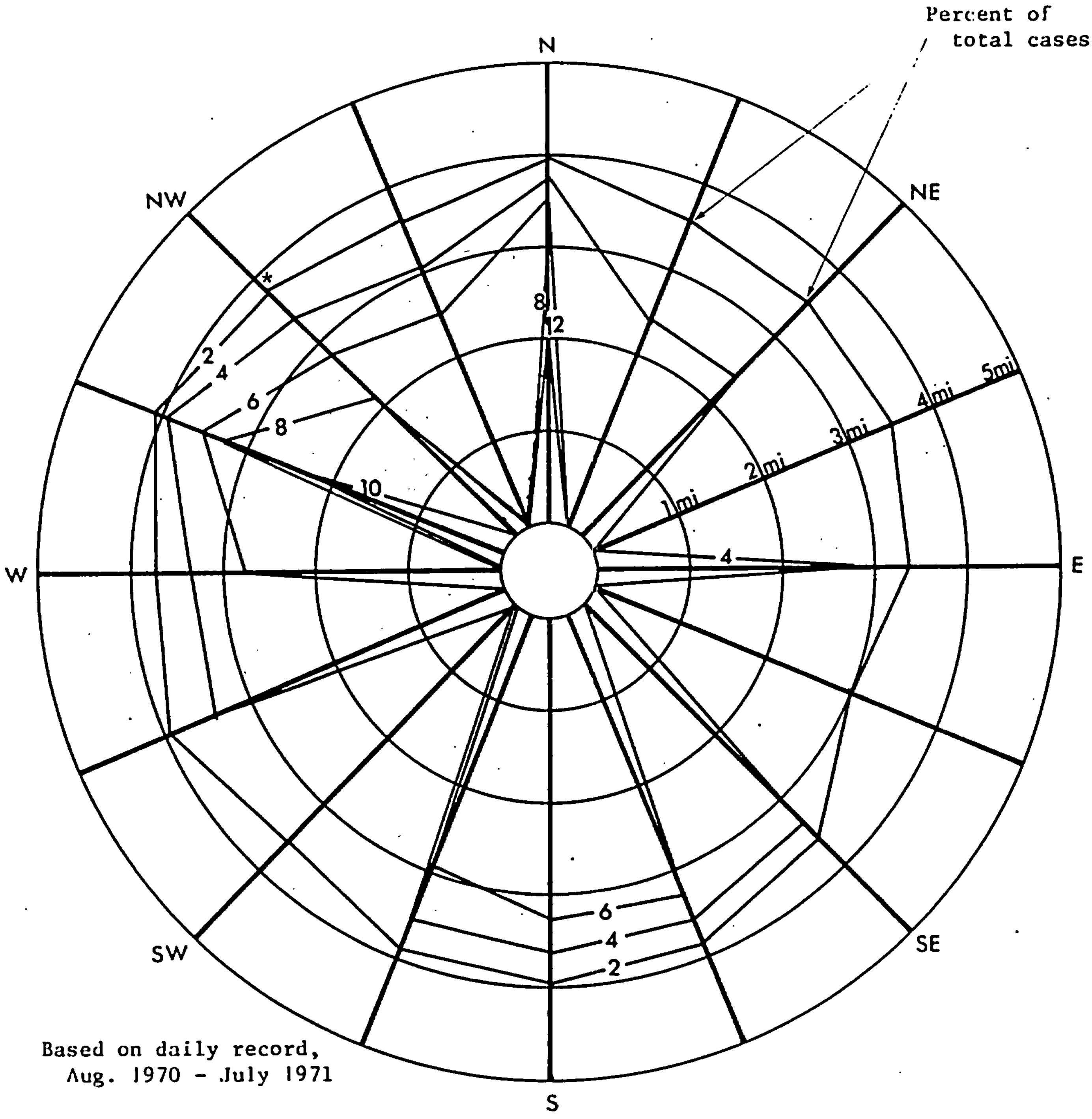


Figure 3.4-9 FREQUENCY OF WIND DIRECTION
WITH WIND SPEED $\geq$ 12 MPH
BROWNS FERRY NUCLEAR PLANT

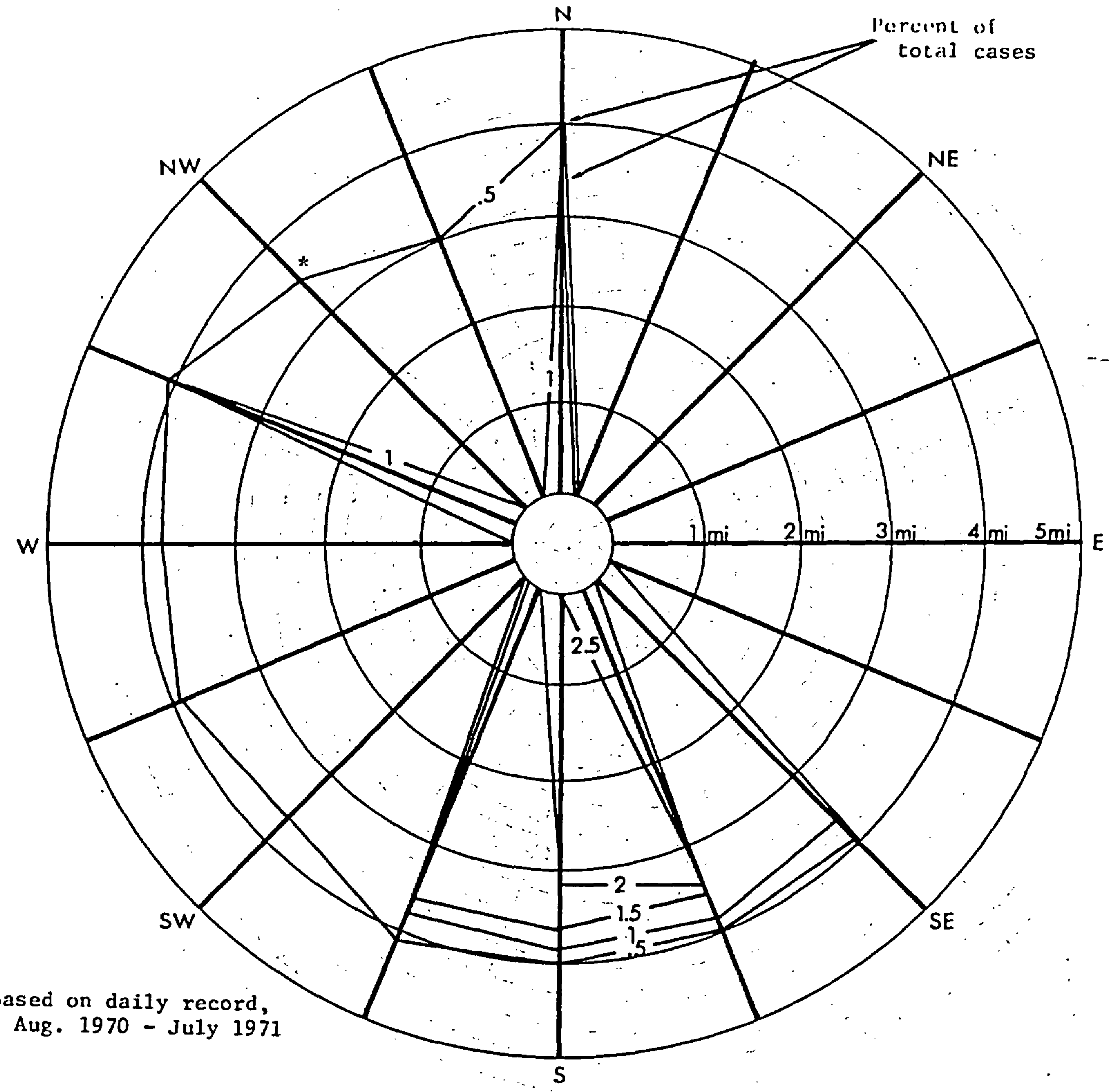
*Example: 2% of total cases occur in the 22-1/2° sector northwest of plant with plume length ≥ 3.8 mi.



Based on daily record, Aug. 1970 - July 1971

Figure 3.4-10 PREDICTED PLUME LENGTH AND FREQUENCY OF OCCURRENCE FOR 16 COMPASS POINT SECTORS SPRAY CANALS BROWNS FERRY NUCLEAR PLANT

*Example: 0.5% of total cases occur in the 22-1/2° sector northwest of the plant with plume length $\geq$ 3.5 mi.



Based on daily record, Aug. 1970 - July 1971

Figure 3.4-11 PREDICTED PLUME LENGTH AND FREQUENCY OF OCCURRENCE FOR 16 COMPASS POINT DIRECTIONS (AMBIENT TEMPERATURE BELOW FREEZING) SPRAY CANALS BROWNS FERRY NUCLEAR PLANT

STATION LOCATED 0.12 MILE NNW OF BROWNS FERRY SITE;
ELEVATION 600 FEET MSL; INSTRUMENT MOUNTED
75 FEET ABOVE GROUND

August 1970 - July 1971

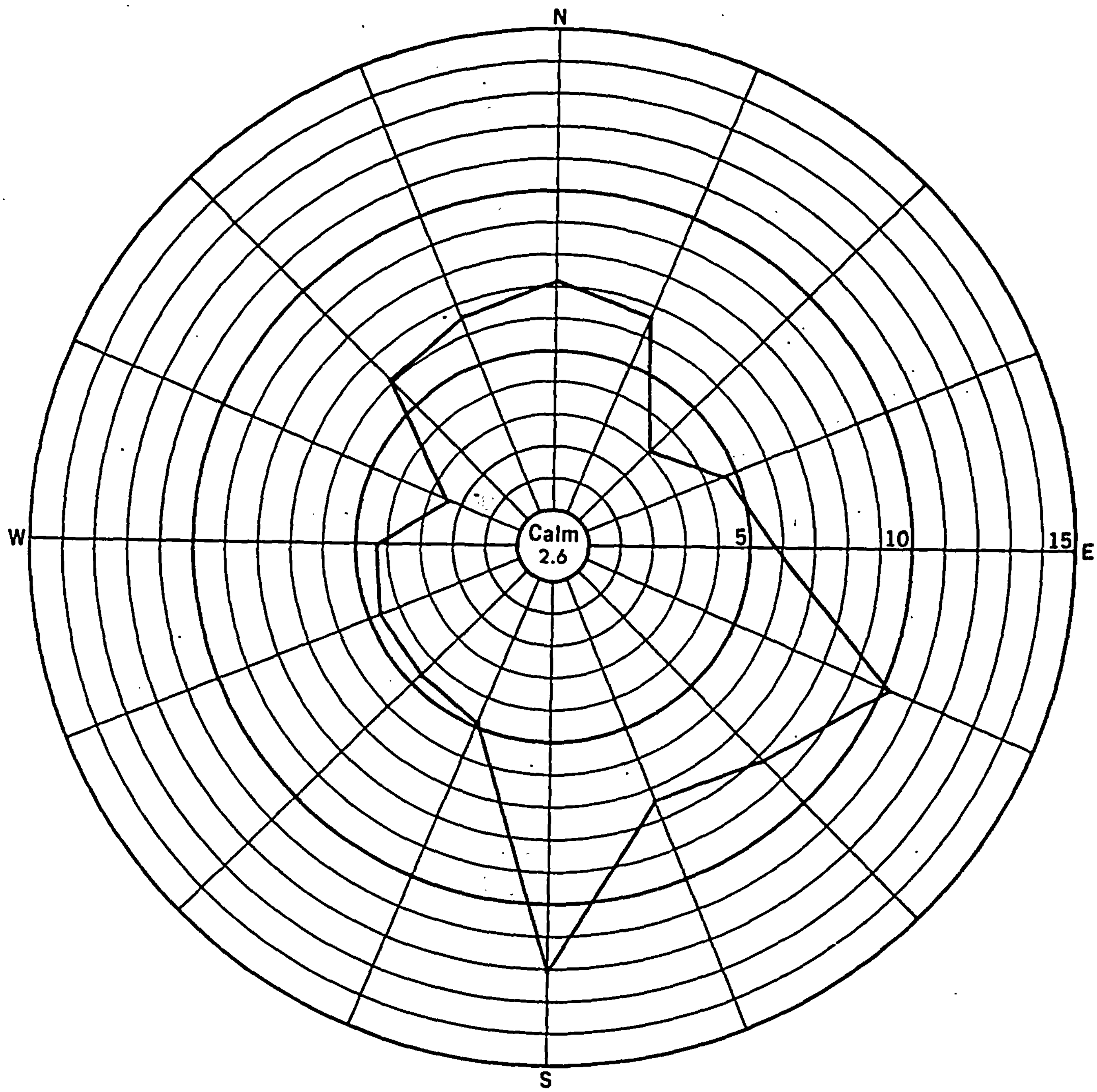


Figure 3.4-12 WIND DIRECTION FREQUENCY -
BROWNS FERRY NUCLEAR PLANT

STATION LOCATED 0.12 MILE NNW OF BROWNS FERRY SITE;
ELEVATION 600 FEET MSL; INSTRUMENT MOUNTED
75 FEET ABOVE GROUND

August 1970 - July 1971

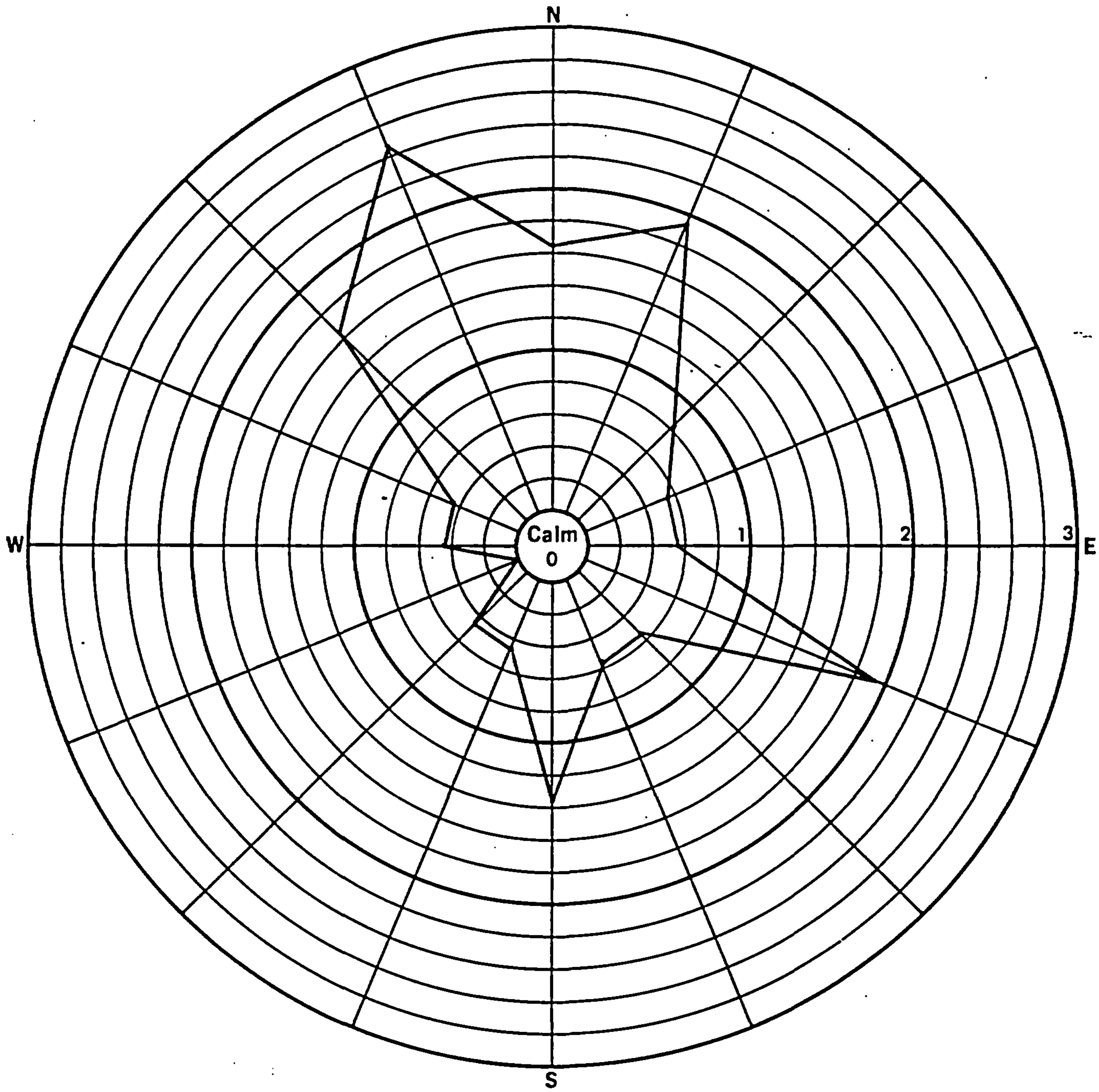


Figure 3.4-13 WIND DIRECTION FREQUENCY -
BROWNS FERRY NUCLEAR PLANT
(AMBIENT TEMPERATURE BELOW FREEZING)

3.5 <u>Conclusions as to the Adequacy of Cooling Facilities</u> - As has been stated previously (Browns Ferry Environmental Statement, 7/14/71, pages 5.21 ff, Appendix III), it was concluded by TVA that its proposed method of discharging heated water at Browns Ferry would not have significant adverse effects on aquatic life. This conclusion was reached after weighing and balancing the estimated heat load to Wheeler Reservoir in relation to observed (by TVA) and reported (in technical literature) conditions and biological activity following the addition of heat to various aquatic ecosystems. Because of the divergence of professional opinion on the question of the effects of added heat on aquatic life, TVA has stated and continues to maintain the position that it will comply with whatever standards are ultimately adopted and further that it will take action in addition to that required by standards if future studies disclose such action to be necessary to protect aquatic life.

Alternative methods of heat dissipation were discussed in section 3.4. TVA has concluded, based on studies and analyses which have been performed, that a scheme which would utilize six mechanical draft cooling towers and would accommodate closed cycle operation, operation as a helper system in conjunction with the present diffuser system and Wheeler Reservoir, and operation using the present diffuser system alone probably is the best alternative heat dissipation method if auxiliary cooling facilities are required at Browns Ferry. However, until thermal standards have been established or other indications of the need for different temperature limits are observed, TVA cannot accurately determine what, if any, additional cooling facilities will be required. The first power unit at Browns Ferry is scheduled to come on line commercially in October 1972 and the second in July 1973. Even if construction were started now, it would not be feasible to provide cooling facilities for even the first unit before 1974. Consequently, until any needed auxiliary cooling facilities can be provided, TVA will so operate the plant and so regulate the flow of water through Wheeler Reservoir as to meet the finally adopted thermal standards.

3.6 Emergency Planning - TVA is developing a Radiological Emergency Plan* (REP) which sets forth the policies, purposes, delegations, standards, guidelines, and, where feasible, specific instructions necessary for TVA to discharge its responsibilities during a radiological emergency in order to comply with pertinent directives applicable to the protection of the health and safety of the public and TVA personnel, plants, and properties.

The REP consists of the basic document and annexes. The basic document contains program delegations and broad guides, which apply generally to all TVA nuclear operations. Annexes to the basic document will be specific plant emergency plans prepared by the particular TVA office or division responsible for that operation. In addition, the annexes will contain the Radiological Emergency Medical Assistance Plan. An emergency plan is being prepared for the Browns Ferry Nuclear Plant.

The standards and procedures used are consistent with regulatory programs of state and other Federal agencies. To ensure that their latest recommendations are considered, TVA maintains liaison with these agencies.

In developing the Radiological Emergency Plan, meetings have been held with the State Health Departments of Alabama, Georgia, South Carolina, and Tennessee to ensure workability of the plan and delegation of responsibility, authority and emergency assignments. In addition, the State Health Departments of Kentucky and Illinois have been contacted and arrangements made for participation of those agencies in the event of a transportation accident.

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* Being reviewed inside TVA.

Each state through which radioactive material from a TVA plant is transported either has or will have a radiological assistance plan for use in the event of a transportation accident within its jurisdiction. These plans have been or will be obtained and incorporated in the REP as they are available. The plans will be completed prior to shipment of radioactive material from the facility.

Other state agencies, such as the Alabama Departments of Civil Defense, Pensions and Security, Public Safety, and the Alabama National Guard have agreed to provide assistance to the State Health Department in order for the plan to be effectively administered. Each of these agencies has provided supplements to the Alabama State Health Department radiological assistance plan describing their responsibilities and how these responsibilities will be implemented. TVA will continue to assist in the development of these plans and ensure that the plans are adequate to cover any emergency which may arise at a nuclear facility.

Contacts have also been made with the appropriate Atomic Energy Commission Operations Offices to ensure that assistance can be obtained through the Interagency Radiological Assistance Plan, if necessary.

The Eastern Environmental Radiation Laboratory, EPA, has agreed to provide additional analytical laboratory services in the event of an accident if these services are not available within TVA.

Written agreement among participating state and Federal agencies and TVA will be obtained outlining each agency's responsibilities. The individual states' health department radiological assistance plan will be incorporated as an annex to the TVA Radiological Emergency Plan.

1. Meetings with outside agencies - Representatives of TVA have met with representatives of the following states and agencies to discuss and plan for radiological emergencies which might result as a consequence of the construction and operation of the Browns Ferry Nuclear Plant.

(1) State of Alabama -

Department of Public Health - May 19, 1971
- June 10, 1971
- July 8-9, 1971
- September 16-17, 1971

Civil Defense Department - July 9, 1971
- July 17, 1971

Alabama National Guard - July 9, 1971

Department of Pensions and Security - July 9, 1971

Department of Public Safety - July 9, 1971
- September 17, 1971

(2) State of Georgia -

Department of Public Health - December 4, 1970

(3) State of South Carolina -

Department of Public Health - August 27, 1971

(4) State of Tennessee -

Department of Public Health - October 12, 1971

(5) Environmental Protection Agency -

Eastern Environmental Radiation Laboratory - October 22, 1970
- June 9, 1971

2. <u>Summary of responsible agencies and contact personnel</u> - Appropriate TVA personnel receiving notice of a transportation accident shall notify the TVA load dispatcher who notifies the Central Emergency Control Center director who shall notify as appropriate the following "key persons" in the states involved, as well as the EPA and AEC.

(1) <u>State of Alabama</u> -

Department of Public Health - W. T. Willis
- A. V. Godwin
- L. G. Linn

Department of Civil Defense - Lawrence Bowden

Department of Pensions and Security - Miss Heaton Crook

Department of Public Safety - Capt. R. P. Hooks
- Sgt. D. H. Tidwell (Decatur command)

Alabama National Guard - Lt. Col. Wash B. Ray

(2) <u>State of Tennessee</u> -

Department of Public Health - Francis P. Jung
- Bill Graham
- Charles P. West

(3) <u>State of Kentucky</u> -

Department of Public Health - Charles Hardin
- Richard M. Fry
- David T. Clark

(4) <u>State of Georgia</u> -

Department of Public Health - Richard H. Fetz
- Cecil D. Posey
- Henry P. Copeland

(5) <u>State of South Carolina</u> -

Department of Public Health - Heyward G. Shealy
- Walter K. Maginnis
- Emory F. Williams

(6) <u>State of Illinois</u> -

Department of Public Health - Phillip Brunner
- Pete Tedeschi
- Russell W. Courtney

(7) Environmental Protection Agency -

Eastern Environmental Radiation Laboratory - Charles R. Porter
- Charles Phillips

(8) Atomic Energy Commission -

Oak Ridge Operations Office* - Notification according to directory

Savannah River Operations Office* - Notification according to directory

* Interagency radiological assistance teams will be requested through these offices.

3.7 Electric Power Supply and Demand - TVA is the power supplier for an area of approximately 80,000 square miles containing about six million people. TVA generates, transmits, and sells power to 160 municipalities and rural electric cooperatives which in turn retail power to their own customers. The approximate areas served by these distributors are shown in figure 3.7-1. These distribution systems, which purchase their power requirements from TVA, serve more than two million electric customers, including homes, farms, businesses, and most of the region's industries. TVA also supplies power directly to 46 industries which have large or unusual power requirements and to 11 Federal installations, including the Atomic Energy Commission plants at Oak Ridge, Tennessee, and Paducah, Kentucky.

The importance of an adequate supply of power on the TVA system is by no means limited to electric consumers in the area which TVA supplies directly. This system, which with 19.4 million kilowatts of presently installed generating capacity is the Nation's largest, is interconnected at 26 points with neighboring systems with which TVA exchanges power. The TVA system is, in effect, part of a huge power network. In a time of power emergency, operation of the TVA power system could have a definite impact on power supply conditions from the Great Lakes to the Gulf of Mexico, and from New England to Oklahoma and Texas.

During the past 20 years, loads on the TVA power system have increased approximately seven percent per year. This rate of growth in power requirements has meant that the capacity of the generating and transmission system has been doubled every 10 years. Until the end of World War II, most of TVA's generating capacity was hydroelectric. By that time, however, most of the suitable hydroelectric sites had been developed, and beginning in 1949 substantially all of the capacity increases were met by the construction of fossil-fueled plants. In the middle 1960's, large-scale nuclear plants had become feasible, and TVA began to take steps to add nuclear capacity to its system. TVA has also begun providing pumped-storage and gas turbine capacity to meet system peak loads. Table 3.7-1 shows major TVA system capacity additions since 1949.

The amount of electricity generated in 1965 to meet customer requirements for power exceeded 70.0 billion kilowatt-hours. By 1970, annual electric generation for customer needs had totaled 92.7 billion kilowatt-hours. Generating needs are expected to reach 135 billion kilowatt-hours by 1975. TVA presently must add an average of 1500 megawatts or more of new generating capacity each year to keep up with the rapid increase in electrical power usage in this region.

1. Power needs - The TVA power system is a winter and summer peaking system with the highest annual peak loads in the TVA service area usually occurring between November and March. Due to seasonal exchange agreements with other power systems, however, the loads which the TVA generating capacity must actually serve during the remainder of this decade will be greater in the summer than in the preceding winter. The following tabulation indicates TVA's expected power supply outlook during the 1972-1975 peak load seasons based on the current capacity installation schedules:

Period	Estimated Peak Demand TVA System-MW	Interchange Delivered or Received-MW	Load Served by TVA-MW	Dependable Capacity-MW	Margin MW	Margin %
Winter 1971-72	18,300	-2,917	15,383	18,635	3,252	21.1
Summer 1972	16,240	+1,800	18,040	20,746	2,706	15.0
Winter 1972-73	20,200	-2,060	18,140	21,605	3,465	19.1
Summer 1973	18,060	+2,060	20,120	24,151	4,031	20.0
Winter 1973-74	21,775 1/	-2,060	19,715 1/	23,940	4,225	21.4
Summer 1974	19,630	+2,060	21,690	26,341	4,651	21.4
Winter 1974-75	23,700	-2,060	21,640	27,605	5,965	27.6

1/ Could be 625 MW greater if AEC load increase is supplied

The above power supply projection is based on the following schedule of capacity additions to the TVA system during 1972-1974: gas turbines (660 MW) May 1972; Cumberland Units 1-2 (1275 MW each) July 1972 and April 1973; Browns Ferry Nuclear Units 1-3 (1065 MW each) October 1972, July 1973, and February 1974; Sequoyah Nuclear Units 1-2 (1125 MW each) April 1974 and December 1974; and Raccoon Mountain pumped-storage Unit 1 (325 MW) November 1974.

2. Consequences of delays - With the exception of the summer of 1972, the margins shown in the above tabulation are expected to be adequate if the currently projected schedules of capacity additions are achieved. Due to delays already experienced in the operation of the Browns Ferry units, the power supply situation on the TVA system during the summer of 1972 is already expected to be very tight, even with the addition of 660 MW of gas turbine capacity and Cumberland Unit 1 scheduled to be added to the system between now and then. Further delays in the operation of the Browns Ferry units could result in the inability of the TVA system to meet adequately its obligations under the other peak load conditions during 1973-1975. The total consequences of additional Browns Ferry delays will be determined by the extent of the delays. The following tabulation indicates the amounts by which reserves on the TVA system will be inadequate during various peak load seasons of 1973-1975, postulating delays of six and twelve months at each of the Browns Ferry units from their current schedule. (A delay of any unit results in an equal delay in all subsequently scheduled units in the same plant.) The deficiencies shown are based on the assumption that the winter peak occurs in January and the summer peak occurs in August since these are the months having the highest probability of the peaks occurring. The winter peak has occurred as early as November and the summer peak as early as June.

	TVA System Reserve Deficiencies Due to Browns Ferry Unit Delays	
	6 Months' Delay	12 Months' Delay
Winter 1972-73	1,065	1,065
Summer 1973	1,065	1,530
Winter 1973-74	0	1,065
Summer 1974	0 1/	440 1/
Winter 1974-75	0 2/	1,065 2/

Deficiencies of these magnitudes must be replaced either by the installation of alternative capacity on the TVA system or by the import of power from other utility systems; otherwise, the reliability of power supply to TVA's customers will be drastically reduced. Due to similar power supply problems faced by other power systems (in regions contiguous to TVA there are 30 nuclear units amounting to 24,000 MW 3/ which could also be delayed), it does not appear likely that requirements of the magnitude shown with purchases from neighboring utilities could be met, although another 600 MW of seasonal exchange power could be scheduled from the South Central Electric Companies for the winter of 1972-73 provided notice were given by February 1972. The only feasible means of obtaining sufficient additional reliable generation during the time period being considered is the installation of gas turbines; even now it would be difficult or impossible to install replacement gas turbine capacity to offset capacity shortages during the winter of 1972-73, since the lead time (period from decision to purchase until commercial operation) for such units is about 18 months.

The economic costs of any additional Browns Ferry delays (which must ultimately be borne by the consumer) would consist

---

1/ Deficiency would be increased by 1,125 MW if Sequoyah is delayed.

2/ Additional deficiencies would exist if either one or both Sequoyah units were delayed.

3/ EEI 49th Semiannual Survey.

of three parts: additional construction costs at Browns Ferry; investment costs of the replacement gas turbine capacity; and increased production expense during the delay period due to unavailability of low cost nuclear energy.

The additional construction costs for suspending construction on the Browns Ferry plant would be approximately $3 million for each month of delay. In addition to this monthly cost, a substantial cost would be incurred for interrupting construction of the project.

Based on an estimated investment of approximately $100 million for the 980 MW of dependable gas turbine capacity already in service or scheduled for the TVA system, the investment costs of gas turbine additions required due to Browns Ferry delays alone is estimated to exceed $100 million. Annual fixed charges of about $10 million must be borne by consumers in the form of higher rates until the effect of these additions can be absorbed in later years by system growth. The present value of these fixed charges (assuming an eight percent discount rate and a discount period of eight years) would be about $57.5 million. Since TVA has already made commitments for the required generating capacity during this period, the $57.5 million represents an increased cost unless it can be utilized because of unanticipated delays in scheduled unit operating dates or can be sold as surplus capacity.

Energy from the Browns Ferry nuclear units is estimated to cost about 1.8-1.9 mills per kWh during the 1973-75 period, while replacement energy which would be used in lieu of this nuclear energy, in the event of delays, would cost from 3.5 to 10 mills per kWh, depending upon whether this replacement energy came from older TVA units, purchases, or gas turbines. Computer studies of the effects of Browns Ferry unit delays indicate that each month's delay on these three units would result in increased production expenses on the TVA system of approximately $4 million.

In addition to these economic costs, each month's delay on the three Browns Ferry nuclear units could require that approximately 750,000 tons of additional coal and 8.5 million gallons of oil be burned in plants on the TVA system or other systems to replace the lost nuclear energy. This would have an adverse environmental impact in terms of increased emissions of particulates, sulfur dioxide and other materials to the atmosphere.

In addition to the monetary and environmental effects of any additional Browns Ferry delays, another consequence of such delays would be a reduction in the reliability of the region's power supply. With a reduction in reliability of the magnitude that could result from delays in the Browns Ferry plant before alternative sources of power could be developed, the probability of load reductions in the TVA service area would be greatly increased. Such reductions, which might be reflected in systematic reductions to the region's industrial and commercial loads and possibly to the residential consumers, could result in severe economic penalties to the region's industrial operations as well as to the employees of such industries and to the general populace. Further, since the TVA system operates as a part of an interconnected network covering essentially the entire eastern United States, such reductions in capacity on the TVA system would affect the reliability of a large part of the Nation's power supply.

In summary, the suspension of construction at the Browns Ferry Nuclear Plant would have a threefold effect on the TVA power system:

1. The reliability of the region's power supply would be jeopardized.

2. Costs to TVA's consumers would be increased by over $7.0 million for each month of delay, assuming the delay did not require the installation of gas turbines. If additional gas turbine capacity were required to replace the capacity of one Browns Ferry unit, costs to TVA's consumers over and above those shown above could be increased by $57.5 million. These costs could total nearly $150 million for a 12-month delay.

3. Increased operation of TVA's older, less efficient fossil-fired units would be required during the period of Browns Ferry delays. Such operation would result in the increased emission of particulates, sulfur dioxide, and other materials into the atmosphere.

Table 3.7-1

MAJOR TVA SYSTEM CAPACITY ADDITIONS
SINCE CALENDAR YEAR 1949

Plant	Number of Units	Nameplate Capacity-kW Unit	Nameplate Capacity-kW Total	Commercial Operating Date First Unit	Commercial Operating Date Last Unit
Thomas H. Allen 1/	3	330,000	990,000	5-22-59	10-25-59
Bull Run	1	950,000	950,000	6-12-67	6-12-67
Colbert	5	2 @ 200,000	1,396,500	1-18-55	11- 7-65
		2 @ 223,250			
		1 @ 550,000			
Gallatin	4	2 @ 300,000	1,255,200	11- 8-56	8- 9-59
		2 @ 327,600			
John Sevier	4	1 @ 223,250	823,250	7-12-55	10-31-57
		3 @ 200,000			
Johnsonville	10	4 @ 125,000	1,485,200	10-27-51	8-20-59
		2 @ 147,00			
		4 @ 172,800			
Kingston	9	4 @ 175,000	1,700,000	2- 8-54	12- 2-55
		5 @ 200,000			
Paradise	3	2 @ 704,000	2,558,200	5-19-63	2-27-70
		1 @ 1,150,200			
Shawnee	10	175,000	1,750,000	4- 9-53	6-17-57
Widows Creek	8	5 @ 140,625	1,977,985	7- 1-52	2- 7-65
		1 @ 149,850			
		1 @ 575,010			
		1 @ 550,000			

1/ Leased January 1, 1965, from Memphis, Tennessee, Light, Gas, and Water Division

Table 3.7-1
(Continued)

MAJOR TVA SYSTEM CAPACITY ADDITIONS
SINCE CALENDAR YEAR 1949

Plant	Number of Units	Nameplate Capacity-kW Unit	Nameplate Capacity-kW Total	Commercial Operating Date First Unit	Commercial Operating Date Last Unit
TVA Hydro					
Boone	3	25,000	75,000	3-16-53	9- 3-53
Chatuge	1	10,000	10,000	12- 9-54	12- 9-54
Cherokee *	2	30,000	60,000	1-29-53	10- 7-53
Chickamauga *	1	27,000	27,000	3- 7-52	3- 7-52
Douglas *	1	26,000	26,000	8- 3-54	8- 3-54
Fontana *	1	67,500	67,500	2- 4-54	2- 4-54
Ft. Patrick Henry	2	18,000	36,000	12- 5-53	2-22-54
Guntersville *	1	24,300	24,300	3-24-52	3-24-52
Hiwassee *	1	59,500	59,500	5-24-56	5-24-56
Melton Hill	2	36,000	72,000	7- 3-64	11-11-64
Nickajack	4	24,300	97,200	2-20-68	4-30-68
Nottely	1	15,000	15,000	1-10-56	1-10-56
Pickwick *	2	36,000	72,000	10-31-52	12-31-52
South Holston	1	35,000	35,000	2-13-51	2-13-51
Wheeler *	5	32,400	162,000	3- 4-50	12-18-63
Wilbur *	1	7,000	7,000	7-19-50	7-19-50
Wilson *	6	3 @ 25,200 3 @ 54,000	237,600	1- 6-50	4-12-62

* Other units in this plant installed in period prior to 1950.

3.8 <u>Chemical Discharges</u> - All chemical wastes will receive the highest degree of treatment that is technically feasible within reasonable economic limits.

The exact type and degree of treatment for all of these chemicals has not yet been determined. However, if these chemicals were discharged untreated to the diffusers, the maximum concentrations would be as given in section 5.4 of the draft environmental statement. Those concentrations are not expected to have a significant adverse environmental impact on water quality in the Wheeler Reservoir.

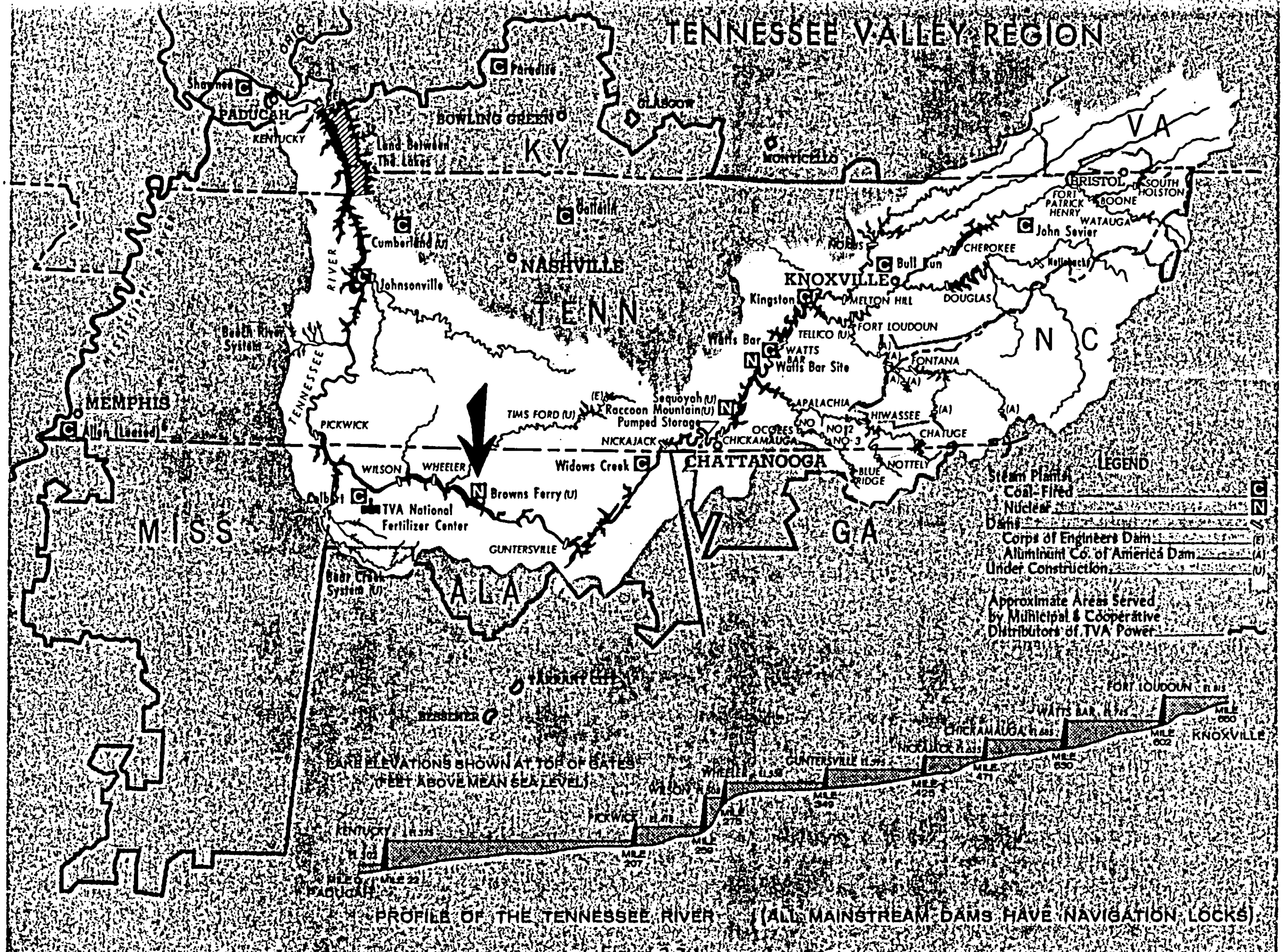
TENNESSEE VALLEY REGION
Paradise
Shawnee
PADUCAH
KENTUCKY
BOWLING GREEN
GLASGOW
Land Between The Lakes
KY
MONTICELLO
VA
BRISTOL
SOUTH HOLSTON
FORT PATRICK HENRY
BOONE
WATAUGA
Gallatin
Cumberland (U)
John Sevier
CHEROKEE
NORRIS
Bull Run
NASHVILLE
KNOXVILLE
Johnsonville
RIVER
TENN
Kingston
MELTON HILL
DOUGLAS
FORT LOUDOUN
TELLICO (U)
Watts Bar
WATTS BAR
Watts Bar Site
FONTANA
N C
Beech River System
TENNESSEE
MEMPHIS
Allen (Leased)
PICKWICK
TIMS FORD (U)
Sequoyah (U)
Raccoon Mountain (U) Pumped Storage
APALACHIA
HIWASSEE
OCOEE
CHATUGE
NICKAJACK
CHICKAMAUGA
CHATTANOOGA
NOTTELY
BLUE RIDGE
Widows Creek
WILSON
WHEELER
Browns Ferry (U)
Colbert
TVA National Fertilizer Center
MISS
GUNTERSVILLE
GA
Bear Creek System (U)
ALA
LEGEND
Steam Plants
Coal-Fired
Nuclear
Dams
Corps of Engineers Dam (E)
Aluminum Co. of America Dam (A)
Under Construction (U)
Approximate Areas Served by Municipal & Cooperative Distributors of TVA Power
LAKE ELEVATIONS SHOWN AT TOP OF GATES (FEET ABOVE MEAN SEA LEVEL)
FORT LOUDOUN
WATTS BAR
CHICKAMAUGA
NICKAJACK
GUNTERSVILLE
WHEELER
WILSON
PICKWICK
KENTUCKY
KNOXVILLE
MILE 22
MILE 207
MILE 259
MILE 275
MILE 349
MILE 425
MILE 471
MILE 530
MILE 602
MILE 650
PADUCAH
PROFILE OF THE TENNESSEE RIVER (ALL MAINSTREAM DAMS HAVE NAVIGATION LOCKS)

Figure 3.7-1

Table 3.7-1
(Continued)

MAJOR TVA SYSTEM CAPACITY ADDITIONS
SINCE CALENDAR YEAR 1949

Plant	Number of Units	Nameplate Capacity-kW Unit	Nameplate Capacity-kW Total	Commercial Operating Date First Unit	Commercial Operating Date Last Unit
Alcoa Hydro					
Bear Creek	1	9,000	9,000	4-14-54	4-14-54
Cedar Cliff	1	6,375	6,375	8-22-52	8-22-52
Chilhowee	3	16,667	50,000	8-28-57	10-18-57
Tennessee Creek	1	10,800	10,800	5-19-55	5-19-55
Corps of Engineers Hydro					
Barkley	4	32,500	130,000	1-20-66	3-30-66
Center Hill	3	45,000	135,000	12-11-50	4-11-51
Cheatham	3	12,000	36,000	11-21-59	11- 9-60
Dale Hollow *	1	18,000	18,000	11-17-53	11-17-53
Old Hickory	4	25,000	100,000	4- 9-57	12-23-57
J. Percy Priest	1	28,000	28,000	2- 3-70	2- 3-70
Wolf Creek	6	45,000	270,000	10- 6-51	8-22-52

* Other units in this plant installed in period prior to 1950.

TVA-OHES-EIS-72-6

TENNESSEE VALLEY AUTHORITY

ENVIRONMENTAL STATEMENT

BROWNS FERRY NUCLEAR PLANT UNITS 1, 2 and 3

VOLUME 1

TVA-OHES-EIS-72-6

Tennessee Valley Authority
Office of Health and Environmental Science

FINAL ENVIRONMENTAL STATEMENT
BROWNS FERRY NUCLEAR PLANT
UNITS 1, 2, AND 3
VOLUME 1

Chattanooga, Tennessee
September 1, 1972

SUMMARY SHEET

ENVIRONMENTAL STATEMENT

BROWNS FERRY NUCLEAR PLANT UNITS 1, 2, AND 3

( ) Draft (X) Final Environmental Statement Prepared by the Tennessee Valley Authority

1. (X) Administrative Action ( ) Legislative Action

2. This action is the construction and operation of a three-unit nuclear power generating station in Limestone County, Alabama.

3. Environmental impacts associated with the construction and operation of the Browns Ferry Nuclear Plant include:

   (1) Minute additions of radioactivity to the air and water.
   (2) Release of large quantities of heat to the environment.
   (3) Change in approximately 840 acres of land for the plant site from farming to industrial use and easements on 1,350 acres of land for transmission lines.
   (4) Release of small quantities of nonradioactive materials to the air and water.
   (5) Temporary stress on social infrastructure (schools, roads, housing, and similar services).
   (6) Stimulus to area economic development (jobs, attraction of visitors, etc.).
   (7) Some loss of aquatic organisms due to entrainment in condenser cooling water.

   No significant adverse environmental effects are expected to occur as a result of these impacts.

4. To meet projected peak loads, TVA considered the following alternatives: (1) base-loaded coal-fired units and (2) nuclear-fueled units. The second alternative provides the lowest cost of generating power and the least environmental impact. The purchase of power in the quantities needed is not a realistic alternative.

   Alternative systems were considered for waste heat dissipation and reduction of releases of radioactive products from the plant.

   Alternative heat dissipation systems considered included:

   (1) Mechanical draft cooling towers
   (2) Natural draft cooling towers
   (3) Spray canal system
   (4) Cooling lake

SUMMARY SHEET (continued)

Considering feasibility, environmental impact, and cost, the mechanical draft cooling towers represent the best balance and has been adopted to meet proposed water temperature standards.

Alternatives considered for augmenting the original system to further reduce gaseous radioactive emissions included:

(1) Hydrogen recombiners
(2) Hydrogen recombiners in combination with charcoal adsorbers
(3) Solvent absorption system
(4) Cryogenic distillation system

Selection of hydrogen recombiners in combination with six charcoal beds per unit was made as a result of balancing feasibility, environmental benefit, and cost.

Demineralizers and evaporators were considered as alternate means to further reduce radioactive liquid discharges. Consideration of feasibility, environmental benefit, and cost shows that the use of evaporators for this purpose represents the best balance and TVA is proceeding with plans to install this alternative.

5. Comments have been received from the following agencies:

Environmental Protection Agency
Department of Transportation
Alabama Development Office, State of Alabama
- Alabama Department of Conservation
- Alabama Historical Commission
- State of Alabama, Department of Public Health
- Comprehensive Health Department
- Bureau of Environmental Health
- Alabama Water Improvement Commission
- North Central Alabama Regional Planning and Development Commission
- Top of Alabama Regional Council of Governments
- Alabama Development Office Coordinator

Department of Commerce
Department of Agriculture
Department of Health, Education, and Welfare
Department of the Interior
Atomic Energy Commission
Federal Power Commission
Department of Housing and Urban Development
Department of the Army

6. The draft statement was sent to the Council on Environmental Quality and made available to the public on July 14, 1971. Supplements and additions to the draft was sent to the Council and made available to the public on November 8, 1971. The final statement was sent to the Council and made available to the public on September 1, 1972.

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INDEX CROSS-REFERENCE FOR

KEY TOPICS IN VOLUMES 1, 2, AND 3

PREFACE

This detailed statement of environmental considerations, prepared by the Tennessee Valley Authority, evaluates the effects on the environment of construction and operation of the Browns Ferry Nuclear Plant (Docket Nos. 50-259, 50-260, and 50-296) and is made in accordance with the National Environmental Policy Act of 1969 (NEPA; 42 U.S.C. §§ 4331 et seq).

TVA, a corporate agency of the Federal government, and the Atomic Energy Commission, a regulatory agency of the Federal government, have agreed that TVA is the lead agency for the preparation and circulation of detailed statements of environmental considerations for TVA nuclear plants. AEC has concluded that this statement is adequate to support the proposed license to operate the plant. AEC's letter to this effect follows the preface.

The Browns Ferry draft statement was circulated for review and comments by other government agencies and made available to the public on July 14, 1971. This was supplemented on November 8, 1971, with additional information responding to AEC's revisions to 10 CFR Part 50, made pursuant to the Calvert Cliffs decision (Calvert Cliffs' Coordinating Committee v. Atomic Energy Commission, 449 F.2d 1109 (D.C. Cir. 1971)). The draft and the supplement are included as part of the final environmental statement as Volume 2 and 3, respectively.

Comments have been received on both the draft and the supplement. In preparing the final statement TVA consulted with the Environmental Protection Agency and AEC.

On July 7, 1966, TVA filed an application for a construction permit for units 1 and 2. Construction Permit Nos. CPPR-29 and CPPR-30 were issued on May 10, 1967, and construction started on May 17, 1967. Construction Permit No. CPPR-48 was issued on July 31, 1968, for unit 3, and construction began on August 1, 1968. The final safety analysis report and a request for authorization to operate the three units were submitted to AEC on September 25, 1970.

The TVA Board of Directors has determined that it is not practicable to reassess the basic course of action in the design and construction of the plant. The environmental statement considers the ways in which the plant will interact with the environment by reevaluating environmental consequences considered at the outset of the project. This process minimizes adverse environmental consequences that would affect the overall balance of environmental costs and benefits by studying and adopting appropriate alternatives.

1.0 SUMMARY

TVA as a resource development agency generates electric power as part of its responsibility for the physical, social, and economic development of the Tennessee Valley region and as part of the national defense. An ample supply of low cost electrical energy together with a total resource development program has been a major factor in the progress achieved by the Tennessee Valley region since 1933. Employment, income, and productivity have all increased as the economy has shifted from primarily agricultural to industrial. The addition of the Browns Ferry Nuclear Plant to the TVA power system is a key element in continuing to provide an ample supply of electricity to the region.

In carrying out its responsibility, TVA has long used the type of interdisciplinary approach which the National Environmental Policy Act requires. In the case of Browns Ferry, Federal, state, and local agencies were consulted early in project development. The original design of the plant incorporated several features to lessen adverse environmental impacts. As part of TVA's continuing effort and through the environmental review process, further provisions have been made to maintain a quality environment. These are summarized below in the discussion of the principal ways in which the plant interacts with the environment. The three volumes of the environmental statement trace the environmental considerations and the manner in which they were incorporated into TVA's decision-making process.

1. Principal ways in which Browns Ferry interacts with the environment - The principal ways in which the plant will interact with the environment are:

1. Minute additions of radioactivity to the air and water.
2. Release of large quantities of heat to the environment.
3. Change in land use from farming to industrial.

(1) Radioactive releases - As a result of environmental considerations, the original plant design has been changed to incorporate provisions which will further reduce the release of radioactivity to the air and water. With regard to gaseous radioactive releases to the air, a system of hydrogen recombiners and charcoal beds will be added which will reduce the radiation dose to an individual at the site boundary by a factor of 100 below the dose with the system as originally designed. Radioactivity in releases to the water of Wheeler Reservoir will also be reduced by a factor of approximately 100 below that with the original system by adding an evaporator to treat the liquid releases. With this extended treatment of gaseous and liquid effluents, environmental concentrations of radioactivity from the Browns Ferry Nuclear Plant will be so low as to be indistinguishable from natural environmental radioactivity. For example, if a person were to stand at the site boundary continuously for a period of a year, he would receive a maximum dose of about two millirems from the operation of the plant. This is less than two percent of the dose from natural background radiation and is, in fact, less than the variations which occur in natural background radiation. In actuality this dose and percentage would, of course, be even smaller. The total dose from the operation of the plant to the population within 50 miles of the plant site is calculated to be about 0.01 percent of the dose from natural background radiation.

(2) Release of large quantities of heat to the environment - A diffuser system for releasing heat to Wheeler Reservoir was included in the original design for Browns Ferry. Use of this system to limit the temperature rise in the reservoir to 10°F and the maximum temperature

to 93°F was judged to be adequate to protect aquatic life. Reevaluation of these criteria through the environmental review process has reaffirmed this judgment. However, in order to meet proposed new thermal standards for Alabama which limit the temperature rise to 5°F and the maximum temperature to 86°F, a supplementary cooling system is required. After evaluation of the feasibility, environmental and economic considerations of alternative systems for supplementary cooling, TVA selected mechanical draft cooling towers as the best way to meet the new standards. The mechanical draft towers are estimated to have a capital cost of $36 million and a total cost, including operation and maintenance, of $44 million.

From the time the plant goes into operation until the construction of the cooling towers is completed, TVA will use the diffuser system to limit reservoir temperatures to the original thermal design criteria. The cooling waterflow through the plant amounts to about 10 percent of the mean annual flow of the Tennessee River at this point. When operating with the diffusers, water will be drawn from and returned to Wheeler Reservoir, and its temperature will be raised 25°F in passing through the plant's condensers. The diffuser system will cause the heated water discharge to be mixed quickly and will create no excessively warm surface strata. Under average flow conditions, the temperature of the reservoir will be increased not more than 2.5° to 3.5°F. TVA's environmental review concluded that this interim operation will adequately protect all water uses and aquatic life.

After its completion, the mechanical draft cooling tower system will supplement the diffuser system to the extent required to comply with the new standards. The natural heat dissipation capacity of the reservoir will still be used as much as practicable. The cooling tower system can be operated in the open, helper, or closed modes. In the open mode the system will operate only on the diffusers and no water will be passed through the cooling towers. The helper mode will be used when reservoir conditions require cooling of the condenser water by passing it through the towers prior to discharge. When reservoir conditions require minimum heat releases, the plant will be operated in the closed mode which recirculates the cooling water through the towers. During the closed mode water will be withdrawn from Wheeler Reservoir only to replace evaporative losses and drift from the towers and the blowdown water which is removed to control the quality of water recirculating in the system. It is estimated that the cooling towers will have to be used in the helper and closed modes about 28 percent of the time to meet the new thermal standards.

(3) Change in land use - The construction and operation of Browns Ferry will result in changing the use of the 840-acre tract from agriculture to a power plant site. The environmental review has concluded that the presence of the plant will be compatible with the surrounding area and will have no significant adverse impact upon it. A recent TVA survey shows that the value of land adjacent to the Browns Ferry site has generally increased at the same rate as that of other land in Limestone County. The location of the plant at this site is compatible with the regional land use plan. Although the facility will occupy certain amounts of space, the range of beneficial uses of the environment will not be curtailed.

2. Other topics discussed - The statement also dicusses other impacts, including the transportation of nuclear fuel and radioactive

2.0 RESPONSES TO COMMENTS ON DRAFT AND SUPPLEMENT

This section of the final environmental statement for the Browns Ferry Nuclear Plant contains TVA's responses to agency review comments discussed on a topical basis. The topical discussions consider and are based on commercial operating dates of March 1973, December 1973, and July 1974 for units 1, 2, and 3, respectively. Section 3.0 provides a table which keys the responses to the comments. Information in Volumes 2 and 3 is still valid unless otherwise noted and is repeated in section 2.0 only as required to respond to the comments.

2.1 Transportation of Nuclear Fuel and Radioactive Waste - About one quarter of the 764 fuel assemblies in each of the three units' cores are expected to be replaced with new fuel assemblies on an annual cycle. As stated in Volume 3, this annual refueling cycle will involve about 200 tons of nuclear fuel shipped to and from the plant. Packaged low-level radioactive waste totaling about 300 tons annually will also be shipped from the plant to AEC-licensed disposal areas.

Packaging for the low-level compressible waste material is designed to remain leakproof under normal transport conditions of temperature, pressure, vibration, rough handling, exposure to rain, etc. This packaging may release its contents in an accident. However, since these materials normally fall under the classification of Low Specific Activity (LSA) as defined by AEC[1] and considering the solid form of the waste, the likelihood of significant exposure to people is extremely small.

As stated in Volume 3, the packaging for a large quantity of radioactive material must be capable of withstanding, without loss of contents or shielding, the damage which might result from a severe accident. Test conditions for this Type B packaging are specified in the regulations and include tests for high-speed impact, puncture, fire, and immersion in water.[2] Adequate shielding must also be provided to limit the exposure of transport workers and the general public. In addition, the package for irradiated fuel must have heat-dissipation capability to protect against overheating from radioactive decay heat. Nuclear criticality safety for both normal transport and accidental damage must also be provided for both new and irradiated fuel.

Truck accident statistics for 1969[3] show a rate of 2.46 accidents per million miles travelled. Based on these data and assuming that new fuel and radioactive waste material shipments are made by truck using the estimated annual shipment miles for the Browns Ferry plant, truck accidents may be expected to occur about once every 10 years.

Spent fuel shipments are to be transported about 7 miles by a multiwheeled vehicle from the plant to the nearest railhead at Tanner, Alabama, and by rail to Morris, Illinois, a distance of about 625 miles.

In case of a transportation accident, procedures[4] which carriers will be required to follow will reduce the consequences of an accident. The procedures include segregation of damaged and leaking packages from people and notification of TVA and the Department of Transportation. Radiological assistance teams are available through an intergovernmental program to provide equipped and trained personnel. These teams, dispatched in response to calls for emergency assistance, can mitigate the consequences of an accident. The effect of various other special precautions, such as routing, speed limitations, much lower speeds in heavily populated cities, and expert driving, are also factors that help to minimize the environmental risks.

Selection of shipping routes and shipping safeguards to be followed in the transport of nuclear fuel and radioactive waste are important considerations.

1. Shipping routes - New fuel will be shipped by truck; spent fuel will be transported by truck to Tanner, Alabama, and shipped by rail; and radioactive wastes will be shipped by truck. These

are the most probable modes of transportation for shipment of radioactive material from Browns Ferry. The population centers en route, the radionuclide inventory, and the environmental effects for these materials are discussed for the probable transportation modes. Shipping routes for spent fuel and radioactive waste will be selected to avoid population centers as much as possible. Escorts will be provided as required by regulations and, in addition, where TVA considers them necessary.

(1) New fuel - General Electric Company will ship new fuel assemblies by truck from its fabrication plant in Wilmington, North Carolina, to the plant. The major population centers encountered over the approximately 700-mile route include the following:

City	1970 Population	Density Persons/mile^2
1. Wilmington, NC--State 211, I-95	46,169	2,638
2. Columbia, SC--by way of I-20 to	113,542	1,069
3. Augusta, GA--by way of I-20 to	59,864	3,938
4. Atlanta, GA--by way of I-285 and I-20 to	496,973	3,779
5. Birmingham, AL--by way of I-65 to	300,910	3,785
6. Decatur, AL--by way of I-65 and U.S. 72 to	38,044	1,430
7. Browns Ferry plant site	-	-

As indicated, interstate highways will be used to the maximum extent possible for the shipment of nuclear fuel and radioactive wastes. Alternate parallel routes will be used whenever necessary because of construction or temporary closure of interstate highway segments.

(2) Spent fuel - General Electric Company will ship the spent fuel from the plant approximately 625 miles to its Midwest Fuel Recovery Plant at Morris, Illinois. The major population centers through which the rail shipments will pass include the following:

City	1970 Population	Density Persons/mile^2
1. Browns Ferry plant site by land to rail siding at Tanner, Alabama, and thence to	-	-
2. Nashville, TN--by way of L&N to	448,003	882
3. Evansville, IN--by way of L&N to	138,764	3,855
4. Terre Haute, IN--by way of L&N to	70,335	2,695
5. Danville, IL--by way of C&EI to	42,570	3,300
6. Chicago Heights, IL--by way of EJ&E	40,900	5,382
7. Park Forrest, IL --by way of EJ&E to Joliet, IL	109,525	5,215
8. Morris, IL (MFRP site)	8,194	2,643

(3) Radwaste - TVA will either ship the low-level radioactive wastes to the Nuclear Engineering Company waste burial facility at Morehead, Kentucky, or to the Chem-Nuclear Services, Inc., waste burial facility at Barnwell, South Carolina. The proposed route to the former facility is approximately 400 miles and the following major population centers are encountered en route:

City	1970 Population	Density Persons/mile^2
1. Browns Ferry site--by way of U.S. 72 and I-65 to		
2. Nashville, TN--by way of I-65 to	448,003	882
3. Bowling Green, KY--by way of I-65 and Toll Highway to	36,253	2,238
4. Lexington, KY--by way of I-64 to	108,137	4,702
5. Morehead, KY (NECO facility)	7,191	4,494

The proposed route to the Chem-Nuclear Services facility is approximately 450 miles and the following major population centers are encountered en route:

City	1970 Population	Density Persons/mile^2
1. Browns Ferry site--by way of U.S. 72 and I-65 to		
2. Decatur, AL--by way of I-65 to	38,044	1,430
3. Birmingham, AL--by way of I-20 and I-285 to	300,910	3,785
4. Atlanta, GA--by way of I-20 to	496,973	3,779
5. Augusta, GA--by way of U.S. 278 to	59,864	3,938
6. Barnwell, SC (Chem-Nuclear facility)	4,439	562

2. Shipment activity -

(1) Spent fuel activity - Fuel elements are removed from the reactor after only a fraction of the available fuel has been used, since accumulation of fission products and possible cladding degradation prevents further usage of the element. This radioactive

"spent fuel" is subsequently shipped to a reprocessing plant for recovery of its unused fuel content (uranium and plutonium) for future use.

The inventory of fission product activity and the isotopic distribution of the Browns Ferry spent fuel at the time of shipment is given in Table 2.1-1. However, it should be noted that effectively all of this contained radioactivity, except for about 30 percent of the noble gases and about 3 percent of the iodines, is tightly bound within the insoluble, high-melting-point ceramic UO_2 pellets. Therefore, even if the shipping cask should be breached in an accident and the clad fuel were to be breached, there is still no ready mechanism for dispersing any substantial fraction of the total contained radioactivity.

(2) Waste activity - Radioactive liquid wastes are treated by filtration, demineralization, and evaporation to concentrate the wastes into low-volume higher-activity wet solid wastes. These wastes, consisting of spent powdered ion exchange resins, filter aid sludges, bead-type ion exchange resins, and evaporator bottoms, are stored in the radwaste building, solidified or dewatered, and packaged in accordance with applicable regulations for shipments to a licensed burial site for disposal. Miscellaneous low-level compressible and incompressible wastes and irradiated or contaminated equipment components are also packaged in accordance with applicable regulations for shipment to a disposal site for land burial.

The values shown in section 9.3 of the final safety analysis report[5] indicate that the normal and maximum activities of the reactor water cleanup system sludge will be 16 Ci/ft^3 after a 60-day decay period. However, studies based on resin exposure to the reactor coolant of about 16 days, followed by intermittent backwashes over a period of 120 days, show that the activity of the reactor cleanup system sludge will be about 8.7 Ci/ft^3. The solid radwaste system is designed to handle about 70 ft^3 of sludge from the reactor water cleanup filter-demineralizers every 60 days. These sludges are accumulated and stored in three phase separator tanks. Each tank has a capacity of about 785 ft^3, of which 375 ft^3 is for settled sludge. Normal operating requirements can be met with two tanks with a 60-day decay period. The third tank provides operating flexibility and additional decay time. Since the container designed for this sludge will hold 150 ft^3 per load, this also permits additional decay time before shipment.

Evaporator bottoms will be solidified with cement or other solidification agent and will be packaged in 55-gallon drums or larger containers.

The estimated activity and quantities of the solid wastes to be shipped from Browns Ferry are summarized as follows:

	Type Waste	Annual Amount-ft^3	Expected Activity @ Shipment
1.	Reactor water cleanup system sludge	450	8.7 Ci/ft^3
2.	Condensate system sludge	5,000	
3.	Fuel pool demineralizer, waste, and floor drain filter sludge	2,500	0.5 Ci/ft^3
4.	Waste demineralizer resins	1,250	
5.	Waste evaporator bottoms	1,000	
6.	Miscellaneous dry solids	4,500	$\ll$0.5 Ci/ft^3

The packaging system at Browns Ferry is designed to permit the use of several different types of containers. These include 55-gallon drums, disposable tanks in reusable shields, and disposable tanks with integral shields. One of the reusable shields has been fabricated for use in transporting radioactive wastes classified as reactor water cleanup system sludge from Browns Ferry to the waste disposal facility. The LL-60-150 (AEC License No. 41-08165-06) container for the higher level radioactive waste and the all-steel container for the lower level waste will be equipped with a disposable liner holding about 150 ft^3 and 183 ft^3 of waste respectively. The table shown below gives the dimensions of the two liners:

	I.D.	O.D.	IN.HT.	OUT.HT.
150 ft^3 liner	70"	70-1/2"	75"	78-1/2"
183 ft^3 liner	76"	76-1/2"	76"	79-1/2"

The liner walls are 1/4-inch carbon steel while the top and bottom are at least 1/2-inch carbon steel. The following criteria will be followed by the manufacturer in fabricating the liners:

1. All material to conform to ASTM-A36 or an approved equivalent.
2. All welds to be complete penetration, visually inspected for defects, and watertight.
3. Liner is to successfully pass a 2.0 lb/in^2 gauge hydro or pneumatic test lasting at least 10 minutes to check integrity.
4. All pipe fittings to conform with ASA-B36, 10-1950.

Upon the arrival at the waste disposal facility, the container cover is removed and slings permanently attached to the disposable liner are attached to a crane. The liner is then lifted from the container and lowered into a trench for burial. The disposable liners could eventually leak. However, a leak in the liner is not an overriding factor since neither NECO or Chem-Nuclear takes credit for containment of the low-level radioactive material in special liners in their license applications. In both cases each concluded in its analysis that contamination of ground water by this uncontained burial would be insignificant.[6,7,8] Extensive monitoring by each company, supported by monitoring from the state, is conducted to assure adjacent areas are not contaminated.

(3) Environmental effects for spent fuel - Following its removal from the reactor, spent fuel is stored for 3 to 4 months prior to shipment. During this time essentially all of the noble gases except krypton-85 decay to very low levels and the

decay heat will have decreased. Of the iodine isotopes, only iodine-131 is present in significant amounts (see Table 2.1-1). Fission products other than the noble gases and iodine are strongly held within the uranium dioxide fuel particles. Hence, only noble gases and iodine would escape through a penetration in fuel clad to the shipping cask cavity. Fuel known to have ruptured cladding prior to shipment is sealed in a container for ruptured fuel.

(a) Normal shipment - The principal normal environmental factor from spent fuel shipments would be the direct radiation dose as they move from the reactor to the reprocessing plant. The population exposure resulting from normal shipments of radioactive materials has been evaluated on the basis that there would be about 5,000 people living on both sides of the transport route along the estimated 625-mile route. It has also been assumed that the shipments are made at the maximum permitted level of 10 mrem/h at 6 feet from the nearest accessible surface. Figure 2.1-1 shows the location of the shipping container relative to people living adjacent to the railroad that was used to calculate the radiation exposures. The calculation does not include reductions of exposures due to shielding from structures, topographic features, or other radiation-attenuating materials.

The radiation dose as a function of distance from a stationary shipping container is shown in figure 2.1-2. As shown, the radiation exposure rate drops off quite rapidly and beyond 260 feet from the container can be considered insignificant.

The radiation exposure rate from a stationary container to a resident living within 260 feet of the container travel path is approximately equal to natural background. Because the container will normally be moving, the total exposure from the containers to such an individual will be an insignificant fraction of the exposure from natural background radiation. For the estimated 32 shipments per year, each moving at only 20 mi/h, the maximum exposure received by any individual along the route would be about 0.0042 mrem per year.

On the basis that there would be a total of about 5,000 people living on both sides of the transport route between Browns Ferry and the Midwest Fuel Recovery Plant at Morris, Illinois, these people would receive an annual dose of about 0.008 man-rem per year. Train brakemen or a member of the general public might spend a few minutes in the vicinity of the car, at an average distance of 6 feet, for an average exposure of about 0.5 mrem per shipment. With 10 different brakemen and 10 members of the general public so involved along the route, the total dose for 32 shipments during the year is estimated to be about 0.32 man-rem.

Since the exposure to the 5,000 people who reside along the route and to a person who might come within 6 feet of the railcar for a short period is only 0.001 and 0.4 percent respectively of the exposure these same people receive from natural background radiation, it is concluded that no adverse environmental effects will result from the normal transportation of spent fuel from Browns Ferry to the fuel reprocessing plant.

(b) Accident occurrences - The principal potential environmental effects from an accident are those from direct radiation resulting from increased radiation levels, from gaseous release of noble gases and iodine, and from release of contaminated coolant.

Evaluation of exposure from direct radiation assumes that the radiation exposure rate is the maximum permitted by regulations, 1,000 mrem/h at 3 feet from the surface of the container, and that people have surrounded the container beginning at about 50 feet from the container. Figure 2.1-3 shows the exposure rate for accident conditions as a function of distance from the container. The exposure rate at 50 feet would be about 9 mrem/h. Assuming a tightly packed crowd, there would be 154 people in the front row and, as shown on figure 2.1-3, these people would provide shielding such that people in subsequent rows would receive greatly reduced radiation exposure. Even if a person remained in the front row for 2 hours, his exposure would be less than 20 mrem. Further, the increased radiation level would most likely be from only a localized areas on the continer, and thus only a small number of the people in even the front row of a crowd would be exposed to these low radiation levels.

Calculations indicate that there would be no gaseous releases without a substantial quantity of decay heat in the shipping container plus the addition of external heat such as from a fire. Thus, it is assumed that the thermal currents surrounding the container fission gases carry any released fission gases to a height of 10 meters before they are dispersed in the environment. On this basis it is calculated that the maximum dose in the environs would occur at about 300 feet from the containers. Assuming a person stands in the plume during the entire accident, the resulting whole body exposure would be 2 mrem and the maximum thyroid dose would be about 5 rem. For the noble gas release, assuming an average population density of 130 people per square mile, the total whole-body population dose from the accident would be 0.09 man-rem. TVA considers the average population to be a more realistic number for analyzing transportation accidents because of the small fraction of the total distance travelled in high population density areas and because accidents in such areas generally occur at lower speeds and therefore would be less severe.

The contaminated coolant is basically low specific activity material. If it were drained from the container and accumulated in a pool on the ground, the exposure rate near the surface of the pool or collection would be less than 4 rem per hour and would be only about 16 mrem per hour at 50 feet, assuming no shielding. However, because the coolant would be absorbed in the ground, there would be significant shielding afforded by the soil and the actual exposure rate would be much less than the levels calculated.

The principal environmental risk resulting from an accident would be potential whole body radiation exposure due to the release of noble gases and from direct radiation and potential thyroid dose due to the release of iodine. Because of the dose reduction with distance and the mitigating effect of proposed emergency actions, it can be concluded that the whole body radiation exposure to the public will be negligible. Because of the unlikely combination of circumstances which must be present to result in a significant dose due to the release of iodine, the probability of significant doses due to this occurrence is considered extremely small.

(4) Environmental effects for radioactive waste - Materials which are in contact with the reactor fuel, its radioactive products, or neutron flux may become radioactive. Consequently, the operation of any nuclear power generating plant will produce radioactive materials in the normal functioning of the various water purification and treatment equipment, as well as routine maintenance operations. The environmental effects for these radioactive wastes for normal shipments and during accident occurrences are evaluated for the potential exposure to transport workers and the general public.

(a) Normal shipments - There will be approximately 53 shipments annually of the radioactive waste resulting from the operation of Browns Ferry. In order to assess the environmental effects of these shipments it is assumed that they are made at the regulatory radiation level limit of 10 mrem/h at 6 feet from the nearest surface. It is also assumed that the exposure rate to transportation personnel is not greater than the regulatory radiation level limit of 2 mrem/h in occupied positions of vehicles.[9]

Under normal conditions, the truck driver might receive as much as 15 mrem per shipment. A total dose to all drivers for a given year, assuming two drivers per vehicle, would not exceed 1.6 man-rem.

Because of the low dose rates permitted at the time of shipment (10 mrem/h at 6 feet from the container), the only exposure to people from routine shipments is for the brief period such a shipment is in direct view. For example, a member of the general public who spends 3 minutes at an average distance of 6 feet from the container would receive a dose not exceeding 0.5 mrem. If 10 persons were so exposed per shipment, the total annual dose for the 53 shipments of spent powdered ion exchange resins, filter aid sludge, and bead-type ion exchange resins would be about 0.3 man-rem.

Figure 2.1-1 shows the location of the shipping container relative to people living adjacent to the transport route that was used to calculate radiation exposures. The radiation dose as a function of distance from a stationary shipping container is shown in figure 2.1-2. On the basis that there would be a total of about 2,500 people living on both sides of the assumed 450-mile transport route between Browns Ferry and either the waste burial facility at Morehead, Kentucky, or at Barnwell, South Carolina, these 2,500 people would receive an annual dose of about 0.006 man-rem per year.

Since the exposure to the 2,500 people who reside along the route, to each truck driver per shipment, and to a person who might come within 6 feet of the container for a short period is only 0.002, 11, and 0.4 percent, respectively, of the exposure these same people receive from natural background radiation, it is concluded that no adverse environmental effects will result from the transportation of radioactive waste from Browns Ferry to either of the burial facilities.

(b) Accident occurrences - Although transportation accidents involving either new fuel or radioactive waste may be expected to occur about once every 10 years based on the national truck accident statistics for 1969, it is highly unlikely that a shipment of solid radioactive waste will be involved in a severe accident during the 40-year life of the plant. This is based on data on accidents involving TVA trucks during the past 10 years which show a rate of 4.06 accidents per million miles travelled. Based on these data and assuming that new fuel and radioactive waste shipments are by truck using the estimated annual shipment miles of radioactive material for the Browns Ferry plant, truck accidents may be expected to occur about once every 5 years. However, about 90 percent of the accidents included in the TVA data are of a minor nature and since radioactive shipments will be made in accordance with the stringent conditions imposed by AEC and DOT procedures and regulations, the probability of an accident of a severity which would result in release of significant quantities of radioactive materials to the environment would not be likely during the 40-year life of the plant.

If a shipment of compressible wastes in appropriate containers becomes involved in a severe accident, some release of waste might occur, but the specific activity of the waste will be so low that the exposure of personnel or the public would not be expected to be significant. Spent powdered ion exchange resins, evaporator bottoms, filter aid sludge, and bead-type ion exchange resins which have been solidified or dewatered will be shipped in Type B packages. The probability of release from a Type B package in a severe accident is sufficiently small that, considering the form of the waste and the very low probability of the severe accident occurrences, the likelihood of significant exposure would be extremely small.

3. Shipping safeguards - The protection of the public from radiation during shipment of nuclear fuel and radioactive waste is achieved by a combination of limitations on the contents of the package according to the quantities and types of radioactivity, the package design, and the external radiation levels. In addition to these shipping safeguards, the transportation emergency plans will provide for rapid and orderly use of personnel and equipment in the event an accident occurs in the shipment of radioactive materials by TVA.

The Department of Transportation (DOT) has regulatory responsibility for safety in the transport of radioactive materials by all modes of transport in interstate or foreign commerce (rail, road, air, and water), except postal shipments.[10] Those shipments not in interstate or foreign commerce are subject to control by a state agency in most cases. The Atomic Energy Commission (AEC) also has responsibility for safety in the possession and use, including transport of radioactive materials.[11] Both Title 10 and Title 49 of the Code of Federal Regulations set forth the limitations and classifications of the contents, design, and external radiation levels of transport packages.

(1) Governing regulations - This section identifies and summarizes the governing regulations affecting the transport of nuclear fuel and radioactive material. The major aspects of package design and the technical bases of the regulations and the control of the radiation emitted from individual packages are also discussed. In addition, the external radiation levels permitted for low specific activity (LSA) are listed.

Package classification depends upon the type, form, and quantity of radioactive material being shipped in the individual container. Small quantities and certain materials of low specific activity are exempted from specification packaging, marking, and labeling when transported on a sole-use vehicle. All other types and quantities of radioactive materials are divided into two broad classes as either "special form" or "normal form." "Special form" radioactive materials means those which, if released from a package, might present some direct radiation exposure but would present little hazard due to radiotoxicity and little possibility of contamination. This may be the result of inherent properties of the material (such as metals or alloys) or acquired characteristics, as through encapsulation. "Normal form" materials which do not meet these criteria are classified into one of seven transport groups and listed in a table of individual radionuclides.

Varying quantities of special form and normal form radioactive materials are specified for Type A packaging, larger quantities for Type B packaging, and in excess of Type B quantities for "large quantity" radioactive materials. The Type A packaging standards are for normal conditions of transport. Type B packaging standards are for accident conditions. The large quantity standards are for accident conditions. The large quantity standards, in addition to considering both normal and hypothetical accident test conditions, must take into account other factors such as radioactive decay heating of the contents. Fissile radioactive materials also require consideration of the potential for accidental criticality.

Low specific activity packages must not have any significant removable surface contamination, and the external radiation levels must not exceed the following dose rates:

(a) 1,000 millirem/h at 3 feet from the external surface of the package (closed transport vehicle only);

(b) 200 millirem/h at any point on the external surface of the car or vehicle (closed transport vehicle only);

(c) 10 millirem/h at 6 feet from the surface of the car or vehicle; and

(d) 2 millirem/h in any normally occupied position in the car or vehicle.

The shipment of radioactive material from Browns Ferry will be in full accordance with these and other regulations governing such shipments.

(2) Package design - The following discussion is directed toward relating the 10 CFR Part 71 accident conditions to similar conditions for the container which might be experienced as a result of a transportation accident.

It should be noted that there is a wide margin of safety in the container design itself. The container is required to withstand the accident conditions imposed pursuant to 10 CFR Part 71 with only relatively minor damage to the container and no release of the contents except for a small amount of coolant and a small quantity of noble gases. For example, the IF-300 spent fuel shipping cask to be used at Browns Ferry is designed to absorb the total effects of the impact of a 30-foot free fall onto an essentially unyielding surface with deformation of the outer fins only. Because the outer shell has considerable strength as opposed to the impact energy-absorbing fins, there is a wide margin between the damage that would be experienced by the cask in absorbing the energy of the 30-foot free fall and that which would be required to breach the container such that there could be a release of the radioactive contents. It is estimated that the amount of energy involved to sustain a significant breach would be from five to ten times that which the cask experiences in a 30-foot free fall.

Thus, as pointed out below, it is unlikely that the casks will experience conditions as severe as those imposed by the 10 CFR Part 71 requirements and, in any event, conditions far more severe than those would be required to result in a substantial breach of a container. As shown in the analysis below, the proposed tests are representative of conditions at least as severe as those which would be experienced by containers in transport. Further, since the tests are required to be applied to the containers in sequence, the cumulative severity of conditions to which the containers are subjected in all probability far exceeds that to which the containers would ever be subjected as a result of an accident in the course of transportation. It is highly improbable that a container would be subjected to conditions as severe as even one of these conditions, let alone all three, in the sequence provided for in the test.

(a) <u>30-foot free fall</u> - The shipping cask is required to withstand a 30-foot free fall onto an essentially unyielding surface. This requires that all the energy of the impact be absorbed by deformation of the container. In addition, the container impact must be considered from all possible orientations to assure that the impact protection provided is adequate regardless of the orientation of the fall. Based on previous design experience, it is estimated that a shipping cask will decelerate (stop) upon impact within a distance of 2 to 8 inches. To provide a basis for this comparison it has been assumed that a shipping cask would decelerate completely within 6 inches after impact with the unyielding surface. Table 2.1-3 shows a comparison of the various forces which would be generated by the stopping of the shipping cask, an overweight truck, or an automobile traveling at various speeds upon striking an unyielding surface.

As indicated in the table, a 45,000-lb shipping cask traveling at 30 mi/h, which is the terminal velocity following a 30-foot free fall, would create 2,700,000 pounds of force if stopped within a distance of 6 inches. A 130,000-lb cask, which is equivalent to the IF-300, would generate about 7,800,000 pounds of force. A loaded truck, weighing 75,000 lb and traveling at 60 mi/h, coming in contact with the unyielding surface is assumed to decelerate within 10 feet. Under these conditions, the truck would generate a maximum of 900,000 pounds of force, or about one-third of the force that would be generated by the 45,000-lb cask as a result of the 30-foot free fall. Likewise, a 5,000-lb automobile traveling at 80 mi/h hitting an unyielding surface is assumed to stop in only 5 feet, which would generate about 220,000 pounds of force. Thus, it is seen that typical objects which the cask might encounter would generate substantially less force than the shipping cask because of the relatively weaker sections of their structures and the greater distance required to decelerate those bodies.

A second area of concern is the shipping cask colliding with stationary objects such as bridge abutments, etc. In this regard, it should be noted that even heavily loaded trucks contacting such stationary objects generally severely damage the object and displace it by some measurable amount. Therefore, these stationary objects generally cannot be considered as unyielding surfaces for the purposes of assessing the effects of a shipping cask impact. As demonstrated in Table 2.1-3, the force developed by the shipping cask would be far greater than that developed by even a loaded truck, and thus the displacement of the "stationary objects" would be even greater than that encountered in a truck-type accident. Additionally, these impacts with the shipping cask assume that the shipping cask contacts the surface with the center of gravity directly behind the point of impact and in the line of travel such that the maximum force is exerted on the cask. In all likelihood, a shipping cask contacting such surfaces would strike a glancing blow, in which case the energy required to be absorbed by the shipping cask would be greatly diminished over that which would result from a direct impact.

The required analysis of a 30-foot drop onto an essentially unyielding surface adequately provides for forces to which a cask might be subjected as a result of a transportation accident. Therefore, as a result of these conditions and the ruggedness of the cask, the possibility of encountering a transportation accident of sufficient severity to result in rupture of the container has an extremely low, if not incredible, probability.

(b) 40-inch drop test - The 40-inch puncture test requires that the cask be dropped from a height of 40 inches, with the center of gravity directly above the point of impact, onto a 6-inch diameter pin of sufficient length to puncture the container but without allowing the puncture of even the outer shell of the vessel. The formula for analysis of this condition was developed at Oak Ridge National Laboratories[12] and other places based on extensive testing of steel and lead shipping containers.

In regard to the relationship of this test to the transportation environment, it was originally intended that the 6-inch diameter pin would approximate that of the end of a rail for rail transportation accidents. It should be noted that the puncture so specified would require that the cask hit the pin exactly perpendicular to the cask surface. Any deviation from this would result in a substantially reduced loading on the side of the cask and enhance chances of deflection. Further, the pin must be long enough to penetrate through the walls of the container, which would require damage to the contents. In most cases this would require that the pin be approximately 12 to 18 inches in length. However, if the pin is much longer than this, it becomes doubtful that the column strength of the pin is sufficient to rupture the container without buckling of the proposed pin.

It should be noted that the containers are required to pass the puncture test without rupture of even the outer shell. As generally there is a heavy outer shell backed up by several inches of shielding material followed by an inner steel shell, there is a wide margin between the damage that the container would sustain as a result of the required puncture test and that would be required to rupture the inner vessel such that there could be dispersal of the radioactive contents. This test provides conditions at least as severe as those to which a container would be subjected as a result of a transportation accident.

(c) <u>30-minute fire test</u> - The 30-minute fire test was proposed as that to which a container would be subjected as a result of large open burning of petroleum such as diesel or jet fuel. In this regard it should be noted that the test conditions require that it be assumed that the cask is perfectly surrounded by a uniform heat flux corresponding to a thermal emissivity of 0.9 at a temperature of 1475°F. In actuality, the cask will most likely be lying on the ground near the cooler part of the flames such that it is not surrounded completely by the fire environment. Further, while there may be individual flame temperatures hotter than the proposed 1475°F, the average flame temperatures will not exceed these values. As evidenced from pictures of large fires, it is unlikely that a container the size of a large shipping cask would be completely engulfed in flames due to lack of the required quantities of combustible materials, winds which tend to blow the flames away from the container, and other factors which act to reduce the idealized conditions assumed for compliance with the 10 CFR Part 71 requirements. It is felt that the test conditions proposed in the regulations provide adequate, if not more severe, simulation of the fire conditions to which a container might be subjected during the course of transportation.

(d) <u>Conclusion</u> - In summary, the casks are designed to meet the requirements of applicable regulations, and it is unlikely that accident conditions more severe than those postulated in the regulations would be encountered.

(3) <u>Transportation procedures</u> - Elements of the procedures to be followed by TVA for handling radioactive materials for transportation and while in shipment are given below. These procedures will cover the normal conditions of transport as well as accident occurrences which might be encountered.

(a) Onsite procedures - The administrative control of radioactive materials intended for offsite shipment will include the following elements:

a. Certify container contents.

b. Assure performance of all tests on loaded containers as required by 10 CFR Section 71.35(a)(4), 49 CFR Section 173.393(j), and 49 CFR Section 173.397(a).

c. Ensure that container and vehicle meet the requirements of applicable regulatory bodies for movement offsite.

d. Qualified manpower and appropriate equipment to be available to make routine determinations as required by (b) above.

e. Estimated time of arrival (ETA) at destination.

f. Driver of vehicle will be responsible for control of shipments en route and for following transportation procedures delivered to him before leaving site.

(b) Offsite procedures - Spent fuel is scheduled to be shipped intermodal which requires offsite handling at the rail siding at Tanner, Alabama. The roll-on-roll-off (RORO) procedure used for the intermodal transfer is shown on figure 2.1-4. The cask is mounted on a skid which becomes the trailer deck for highway transport. The multiwheeled front gooseneck and rear axle assemblies each have self-contained hydraulic lift units for raising and lowering the skid. To remove the cask from the railcar, the front and rear units are positioned and attached to the skid, and the skid is then lifted to provide about 1 foot clearance for the highway transport. On return the procedure is reversed to place the cask back on the railcar. As the cask is never lifted more than 1 foot and as it is designed to withstand a 30-foot free fall onto a completely unyielding surface, there is effectively no possibility that a handling accident would result in the release of any radioactive materials from the cask.

(c) Normal conditions of transport - TVA presently has nine nuclear units under construction or planned for operation between 1972 and 1979. Because of these commitments to the use of nuclear power for substantial portions of its generating capacity and the necessity to ship radioactive materials associated with the operation of these and future nuclear plants, an interdisciplinary task force to evaluate the environmental implications, available technology, economics, and other factors related to the consequent shipment of radioactive material to and from these plants has been established.

The task force is investigating the various transportation modes, prevention of accidents, environmental risks and effects and is developing criteria for establishing TVA's policies and procedures relative to the applicable regulations. The findings and recommendations of the task force will be used in formulating the detailed plans for shipment of all radioactive material to and from all of TVA's nuclear plants currently under construction or planned for the future.

(d) Accident occurrences during transport - Each state through which these materials pass will have developed emergency plans for radioactive transportation accidents. These plans, in conjunction with TVA transportation emergency procedures, will provide for rapid and orderly use of state facilities and personnel, augmented as necessary by TVA, carrier, and municipal emergency personnel and AEC radiological assistance teams in the event an accident occurs in the shipment of radioactive materials by TVA. In the event of an accident, emergency plans for containing the contaminated material and preventing a radiation hazard to the public and the environment will be initiated.

Emergency procedures regarding transportation of radioactive material are described in the TVA Radiological Emergency Plan. Elements of the emergency procedures for handling transportation accidents for which TVA has responsibility will include, but are not limited to, the following:

1. Vehicular Accidents - General
   a. In the event of a vehicular accident involving radioactive material, establish a restricted area [10 CFR Section 20.203(b) and (c)].
   b. Use radiation survey meter to establish the perimeter of the restricted area.
   c. If survey meter is inoperable, calculate from experience and training a very conservative perimeter.
   d. If survey meter is operable and no radiation hazard exists, and the vehicle is in safe operating condition, the driver may continue on way if not detained by other accident-related conditions.
   e. In any case, immediately after establishing a restricted area or before proceeding on way, TVA shall be notified.

2. Notification and Reports of Incident

   a. Appropriate TVA personnel receiving notice of a transportation accident shall notify the TVA load dispatcher who notifies the Central Emergency Control Center director.

   b. The CECC director notifies as appropriate the AEC Operations Office, the State Department of Public Health, the state police, and the AEC Division of Compliance.

TVA has consulted and will consult further with appropriate state agencies regarding the necessary emergency planning for shipments of radioactive material through the state and to seek the state's agreement with TVA's Radiological Emergency Plan.

4. Conclusion - Due to the integrity of the containers used for shipping new fuel elements, spent fuel elements, and low-level radioactive wastes; the emergency plans for vehicular accidents; the administrative control exercised over transportation; and coordination with appropriate state agencies; it is concluded that an insignificant environmental risk will result from the transportation of fuel elements from the fuel fabrication plant to the reactor, or spent fuel elements to the fuel reprocessing plant, and of low-level waste to offsite disposal grounds.

Table 2.1-1

SPENT FUEL FISSION PRODUCT ACTIVITY[a]

(Ci/MTU)[b]
Specific Power = 40 kW/kgU

Isotope	Half-Life	24,000 MWd/T 90D[c]	24,000 MWd/T 160D[c]	44,000 MWd/T 90D[c]	44,000 MWd/T 160D[c]
Noble Gases					
Kr-85	10.8y	7,385	7,294	11,540	11,390
Xe-131m	12d	108	2	113	2
Xe-133	5.3d	20	-	20	-
Total		7,513	7,296	11,673	11,392
Halogens					
I-129	1.6×10^{7}y	2.3×10^{-2}	2.3×10^{-2}	4.09×10^{-2}	4.09×10^{-2}
I-131	8.05d	507	~1	532	~1
Total		507	~1	532	~1
Tritium-H3[d]	12.26y	290	290	505	505
Transuranics[e]					
Am-241	458y				320
Am-243	7,650y				75
Cm-242	163d				65,000
Cm-244	18y				11,000
Total					76,395
All Remaining Fission Products (ARFP)					
Rb-86	18.7d	25	2	42	3
Sr-89	50.4d	316,700	121,400	249,100	95,480
Sr-90	28y	60,180	59,910	95,380	94,940
Y-89m	16s	32	12	25	10
Y-90	64.2h	60,200	59,920	95,400	94,970
Y-91	59d	502,300	220,700	413,600	181,700
Zr-93	9.5×10^{5}y	2	2	4	4
Zr-95	65d	736,400	349,100	707,600	335,400
Nb-95m	90h	15,630	7,409	15,020	7,119
Nb-95	35d	1,226,000	664,300	1,175,000	637,700
Tc-99	2.1×10^{5}y	11	11	19	19
Ru-103	40d	304,700	89,500	346,200	101,700
Rh-103m	57m	298,900	87,800	339,600	99,730
Ru-106	1.0y	366,900	321,400	684,900	600,100
Rh-106	30s	366,900	321,400	684,900	600,100

Table 2.1-1 (continued)

SPENT FUEL FISSION PRODUCT ACTIVITY[a]

(Ci/MTU)[b]
Specific Power = 40 kW/kgU

Isotope	Half-Life	24,000 MWd/T 90D[c]	24,000 MWd/T 160D[c]	44,000 MWd/T 90D[c]	44,000 MWd/T 160D[c]
Ag-110m	260d	320	265	1,104	916
Ag-110	24s	6	5	22	18
Ag-111	7.5d	12	-	16	-
Cd-115M	43d	133	43	168	54
Sn-119m	250d	35	29	50	41
Sn-121m	25y	1	1	2	2
Sn-123	125d	862	592	1,243	855
Sn-125	9.4d	22	-	28	-
Sb-124	60.2d	2,875	1,284	4,185	1,847
Sb-125	2.7y	5,164	4,916	10,430	9,932
Sb-126	12.5d	18	-	27	1
Te-125m	58d	1,069	1,061	2,253	2,184
Te-127m	105d	8,794	5,634	11,480	7,355
Te-127	9.3h	8,755	5,609	11,430	7,322
Te-129m	33d	8,280	1,987	8,346	2,003
Te-129	67m	5,307	1,274	5,349	1,284
Cs-134	2.1y	31,650	29,710	85,060	79,840
Cs-136	13d	207	5	313	7
Cs-137	30y	78,540	78,200	143,000	142,400
Ba-137m	2.6m	73,440	73,110	133,700	133,100
Ba-140	12.8d	14,870	336	14,350	324
La-140	40.2h	17,110	386	16,510	373
Ce-141	32.5d	291,700	65,250	288,300	64,490
Ce-144	285d	993,600	837,500	1,113,000	938,000
Pr-143	13.7d	19,690	556	18,620	525
Pr-144	17.3m	993,600	837,600	1,113,000	938,000
Nd-147	11.1d	2,499	32	2,427	31
Pm-147	2.7y	187,800	178,600	239,900	228,100
Pm-148m	41d	3,208	1,010	4,149	1,307
Pm-148	5.4d	222	70	287	90
Sm-151	90y	107	107	146	146
Eu-154	16y	1,073	1,065	3,135	3,109
Eu-155	1.8y	29,260	27,190	77,030	71,570
Eu-156	15.2d	305	13	396	16
Tb-160	72y	160	81	256	131
Total ARFP (10^6)		7.04	4.46	8.13	5.50

a. Fission product quantities are based on the RIBD code.
b. ~5 assemblies per MTU.
c. Cooling time before shipment.
d. Tritium yields are based on 10^{-4} atoms H3/fission.
e. Transuranic isotopic quantities are based on data extrapolation and calculation.

Table 2.1-2

RADIOACTIVE MATERIALS TRANSPORTATION - SUMMARY OF EFFECTS

(Normal Conditions)

Type Shipment	Transportation: Mode	Transportation: Frequency (Shipments/yr)	Stationary Cask Radiation Exposure (mrem/h): at 6 ft	Stationary Cask Radiation Exposure (mrem/h): at 100 ft	Cask Moving at 20 mi/h Individual Exposure (mrem): Maximum	Cask Moving at 20 mi/h Individual Exposure (mrem): Average	Population Exposure (man-rem/yr)
Spent Fuel	Rail (~3.5 MTU)	32	10	0.085	0.0042	0.0015	0.008
Waste							
Low Level	Truck	53[a]	10	0.085	0.0070	0.0025	0.006
						Total	0.014[b]

(10 CFR Part 71 Accident Conditions)

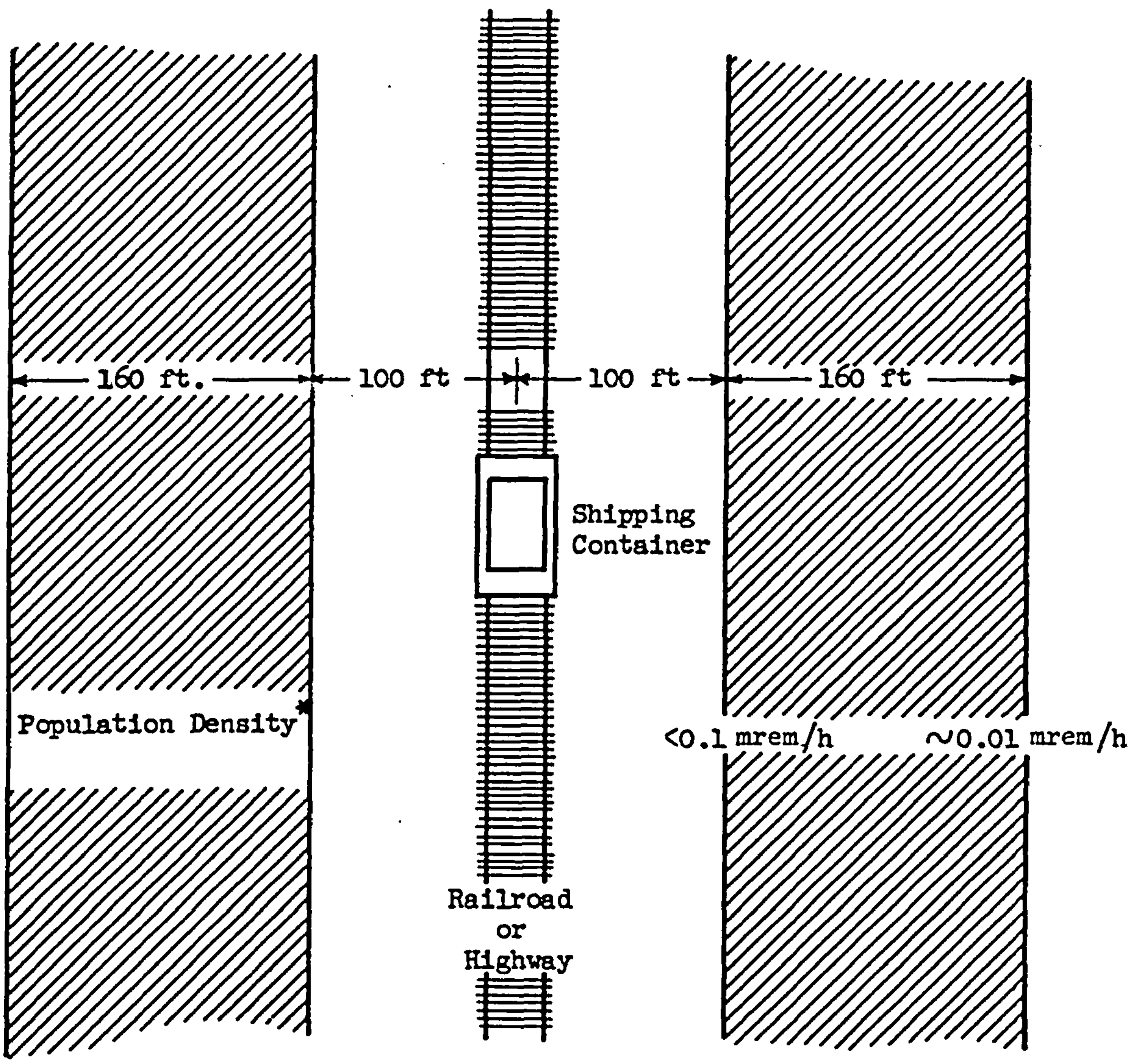
Type Shipment	Transportation: Mode	Transportation: (Shipments/yr)	Direct Radiation Dose Rate (mrem/h): at 3 ft	Direct Radiation Dose Rate (mrem/h): at 50 ft	Fission Gas Release External Dose (mrem): Whole Body	Fission Gas Release External Dose (mrem): Skin	Fission Gas Release Whole Body Population Dose (man-rem)	Thyroid Dose (rem)
Spent Fuel	Rail (~3.5 MTU)	32	1,000	9	2	80	0.09	5
Waste								
Low Level	Truck	53[a]	<500					

a. Design conditions.
b. This population group receives 1,100 man-rem/yr exposure from natural background radiation (~140 mrem/yr).

Table 2.1-3

IMPACT ACCIDENT COMPARISON

Object	Weight (lb)	Initial Velocity (mi/h)	Stopping Distance (ft)	G's	Deceleration Force (lb)
Cask	45,000	30	0.5	60	2,700,000
Cask	130,000	30	0.5	60	7,800,000
Truck	75,000	60	10.0	12	900,000
Car	5,000	80	5.0	44	220,000



When Container is moving at 20 mph:

Maximum Individual Exposure = 0.00013 mrem/trip
Average Individual Exposure = 0.000046 mrem/trip

* Assume 130 persons/mi^2 for spent fuel shipments and 85 persons/mi^2 for radioactive waste shipments.

Figure 2.1-1
Spent Fuel and Radioactive Waste Shipments Population Exposure Distribution

BROWNS FERRY NUCLEAR PLANT

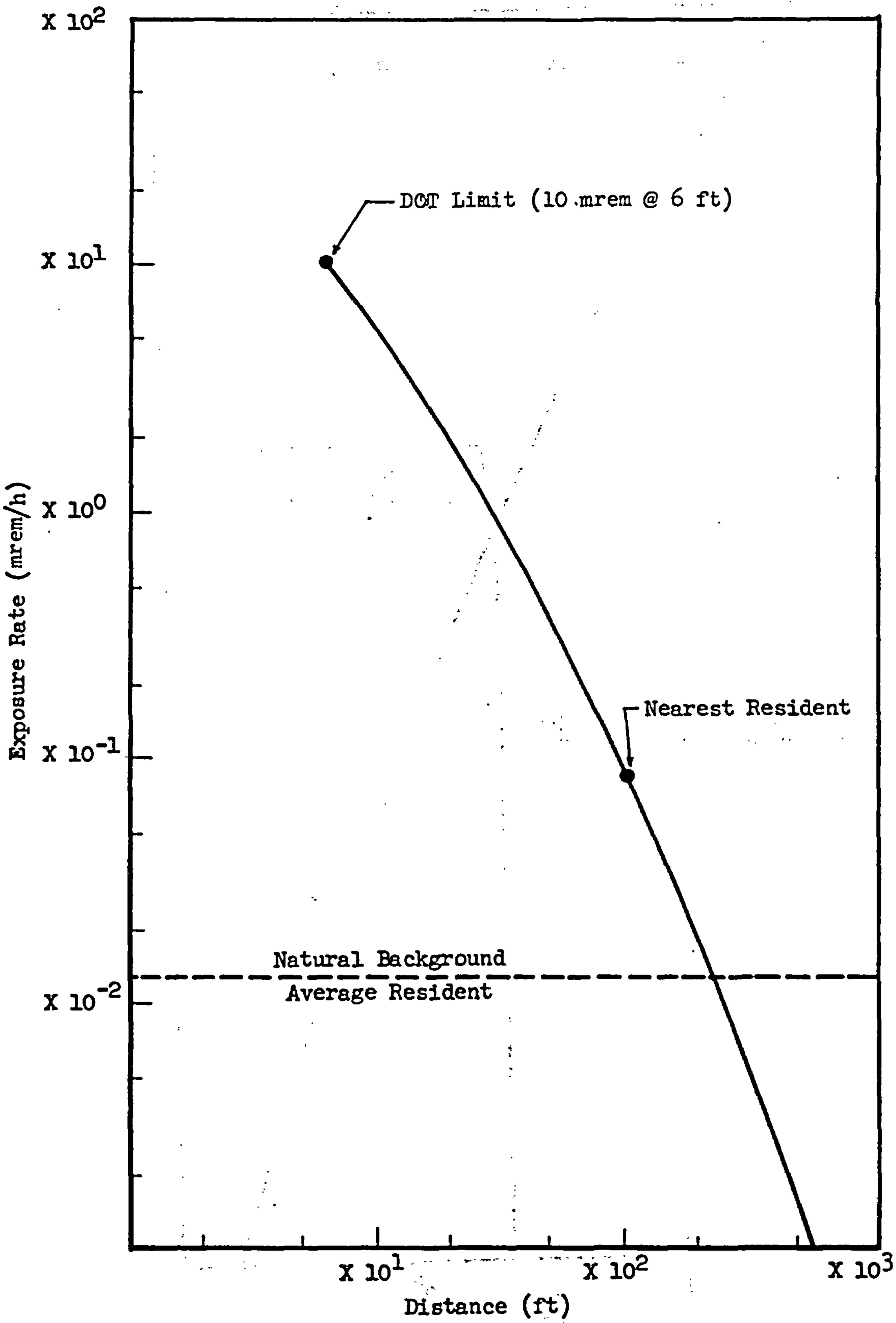


Figure 2.1-2
Direct Radiation Exposure Rate
From Stationary Shipping Container

BROWNS FERRY NUCLEAR PLANT

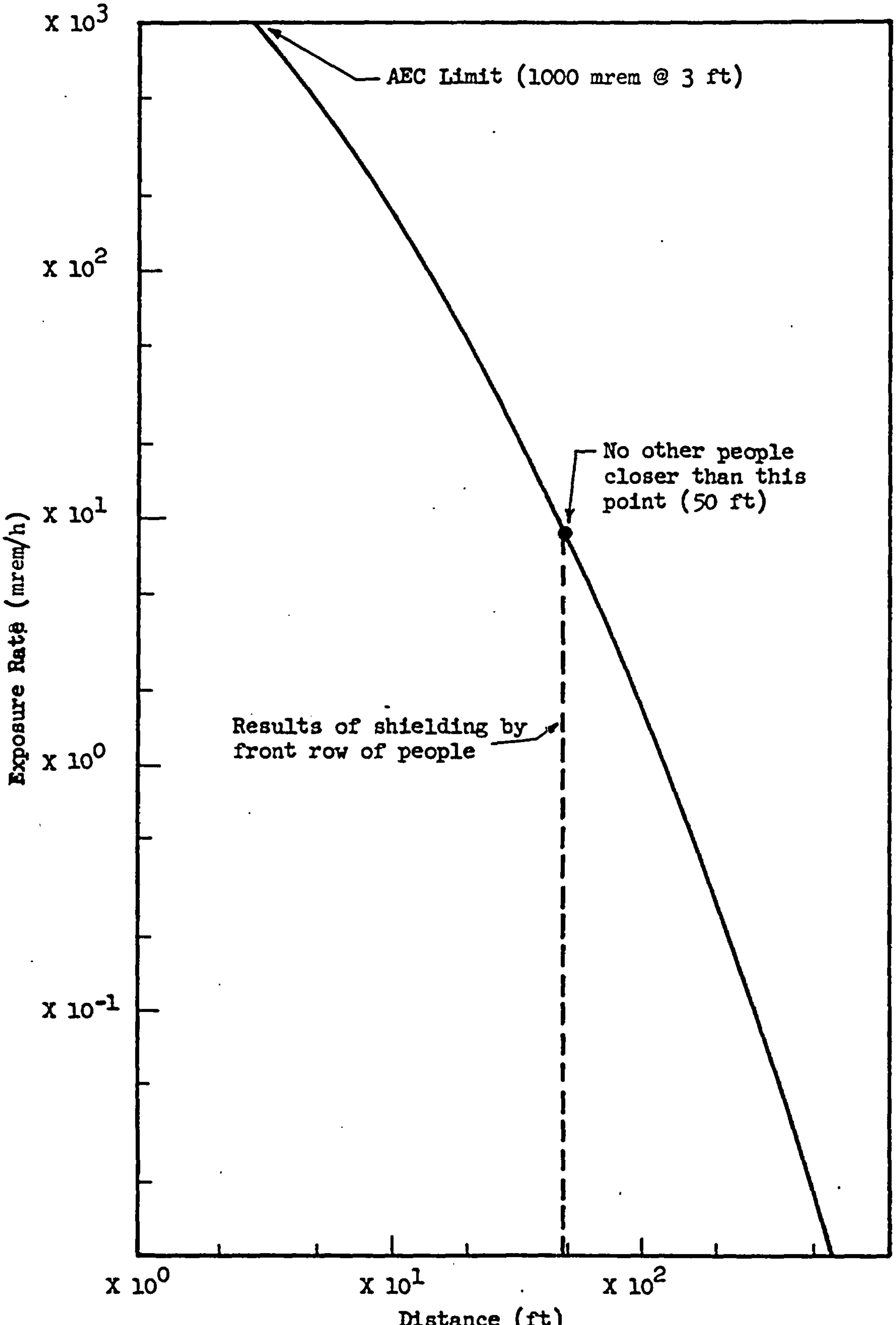


Figure 2.1-3
Direct Radiation Exposure
From Shipping Container
Accident Conditions
BROWNS FERRY NUCLEAR PLANT

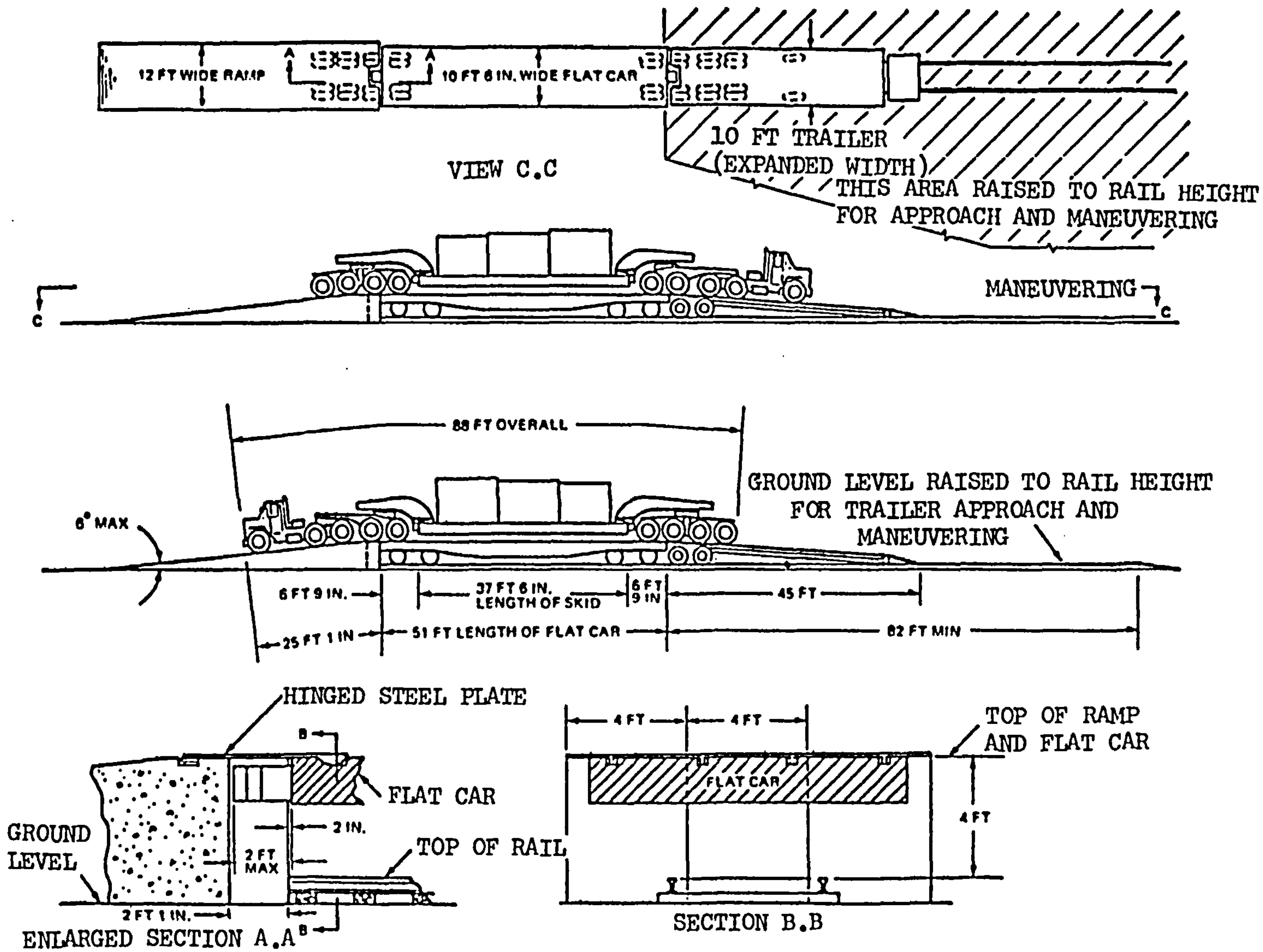


Figure 2.1-4
Intermodal Transfer Site
IF - 300 Shipping Package
Rail Siding - Tanner, Alabama
BROWNS FERRY NUCLEAR STEAM PLANT

2.2 Environmental Aspects of Transmission Lines - Construction of all transmission lines required for the Browns Ferry Nuclear Plant has been completed as stated in Volume 3. All new transmission line construction was within a 20-mile radius of the generating plant, as indicated schematically on figure 2.2-1 of Volume 3. Approximately 70 miles of new transmission construction was required to connect Browns Ferry to TVA's existing 500-kV transmission grid using six terminals. In addition, two 161-kV transmission lines totaling 25 miles were constructed to connect with the existing system.

Both economic and technical advantages dictate the development and operation of extra high voltage (EHV) power lines for the transport of electrical power over long distances. It is well known that ozone can be generated by conductor corona from EHV transmission lines if the conductors are operated at very high surface gradients. Ozone generation, its characteristics, its potential sources, and tests conducted by others are discussed below. The possibility of interference between transmission lines and communication lines is discussed relative to the potential for inductive coupling and direct faulting.

1. Ozone production and its potential effects - This report summarizes and references the literature on the characteristics of ozone and its potential effects on plants, animals, and man. Natural sources of ozone are compared with reference values of the quantities measured during tests on EHV transmission lines. Ozone quantities are also compared with the "Community Air Quality Guides"[1] and the "National Primary and Secondary Ambient Air Quality Standards"[2] for oxidants.

(1) Ozone characteristics and potential effects on plants, animals, and man - The characteristic pungent odor of ozone can be detected at very low concentrations (0.02 to 0.05 ppm depending on individual acuity). At somewhat higher concentrations (0.05 to 0.10 ppm) the odor becomes more pronounced and disagreeable. Ozone is one of the most powerful oxidizing substances known and combines readily with many materials.

Ozone is not considered to be injurious to vegetation, animals, and humans unless concentrations exceed about 0.05 ppm over prolonged periods.[1] Extremely sensitive varieties of tobacco can be injured after about 8 hours of exposure of 0.05 ppm ozone or a 1-hour exposure of 0.07 ppm.[1,3] Most other vegetation, however, can withstand exposures exceeding 0.10 ppm/8 hours without injury.[1,3] Mice exposed to ozone levels of 0.08 ppm in the laboratory for 3 hours which were then infected with streptococcus experienced a 23 percent increase in mortality rate.[4] TVA is not aware of any similar correlation studies of reduced tolerance to diseases versus ozone exposure which may have been made for humans. Most humans generally experience discomfort from ozone's unpleasant odor by the time concentrations approach 0.05 ppm.[4] Spectrograph operators who have experienced intermittent exposures of ozone concentrations in the range of 0.10 to 1.00 ppm over a 2-week period complained of shortness of breath and continuous headaches.[4] The visual acuity of humans can be reduced by prolonged exposures of 0.20 to 0.50 ppm.[3] Technical literature dealing with possible ozone-induced chromosome aberrations extrapolated from animal studies indicated that presently permitted ozone exposure would be expected to result in break frequencies that are orders of magnitude greater than those resulting from permitted radiation exposures.[5] The recent "Community Air Quality Guide"[1] issued for ozone by the American Industrial Hygiene Association after consideration of the radiomimetic nature of ozone and the need for a realistic limit recommended an upper concentration limit of 0.05 ppm for not more than 1 to 2 hours per day to protect very sensitive plants and an exposure limit of 0.1 ppm/hr/d on the average during any year if human health is not to be significantly impaired during a lifetime of exposure. By projecting observed impacts from experimental ozone exposures of Chinese hamsters, one observer estimates that even these levels could possibly produce about 1,270 times more lymphocyte chromosome breaks than the maximum permitted occupational radiation exposure.[5]

(2) Natural ozone sources.- Ozone is formed in nature by the dissociation action of solar ultraviolet radiation below 2,450A on the oxygen molecules present in the atmosphere. Peak natural-formed concentrations of ozone as high as 11 ppm or more have been measured in the stratosphere; however, chemical, photochemical, and catalytic reactions tend to destroy the major portion of the ozone at ground levels where peak natural-formed concentrations would be expected to exceed 0.05 ppm only under rare circumstances, i.e., about 1 percent of the time.[1] Average ground level concentrations of naturally formed ozone is estimated to be about 0.01 ppm in the United States.[4]

The actual instantaneous values for any specific location can vary from less than 0.01 ppm to over 0.05 ppm, depending on altitude, meteorological factors, geographical latitude, time of day, and time of year. Figure 2.2-1 illustrates how ozone concentrations vary with altitude; however, vertical air currents constantly change the distribution, pattern, and magnitude of peak concentrations from those indicated. Similarly, figures 2.2-2 and 2.2-3 illustrate the magnitude of the diurnal variations which can occur between daytime ozone levels produced by the sun and nighttime levels when ozone tends to dissociate to its original oxygen form. The implications of figure 2.2-2 will be discussed in greater detail later as it relates to the environmentally insignificant levels of ozone produced by transmission lines. Lightning is another natural phenomena which produces large instantaneous quantities of extremely localized ozone; however, this accounts for very little of the total ozone existing in nature.

(3) Ozone generation by transmission facilities and other potential sources - Ozone may be generated by any corona or electrical discharge in air or other oxygen medium. Quantities produced are dependent on the severity of the discharge and the quantity of oxygen in the energy envelope. Ozone may, therefore, be generated in undetermined quantities by motors, circuit breakers, electric welding torches, plasma sources, ultraviolet and fluorescent lamps, applicances, switches, transmission lines, or any other device which produces corona or electrical discharges.

Corona discharges can increase as a result of abrasions, foreign particles or sharp points on electrical conductors and electrical equipment, or incorrect design which produces excessively high potential gradients. However, the design and construction of TVA transmission facilities minimize corona discharges and arcing. TVA specifications require that transmission line hardware and electrical equipment for operation at 500,000 volts be factory tested to assure as near corona-free performance as possible up to maximum operating voltage levels.

An extensive field-test program of detection of ozone in the vicinity of 765-kV lines has recently been completed, and full details and conclusions will be incorporated in papers being submitted for presentation at the 1972 IEEE Summer Power Meeting, San Francisco, California, July 1972.[6,7] Tests were conducted by Battelle Memorial Institute at 20 locations and under a variety of meteorological conditions, including several tests in which the instruments were placed as close as 6 meters downwind from the energized 765-kV conductors, at the conductor height. Ozone, NO_x, and corona-loss measurements were simultaneously conducted under contract to AEP at the Westinghouse EHV Laboratory at Trafford to measure the rates of ozone and NO_x production from full-scale conductor bundles which could be operated at 765 kV.[8] Diffusion models developed from these tests agreed closely with the actual transmission line measurements. No ozone contribution to the natural ozone levels was detected which could be attributed to the transmission lines.

Under tests sponsored by the Electric Research Council and jointly financed by the Edison Electric Institute and the Bonneville Power Administration, the General Electric Company[9,10,11,12] is conducting transmission research in the 1,000-kV to 1,500-kV range. As a result of questions posed about the possible levels of ozone generation from the UHV configurations, ozone was monitored at the project. Figure 2.2-2 shows ozone concentrations during the time the UHV test line was energized and deenergized over a 2-week period and graphically illustrates the following conclusions:

> "From the results, it was evident that sunlight on a clear day is a more efficient producer of ozone than UHV lines, and any amounts created by the lines were so small that they were lost in the background produced by the sun's radiation."[13]

(4) Conclusion - No significant adverse effects on vegetation, animals, or humans (including any significant increase in chromosome aberrations) are expected to result from possible levels of ozone production attributable to transmission facilities for transmission voltages up to 765 kV. It is concluded that any levels of ozone that can reasonably be expected to be generated by TVA's transmission facilities (500-kV maximum voltage), either resulting from normal transmission operations or following breaker or switching operations for the periods and the levels that they could be expected to persist, are environmentally inconsequential to humans, animals, or vegetation.

2. Inductive coupling - It is TVA's normal practice to send transmission line vicinity maps to railroad and telephone companies having tracks or communication lines in the general vicinity of proposed transmission lines for inductive coordination study. This was done in the case of transmission line connections for Browns Ferry Nuclear Plant, with proposed location maps being sent to the L&N and Southern Railroad Companies and the South Central Bell Telephone Company. No inductive coupling problems were anticipated by either TVA or the companies, and none has been experienced since the lines were energized and placed in service.

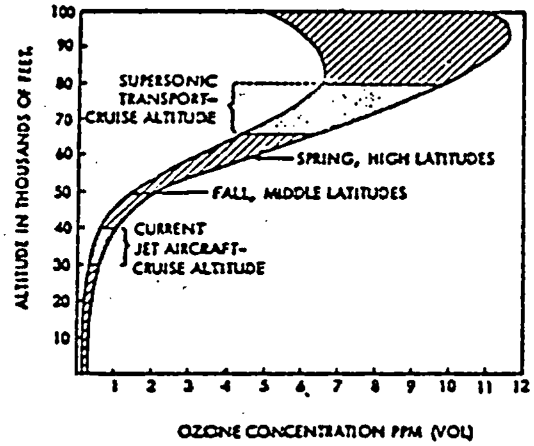


FIGURE 1. Ozone distribution—Northern Hemisphere.

Figure 2.2-1
(See Reference 5)

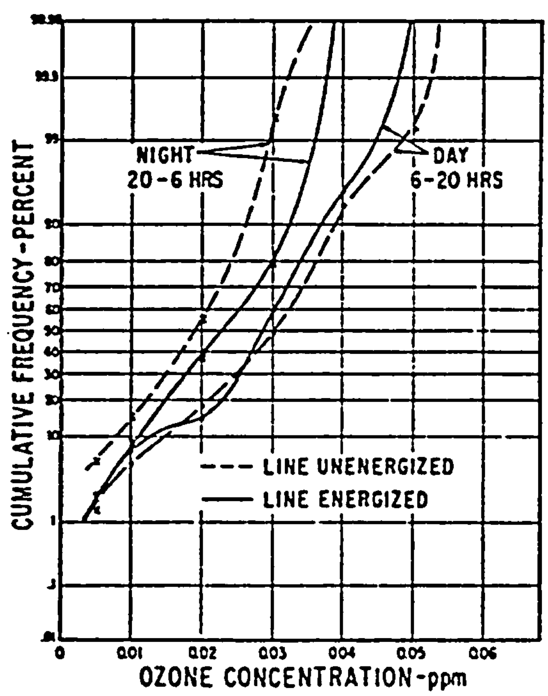


Fig. 2. Ozone statistic obtained near UHV test line during 8 days of energization and 10 days without energization.

NOTE: Test used single-phase UHV voltage of $1{,}260/\sqrt{3}$ kV.

Figure 2.2-2
(See Reference 10)

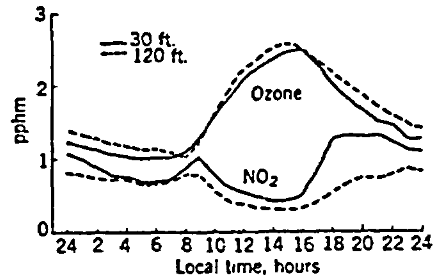


Figure 1. Averages of ozone and nitrogen dioxide for five months (Sept. 1966–Jan. 1967).

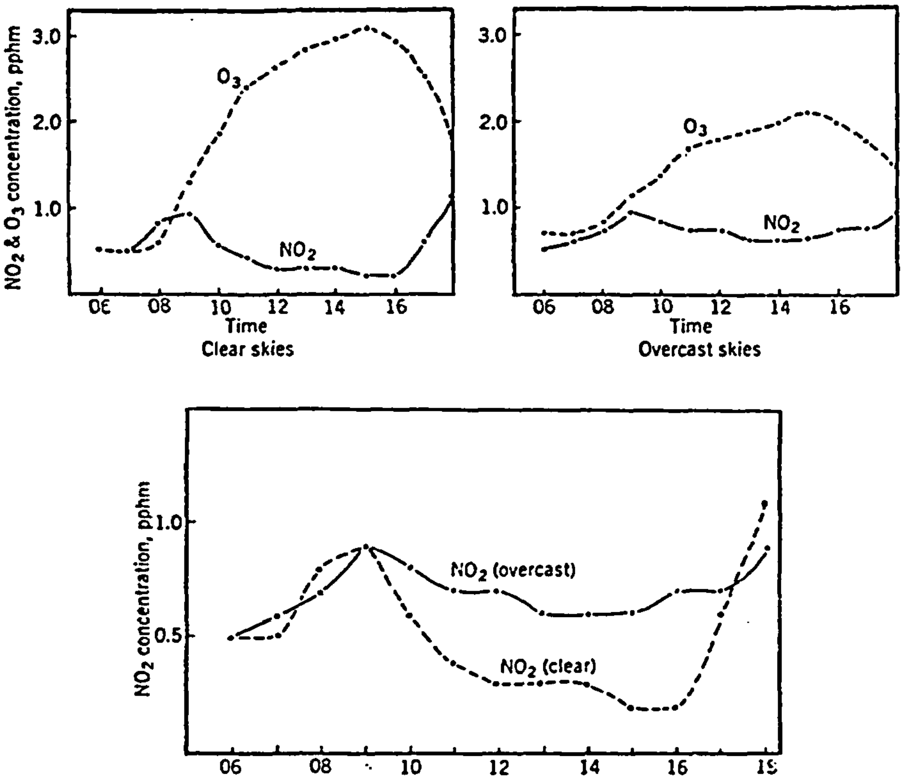


Figure 2. Nitrogen dioxide on clear and overcast days (Sept. 1966–Jan. 1967)

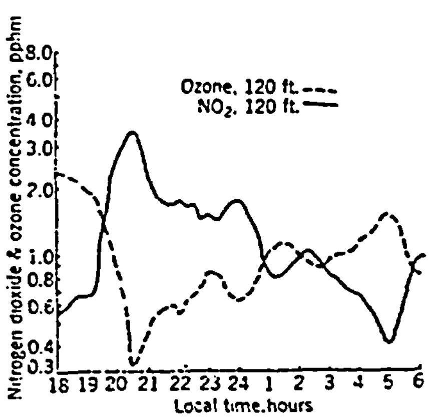


Figure 3. Nitrogen dioxide and ozone (1800–0600 hr on 11/24/66).

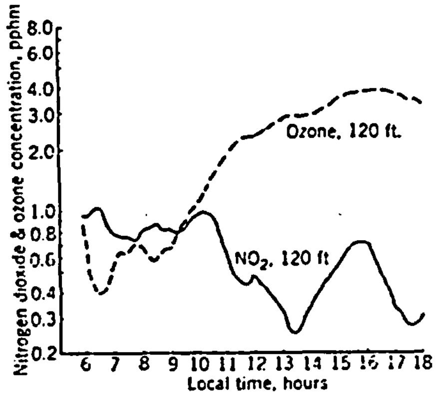


Figure 4. Nitrogen dioxide and ozone (0600–1800 hr on 11/25/66).

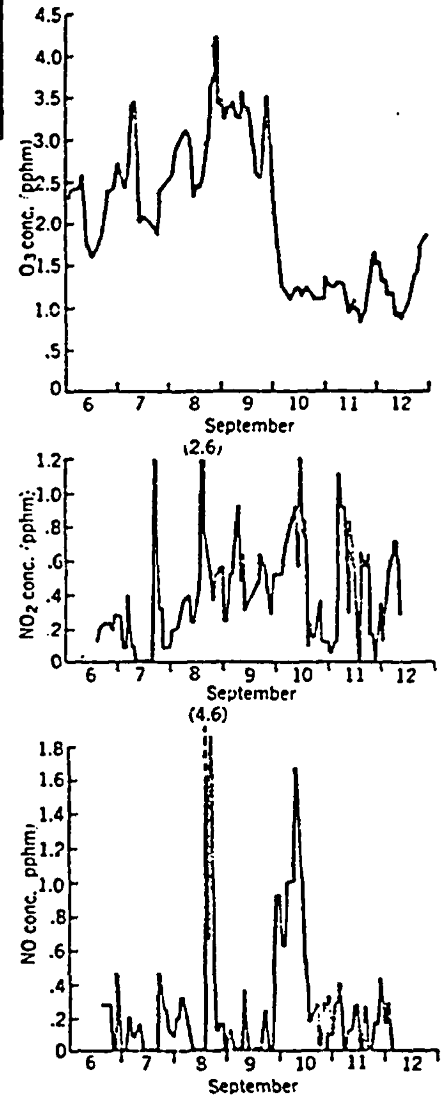


Figure 5. Diurnal averages for nitrogen dioxide and ozone at Green Knob, N. C. (Sept. 1965).

Figure 2.2-3
(See Reference 14)

2.3 <u>Radiological Effects of Accidents</u> - To aid in developing the overall balancing of environmental costs and benefits of the Browns Ferry Nuclear Plant, an assessment has been made of the consequences that could result from the occurrence of postulated accidents. Parameters, physical characteristics, and phenomena are used in the analyses to appraise realistically the environmental risks of postulated radiological accidents. Best estimates are used where experimental evidence is not sufficient to describe a situation. This approach to the analyses is therefore different from that used in safety analysis reports where conservatisms are supplied in order to place upper bounds on radioactive releases from postulated accidents.

Indications of the probable frequency or probability of occurrence of certain accidents are given; however, it is not possible at this time to quantify the probability or frequency of occurrence of any accident. This is principally due to the lack of statistically significant data available on which to base the probability determinations.

In accordance with AEC requirements, TVA has submitted with its application for permits to construct and operate units 1, 2, and 3 a final safety analysis report[1] which describes the technical features of the plant and the provisions for protecting the health and safety of the public. The analyses presented in this report demonstrate that even for postulated accidents of great severity, analyzed using conservative assumptions, the radiological consequences would be within the reference values of 10 CFR Part 100.

1. <u>Minimizing the probability of occurrence</u> - The probability of an accident occurrence is minimized in a number of ways:

(1) employment of conservative design criteria in selection and manufacture of system components; (2) incorporation of automatic protection systems; (3) quality assurance programs for design, construction, and operation; (4) administrative control of the conduct of operations; and (5) safety review. These matters are covered in greater detail in the context of the 10 CFR Part 50 licensing procedures.

2. Mitigating consequences of an accident - Several measures mitigate the consequences of an accident. These include: (1) multiple fission product barriers; (2) engineered safety features; and (3) emergency plans.

(1) Multiple fission product barriers - Fission product containment barriers are the basic features which minimize the release of radioactive materials. The design of Browns Ferry Nuclear Plant provides the following means of containing and/or minimizing the release of fission products: fuel barriers--high density ceramic UO_2 fuel sealed in zircaloy cladding; nuclear system process barrier--reactor vessel, pipes, pumps, valves, and similar process components; steel primary containment; and secondary containment building.

(2) Engineered safety features - The engineered safety features include those systems which are essential for the safe shutdown of the reactor and for maintaining it in a safe shutdown condition. They are designed to provide high reliability and ready testability. Even if an improbable maloperation or equipment failure, including a double-ended circumferential rupture of any primary coolant pipe, allowed variables to exceed their operating limits, the nuclear safety systems and engineered safeguards would limit the environmental effects from such an event.

(3) Emergency plans - The Browns Ferry Nuclear Plant emergency plans contain individual plans for coping with emergencies. They also include the radiological emergency plan which provides a description of action to be taken for events which could result in the release of signigicant amounts of radioactivity to the offsite environment. Procedures for operating the plant equipment under emergency or abnormal conditions are contained in emergency operating procedures. The Browns Ferry radiological emergency plan[2] is a part of the TVA radiological emergency plans.[3]

3. Accident analysis - Those postulated accidents having the potential for uncontrolled releases of radioactive material to the environment have been divided by the Atomic Energy Commission into nine classes based on the systems involved and the type and potential consequences of the release. The accident analyses presented here are based on the guidance given by AEC in Appendix D, 10 CFR Part 50.[4]

TVA has evaluated the fuel design as well as current BWR operating experience and have concluded that the design basis coolant activity and radioactive source term used for routine radioactive discharges provide a reasonable basis for evaluating the environmental impact of postulated accidents. Therefore, the results given in Table 2.3-1 are based on the design basis condition. TVA has also investigated the effect of a higher coolant activity on postulated accident releases. These analyses are based on TVA's estimate of the coolant activity due to 0.5 percent failed fuel and show that even with a higher coolant activity there are no significant adverse environmental effects (Table 2.3-2).

Class one events are defined as trivial incidents including minor spills and pipe leaks that can release small quantities of radioactive material inside the containment. Class two events include miscellaneous small spills and leaks of radioactive material that may occur in structures other than containment. Both class one and class two events have been included in the routine radioactive discharges.

Class three accidents include uncontrolled releases of radioactivity from waste disposal systems as a result of an equipment malfunction or an operator error. The largest potential for release in this class is the hypothetical complete failure of the gas holdup pipe (subclasses 3.1 and 3.2). The postulated liquid radwaste accidents (subclass 3.3) lead to significantly smaller releases.

Class four accidents include postulated events which release radioactivity into the primary coolant system, including anomalous fuel failures (subclass 4.1) and fuel failure which might result from abnormal operating transients (subclass 4.2). Subclass 4.1 is included in the analysis of routine radioactive discharges. While no off design transient has been identified which can lead to fuel failures, subclass 4.2 has been analyzed using AEC guidance.

The off design transient (subclass 4.2) is assumed to result in release of 0.02 percent of the core inventory of noble gases and halogens to the coolant. One percent of the halogens and 100 percent of the noble gases in the reactor coolant are assumed to be released to the steam and transported to the condenser. This activity is assumed to leak to the atmosphere at the rate of 0.5 percent of condenser volume per day for one day. A decontamination factor in the condenser of 10 is assumed for halogens.

The Atomic Energy Commission has not identified a class five accident which applies to BWR's. The refueling accident inside the primary containment is represented by two examples: Subclass 6.1 is based on failure of one row of fuel pins while the fuel is being handled one week after plant shutdown. One percent of the halogens and 1 percent of the noble gases in the failed fuel pins are assumed to be released to the water. One hundred percent of the noble gases are assumed to be released to the building atmosphere along with 0.2 percent of the halogens and are exhausted to the atmosphere through the stack after passing through charcoal filters (which are assumed to remove 99 percent of the halogens). No credit is taken for holdup in the secondary containment. Accident subclass 6.2 is similar to 6.1, except that all the pins in one element are assumed to fail after only 100 hours of decay time.

Accident subclasses 7.1 and 7.2 are fuel failure events in the fuel storage pool which is inside the secondary containment. The event in subclass 7.1 is identical to the event in subclass 6.1. The event in subclass 7.2 is identical to the event in subclass 6.2 except that the assumed decay time prior to failure is 30 days. The cask drop accident is based on the failure of all the pins in one element after 120 days of decay. The secondary containment integrity will be maintained during the handling process, therefore, the release path is identical to the rest of the fuel handling accidents except that no credit is taken for iodine removal in water.

The loss-of-coolant accidents, accident subclass 8.1, result in releases of fission products to the secondary containment due to leakage of the primary containment. No credit is taken for holdup in the secondary containment. The release from the secondary containment is via the standby gas treatment system (which is assumed to be 99 percent efficient for the removal of halogens) to the stack for release to the atmosphere. The source term for the "small" loss-of-coolant accident is the activity in the coolant due to routine operation with failed fuel. The "large" loss-of-coolant accident source term is the sum of the primary coolant inventory plus the release to the coolant of 0.2 percent of the core inventory of noble gases and halogens. For both events it is assumed that core spray, plateout, etc., remove 80 percent of the halogens. Accident subclass 8.1(a) is not applicable to the Browns Ferry plant.

The control rod drop accident, subclass 8.2(b), is similar to the off design transient except the source term is due to the primary coolant activity plus the release of 0.025 percent of the core inventory of noble gases and iodine. The steamline break accidents, subclass 8.3(b), are represented by a "small" and a "large" break size. The total amount of coolant released to the atmosphere for each is assumed to be 2,750 pounds and 52,000 pounds, respectively. The reduction factor for transfer of iodines to the atmosphere from the primary coolant is assumed to be 0.1 and 0.5, respectively.

In order to assess risk, some measure of probability is required. In general TVA believes that certain releases which have been classified as accidents may reasonably be expected to occur during the lifetime of the plant. These (accident subclasses, 1.0, 2.0, and 4.1) are included in the estimates of routine radioactive discharges. The accidents in classes 3.0, 4.0, and 5.0 are considered improbable; that is, not likely during the 40-year life of the plant. Accidents in classes 6 and 7 are relatively less probable but still are possible. The probability of occurrence of class 8 accidents is very small. The postulated occurrences in class 9 involve sequences of successive failures more severe than those required to be considered in the design basis of protection systems and engineered safety features. Their consequences could be severe. However, the probability of their occurrence is so low that their environmental risk is extremely small. Defense in depth (multiple physical barriers); quality assurance for design, manufacture, and operation; continued surveillance and testing; and conservative design are all applied to provide and maintain the required high degree of assurance that potential accidents in this class are, and will remain, sufficiently low in probability that the environmental risk is extremely small.

Table 2.3-1 indicates that the realistically estimated radiological consequences of the postulated accidents would result in exposures of an assumed individual at the site boundary to concentrations of radioactive materials less than the maximum permissible concentrations (MPC) of Table II of Appendix B of 10 CFR Part 20. Figure 2.3-1 shows the minimum exclusion distance and site boundary. Table 2.3-1 also shows that the estimated integrated exposure of the population projected for the year 2010 within 50 miles of the plant from each postulated accident would be orders of magnitude smaller than that from naturally occurring radioactivity, which corresponds to approximately 174,000 man-rem/yr based on a natural background level of 0.145 rem/yr. When the probability of occurrence is considered, the annual potential radiation exposure of the population from all the postulated accidents is an even smaller fraction of the exposure from natural background radiation and, in fact, is well within naturally occurring variations in the background. It is concluded from the results of the analysis that the environmental risks due to postulated radiological accidents are exceedingly small.

Table 2.3-1

SUMMARY OF RADIOLOGICAL CONSEQUENCES OF POSTULATED ACCIDENTS

Class	Event	INDIVIDUAL DOSES AT THE SITE BOUNDARY (rem) Gamma Radiation	Beta Radiation	Gamma Plus Beta	Iodine Inhalation	Fraction of Limit[b]	DOSE TO POPULATION[a] (man-rem) Gamma Radiation	Beta Radiation	Iodine Inhalation	Total
1.0	Trivial incidents	*	*	*	*	*	*	*	*	*
2.0	Small releas outside containment	*	*	*	*	*	*	*	*	*
3.0	Radwaste system failures									
3.1	Equipment leakage or malfunction	1.7 (-3)[c]	8.8 (-4)	2.6 (-3)	**	5.2 (-3)	3.5 (-1)	1.9 (-1)	**	5.4 (-1)
3.2	Release of waste gas storage tank contents	6.7 (-3)	3.5 (-3)	1.0 (-2)	**	2.0 (-2)	1.4 (0)	7.7 (-1)	**	2.2 (0)
3.3	Release of liquid waste storage tank contents	**	**	**	**	**	**	**	**	**
4.0	Fission products to primary system (BWR)									
4.1	Fuel cladding defects	*	*	*	*	*	*	*	*	*
4.2	Off-design transient	1.7 (-4)	1.3 (-4)	3.0 (-4)	7.7 (-4)	1.1 (-3)	4.5 (-2)	4.4 (-2)	2.4 (-1)	3.3 (-1)
5.0	Fission products to primary system (PWR)	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 2.3-1 (continued)

SUMMARY OF RADIOLOGICAL CONSEQUENCES OF POSTULATED ACCIDENTS

		INDIVIDUAL DOSES AT THE SITE BOUNDARY (rem)					DOSE TO POPULATION[a] (man-rem)			
Class	Event	Gamma Radiation	Beta Radiation	Gamma Plus Beta	Iodine Inhalation	Fraction of Limit[b]	Gamma Radiation	Beta Radiation	Iodine Inhalation	Total
6.0	Refueling accidents									
6.1	Fuel bundle drop	1.3 (-6)	3.1 (-6)	4.4 (-6)	7.7 (-7)	9.3 (-6)	4.4 (-3)	1.0 (-2)	2.5 (-3)	1.7 (-2)
6.2	Heavy object drop onto fuel in core	1.4 (-5)	3.1 (-5)	4.5 (-5)	7.0 (-6)	1.0 (-4)	4.5 (-2)	1.0 (-1)	2.3 (-2)	1.7 (-1)
7.0	Spent fuel handling accident									
7.1	Fuel assembly drop in fuel storage pool	1.3 (-6)	3.1 (-6)	4.4 (-6)	7.7 (-7)	9.3 (-6)	4.4 (-3)	1.0 (-2)	2.5 (-3)	[illegible] (-2)
7.2	Heavy object drop onto fuel rack	4.7 (-7)	1.8 (-6)	2.3 (-6)	7.4 (-7)	5.1 (-6)	1.5 (-3)	6.0 (-3)	2.4 (-3)	9.9 (-3)
7.3	Fuel cask drop[d]	7.2 (-9)	7.7 (-7)	7.8 (-7)	3.2 (-10)	1.6 (-6)	2.4 (-5)	2.5 (-3)	1.0 (-6)	2.5 (-3)
8.0	Accident initiation events considered in design basis evaluation in safety analysis report									
8.1	Small loss-of-coolant	4.3 (-6)	2.6 (-6)	6.9 (-6)	1.1 (-7)	1.4 (-5)	1.5 (-2)	9.0 (-3)	4.0 (-4)	2.4 (-2)
8.1	Large loss-of-coolant	2.1 (-4)	2.1 (-4)	4.2 (-4)	2.7 (-3)	2.6 (-3)	7.6 (-1)	8.0 (-1)	1.0 (+1)	1.2 (+1)
8.1(a)	Instrument line break	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 2.3-1 (continued)

SUMMARY OF RADIOLOGICAL CONSEQUENCES OF POSTULATED ACCIDENTS

		INDIVIDUAL DOSES AT THE SITE BOUNDARY (rem)					DOSE TO POPULATION[a] (man-rem)			
Class	Event	Gamma Radiation	Beta Radiation	Gamma Plus Beta	Iodine Inhalation	Fraction of Limit[b]	Gamma Radiation	Beta Radiation	Iodine Inhalation	Total
8.2(b)	Rod drop accident (BWR)	2.1 (-4)	1.6 (-4)	3.7 (-4)	9.6 (-4)	1.4 (-3)	5.6 (-2)	5.5 (-2)	3.0 (-1)	4.1 (-1)
8.3(b)	Small main steam line rupture	1.5 (-6)	3.2 (-7)	1.8 (-6)	1.5 (-4)	1.0 (-4)	3.2 (-4)	6.8 (-5)	3.2 (-2)	3.2 (-2)
8.3(b)	Large main steam line rupture	1.4 (-4)	3.0 (-5)	1.7 (-4)	1.4 (-2)	9.4 (-3)	3.0 (-2)	6.5 (-3)	3.0 (0)	3.0 (0)

* Evaluated as routine releases in Section 2.4, Radioactive Discharges
NA Not Applicable
** Results in doses less than 10^{-4} rem and population doses less than 10^{-3} man-rem
a. Based on projected population for the year 2010 within 50 miles of the plant
b. Estimated fraction of 10 CFR Part 20 limit at site boundary
c. 1.7×10^{-3}
d. Represents the release from a single fuel element, since the number of elements in a cask varies with shipping method

Table 2.3-2

ACCIDENT RESULTS BASED ON A CONSERVATIVE COOLANT ACTIVITY[a]

Class	Site Boundary Dose Fraction of Limit[b]	Population Dose Man-Rem
1.0 Trivial incidents	*	*
2.0 Small release outside containment	*	*
3.0 Radwaste system failures		
3.1 Equipment leakage or malfunction	1.1 (-2)	1.2 (0)
3.2 Release of waste gas storage tank contents	4.3 (-2)	4.7 (0)
3.3 Release of liquid waste storage tank contents	**	**
4.0 Fission products to primary system (BWR)		
4.1 Fuel cladding defects	*	*
4.2 Off-design transient	1.1 (-3)	3.3 (-1)
5.0 Fission products to primary system (PWR)	NA	NA
6.0 Refueling accidents		
6.1 Fuel bundle drop	9.3 (-6)	1.7 (-2)
6.2 Heavy object drop onto fuel in core	1.0 (-4)	1.7 (-1)
7.0 Spent fuel handling accident		
7.1 Fuel assembly drop in fuel storage pool	9.3 (-6)	1.7 (-2)

Table 2.3-2 (Continued)

ACCIDENT RESULTS BASED ON A CONSERVATIVE COOLANT ACTIVITY[a]

Class	Site Boundary Dose Fraction of Limit[b]	Population Dose Man-Rem
7.2 Heavy object drop onto fuel rack	5.1 (-6)	9.9 (-3)
7.3 Fuel cask drop	1.6 (-6)	2.5 (-3)
8.0 Accident initiation events considered in design basis evaluation in safety analysis report		
8.1s Small loss-of-coolant	3.0 (-5)	5.2 (-2)
8.1l Large loss-of-coolant	2.6 (-3)	1.2 (+1)
8.1a Instrument line break	NA	NA
8.2b	1.4 (-3)	4.1 (-1)
8.3(b)s Small MSLR	2.2 (-4)	6.9 (-2)
8.3(b)l Large MSLR	2.0 (-2)	6.5 (0)

Notes

a. Coolant activity consistent with a noble gas release rate after 30-minute decay of 215,000 μCi/s per unit.

b. Estimated fraction of 10 CFR Part 20 limit at site boundary.

* Evaluated as routine releases in section 2.4, Radioactive Discharges.

** Results in doses less than 10^{-4} rem and population doses less than 10^{-3} man-rem.

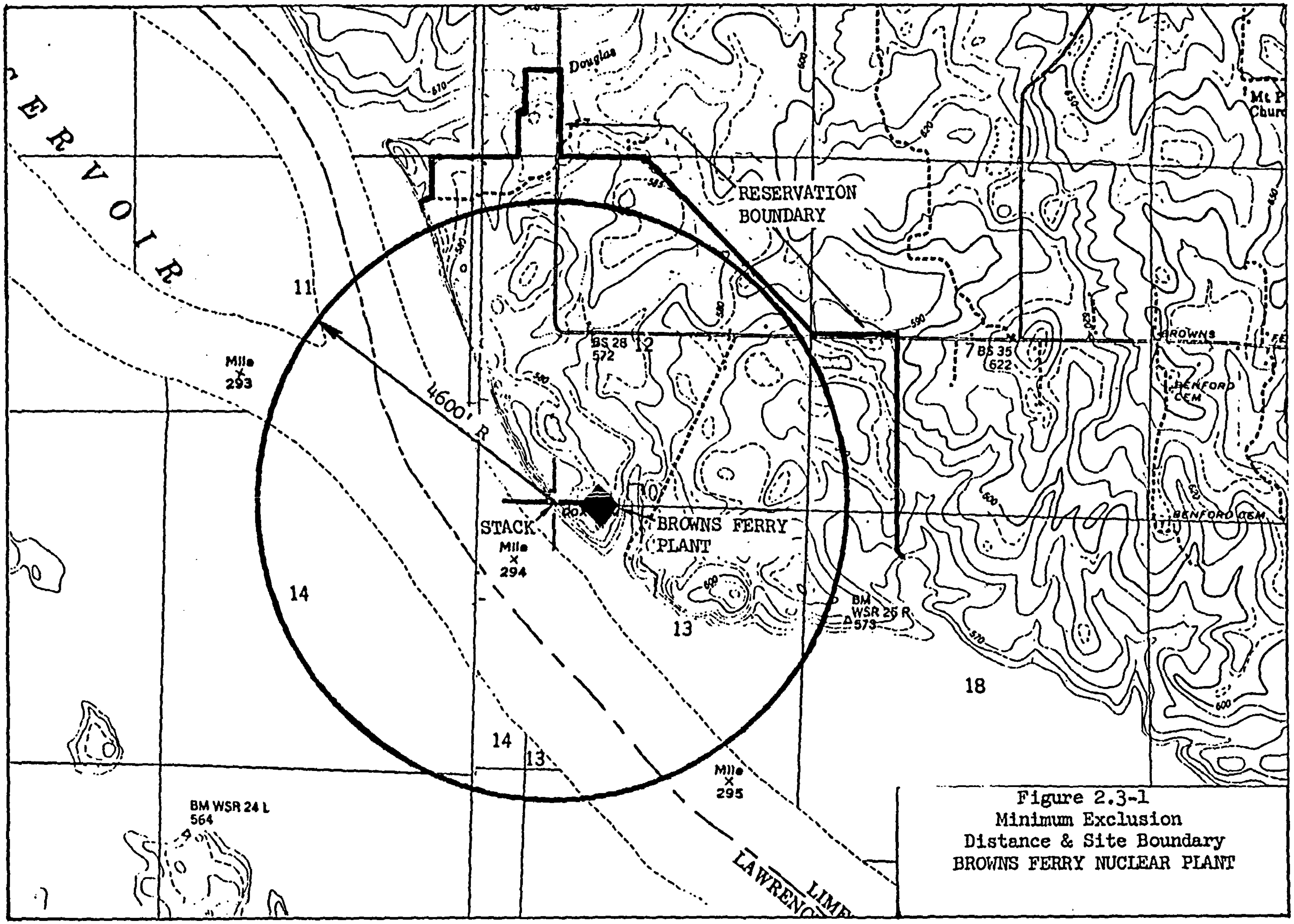


Figure 2.3-1
Minimum Exclusion
Distance & Site Boundary
BROWNS FERRY NUCLEAR PLANT

2.4 Radioactive Discharges - TVA's waste management policy has been implemented at Browns Ferry by improving plant design to include extended treatment for both gaseous and liquid radwaste. Alternatives available for keeping the radioactivity in effluents released to unrestricted areas as low as practicable were investigated by TVA and are discussed in section 5.7 of Volume 2 and section 3.1 of Volume 3. Hydrogen recombiners and six charcoal beds will be added to each unit to reduce radioactive gaseous wastes to very low levels. An evaporator along with its associated equipment will be added to treat liquid radwaste.

All equipment installed by TVA to reduce radioactive effluents to the minimum practicable level will be maintained in good operating order and will be operated to the maximum extent practicable. The technical specifications[1] for the Browns Ferry Nuclear Plant will set forth limits beyond which a reduction in load or a change in operating procedures is required. Operating procedures will be provided and maintained in an up-to-date condition to assure that this equipment is operated as designed to reduce radioactive effluents to the maximum extent practicable. Preventive maintenance will be performed to assure the equipment is in good operating order.

1. Gaseous radwaste system -

(1) Description of system - The gaseous radwaste system for the Browns Ferry Nuclear Plant is described in section 5.7 of Volume 2 and section 3.1 of Volume 3. This system will include hydrogen recombiners and six charcoal beds for each unit (18 charcoal beds for the three units) to reduce radioactive gaseous wastes

to very low levels. Studies have been made on aging characteristics and degradation of the charcoal beds and on the buildup of radionuclides on the charcoal beds.

(a) Aging characteristics of charcoal beds - Operation of the charcoal adsorption system on the German KRB reactor over a period of 5 years indicates that the charcoal will last for the life of the plant. In the 5-year period, there was no evidence that the effectiveness of the charcoal was decreasing. There was no increase in the pressure drop through the beds. Such an increase would be expected if degradation of the charcoal were occurring. Moreover, the dynamic nature of the process results in no continuing buildup of noble gas, which enhances the ability of the charcoal to function for the life of the plant.

During operation of the charcoal adsorber systems, the radioactivity concentrations of the inlet and outlet gas, the gas flow rate, and pertinent temperatures will be continuously monitored for each system. Hence, data needed to evaluate the retention characteristics of the charcoal will be obtained continuously.

The charcoal adsorber is a passive system and it is expected to last for the life of the plant. If it were to be necessary to replace the charcoal, the radioactivity of the charcoal at the time of disposal would be as given below.

(b) Buildup of radionuclides on charcoal beds - A study has been made of the buildup of radionuclides on the charcoal beds. Two cases were considered. In one case the high efficiency particulate absolute (HEPA) filter was assumed 99.99 percent efficient, and in the second case it was assumed 90 percent efficient. In both cases the HEPA filter was assumed to remove only the nonnoble isotopes. Noble gases will pass through the (HEPA) prefilter and enter the charcoal bed. The charcoal bed is then assumed to retain 100 percent of the nonnoble isotopes entering or generated by noble gas precursors. Since the charcoal beds are designed to remain in place for the life of the plant, the buildup for 40 years has been computed for the two assumed HEPA efficiencies. Decay of each isotope was then computed for 1 week, 1 month, and 6 months. It is assumed that all of the activity is concentrated in the first 3 feet of the first charcoal bed. The concentrates resulting with the indicated decay after 40 years of use would be:

Assuming 99.99 percent efficient HEPA filter:

6-month decay	0.00040 Ci/ft^3
1-month decay	0.00047 Ci/ft^3
1-week decay	0.00051 Ci/ft^3

Assuming 90 percent efficient HEPA filter:

6-month decay	0.207 Ci/ft^3
1-month decay	0.272 Ci/ft^3
1-week decay	0.315 Ci/ft^3

Assuming a HEPA filter efficiency of only 90 percent and assuming that all of the activity is concentrated in the first 3 feet of the first charcoal bed, the activity after 40 years of use and 1-week decay is 0.315 Ci/ft^3. Since the cask built to transport condensate system sludge is designed for an activity of 0.5 Ci/ft^3, this cask could be used to transport the charcoal to a suitable disposal site. These assumptions are on the extremely conservative side. Using a realistic HEPA filter efficiency for two series filters of about 99.99 percent and distribution of the activity throughout the first charcoal bed, the actual concentration experienced after 6 months' decay would be close to 0.000060 Ci/ft^3. Charcoal with this low level of activity could then be loaded in 55-gallon drums for disposal.

(2) Release of radioactivity - TVA recognizes that actual operating experience of nuclear power plants with failed fuel is limited. As experience accumulates, it will be possible to predict more accurately the amount of fission products that are released by defective fuel. The design of the Browns Ferry Nuclear Plant and calculations given in section 9.4 of the FSAR are based on an average annual offgas release rate (after 30 minutes' decay) of 100,000 µCi/s per unit. This release rate is also used for dose calculations for this final environmental statement and replaces that used in Volumes 2 and 3. The distribution of radionuclides expected to be released is shown in Table 2.4-1.

AEC's Division of Compliance[2] published the following information on noble and activation gas releases from operating BWR's:

Facility	Total Annual Curies Released 1970	1969	1968	1967
Oyster Creek	110,000	7,000	-	-
Dresden 1	900,000	800,000	240,000	260,000
Nine Mile Point	9,500	55	-	-

(Continued)

Facility	Total Annual Curies Released 1970	1969	1968	1967
Humboldt Bay	540,000	490,000	897,000	900,000
Dresden 2	250,000	-	-	-
Big Rock Point	280,000	200,000	232,000	264,000

The highest value in this tabulation, 900,000 Ci/yr, corresponds to a release rate of 28,500 μCi/s. This is substantially below the release rate of 100,000 μCi/s per unit used by TVA for estimating doses in the FSAR and this environmental statement.

2. Liquid radwaste system -

(1) Description of system - The liquid radwaste system for the Browns Ferry Nuclear Plant is described in section 5.7 of Volume 2. This system will include demineralizers and an evaporator to reduce radioactive liquid waste to very low levels. Table 2.4-2 gives expected releases of radioactive materials on the basis that floor drain and chemical wastes will be treated and discharged. Actually, a large portion of these liquids will be recycled after the evaporator is placed in service which will minimize radioactive releases. Prior to installation of the evaporator, floor drain waste will be processed with the waste demineralizer as required to meet the proposed Appendix I limits. This flexibility will be retained after installation of the evaporator.

The liquid radwaste system has the capability to treat the water contained within the pressure suppression torus. Water inputs to the suppression chambers result primarily from tests of the emergency core coolant pumps, which are driven by steam turbines utilizing reactor steam. The exhaust from these turbines is discharged below the water surface in the suppression chambers. Inputs from these tests will amount to about 50,000 gal/unit/yr. Inputs from other possible sources cannot be predicted, but TVA is designing for an additional 50,000 gal/unit/yr. The radioactivity content of the added liquid will be approximately that of the condensate in the hotwell.

Treatment is needed to remove excess water and radioactive material. Prior to installation of the radwaste evaporator, one of the auxiliary boilers will be used to remove excess water, but not radioactivity. Thereafter, the radioactivity content and the water level will be maintained within acceptable limits by a feed-and-bleed procedure whereby a portion of the chamber contents is drawn off to radwaste periodically and is replaced as needed with fresh solution. In the liquid radwaste system, the liquid will be processed through the evaporator. If necessary, the condensate will be passed through the waste demineralizer to make it suitable for reuse or discharge. These operations do not have to be performed at specific times but can be carried out at the convenience of the radwaste system operation.

(2) Releases of radioactivity - AEC's Division of Compliance[2] published the following information on radioactivity contained in the liquid releases from operating BWR's:

Facility	Total Annual Curies Released 1970	1969	1968	1967
Oyster Creek	18.5	0.48	-	-
Dresden 1	8.2	9.5	6.0	4.3

(Continued)

Facility	Total Annual Curies Released 1970	1969	1968	1967
Nine Mile Point	28.0	0.9	-	-
Humboldt Bay	2.4	1.5	3.2	3.1
Dresden 2	13.0	-	-	-
Big Rock Point	4.7	12.0	7.9	10.0

It should be noted that these units employ condensate demineralizers which are chemically regenerated. The amount of radioactivity in liquid releases from these units depends to a significant extent on the degree to which the spent regenerant solutions are processed by evaporation. Browns Ferry, on the other hand, uses Powdex-type condensate demineralizers. With this type of demineralizer, none of the radioactivity removed from the condensate enters the plant liquid effluent. Therefore, releases of radioactivity are reduced.

The distribution of radionuclides in Browns Ferry liquid wastes will be different from that in the wastes from plants with regenerable deep bed demineralizers. The estimated composition of radionuclides expected to be released based upon the particular processes to be employed at Browns Ferry is shown in Table 2.4-2. Isotopic analyses of the effluent will be made to determine the actual composition.

3. <u>Estimated increase in annual environmental radioactivity levels and potential annual radiation doses from principal radionuclides</u> - With extended treatment of gaseous and liquid effluents, environmental concentrations of radioactivity due to releases to unrestricted areas from the Browns Ferry Nuclear Plant will be so low as to

be unmeasurable with present techniques. However, TVA has calculated the expected increase in radioactivity levels and potential radiation doses as a result of these low-level releases.

(1) Radionuclides in gaseous effluents - The following doses to humans living in the vicinity of the Browns Ferry Nuclear Plant are calculated for routine releases of radioactive gases:

1. External beta doses
2. External gamma doses
3. Thyroid doses due to inhalation of radioactive iodine
4. Thyroid doses due to reconcentration of radioactive iodine in milk produced near the site

The external beta and gamma doses to terrestrial plants and animals are considered to be the same magnitude as the doses estimated for humans.[3]

The gaseous effluents are released either from vents located near the top of the plant buildings or from the 600-foot plant stack. Dilution of the gaseous effluents will take place due to diffusion and turbulent mixing as the gases travel downwind from the point of release. The downwind, ground-level air concentrations of radioactive gases are determined using sector-averaged diffusion equations.

External beta doses are computed using a semi-infinite cloud, immersion dose model. In computing external gamma doses, a technique employing both an immersion dose model and a finite-volume-element integration model is used. Iodine inhalation doses are calculated by assuming that these doses are proportional to the ground-level air concentration and the receptor breathing rate. Iodine ingestion doses are calculated by assuming that these doses are proportional to the rate of iodine deposition on pasturage, the concentration of iodine in milk due to uptake by cows, and the milk consumption rate of the receptor.

Iodine releases are estimated using reasonable assumptions of coolant activities, leakage rates, and release mechanisms. Table 2.4-3 shows that with these assumptions, iodine releases from the Browns Ferry Nuclear Plant should be less than the design objectives of proposed Appendix I.

The extended gaseous radwaste system virtually eliminates iodine releases from the condenser offgas. Therefore, the principle potential for iodine release is the plant ventilation systems. The primary containment is purged periodically, thereby providing significant decay time prior to release. TVA has concluded that it is not practical to treat iodine releases from other structures because of the large flow rates and small iodine concentrations involved.

Should the operating conditions significantly exceed those used in the analysis and result in iodine releases exceeding proposed Appendix I guidelines, the offsite concentrations would still be only a small fraction of one percent of the 10 CFR Part 20 limits.

A more detailed description of the analytical methods used in calculating these doses and a detailed listing of results are given in Appendix I.

(2) Radionuclides in liquid effluents - The following doses to biota including man are calculated for exposures to radionuclides routinely released in liquid effluents:

1. Doses to man
    a. from the ingestion of water
    b. from the consumption of fish
    c. from water sports
2. Doses to terrestrial vertebrates from the consumption of aquatic plants
3. Doses to aquatic plants, aquatic invertebrates, and fish

The organisms and pathways that are considered in this report are those that are thought to be the most significant because of species, habitat, diet, or patterns of living. Conservative assumptions are applied in these analyses which should result in overestimation of the doses.

Internal doses are calculated using methods outlined by the ICRP[4] which describe internal retention of radionuclides with a single-exponential model. This model is used for estimating the doses to man from ingestion of water and consumption of fish and for estimating the doses to terrestrial vertebrates from the consumption of green algae. For calculating the internal doses to aquatic organisms it is assumed that an equilibrium exists between the activity concentrations in the water and those inside the organisms.

Internal doses to man are calculated for the bone, G.I. tract, thyroid, and total body. The internal dose given in Volumes 2 and 3 is the maximum organ dose. The total body dose is much lower (Table 2.4-3).

External doses are estimated using either an infinite or a semi-infinite, homogeneous-medium approximation depending on whether the organism is considered to be immersed in or floating on the water.

A more detailed discussion of the analytical methods used in calculating these doses and a detailed listing of the results are given in Appendix II.

(3) <u>Summary of radiological impact</u> - Table 2.4-3 summarizes the radiation doses calculated for release of radionuclides in gaseous and liquid effluents during normal operation of the Browns Ferry Nuclear Plant. External radiation exposure from sources inside the reactor and turbine buildings is treated in Appendix III. TVA has also calculated potential doses resulting from releases during the 12-month interim operating period prior to the installation of extended radwaste treatment systems. Table 2.4-4 summarizes the doses for this interim period.

A comparison of doses resulting from the operation of Browns Ferry Nuclear Plant to those occurring from natural radioactivity assists in placing the doses from Browns Ferry in perspective. Near the plant site the average annual dose from naturally occurring external sources of radiation is 125 mrem (Table 2.4-5). An individual receives an additional dose of approximately 20 mrem per year from naturally occurring internal sources. Therefore, the average total dose from natural radioactivity in the vicinity of the Browns Ferry plant is approximately 145 mrem per year. Individual doses vary widely around this average value because of local differences in the concentrations of terrestrial radioactivity and because of variances in dose rates within different types of buildings. Large variations are also observed between different areas within the United States because of the correlation of cosmicray dose rates with altitude and geomagnetic latitude. Due to these variations, the annual total-body doses to individuals in the United States from natural radioactivity range from less than 110 mrem to greater than 240 mrem.

A hypothetical individual at the site boundary would receive a maximum dose of 2.2 mrem from the normal operation of the Browns Ferry Nuclear Plant. For this individual to receive the maximum dose he would have to stand in the open at the highest dose point on the site boundary for 24 hours a day, 365 days per year. The maximum dose to the hypothetical individual is 1.5 percent of the dose from natural background radiation. The maximum dose to an actual individual should be significantly less than the calculated dose to the hypothetical individual.

The population dose within 50 miles of Browns Ferry from naturally occurring radioactivity is estimated to be approximately 174,000 man-rems in the year 2010 (Table 2.4-5). The population dose in the year 2010 due to normal operation of the Browns Ferry Nuclear Plant is calculated to be 23 man-rems (Table 2.4-3), which is 0.013 percent of the dose from natural background radiation.

TVA has evaluated the potential radiation dose from a broad spectrum of possible pathways of exposure. It should be emphasized that it is possible to theoretically calculate an environmental radioactivity level or potential radiation dose that is minutely small. The dose calculated in this evaluation is only a small fraction of the dose from the natural background radiation and is, in fact, much less than the variations in natural background radiaticn doses. It is concluded that the Browns Ferry Nuclear Plant will operate with no significant risk to the health and safety of the public.

Table 2.4-1

EXPECTED RELEASES OF PRINCIPAL RADIONUCLIDES
IN GASEOUS EFFLUENTS

	Sources of Release					
Isotope	Original Offgas System[a] Ci/yr	Extended Offgas System[b] Ci/yr	Gland Seal Ci/yr	Containment Purge[c] Ci/yr	Mechanical Vaccum Pump[c] Ci/yr	Turbine Building[d] Ci/yr
Kr-83m	2.7 (5)[e]	6.1 (2)	3.2 (2)			
85m	5.3 (5)	4.2 (4)	5.8 (2)			
85	1.9 (3)	1.9 (3)	1.9 (0)			
87	1.4 (6)	2.4 (2)	1.9 (3)			
88	1.7 (6)	3.0 (4)	1.9 (3)			
Xe-131m	1.4 (3)	9.2 (2)	1.4 (0)	2.0 (0)		
133m	2.6 (4)	2.8 (3)	2.7 (1)	4.0 (0)		
133	7.8 (5)	2.9 (5)	7.7 (2)	1.6 (2)	5.8 (3)	
135m	6.5 (5)		2.5 (3)	2.0 (1)		
135	2.1 (6)		2.1 (3)	6.5 (1)	8.6 (2)	
137	6.3 (4)		1.4 (4)			
138	2.0 (6)		8.4 (3)			
I-131	6.5 (-3)[f]			1.8 (-2)		1.1 (-2)
132	6.0 (-2)[f]			2.1 (-3)		1.0 (-1)
133	4.5 (-2)[f]			1.4 (-2)		7.5 (-2)
134	1.2 (-1)[f]					2.1 (-1)
135	6.5 (-2)[f]					1.1 (-1)

a. Based on an air ejector flow rate of 18.5 scfm and 30-minute holdup system.
b. Based on an air ejector flow rate of 18.5 scfm and extended offgas system including recombiners and six charcoal beds per unit.
c. Taken from FSAR.
d. Based on 100 gal/day/unit leakage, a total DF of $2x10^3$, and no decay.
e. $2.7x10^5$
f. Based on a DF of 100 due to washout.

Table 2.4-2

EXPECTED RELEASES OF PRINCIPAL LIQUID RADIONUCLIDES EXCLUDING TRITIUM [a]

Isotope[b]	Half-Life	Release Rate (Ci/yr)[c] Original System Design	Original System With Added Demineralization	Original System With Evaporator
Sr-89	52.7d	3.2 (-1)[e]	4.0 (-2)	3.2 (-3)
Sr-90[d]	28y	2.4 (-2)	3.0 (-3)	2.4 (-4)
Sr-91[d]	9.7h	3.0 (0)	3.7 (-1)	3.0 (-2)
Mo-99[d]	66h	2.1 (0)	2.6 (-1)	2.1 (-2)
I-131	8.05d	1.3 (0)	1.6 (-1)	1.3 (-2)
I-133	20.8h	6.2 (0)	7.7 (-1)	6.2 (-2)
I-135	6.7h	3.9 (0)	4.9 (-1)	3.9 (-2)
Cs-134	2.1y	1.7 (-2)	2.1 (-3)	1.7 (-4)
Cs-137	30y	2.5 (-2)	3.1 (-3)	2.5 (-4)
Ba-140[c]	12.8d	9.0 (-1)	1.1 (-1)	9.0 (-3)
Ce-144[c]	284d	3.6 (-3)	4.5 (-4)	3.6 (-5)
Np-239	2.35d	2.2 (+1)	2.8 (0)	2.2 (-1)
Co-58	70d	5.2 (-1)	6.5 (-2)	5.2 (-3)
Co-60	5y	5.2 (-2)	6.5 (-3)	5.2 (-4)
	TOTAL	40 Ci/yr	5 Ci/yr	0.4 Ci/yr

a. Tritium releases from the plant are expected to approach 51 Ci/yr. The distribution between gaseous and liquid wastes will depend upon the actual amount of water leaving by each route.

b. Isotopes having a half-life less than 2.3 hours were excluded because the holdup in the plant would generally be sufficient to result in negligible concentrations in released wastes. Other isotopes of the elements listed were considered. The radionuclides Zr-95, Nb-95, Ru-103, Ru-106, Te-219m, Te-132, Nd-147, Na-24, S-35, P-32, Cr-51, Mn-54, Mn-56, Fe-55, Fe-59, Cu-64, Ni-65, Zn-65, Zn-69m, Ag-110m, Ta-182, and W-187 were also considered. These radionuclides may be present, but if present will be of negligible radiological significance relative to those isotopes listed.

c. Although two significant numbers are used in expressing the release rates as a convenience for making further calculations, only one significant figure is warranted by the source data.

d. Daughter isotopes, Yttrium, Technetium, Lanthanum, and Praseodynium, may be observed in waste samples in equilibrium with or approaching equilibrium with their parent depending upon sample and analysis timing and procedure.

e. 3.2×10^{-1}

f. The relative isotopic abundance is based on recent analyses of reactor coolant composition in operating boiling water reactors. The relative abundance of the isotopes in the primary coolant was determined and was modified to reflect 12 hours of decay prior to release. This information updates that used in Vol. 3.

Table 2.4-3

SUMMARY OF RADIOLOGICAL IMPACT

ON ANNUAL BASIS

WITH EXTENDED WASTE TREATMENT SYSTEMS

	Normal Operation[a]	Proposed 10 CFR 50 Appendix I Limits
A. Gaseous Effluents		
I-131 concentration at site boundary	2.4 (-16)[b] $\frac{\mu Ci}{cc}$	1.0 (-15) $\frac{\mu Ci}{cc}$
Maximum individual doses		
1. inhalation at site boundary (thyroid)	0.04 mrem	
2. consumption of milk from nearest dairy farm (thyroid)	0.18 mrem	
3. external exposure at site boundary (β&γ)	1.6 mrem	10 mrem
Population doses within a 50-mile radius		
1. inhalation (thyroid)	0.11 man-rem	
2. consumption of milk (thyroid)	0.73 man-rem	
3. external exposure (β&γ)	23 man-rem	
B. Liquid Effluents[c]		
Activity released	0.43 Ci	15 Ci
Average concentration before dilution in the Tennessee River	1.5 (-10) $\frac{\mu Ci}{ml}$	2.0 (-8) $\frac{\mu Ci}{ml}$

a. Releases consistant with a noble gas release rate of 100,000 μCi/sec/unit (after 30 minutes decay)
b. 2.4×10^{-16}
c. Excluding tritium

Table 2.4-3 (Continued)

	Normal Operation	Proposed 10 CFR 50 Appendix I Limits
Maximum human organ doses		
1. bone	3.5 (-4) mrem	5 mrem
2. G.I. tract	9.7 (-3) mrem	5 mrem
3. thyroid	1.4 (-3) mrem	5 mrem
4. skin	5.7 (-5) mrem	5 mrem
5. total body	5.2 (-5) mrem	5 mrem
Human population doses within a 50-mile radius		
1. bone	1.2 (-2) man-rem	
2. G.I. tract	7.8 (-1) man-rem	
3. thyroid	6.8 (-2) man-rem	
4. skin	1.9 (-3) man-rem	
5. total body	1.9 (-3) man-rem	
Maximum dose to terrestrial vertebrates	0.21 mrad	
Maximum doses to aquatic organisms		
1. plants	0.21 mrad	
2. invertebrates	2.1 mrad	
3. fish	0.52 mrad	
C. Scattered Radiation from Turbine Building[d]	0.6 mrem	
D. Maximum Annual Dose[e] to Any Individual	2.2 mrem	
E. Maximum Population Dose[e] Within a 50-mile Radius	23 man-rem	

d. Upper bound as calculated in Appendix III
e. Skin

Table 2.4-4

SUMMARY OF RADIOLOGICAL IMPACT

ON ANNUAL BASIS

DURING INTERIM OPERATION

	Interim[a] Operation
A. Gaseous Effluents	
I-131 concentration at site boundary	1.0 (-16)[b] μCi/cc
Maximum individual doses	
1. inhalation at site boundary (thyroid)	1.7 (-2) mrem
2. consumption of milk from nearest dairy farm (thyroid)	8.0 (-2) mrem
3. external exposure at site boundary (β&γ)	2.9 (1) mrem
Population doses within a 50-mile radius	
1. inhalation (thyroid)	4.7 (-2) man-rem
2. consumption of milk (thyroid)	3.1 (-1) man-rem
3. external exposure (β&γ)	1.5 (2) man-rem
B. Liquid Effluents[c]	
Activity released	6.3 Ci
Average concentration before dilution in the Tennessee River	4.5 (-9) μCi/ml

a. Releases consistant with a noble gas release rate of 100,000 μCi/sec/unit (after 30 minutes decay)
b. 1.0×10^{-16}
c. Excluding tritium

Table 2.4-4 (Continued)

	Interim Operation
Maximum human organ doses	
1. bone	4.8 (-3) mrem
2. G.I. tract	1.3 (-1) mrem
3. thyroid	2.0 (-2) mrem
4. skin	9.0 (-4) mrem
5. total body	7.2 (-4) mrem
Human population doses within a 50-mile radius	
1. bone	1.6 (-1) man-rem
2. G.I. tract	11 man-rem
3. thyroid	0.93 man-rem
4. skin	2.6 (-2) man-rem
5. total body	2.6 (-2) man-rem
Maximum dose to terrestrial vertebrates	2.9 mrad
Maximum doses to aquatic organisms	
1. plants	2.9 mrad
2. invertebrates	28 mrad
3. fish	7.2 mrad
C. Scattered Radiation from Turbine Building[d]	0.3 mrem
D. Maximum Annual Dose[e] to Any Individual	2.9 (1) mrem
E. Maximum Population Dose[e] Within a 50-mile Radius	1.5 (2) man-rem

d. Upper bound as calculated in Appendix III.
e. Skin

Table 2.4-5

DOSES FROM NATURALLY-OCCURRING BACKGROUND RADIATION

Individual Doses (mrem)

External[a]		125
Internal[b]		20
	Total	145 mrem

Population Dose (man-rem)

0.145 rem x 1,200,000[c] people = 174,000 man-rem

a. Measured by TVA personnel
b. See Reference 5 for this section
c. Estimated population within a 50-mile radius of the Browns Ferry Nuclear Plant in the year 2010

2.5 Nonradioactive Wastes - It is TVA's policy to keep the discharge of all wastes from its facilities, including nuclear plants, at the lowest practicable level by using the best and highest degree of waste treatment available under existing technology, within reasonable economic limits. TVA has incorporated extensive control and treatment facilities into the Browns Ferry design for handling nonradioactive plant wastes. This section describes the types and sources of these wastes and discusses the control and treatment to be provided to minimize their impact on the environment.

1. Chemical discharges - Chemicals, which are added from plant processes, will result in only very low concentrations of these chemicals in the Tennessee River near the plant site. The major increase of mineral concentrations, in the form of total dissolved solids, occurs during closed-cycle operation of the cooling towers when these substances drawn into the condenser cooling water system from the reservoir are concentrated to approximately twice their reservoir concentrations prior to release in the cooling tower blowdown. The sources of these chemicals and the expected maximum quantity of chemical end products that could be discharged are summared in Table 2.5-1. The average and maximum expected total chemical concentrations in the discharge and in the reservoir for each mode of cooling tower operation are shown in Table 2.5-2. These data show that the operation of the Browns Ferry plant will result in only minimal increases in the chemical and mineral concentrations of the discharge water and after mixing with the reservoir water. During periods of closed-cycle cooling tower operation

the largest increase in the reservoir will be a 3 mg/l increase in total dissolved solids as compared to an average concentration of about 104 mg/l. The allowable dissolved solids concentration to meet the Alabama Water Improvement Commission's standards[1] is 500 mg/l. During extended periods of closed-cycle operation of the cooling towers, the maximum total dissolved solids discharge concentration in the blowdown would not be expected to exceed 260 mg/l. No significant adverse environmental impact on the water quality of Wheeler Reservoir due to chemical discharges is expected to occur and no alteration of the production of living natural resources including fish and wildlife is anticipated.

The sources of chemical wastes and a description of the waste treatment to be provided are discussed in the following paragraphs.

(1) Makeup water filter plant - Operation of the filter plant will require the addition of the following thermal water treatment chemicals: alum, soda ash, coagulation aid,* and sodium hypochlorite. Use of these chemicals in the treatment process will result in increased concentrations of soluble SO_4^{--} and Na^+ in the treated water that will ultimately be discharged to Wheeler Reservoir. The filter plant influent will be chlorinated to prevent slime growths in the filter plant clearwell. A residual of 0.1 mg/l will be maintained in the filter plant effluent. Residual chlorine will be removed in the demineralizers.

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*Referred to in Volume 2 as "polymer."

The filter backwash and water treatment plant sludge will be diverted to a settling pond from which the supernatant water will be decanted and discharged to the condenser circulating water intake channel. The sludge, consisting of the alum floc, most of the coagulation aid, and sediment removed from the water during treatment, will be removed from the lagoon as necessary and, along with other normal solid waste, disposed of by burial. This method of sludge disposal results in only a minimal environmental impact.

Although the discharge of the sludge added by normal plant operation would not result in any significant adverse environmental impact, the settling pond estimated to cost in excess of $100,000 is provided to comply with proposed regulations for the State of Alabama.

All coagulation aids to be used at Browns Ferry will be selected from EPA's approved list[1] of coagulation aids and will be used in accordance with manufacturer's recommendations. The coagulation aid being used is a high molecular weight polyacrylamide containing a soluble toxic ingredient (acrylamide monomer) which is less than 0.05 percent of the product. Most of the coagulation aid is contained in the sludge. The monomer is dissolved in the treated water and eventually released. Its release will result in a maximum discharge concentration of the monomer of less than 2×10^{-6} mg/l. The Dow Chemical Company has conducted tests[3] on a product of this formulation which show that lake emerald shiners and yellow perch showed no ill effects after prolonged exposures to this product in concentrations several orders of magnitude larger than that shown above. Therefore, considering the small release of the monomer and the low concentrations which will occur when released, no significant environmental risk can be associated with its use.

(2) Water treatment plant demineralizer - Regeneration of makeup water treatment plant demineralizers requires the use of sulfuric acid and sodium hydroxide, which results in releases of SO_4^{--} and Na^+. Treatment of these wastes will consist of holding the acid and caustic wastes in a sump for monitoring and adjusting pH prior to discharging to the condenser circulating water intake. Regeneration cycles will be set so that the pH of the mixed water in the waste sump will be near neutral, thereby minimizing the need for further adjustment.

Operating experience with the makeup water treatment facilities during construction of the Browns Ferry plant indicates that the quality of raw water to be treated for reactor makeup will be such that the amounts of chemicals used in the water treatment process shown in Table 2.5-1 represent the maximum usage if the water treatment facilities are operated at full capacity. After plant cleanup and startup it is anticipated that the actual treated water needs will be about 10 percent of the rated capacity of the treatment facilities. The quantity of water treatment chemicals required will be reduced correspondingly. However, as shown in Table 2.5-2, if the equipment were operated at full capacity, the discharge concentrations would be such that they would cause no significant impact on the environment.

(3) Auxiliary steam generator blowdown - Treatment of the feedwater for the auxiliary steam generators will require the use of ammonia for pH control and hydrazine for control of dissolved oxygen. One steam generator will be in daily operation throughout the year. A second will be in service for heating about five months of the year. Hydrazine concentration will be maintained at about 15 ppb in the feedwater, and ammonia will be fed to maintain a pH of about 9.0. This normally requires an ammonia concentration of about 0.25 ppm. To maintain acceptable dissolved solids concentrations when operating at full capacity, provision has been made for about 3 gal/min of blowdown for each steam generator. Continuous release of this amount of blowdown with all steam generators operating at maximum capacity would result in daily release of about 0.002 pounds of decomposed hydrazine as either nitrogen gas or ammonia and about 0.029 pounds of residual ammonia. Annual releases of hydrazine and ammonia shown in Table 2.5-1 are based on full capacity operation of all of the steam generators 12 months per year. These releases would result in insignificant increases in concentrations of ammonia in plant discharges as shown in Table 2.5-2. These releases will not cause any signfiicant adverse environmental impacts.

(4) Raw cooling water system - For the control of Asiatic clams, tentative plans are to chlorinate the 90,000 gal/min raw cooling waterflow which cools the plant auxiliaries to maintain 1.0 mg/l maximum chlorine residual in the raw cooling water system. It is not expected that the use of chlorine will be required more than

three weeks per year and will not be used during closed-cycle operation of the cooling towers. The raw cooling water will be discharged to the condenser cooling water system. Operating experience has shown that the reservoir water has a chlorine demand of about 0.5 mg/l. Based on the relative flow rates of the condenser cooling water and raw cooling water systems (about 20:1), the chlorine demand of the condenser cooling water will be sufficient to react with all of the chlorine residual and result in only chlorides being discharged.

The use of acrolein for this purpose is also being considered. If used, it would have a maximum concentration in the raw cooling water system of 0.3 mg/l. Its use would not be required more than 120 days per year and when used it will be fed into the system one-half hour each day. When the cooling towers are in operation, any acrolein which does not react with the condenser cooling water due to the acrolein demand of the water will essentially all be scrubbed out as the cooling water passes over the cooling tower fill. Additional studies will be required to determine whether the acrolein demand of the condenser cooling water is sufficient to react with all of the acrolein and prevent its discharge during open-cycle operation.

The release of these diluted or decomposed biocides to the reservoir will not significantly affect the reservoir.

(5) Closed cooling water system - Sodium chromate is used as a corrosion inhibitor in components of the closed cooling water system. On rare occasions, when necessary for maintenance purposes, the chromate-containing water will be drained from portions of the closed system. If possible, the water will be returned to the system.

If not, it will be routed to the radwaste system and processed through the nonregenerable mixed bed demineralizers where it will be recycled until the chromate concentration is 1.0 ppm or less. It will then be routed to the condensate storage tank. No chromate will be released to the reservoir.

(6) Cooling tower blowdown and drift - As described in section 2.6, the cooling towers will be operated in the closed-cycle mode about 7 percent of the time. The need for chemical treatment of the condenser circulating water can be eliminated by limiting the concentration of total dissolved solids in the cooling system to about twice the normal reservoir concentration when operating in the closed mode. About 110 ft^3/s of blowdown from the towers would be required to maintain this concentration. The discharge of this blowdown through the diffuser system is described in section 2.6 of this volume. The diffuser should provide thorough mixing of the blowdown with the reservoir flow. In addition to the dissolved solids from the cooling water system, the blowdown will contain the other liquid chemicals discharged from the plant.

Chemical effluent concentrations in the reservoir have been conservatively calculated assuming 5,000 ft^3/s reservoir flow (exceeded 99 percent of the time) for all modes of operation (Table 2.5-2). The cooling tower blowdown could be withheld for relatively short periods of time when reservoir conditions warrant without reaching prohibitive chemical concentrations in the condenser circulating water system. During periods of closed-cycle cooling tower operation the largest increase in the reservoir resulting from the combined effect of tower operation and chemical discharges will be a 3 mg/l increase in total dissolved solids. The allowable dissolved solids concentration to meet the Alabama Water Improvement Commission s standards[1] is 500 mg/l. During extended periods of closed-cycle cooling tower operation, the maximum total dissolved solids concentration in the blowdown would not be expected to exceed 260 mg/l. The dissolved chemical and mineral concentrations of the plant discharge to the diffuser system would be well below the permissible concentrations of the USPH Drinking Water Standards[4] prior to mixing with the reservoir water. Increases in the existing levels of chemicals concentrations in the reservoir during any operating mode are insignificant.

Tower drift, which is expected to be no more than 0.1 percent of the total condenser cooling waterflow or about 3.7 ft^3/s will carry both suspended and dissolved solids from the condenser circulating water system to the atmosphere. Most of these solids will be deposited in the immediate vicinity of the cooling towers and will eventually be returned to the reservoir. No area outside the immediate vicinity of the towers will receive significant concentrations of deposited solids.

Assuming that maximum observed solids concentrations exist in the reservoir and that drift amounts to 3.7 ft^3/s during periods of closed-cycle operation of the cooling towers, about 5,000 pounds per day of solids (both suspended and dissolved) will be released from the towers in the drift. If the towers operate 7 percent of the time in the closed-cycle mode, this will result in a total annual release of solids from the towers of about 66 tons.

When the cooling towers are operating on the helper mode the same maximum amount of drift will occur. The fraction of time on the helper mode is expected to be about 22 percent. However, total solids concentration in the condenser circulating water system and the drift during these periods will be approximately the same as exists in the reservoir, and the solids carried from the towers via drift will amount to about 2,600 pounds per day and about 100 tons annually.

(7) Miscellaneous - As stated in Volume 2, some decontamination operations will involve the use of chemicals such as sodium phosphate, sodium permanganate, ammonium citrate, nitric acid, and hydrofluoric acid. If chemical concentrations in the cleaning solutions are too high to allow treatment in the radwaste system, they will be drummed for offsite disposal at a suitable disposal site. Otherwise, they will be treated in the radwaste system to meet applicable water quality standards prior to release.

Some small quantities of miscellaneous chemicals will be used in the plant laboratory for tests, analyses, etc. This source of chemicals will result in only trace increases in discharge concentrations and will probably be well below detectable levels in the discharge stream. Since these chemicals may contain some radioactivity they will be routed to a chemical drain tank for treatment similar to that provided for the decontamination solutions described above.

The small quantity of detergent wastes which must be handled will be diverted to the radwaste facilities for treatment prior to release. Biological treatment of such small quantities of these wastes is not considered practicable.

2. Sanitary wastes - Two 15,000-gallons-per-day extended aeration sewage treatment plants were initially installed at Browns Ferry to handle construction and operating personnel loads with the intention of ultimately putting one unit in reserve as the construction load diminishes. These plants have timers to regulate aeration times and will be operated in accordance with Federal and state requirements. It is anticipated that the ultimate operating force will number between 175 and 200 persons. In addition, personnel in training will number about 40-45 persons, and it is anticipated there may always be a small maintenance crew on hand in addition to the regular plant maintenance personnel. Browns Ferry will be attractive to many visitors, and considering them in addition to the persons above, a sewage load during normal operating periods from about 300 persons may be anticipated. Based on a flow of 35 gallons per person per day the normal expected load will be about 10,500 gallons per day. With allowances for peak loading, underloading of the plant which could result in inadequate treatment of the wastes would not be expected. It is anticipated that at times of unit outage and during any major overhaul periods both plants may have to be put into operation to handle the increased loads.

3. Gaseous emissions - Three oil-fired auxiliary steam generators supply steam for building heating and other uses. The total annual fuel consumption for these steam generators will not

exceed 5.3 million gallons of No. 2 fuel oil, and it is expected that average annual consumption will be less than half this value. The fuel oil will have a sulfur content of not more than 0.5 percent.

Annual combustion of the maximum amount of the fuel would result in gaseous and particulate releases from the plant in the following quantities:

particulates	20.9 tons/year
sulfur oxides	205.0
carbon monoxide	0.1
hydrocarbons	13.1
nitrogen oxides	274.0

These products of combustion will be released from the plant through a stack which is approximately 175 feet above ground level.

In addition, the four diesel-powered auxiliary generators are estimated to consume about 82,000 gallons of fuel per year. This fuel will be the same type as used for the auxiliary steam generators. The exhaust will be via stacks about 55 feet above ground level and will release the following constituents:

particulates	0.33 tons/year
sulfur oxides	3.2
carbon monoxide	0.002
hydrocarbons	0.21
nitrogen oxides	4.3

Calculated maximum ambient concentrations resulting from these emissions, together with the applicable standards, are given below:

Pollutant	Averaging Time	Calculated Concentrations	Secondary Ambient Standard
Particulates	24 hour	0.29 ug/m^3	150.0 ug/m^3
Sulfur oxides	3 hour	0.0034 ppm	0.5 ppm
Carbon monoxide	1 hour	0.000005 ppm	35.0 ppm
Hydrocarbons	3 hour	0.0011 ppm	0.25 ppm
Nitrogen oxides	1 year	0.000097 ppm	0.05 ppm

An evaluation of the emissions from the auxiliary boilers and diesel generators indicates that the emissions will have a negligible environmental impact. For this reason it is not considered necessary to conduct an ambient monitoring program to determine the effect of these emissions.

4. Solid waste disposal - Normal solid wastes will be disposed of by burial either on the plant site or on other TVA grounds. This method of disposal is considered to minimize environmental impacts from solid waste.

5. Storage and transportation of materials - Oils, chemicals, and other potentially harmful materials will be shipped to Browns Ferry by tank trucks under applicable ICC and state highway regulations.

Oil will be used in various equipment and stored in storage tanks both inside and outside the powerhouse. Oil for various uses stored outside the powerhouse includes a total of 21 miscellaneous insulating oil storage tanks with a combined capacity of 366,000 gallons. These tanks range in capacity from 4,000 gallons to 35,000 gallons. In addition, there are two diesel oil tanks with a capacity of 71,000 gallons each and two lubricating oil tanks at 30,000 gallons each.

Outside storage is also provided for the sulfuric acid which is used in the makeup water treatment plant. The storage tank provided for this purpose has a capacity of 3,400 gallons. This capacity closely corresponds to the minimum shipment quantity of bulk sulfuric acid of 3,000 gallons. Shipment of acid for this use is expected to amount to a maximum of six shipments per year. Chemicals stored in tanks onsite are provided with retention basins and/or crushed limestone beds to either contain or neutralize these chemicals if they should be released from their storage tanks.

In the event of a tank or equipment rupture resulting from plant malfunction, human error, or natural disasters such as tornadoes, earthquakes, etc., oil in any of the outside equipment or storage tanks will be contained in retention basins unless the occurrence were of a severity to destroy the basins. The probability of an occurrence of this severity is very low. Consequently, the environmental risk associated with the storage of these materials is very small.

Oil storage inside the powerhouse includes six 5,700-gallon tanks of turbine lube oil and nine 1,000-gallon tanks of reactor feed pump lube oil. Oils spilled in the powerhouse will flow to appropriate sumps where they are retained until they can be reclaimed. If not suitable for reuse they will be drummed for proper disposal. One method of disposal is to transport the oil to one of TVA's fossil-fired plants and blend it with the fossil fuel used there.

Indoor storage is provided for the sodium hydroxide which is used in the makeup water treatment plant consisting of one

3,200-gallon tank. Should this chemical be released from the storage tank, it will be retained in a sump where it can be reclaimed for reuse.

Chemicals spilled in the powerhouse will flow to sumps where they will be retained until pumped either to appropriate containers for disposal or to the radwaste building where facilities for filtering, settling, and other types of treatment are installed to assure that no harmful substance is released to surface watercourses.

It is concluded that the use of multiple storage tanks and collection sumps and the use of retention basins and limestone beds reduces the risks to the environment associated with storage of potentially hazardous materials to the minimum practicable level. Liquid nitrogen for use in inerting the primary containment vessels is stored in an outdoor insulated tank. Rupture of the tank would result in spilling the liquid nitrogen onto a limestone bed. The liquid would soon vaporize, producing no adverse effect on the environment.

Table 2.5-1

Sources of Added Chemicals and Resulting End Product Chemicals

System	Chemical Added Source Chemical	Maximum Annual Use lbs[a]	Waste End Product Chemical	Maximum Resulting End Product[a] Annual LBS	Maximum Resulting End Product[a] Mean Daily LBS
Makeup Water Treatment Plant	Alum $Al_2(SO_4)_3 \cdot 18\ H_2O$	15,800	$Al(OH)_3$[b]	3,700	~10
			SO_4^{--}	6,800	~21
			Suspended solids[b,c]	13,500	~37
	Soda Ash $Na_2\ CO_3$ (100%)[2]	7,900	Na^+	3,400	~10
	Sodium Hypochlorite NaOCl (21% Solution)	3,950	Na^+	260	~ 1
			OCl^-	570	~ 2
	Coagulation Aid (see text)	590	Coag. Aid[b]	590	~ 2
Makeup water Treatment Plant Demineralizer Regneration	Sulfuric Acid 98%	270,000	SO_4^{--}	259,000	~710
	Sodium Hydroxide (50%)	205,000	Na^+	59,000	~160
Auxiliary Steam Generator Blowdown	Ammonia	Variable[d]	NH_3	6	~0.02
	Hydrazine	Variable[e]	NH_3	0.4	~0.001
Raw cooling water[f] System	Chlorine	34,000	OCl^- and Cl^-	34,000	1,620[f]

a. Based on 24-hour operation 365 days/year at demonstrated maximum capacity of equipment.
b. Suspended materials that will make up the water treatment plant sludge, on a dry weight basis.
c. Estimates from suspended solids data observed at TRM 300.3
d. Ammonia will be added as needed to keep pH of system at 9.0.
e. Hydrazine will be added as needed as a DO scavenger.
f. Chlorination will be required a maximum of 21 days/yr.

Table 2.5-2

SUMMARY OF CHEMICAL DISCHARGES

Waste Product Chemical	Maximum Annual Discharge of Product Chemical[a] lbs	Operating Mode[b] Open (O) Helper (H) Closed (C)	Waste[b] Product Chemical Contribution to Discharge Concentrations mg/l	Observed Concentrations in Reservoir Water at TRM 300.3 mg/l		Total Discharge[b] Concentrations CF=2 for Closed Mode mg/l		Total Concentrations[c] in River After Mixing mg/l		Maximum Allowable Concentrations[1] in River mg/l
				Average	Maximum	Average	Maximum	Average	Maximum	
Sulfates (SO_4^{--})	265,800	O	0.031	15.0	23.0	15.031	23.031	15.027	23.027	250
		H	0.037			15.037	23.037	15.028	23.028	
		C	1.235			31.235	47.235	15.366	23.546	
Sodium (Na^+)	62,700	O	0.007	5.92	9.18	5.927	9.187	5.9263	9.1863	d
		H	0.009			5.929	9.189	5.9264	9.1864	
		C	0.287			12.127	18.647	6.060	9.393	
Chlorides[e]	34,600	O	0.068	14.0	21.0	14.068	21.068	14.060	21.060	250
		H	0.081			14.081	21.081	14.061	21.061	
		C	0.0026			28.0026	42.0026	14.3154	21.4731	
Ammonia[f] NH_3	6.4	O	nil	0.02	0.07	0.02	0.07	0.02	0.07	d
		H	nil			0.02	0.07	0.02	0.07	
		C	nil			0.04	0.14	0.02	0.07	
Total Dissolved Solids	363,106	O	0.106	104.0	129.0	104.106	129.106	104.093	129.093	500
		H	0.127			104.127	129.127	104.095	129.095	
		C	1.528			209.528	259.528	106.38	131.94	

a. Based on 24-hour operation 365 days per year at demonstrated maximum capacity of equipment and chemical requirements.
b. Discharge flows based on 3-unit operation for all modes.
c. Concentrations based on downstream riverflow of 5,000 ft^3/s, less evaporation of 114 ft^3/s for closed and helper modes of operation; 5,000 ft^3/s for open mode. However, heat dissipation considerations will require minimum of 23,000 ft^3/s for open mode.
d. No specific standard has been identified but contribution to dissolved solids has been included.
e. Computation is for chlorides since the chlorine demand of the cooling water is such that no residual chlorine will be discharged. Chlorides and total dissolved solids reflect maximum daily use of chlorine in raw cooling water.
f. Ammonia and hydrazine added to auxiliary steam generator for pH and dissolved oxygen control. Hydrazine conservatively assumed to decompose to ammonia.

2.6 Heat Dissipation

1. Water temperature standards - As discussed in Volume 3 beginning on page 3-18, the diffuser system was designed to meet a temperature criteria of 10°F thermal rise above ambient water temperature with a maximum temperature not to exceed 93°F after reasonable mixing. These criteria, 10°F rise with a 93°F maximum temperature, were the temperature standards proposed by the State of Alabama in compliance with the requirements of the Water Quality Act of 1965.

Since Volume 3 was issued for review, TVA received a letter from the Region IV Administrator, Environmental Protection Agency, dated December 17, 1971, stating that EPA was intensely pursuing the immediate adoption of proposed thermal standards for the State of Alabama. The Region IV Office informed TVA that EPA will not accept any maximums for the water of the Tennessee River Basin in Alabama other than the following: "Temperature shall not be increased more than 5°F above the natural prevailing background temperatures, nor exceed a maximum of 86°F." TVA's interpretation of the EPA-recommended standards is that the 86°F maximum temperature, within the constraints of the 5°F allowable thermal rise, applies for all months. These temperature standards proposed by EPA for the State of Alabama were published by EPA in the March 11, 1972, Federal Register.

In light of these developments and TVA's policy to take appropriate action on a timely basis to meet any future applicable standards, TVA has determined that the diffuser system is not adequate to ensure acceptable conformance with the 5°F rise and 86°F maximum temperature. The alternatives for heat dissipation which are described in Volume 3 beginning on page 3-55 have been reevaluated, and it has been decided that the best long-term solution to meet the more stringent standards is the installation of mechanical draft cooling towers. The towers will supplement the diffuser system in order to comply with the new standards.

The towers will require about 2 to 2-1/2 years to design and construct, which will necessitate operating with diffusers only until the towers are ready. During this interim period when diffusers only are to be used, the 10°F rise and 93°F maximum standard will be observed. However, it is possible that only two units will operate in this manner provided the first set of towers is ready before unit 3 begins commercial operation.

On March 16, 1972, TVA discussed with representatives of EPA the plans for auxiliary cooling facilities and interim operation of the Browns Ferry Nuclear Plant.

2. <u>Required modifications to intake channel</u> - The original design for the intake channel has been modified to include a multigate structure to permit combined-cycle operation. The structure will consist of three bays each 40 feet wide by 24 feet high. During closed-mode operation, a 20-foot high gate will be lowered into each bay leaving an opening of 4 feet x 40 feet for passage of makeup water. Velocity through these openings in this mode will be 2/3 ft/s. During the open and helper modes the gates will be lifted leaving a 40- x 24-foot opening for each bay. The maximum velocity through these openings will occur during the open mode and will be about 1.6

ft/s for 3-unit operation, 1.0 ft/s for 2-unit operation, and 0.5 ft/s for 1-unit operation. The velocity will be independent of the reservoir elevation.

The intake pump structure will consist of 18 bays, each having a traveling screen. Each bay will have a net opening of 8 feet 8 inches by 20 feet. The maximum average velocity through each bay will be about 1.4 ft/s and will be independent of the reservoir elevation. The maximum average velocity through a clean screen which will have net openings 3/8-inch by 3/8-inch will be about 1.8 ft/s during the April through September period when biotic entrainment is of most interest. Velocities through the intake pump structure bays and the traveling screen will be independent of the number of units in operation.

3. Present thermal regime of the Wheeler Reservoir - The hydraulic regime in the reservoir is controlled by the operation of Guntersville and Wheeler Dams. In the past these projects have been operated primarily for power production, navigation, and flood control.

Wheeler Reservoir is one of TVA's main stream reservoirs on the Tennessee River and is not a deep reservoir like the headwater reservoirs. The maximum depth in the main channel just upstream from Wheeler Dam is about 66 feet at normal summer pool elevation.

The reservoir exhibits weak thermal stratification during the summer months due primarily to the relatively short detention time within the reservoir and the fact that the power intakes withdraw water from the entire vertical depth of the reservoir. The dissolved oxygen and temperature profiles of Wheeler Reservoir observed between May 1964 and April 1965 are shown in figure 2.6-1.

Water temperatures in Wheeler Reservoir have been monitored by permanent recording stations for 3 to 4 years. The recorded temperatures range from about 40°F in the winter to a typical maximum of 85-90°F at the surface in the summer. The maximum top to bottom vertical temperature difference is about 5-8°F. Natural water temperatures above the proposed maximum temperature standard of 86°F have been recorded over much of the reservoir depth. The dissolved oxygen and temperatures observed in the tailrace of Wheeler and Guntersville Dams for calendar years 1964 and 1965 are shown in figure 2.6-2. The temperatures of the releases from Guntersville and Wheeler Dams for the period 1960 to 1971 are summarized in Table 2.6-1. Based on these data there is no significant change in the temperature of the inflow and outflow of Wheeler Reservoir. Thus, with the exception of the surface waters which are subject to diurnal temperature fluctuation resulting from meteorological conditions, the temperatures of the Wheeler Dam releases are reasonable estimates of the average water temperatures at the Browns Ferry site. Comparison of the water temperature data collected at the Browns Ferry Nuclear Plant monitoring station located at Tennessee River mile (TRM) 293.6 with the Wheeler Dam tailrace temperature for the years 1969, 1970, and 1971 further verified this conclusion.

The Whitesburg gage is located at Tennessee River mile 333.3, or about 39 miles upstream from the plant. The average annual discharge of the Tennessee River at this gage for 46 years of record is about 42,500 ft^3/s. At the Browns Ferry site the average annual discharge is estimated to be about 45,000 ft^3/s. Based on the Whitesburg gage data for the period 1951 to 1970, the following table lists the percentage of days the mean daily flows at the Browns Ferry site would be below the indicated discharge.

Tennessee River Mean Daily Discharge at Browns Ferry	Percent of Days Mean Daily Discharge Is Lower
50,000 ft^3/s	76
45,000	67
40,000	56
33,000	35
30,000	27
25,000	17
20,000	10
15,000	6
10,000	3
5,000	1
1,000	0.3

It is recognized that the operation of Wheeler and Guntersville Dams results in wide fluctuations within the daily period represented by the mean daily streamflows. The hourly releases from Guntersville and Wheeler Dams for 10 years of record (1959-68) are illustrated by the flow duration curves of figures 2.6-3 and 2.6-4. An examination of the hourly records showed that the periods of no flow are restricted to the offpeak periods of below average flow days and are generally of from about 1 to 6 hours in duration. By comparing the daily duration and hourly duration curves, it is apparent that the periods of low or no flow are only a matter of hours in duration. Therefore, the majority of the no or low flow occurrences can be eliminated by making adjustments in the daily operation of these plants.

4. Reservoir thermohydrodynamics and the diffuser system - At the time Volume 3 was issued TVA had completed extensive 2-dimensional model studies and had begun 3-dimensional thermal model studies of Wheeler Reservoir in the vicinity of Browns Ferry. Since that time TVA has made additional 3-dimensional studies to further assess the performance of the diffuser system and to determine the relationship between reservoir flow and temperature distribution. A detailed discussion and the results of TVA studies are contained in TVA report 63-38, Prediction and Control of Water Temperatures in Wheeler Reservoir During Operation of the Browns Ferry Nuclear Plant, April 1972. Appendix IV contains major excerpts from this report, including discussions of the hydraulic design of the diffusers, the 2-dimensional and 3-dimensional model testing, the predicted temperature and flow distributions, and the downstream water temperature predictions.

The 3-dimensional model studies which have been performed since Volume 3 was written have revealed that the diffuser system will achieve much more thorough mixing with the reservoir flows than had been indicated earlier. Figure 8 of Appendix IV illustrates the high level of mixing which will be achieved by the diffuser system. It is emphasized that the mixed temperature rises between 5°F and 10°F will only occur during the interim operation. After cooling towers are operational the towers will be used during low flows (about 22,000 ft^3/s for 3-unit operation) to prevent mixed temperature increases greater than 5°F.

5. Thermal discharges during interim operation - Until construction of all the cooling towers is completed, TVA will operate the existing heat dispersal system as it was designed; that is, to meet the originally proposed temperature standards of 10°F rise and 93°F maximum. However, as soon as any sets of towers are operable, TVA will use the auxiliary cooling facilities to the extent practicable to meet any lower temperature standards which may be in effect at the time.

Under the current schedule, commercial operation is expected to be March 1973 for unit 1, December 1973 for unit 2, and July 1974 for unit 3. The predicted operating dates for the cooling towers are July 1974 for the first set of towers, October 1974 for the second set of towers, and by January 1975 all the towers are expected to be in operation. Each generating unit requires a set of two towers, so there will be a total of six towers at Browns Ferry. Based on this schedule, Browns Ferry units will be in operation for 16 months during which only the diffuser system and no towers will be available for heat dispersal. The total time period during which one or more units are scheduled to be operating before the installation of all the towers is 22 months. This period includes 12 months of one unit, 10 months of two units, and no months of three units in operation without towers.

it is apparent that the periods of low or no flow are only a matter of hours in duration. Therefore, the majority of the no or low flow occurrences can be eliminated by making adjustments in the daily operation of these plants.

4. Reservoir thermohydrodynamics and the diffuser system - At the time Volume 3 was issued TVA had completed extensive 2-dimensional model studies and had begun 3-dimensional thermal model studies of Wheeler Reservoir in the vicinity of Browns Ferry. Since that time TVA has made additional 3-dimensional studies to further assess the performance of the diffuser system and to determine the relationship between reservoir flow and temperature distribution. A detailed discussion and the results of TVA studies are contained in TVA report 63-38, Prediction and Control of Water Temperatures in Wheeler Reservoir During Operation of the Browns Ferry Nuclear Plant, April 1972. Appendix IV contains major excerpts from this report, including discussions of the hydraulic design of the diffusers, the 2-dimensional and 3-dimensional model testing, the predicted temperature and flow distributions, and the downstream water temperature predictions.

The 3-dimensional model studies which have been performed since Volume 3 was written have revealed that the diffuser system will achieve much more thorough mixing with the reservoir flows than had been indicated earlier. Figure 8 of Appendix IV illustrates the high level of mixing which will be achieved by the diffuser system. It is emphasized that the mixed temperature rises between 5°F and 10°F releases from upstream storage, (3) operation of any available cooling towers, (4) reduction in the generation at Browns Ferry Nuclear Plant, or (5) a combination of these operations.

A daily analysis of these data was also made for the interim period when generating units at Browns Ferry would be in operation but the construction of cooling towers would not be completed. This analysis revealed for low-flow conditions that the 10°F rise above natural temperatures or the 93°F maximum temperature would not be met on only 3 days during the interim period. Under average-flow conditions the 10°F rise and 93°F maximum thermal criteria would not have been exceeded. Another analysis of the 22-month interim period was made assuming that each month was the worst such month that occurred in the 5-year period, i.e., the worst April during the period was followed by the worst May, etc. Under these extreme conditions, the criteria would not be met on only 15 days, or about 2 percent of the days. The 1966-70 streamflow years were about 10 percent below the long-term normal flows. These studies were based on full load output for the Browns Ferry units and the mean daily releases from Guntersville and Wheeler Dams exclusive of modification of the operating schedule for other upstream hydro projects. These studies reveal that only minor amounts of supplemental flows from upstream storage reservoirs or reductions in the output of Browns Ferry would be required to meet the 10°F rise and 93°F maximum standards and that most of the time the thermal rise would be considerable less than 10°F. TVA anticipates that the peaking operation of Wheeler and Guntersville Dams will have to be modified to reduce the periods of low or no flow at the project

An analysis was made to determine if under normal operating conditions a sufficient volume of water is available within a 24-hour period to provide the streamflow required to meet the 10°F-93°F standard. The computed increases in water temperature for the 5-year period 1966 through 1970 are shown in figures 2.6-5, 2.6-6, and 2.6-7. These figures are based on the use of the diffuser system for heat dispersion and do not reflect the use of cooling towers. The streamflow estimates for Browns Ferry site are based on the releases from both Guntersville and Wheeler Dams. These figures have been revised from figures 3.2-27, 3.2-28, and 3.2-29 of Volume 3 to reflect the results of the latest model tests and the estimates of the streamflows at the Browns Ferry site. While average daily releases were used in the computations, it is recognized that operation of the dams for peaking power results in wide fluctuations within the daily period represented by the mean daily streamflows. The computations do show, however, what the corresponding temperatures of the reservoir waters would have been if the releases had been uniform during the 24-hour period.

The number of days during the period 1966 to 1970 in which the originally proposed temperature standards (10°F rise - 93°F maximum) would not have been met are summarized in Table 2.6-2. During daily periods when the evaluations indicate that the standards would not have been met, at least one of the following modifications of the actual operating schedule would have been required: (1) revision of the operation of Wheeler or Guntersville Dam, (2) an increase in the

As presented in Section 3.4, Alternative Heat Dissipation Methods, of Volume 3, the combined-cycle system using the heat dissipation capacity of the reservoir has a considerable economic advantage over a closed-cycle system. The combined-cycle system can be operated in the open, helper, or closed modes.

In the helper mode the temperature of the heated water after leaving the condensers will be reduced by passing it through the cooling tower system before it is discharged through the diffusers. In both the helper and closed modes the condenser flow and temperature rise will be about 1,223 ft^3/s and 31.7°F for each unit; however, the temperature of the water leaving the towers will depend on the wet bulb temperature, which is highly variable, and the tower design, which is not complete.

Based upon an analysis of the natural water temperatures and flow data for 1966 to 1971, the mixing capability of the diffusers (see figure 8 of Appendix IV) and an allowable 5°F rise with a maximum temperature of 86°F, it is estimated that Browns Ferry will be operated about 72 percent in the open, 21 percent in the helper, and 7 percent in the closed mode. This is also based on 3-unit operation with each unit in the same mode at the same time.

(1) Location - Figure 2.6-8 shows the presently anticipated location and arrangements of the six mechanical draft towers on the plant site. Originally TVA planned to build a 5,000-foot long permanent dike about 200 feet from the present shoreline to provide the elevated support surfaces necessary for towers and

site. The extent of the changes in operation of Guntersville and Wheeler will have to be determined by actual operating experience at Browns Ferry as controlled by the temperature monitoring network.

In summary, TVA will operate during this interim period to meet the 10°F rise and 93°F maximum temperature for which Browns Ferry was originally designed, and as the cooling towers become available TVA will utilize them to the maximum extent practicable to meet any lower temperature standards which are in effect.

6. Mechanical draft cooling towers - TVA has reexamined the alternative heat dissipation facilities which were outlined in Volume 3 beginning on page 3-55 and has again concluded that the installation of mechanical draft cooling towers is the best alternative to meet the more stringent thermal standards. Except as discussed in this volume, the engineering and environmental characteristics of the mechanical draft cooling towers are as presented in Volume 3. The principal advantages for mechanical towers over other auxiliary cooling facilities are lower capital expenditures and the nearly 2-year shorter lead time for construction. The disadvantages include higher noise levels, possible higher potential for fogging and icing, and higher operation and maintenance costs. Of these considerations the principal one which determined the use of mechanical draft towers was the shorter time required to complete the plan and thereby reduce the time the plant would be in operation without having auxiliary cooling facilities available.

monitoring activities during this relocation it may be necessary to construct temporary facilities prior to dismantling and reassembling the present structures. The main telephone trunk lines for both construction and permanent plant usage also cross the cooling tower area. New lines will be installed and placed in service before the existing lines are abandoned. The principal access road must be abandoned from a point near the meteorological tower to the permanent parking lot, and a new road must be constructed around the cooling tower area. The sewage treatment plant and possibly the boat harbor will have to be relocated.

While it will be necessary to relocate or change the planned location of numerous facilities, the purchase of additional land beyond that presently owned will not be required.

(3) <u>Environmental considerations</u> -

(a) <u>Physical and chemical characteristics of tower effluent</u> - The water required for continuous operation of the plant will be obtained from the Tennessee River at the plant site. The quantity of water required (makeup) will be dependent on the following items: (1) amount of blowdown necessary to maintain desirable levels for dissolved solids within the system, (2) the amount of evaporation from the tower, and (3) drift losses. With a blowdown dissolved solids concentration factor of 2, the total makeup required would be approximately 6 percent of the circulating flow, or 220 ft^3/s.

flumes. The towers were to be located in a single row in this area. Since making these preliminary plans TVA has discussed with tower manufacturers the most desirable arrangement of towers to attain maximum cooling effect and to minimize the environmental effects of cooling tower operation. As a result of these discussions and the desirability of reducing the length of shoreline which would be disturbed, the towers as now planned will be located inland as shown. This arrangement will reduce the length of the required dike from 5,000 feet to 1,500 feet and thereby reduce the length of shoreline disturbed by about 3,500 feet. The exact spacing and the final dimensions of the towers cannot be determined until the contract has been awarded.

(2) Land requirements - The return channel from the cooling towers to the intake channel will be generally located immediately south of the reactor building. Construction of the return channel will require an earth dike located approximately 375 feet offshore in the reservoir. This dike will run approximately 1,500 feet in an east-west direction from the west bank of the present intake channel to a tie-in point at the previously placed offshore fill originally planned for the biothermal research facility.

The cooling towers will require the relocation of the construction administrative and engineering complex. Project plans were to relocate this complex as the project was nearer to completion, but the timing of the cooling tower construction requires that this be done promptly. The meteorological building and tower facility must also be relocated. To avoid extensive interruption of

Only under extreme conditions can blowdown not be held up at least 12 hours. This capability can be used to restrict blowdown, when natural water temperatures are above 86°F, to the periods of the day when the wet bulb temperature is most favorable. This will result in discharges of blowdown at the lowest possible temperatures.

Nevertheless, there will be very limited times when the natural water temperature is 86°F or more and blowdown will have to be discharged. The quantity of heat to be added to the reservoir will be small and will be dispersed within the receiving waters by whatever mixing device is used. For example, based on historical wet bulb and river temperatures, the maximum temperature rise of the blowdown above the ambient river temperature is expected to be about 10°F. The blowdown diffuser on which studies have been made would result in a mixed temperature rise of about 0.5°F.

(b) Local fogging and icing - These environmental effects of cooling tower operation were discussed in detail beginning on page 3-59 of Volume 3. To minimize the plume drift the mechanical draft cooling towers will have drift eliminators designed to limit drift to a maximum of 0.1 percent of the condenser cooling water flow. The effects of plume drift are discussed in section 2.5 of this volume.

(c) Construction effects - The 1,500-foot long dike will be constructed in an area that has been previously disturbed as described in Volume 3. Maintenance of a navigable channel and installation of the diffuser pipes has already disturbed this area. The construction of the dike will disturb approximately 13 acres of reservoir habitat adjacent to the plant. This is about 5 to 10 acres less than would have been disturbed by the original tower location. Because of previous construction activity this area has not returned to its previous condition.

Riprap will be placed on the reservoir side as the dike is completed to avoid wave action erosion and resultant siltation. The channel section will be shaped with rolled fill, and the inside slopes will be protected by riprap. Any muck removed from the ponded area will be deposited in upland spoil areas. After drying the area will be covered with a light cover of earth-fill, if needed, and will be seeded and mulched.

Some localized siltation is expected in the immediate area of dike construction. Because of the shallow water in this location, the relatively low velocity of the currents, and the use of riprapping, siltation of the reservoir is expected to be localized, minimal, and of short duration.

Some additional trees near the south bank must be cleared for the cooling tower construction. These trees and shrubs will be disposed of by open burning. The burning will be accomplished in accordance with applicable state and local regulations.

About 3.6 million cubic yards of earthwork will be required to grade the cooling tower area. This includes 3 million cubic yards of excavation for the cooling towers, 0.3 million cubic yards of excavation to relocate a drainage diversion ditch, and 0.3 million cubic yards of fill for the present diversion ditch. The excavated material will be disposed of in an area to the northeast of the cooling towers. This material will be shaped to provide a pleasing aesthetic appearance and will be seeded and mulched.

Approximately 130 acres of land must be graded for the cooling tower installation. Special precautions will be employed to avoid excessive runoff from this graded area and the resultant excessive siltation in the Wheeler Reservoir. Erosion control methods will include, but will not be limited to, special sloped grading, drainage ditches, check dams, benches, and seeding and mulching as areas are completed; and if necessary for proper control, settling ponds or other control techniques will be used.

(d) Aesthetics - The general location of the cooling towers as related to the main plant access road, shoreline, offgas stack, parking areas, gatehouse, and visitors' facilities places special emphasis on the aesthetics of the cooling towers. The relatively low profile (60 feet high) of the mechanical draft towers will not present a very large vertical barrier. Without changing the basic functional criteria of the towers, TVA will design and construct the towers to make them an aesthetically integral part of the project. Since the standard materials of construction for mechanical draft towers may not be compatible with the architecture of the powerhouse, design features will be incorporated to achieve architectural compatibility with the main plant. This will be accomplished by selection of materials and colors compatible with overall plant design or by special treatment and modifications of features to achieve compatibility with the total composition. Special site treatment will be provided to relate the towers to the main plant area. Landscaping along the main plant access road and in the tower area will be used to reduce the impact of the plume and towers. Nevertheless, as is apparent in figure 2.6-8, the towers by their very size will present a large horizontal barrier which is an unavoidable consequence.

(e) Noise - The use of mechanical draft cooling towers will increase noise levels outside the plant site by a small increment. The predicted operational noise levels at a distance of 1,000 feet along the two centerlines of the tower complex were calculated. In addition, predicted operational noise levels at greater distances outside the plant boundary were calculated along the centerline in the direction of the highest noise levels and compared to measured background noise data. These values ranged from 33 to 38 dB(A) (1 to 5 dB(A) above background) which is within the normally acceptable range according to the noise criteria developed by the U.S. Department of Housing and Urban Development. The details of this study are presented in Appendix V.

Since the noise levels associated with mechanical draft cooling towers are within the normally acceptable range, no adverse effects are expected.

7. Operating procedure following tower installation - The cooling towers will be designed and sized assuming that the 5°F temperature rise and 86°F maximum temperature standards will be finally adopted. TVA expects that after the installation of the towers is complete all generating units will usually be operated in the same

mode at the same time. During the time when only limited supplemental cooling is required, one or two units may be operated in the helper mode. With the units operating in the open mode (river cooling only) the normal procedure would be to change to the helper mode and then to the closed mode as required to meet the thermal standards. As the temperature standards permit, the units would be changed to the helper mode and then to the open mode.

TVA estimates the cooling tower operation will be required about 28 percent of the time to supplement the diffuser system in meeting the 5°F and 86°F thermal standards. As shown by figure 8 of Appendix IV, a minimum riverflow of about 22,000 ft^3/s is required to meet a 5°F rise criterion for 3-unit operation when utilizing the diffuser system only. There have been periods of several days during which the flow at the Browns Ferry site has been below 22,000 ft^3/s. The five longest periods since 1951 were:

October 3-14, 1954	12 days
December 19-29, 1958	11 days
April 9-26, 1966	18 days
April 1-17, 1967	17 days
September 7-October 1, 1968	24 of 25 days

Table 2.6-3 shows the number of days and the percent of days during the period 1966-71 that the 5°F rise and 86°F maximum temperature criteria would not have been met utilizing the diffuser system only. The two sections of this table are based on the upper and lower limits of the temperature rise as indicated by figure 8 of Appendix IV. The data in this table are indicative of the amount of

time that operation of the cooling towers will be required to meet the 5°F rise and 86°F maximum standards.

TVA will, as far as practicable, make maximum use of the heat dissipation capacity of the river. The extensive thermal monitoring network installed for the Browns Ferry plant will be utilized to assure that thermal standards are met. This system will be used to verify the preliminary operating procedures which are based upon the results of model studies and will serve to develop the operating procedures for unsteady-state flow conditions. The monitor network will permit a rapid determination of impending violations of thermal standards and enable TVA to make operational changes on a timely basis to meet the standards. These operational changes could include: (1) adjustments to the scheduled releases at Wheeler and Guntersville Dams; (2) use of the auxiliary cooling facilities at Browns Ferry; and (3) reductions in the generation from Browns Ferry should auxiliary cooling facilities be unavailable. Any reductions in generation which result from these changes will require either increased generation from alternative power sources or system load reductions.

The Browns Ferry Nuclear Plant is expected to be operated as a base load plant for the first 15 years of the plant life after which, as lower cost generation becomes available, the capacity factor on Browns Ferry will be reduced. Peak power requirements on the TVA system occur during the winter and summer seasons, and it is expected that generation from Browns Ferry will be needed during these periods for the life of the plant.

At this time TVA has no definitive plans for installing additional capacity at the Browns Ferry site or on Wheeler Reservoir. The closest existing TVA facility above Browns Ferry which rejects large amounts of heat to the river is the Widows Creek Steam Plant consisting of eight units. This 1,977,985-kW plant is located on the Guntersville Reservoir at about Tennessee River mile 407, or some 113 miles above the Browns Ferry plant. Because of the distance separating the plants, there are no identifiable temperature effects at Browns Ferry as a result of the heat rejected to Guntersville Lake by the Widows Creek plant.

TVA's Colbert Steam Plant is located on the Pickwick Reservoir at about Tennessee River mile 245, or some 49 miles below the Browns Ferry plant. The prediction of water surface temperatures downstream from Browns Ferry are discussed and illustrated in Appendix IV. Based on these predictions, the mixing of the surface and bottom waters by the Wheeler and Wilson turbines and the distance separating the two plants, Browns Ferry is not expected to cause any identifiable thermal effects at the Colbert plant.

Table 2.6-1

SUMMARY OF WEEKLY OBSERVED WATER TEMPERATURES IN THE RELEASES

FROM GUNTERSVILLE AND WHEELER DAMS

1960 to 1971

Year	Maximum Temperature °F		Minimum Temperature °F		Number of Days Natural Temperature Equalled or Exceeded 86°F	
	Guntersville	Wheeler	Guntersville	Wheeler	Guntersville	Wheeler
1960	82.4	86.0	41.0	42.8	0	16
1961	82.4	82.4	39.2	41.0	0	0
1962	84.2	86.0	39.2	41.0	0	8
1963	82.4	84.2	39.2	39.2	0	0
1964	84.2	86.0	41.0	41.0	0	1
1965	84.2	86.0	42.8	44.6	0	1
1966	86.0	86.0	37.4	37.4	1	36
1967	80.6	80.6	42.8	44.6	0	0
1968	86.0	87.8	41.0	42.8	1	22
1969	88.7	87.8	41.0	41.0	15	30
1970	84.2	87.8	39.2	37.4	0	17
1971	84.2	86.0	41.0	41.0	0	2
					17	133

Table 2.6-2

NUMBER AND PERCENT OF THE DAYS DURING THE 5-YEAR PERIOD 1966-70 THAT THE 10°F RISE AND 93°F MAXIMUM STANDARDS WOULD NOT HAVE BEEN MET FOR OPERATION OF BROWNS FERRY ON THE DIFFUSER SYSTEM ONLY

Operation	10°F Rise With 93°F Maximum Days Equaled or Exceeded					
	10°F Rise		93°F Max.		10°F Rise or 93°F Max.	
	Number	%	Number	%	Number	%
One Unit - Full Load						
1966	0	0	0	0	0	0
1967	2	0.5	0	0	2	0.5
1968	0	0	0	0	0	0
1969	0	0	0	0	0	0
1970	0	0	0	0	0	0
TOTALS	2	0.1	0	0	2	0.1
Two Units - Full Load						
1966	7	1.9	2	0.5	8	2.2
1967	6	1.6	0	0	6	1.6
1968	4	1.1	0	0	4	1.1
1969	2	0.5	4	1.1	4	1.1
1970	0	0	0	0	0	0
TOTALS	19	1.0	6	0.3	22	1.2
Three Units - Full Load						
1966	21	5.8	5	1.4	23	6.3
1967	13	3.6	2	0.5	13	3.6
1968	18	4.9	5	1.4	19	5.2
1969	7	1.9	9	2.5	11	3.0
1970	3	0.8	3	0.8	4	1.1
TOTALS	62	3.4	24	1.3	70	3.8

Table 2.6-3

DAYS DURING THE SIX-YEAR PERIOD, 1966-71, THAT THE 5°F RISE AND 86°F MAXIMUM STANDARDS WOULD NOT HAVE BEEN MET FOR 1-, 2-, AND 3-UNIT OPERATION AT BROWNS FERRY IN THE OPEN MODE

Operation	Upper Limit (3.5°F Rise for Intermediate Flows)						Lower Limit (2.5°F Rise for Intermediate Flows)					
	5°F Rise		86°F Max.		5°F Rise or 86°F Max.		5°F Rise		86°F Max.		5°F Rise or 86°F Max.	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
One Unit - Full Load												
1966	7	1.9	48	13.2	54	14.8	7	1.9	45	12.3	51	14.0
1967	6	1.6	0	0	6	1.6	6	1.6	0	0	6	1.6
1968	4	1.1	50	13.7	53	14.5	4	1.1	42	11.5	45	12.3
1969	2	0.5	74	20.3	74	20.3	2	0.5	62	17.0	62	17.0
1970	0	0	80	21.9	80	21.9	0	0	71	19.5	71	19.5
1971	0	0	76	20.8	76	20.8	0	0	59	16.2	59	16.2
TOTALS	19	0.9	328	15.0	343	15.7	19	0.9	279	12.7	294	13.4
Two Units - Full Load												
1966	32	8.8	53	14.5	77	21.1	32	8.8	50	13.7	74	20.3
1967	28	7.7	2	0.5	28	7.7	28	7.7	2	0.5	28	7.7
1968	39	10.7	61	16.7	86	23.5	39	10.7	55	15.0	80	21.9
1969	13	3.6	78	21.4	82	22.5	13	3.6	69	18.9	73	20.0
1970	12	3.3	83	22.7	90	24.7	12	3.3	76	20.8	83	22.7
1971	7	1.9	76	20.8	79	21.6	7	1.9	60	16.4	63	17.3
TOTALS	131	6.0	353	16.1	442	20.2	131	6.0	312	14.2	401	18.3
Three Units - Full Load												
1966	74	20.3	65	17.8	119	32.6	74	20.3	64	17.5	118	32.3
1967	40	11.0	2	0.5	40	11.0	40	11.0	2	0.5	40	11.0
1968	89	24.3	73	19.9	135	36.9	89	24.3	72	19.7	134	36.6
1969	47	12.9	85	23.3	111	30.4	47	12.9	83	22.7	109	29.9
1970	51	14.0	91	24.9	122	33.4	51	14.0	90	24.7	121	33.2
1971	30	8.2	82	22.5	103	28.2	30	8.2	74	20.3	95	26.0
TOTALS	331	15.1	398	18.2	630	28.8	331	15.1	385	17.6	617	28.1

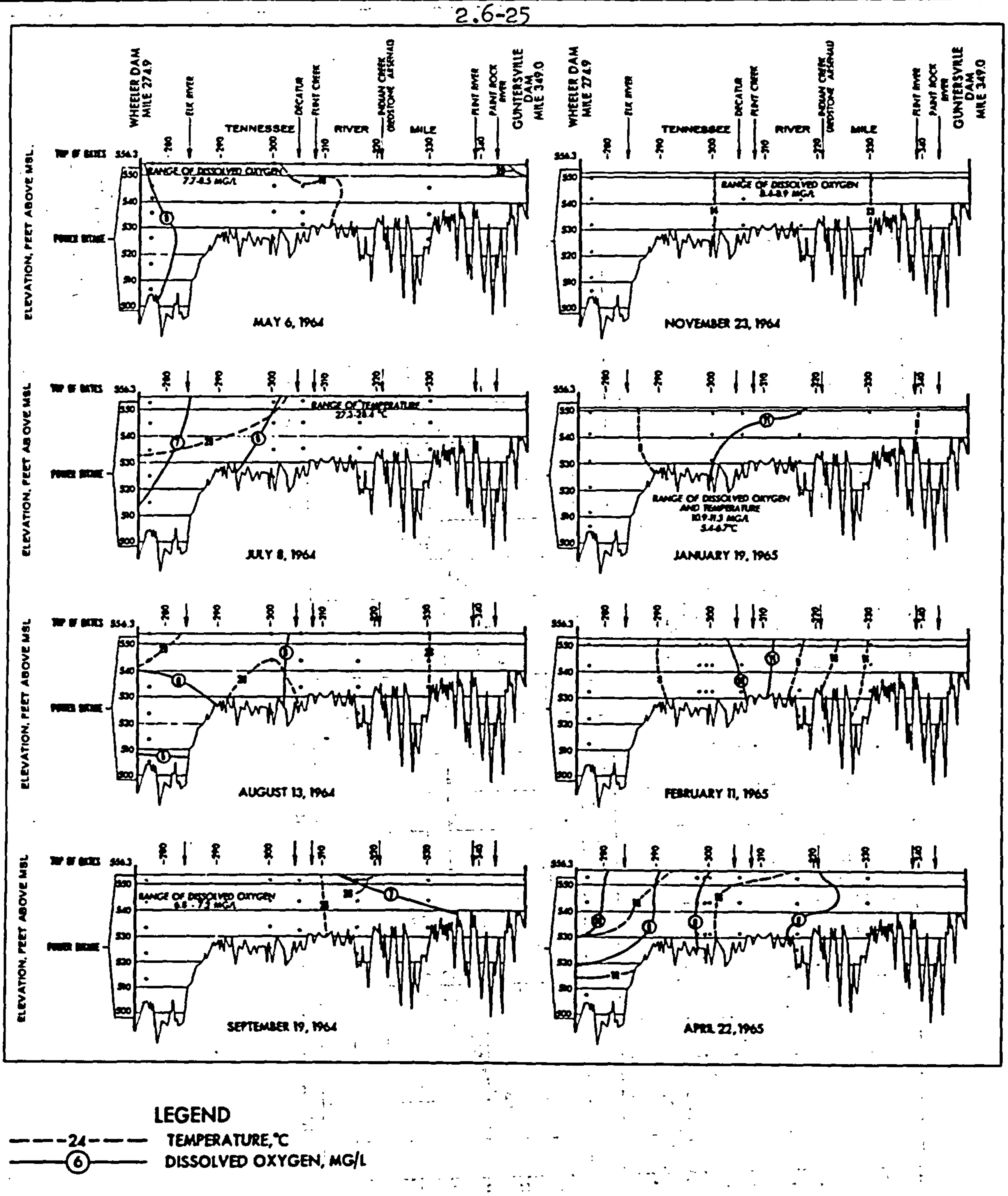


Figure 2.6-1
Dissolved Oxygen
and Temperature Profiles
Wheeler Reservoir
1964-1965

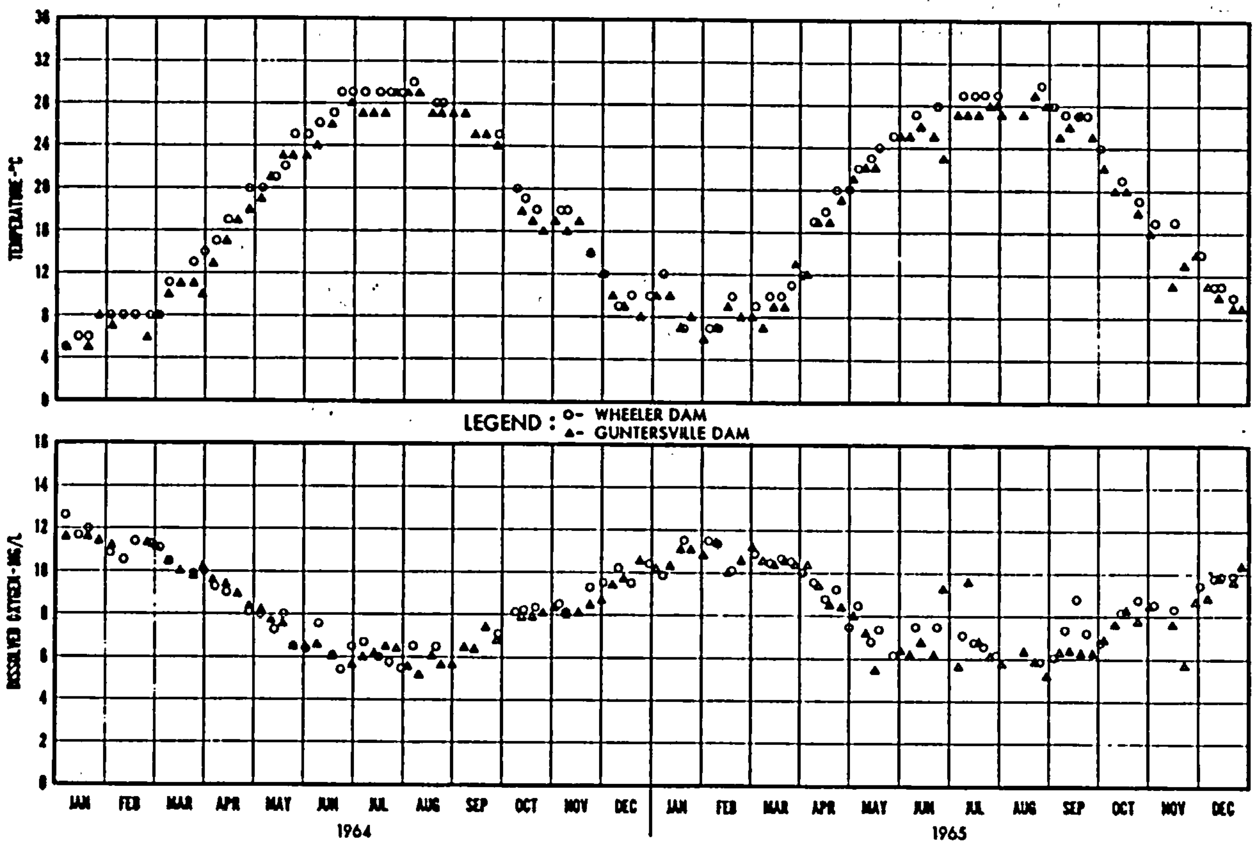


Figure 2.6-2
Dissolved Oxygen and
Temperature at
Wheeler and Guntersville Dams

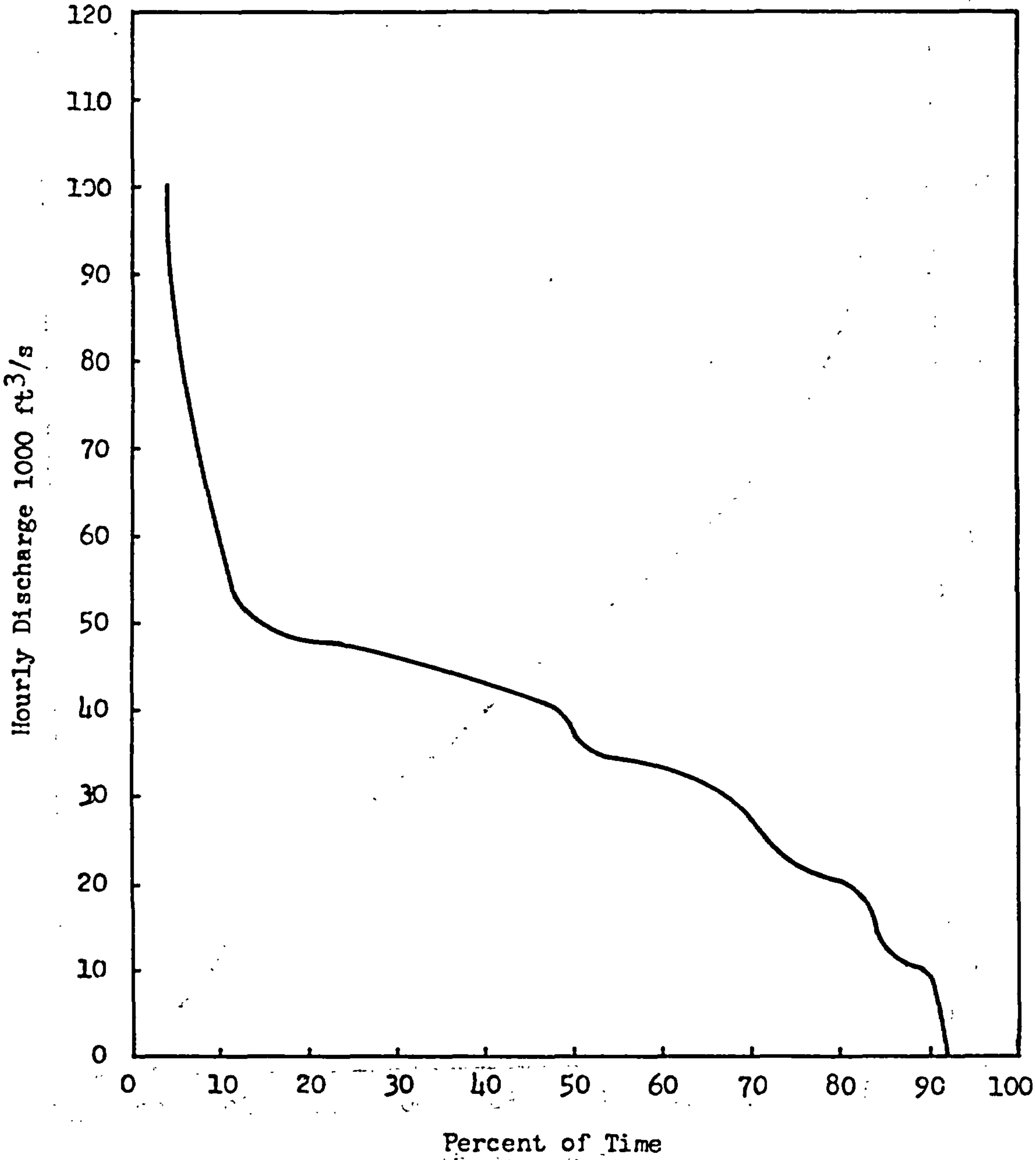


Figure 2.6-3
Guntersville Dam
Hourly Flow
10 Years of Record
1959 - 1968

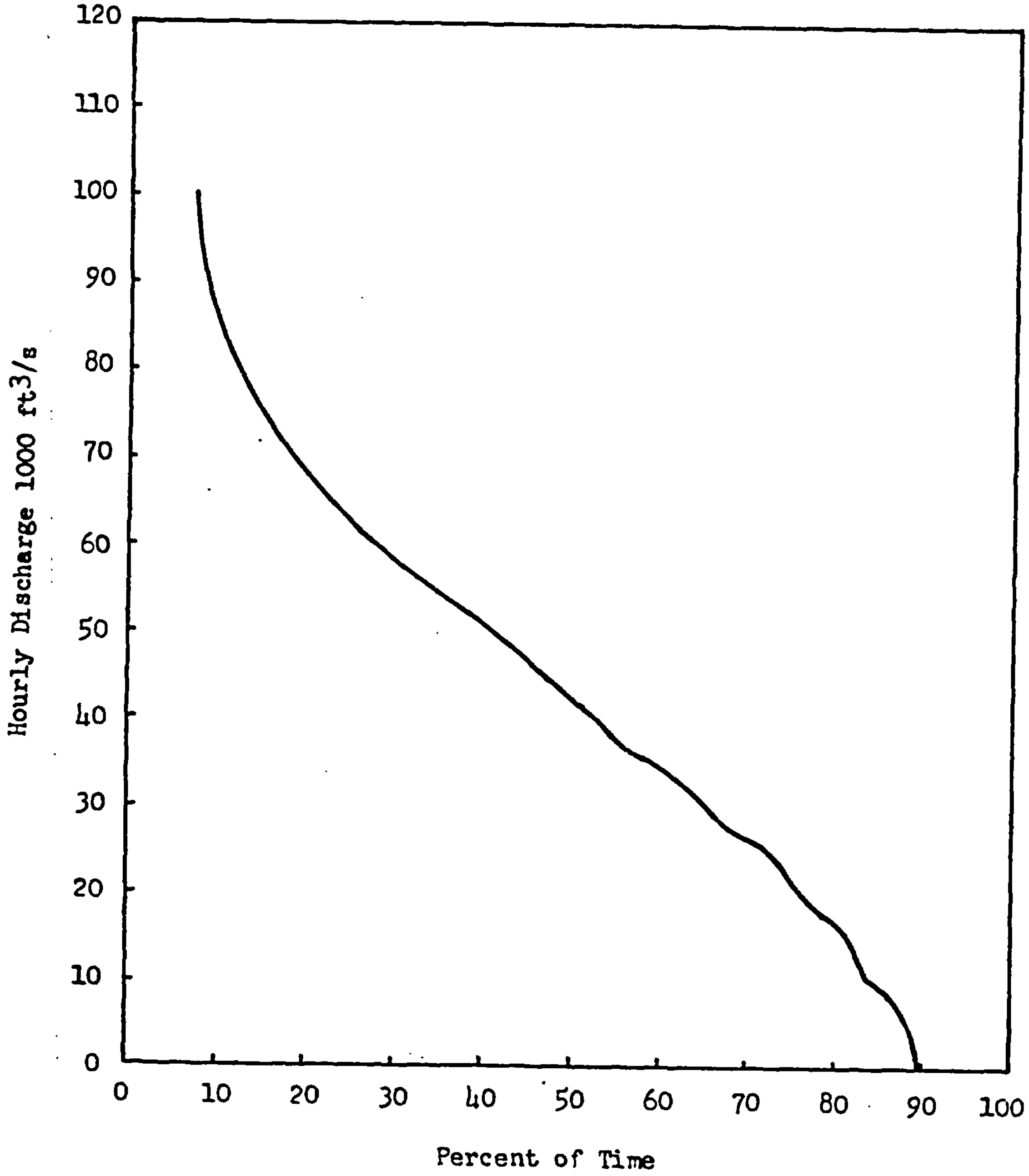
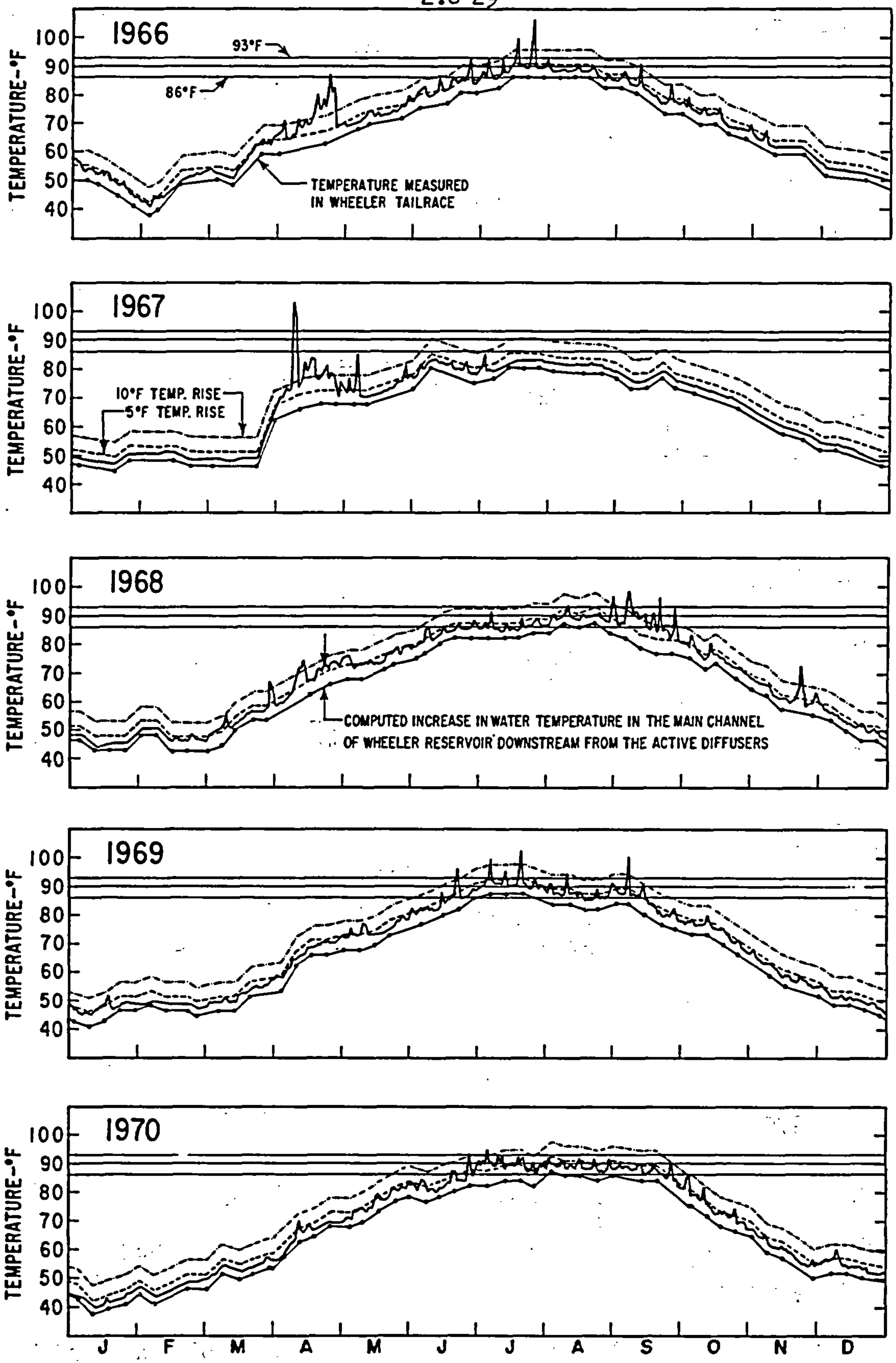


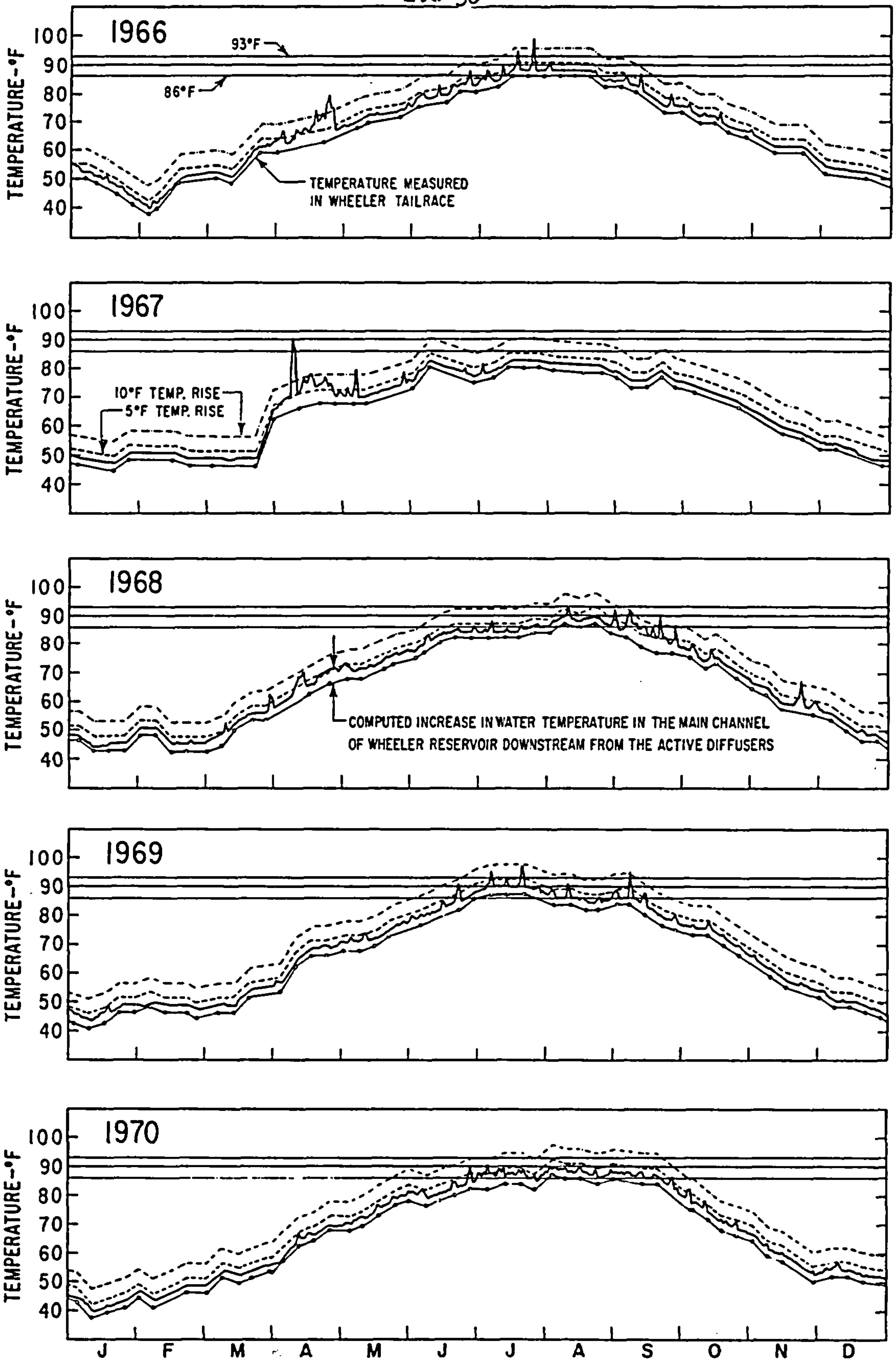
Figure 2.6-4
Wheeler Dam
Hourly Flow
10 Years of Record
1959 - 1968



COMPUTED INCREASE IN WATER TEMPERATURE IN THE MAIN CHANNEL OF WHEELER RESERVOIR DOWNSTREAM FROM THE ACTIVE DIFFUSERS

ASSUMING THREE UNITS IN FULL OPERATION AND STEADY STREAMFLOW CONDITIONS AT BROWNS FERRY NUCLEAR PLANT SITE

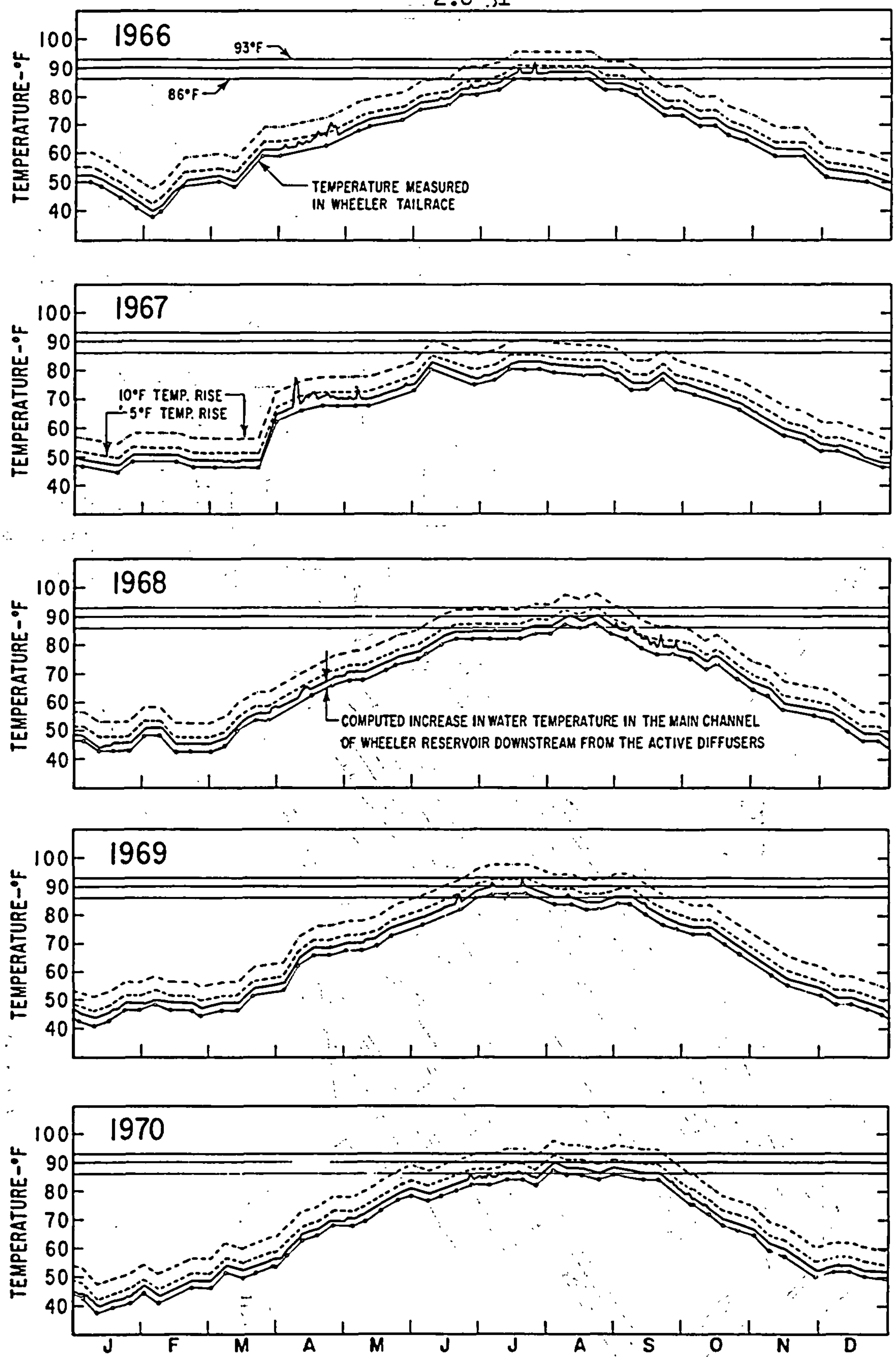
Figure 2.6-5



COMPUTED INCREASE IN WATER TEMPERATURE IN THE MAIN CHANNEL OF WHEELER RESERVOIR DOWNSTREAM FROM THE ACTIVE DIFFUSERS

ASSUMING TWO UNITS IN FULL OPERATION AND STEADY STREAMFLOW CONDITIONS AT BROWNS FERRY NUCLEAR PLANT SITE

Figure 2.6-6



COMPUTED INCREASE IN WATER TEMPERATURE IN THE MAIN CHANNEL OF WHEELER RESERVOIR DOWNSTREAM FROM THE ACTIVE DIFFUSERS

ASSUMING ONE UNIT IN FULL OPERATION AND STEADY STREAMFLOW CONDITIONS AT BROWNS FERRY NUCLEAR PLANT SITE

Figure 2.6-7

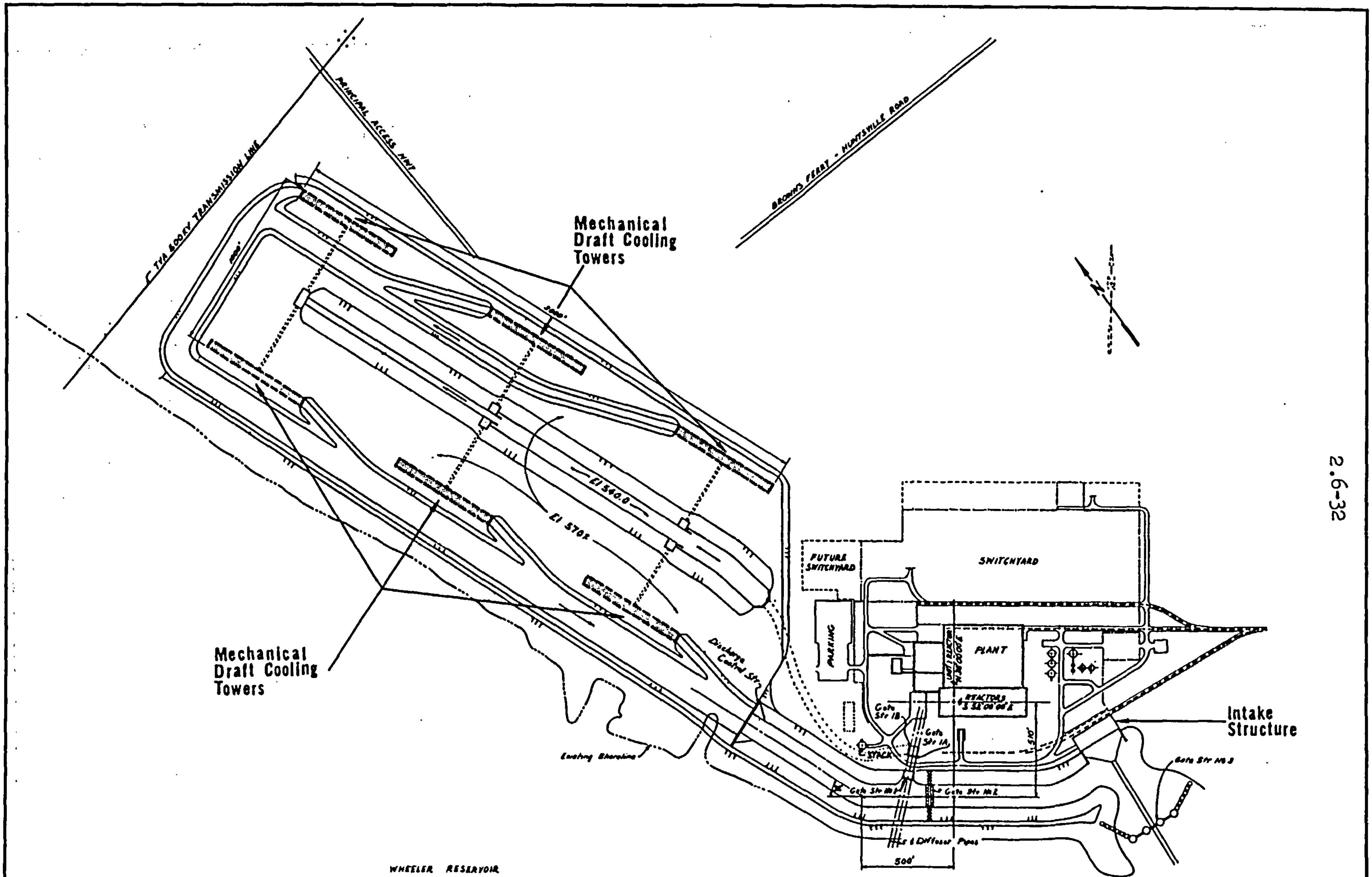


Figure 2.6-8
Mechanical Draft
Cooling Tower Arrangement
BROWNS FERRY NUCLEAR PLANT

2.7 Biological Impacts

1. <u>Thermal effects following cooling tower installation</u> - The impact of thermal discharges from Browns Ferry Nuclear Plant on aquatic life in Wheeler Reservoir based on TVA's design criteria for reservoir temperatures, a 10°F rise and a 93°F maximum, has been discussed in Volume 2, section 5.6, and Volume 3, section 3.3. In these volumes the bottom fauna and fish habitat in Wheeler Reservoir have been described, fish species of interest to sport and commercial fishermen have been identified, and effects of the warmwater discharge on the life history of fish and bottom fauna have been considered.

TVA concluded in these discussions that limiting the Wheeler Reservoir temperatures to the design criteria maximum would not result in significant detrimental impacts to the reservoir ecosystem. This evaluation is still considered valid. However, after Volume 3 was issued for review, TVA made the decision to install mechanical draft cooling towers to meet the more stringent temperature standards of 86°F maximum and 5°F above natural prevailing background temperature proposed by EPA for the State of Alabama.

2. <u>Thermal effects during the interim period</u> - Thermal discharges during the interim period until cooling towers are completed are discussed in section 2.6.5 of this volume. The plant commercial operation schedule and the tower completion schedule discussed in that section indicate that the total time period during which one or more units are scheduled to be operating before installation of all towers is 22 months. This period includes 12 months of

1-unit, 10 months of 2-unit, and no period of 3-unit operation without towers.

In addition to the limited time span when the plant units will be operating without available auxiliary cooling facilities, evaluation of past flow records (see Table 2.6-3) indicates that only about 16 percent of this time will the more stringent 86°F and 5°F rise standard not be met during the period of 1-unit operation, and only about 20 percent of the time will these limits be exceeded during 2-unit operation. This analysis is based on mean daily flows. However, reference to figure 2.6-3 and figure 2.6-4 shows that the minimum flow required to limit the temperature rise in the reservoir to the proposed standard of 5°F, approximately 7,250 ft^3/s for 1-unit operation, is exceeded about 90 percent of time based on hourly flow records. The minimum flow required to meet this standard for two units is about 14,500 ft^3/s and is equalled or exceeded more than 80 percent of the time. Thus, the following discussion of interim operation thermal effects must be evaluated relative to those periods when the proposed standards are exceeded.

As described in section 2.6 of this volume, thermal patterns in Wheeler Reservoir can be separated into three categories. These three categories, which are described below, will be termed Condition I, Condition II, and Condition III.

<u>Condition I</u> - At streamflows greater than ten times the diffuser discharge, warm water will extend in a surface layer across the width of the reservoir at some point downstream from the diffusers, leaving cooler water at "ambient" temperature

in a subsurface layer. The temperature of the warm surface water outside the jet-mixing zone will be approximately 1.4 to 2.0 deg C (2.5 to 3.5 deg F)* above ambient for approximately 2 miles downstream from the plant site, at which point the temperature will begin to decrease because of surface heat losses. The warm layer will impinge on shallow overbank and littoral areas on both sides of the river, including the Mallard Creek embayment, and on the submerged island downstream from the plant.

<u>Condition II</u> - At flows less than ten times the diffuser discharge, the entire flow of the river will mix with the condenser effluent. No subsurface zones at ambient temperature will occur immediately downstream from the diffuser. Temperature increments above ambient in the mixed flow will range from 1.4 deg C (2.5 deg F) to 5.6 deg C (10 deg F) depending on reservoir flow-diffuser discharge relationships. It should be noted that after cooling towers are available the rise will not exceed 2.8°C (5°F). Water elevated in temperature by these increments will impinge on the entire reservoir substrate for approximately 2 miles downstream from the diffusers before significant surface heat loss occurs; warm water will also move upstream, the distance depending on reservoir and diffuser flows; and warm water will invade to an unknown

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*This discussion will follow the convention: deg C (or deg F) refers to a change in temperature; °C (or °F) refers to actual temperature.[1,2]

extent the Mallard Creek embayment located across the reservoir from the plant site.

Condition III - Occasionally there will be very high streamflows for which the thermal regime will be essentially the same as in Condition I except that additional mixing will result in mixed upper layer temperatures lower than 2.5 to 3.5 deg F.

3. Effects on fish -

(1) Reproduction -

(a) Spawning - Under Condition I the expected mixed temperatures on the order of 1.4 to 2.0 deg C above ambient probably will not have a measurable effect on prespawning migrations. In addition, the bottom area in the overbank areas will be at ambient temperatures, thus affording subsurface passage routes.

Under Condition II warm water at the mixed temperature will occupy the entire water column. The extent to which this will serve as a barrier to migrating fish will depend on (1) the magnitude of the temperature elevation in the mixed area and (2) the steepness of the thermal gradients within the mixed zone. Temperatures of from 1.4 to 5.6 deg C above ambient will be experienced by migrating fish. It is important to note that a complex 3-dimensional distribution of thermal gradients within the range noted above will exist in the region of mixed temperature. The literature available on thermal preferences and reactions to thermal gradients is extensive.[2,3] Laboratory investigations have shown that fish can be trained to discern temperature differentials of 0.05 deg C or less;

in natural situations, however, discrimination of thermal differentials of less than 4 to 5 deg C has seldom been demonstrated except where these differentials occur near lethal limits.[4] Certain species may avoid localized areas or "pockets" of highest temperature but should successfully negotiate the mixed region.

Where warm water extends both upstream and downstream from the diffusers, the gradients encountered by migrating fish will vary. Fish moving upstream from below the plant will traverse a gradually increasing gradient, experience the highest temperatures in a localized region in the vicinity of the diffusers, and then traverse a decreasing gradient as they move upstream. The gradient from warm to cooler water upstream from the diffusers will be somewhat steeper than the gradient from cooler to warmer water downstream from the diffusers, but it will not be sufficiently steep to produce cold shock. It is therefore judged that a barrier, in the strict sense of preventing or significantly decreasing or retarding migration, will not result under the proposed interim operating regime.

A recent review of environmental factors which may control teleost reproductive cycles[5] indicates that for most teleost orders rates of gametogenesis are controlled by a combination of temperature and photoperiod and that photoperiodism is partly temperature controlled. The same argument can be extended to spawning per se provided other factors, e.g., availability of suitable substrate, are included. Generalizations regarding the role of increased temperatures on the spawning cycles of fish resulting from plant operation are therefore difficult to make. Depending on the degree to which temperature can override photoperiodic control, those species which reside more or less permanently, expecially during late autumn and winter, in the vicinity of the plant may experience acceleration of gametogenesis and hence spawning. As discussed in Volume 2, results of preoperational monitoring indicate considerable seasonal variation in catch; there are no available data to ascertain the presence or absence of resident subpopulations of any species. It is possible that members of relatively sedentary species such as minnows, bluegills, largemouth bass, and perhaps flathead catfish will remain in the area long enough to be affected. Early spawning by clupeids and largemouth bass and late spawning of bluegill were noted in the discharge cove of a steam plant on Lake Norman, North Carolina.[1] The consequences of earlier maturation and spawning are discussed below in the consideration of thermal effects on egg development.

Under Condition II warm water may encroach upon overbank areas above the plant and across the reservoir. Fish spawning in these areas would experience changes in temperature which may affect normal spawning. Spawning is most likely to be disrupted by a downward shift in temperature early in the spawning season, i.e., when the threshold temperature for spawning has first been passed. During this period a shift from one condition to the other could interrupt spawning in these areas; the significance of this in terms of the fishery resource of the reservoir is unknown.

(b) Egg development - Increased temperatures in the vicinity of the plant under both Condition I and Condition II may accelerate development of both demersal eggs deposited in the area and pelagic eggs which drift past the plant and become entrained in the jet mixing zone.

Under Condition I rates of development of demersal eggs deposited in the vicinity of the plant will be accelerated somewhat, but increased mortality of eggs is not expected to be a significant factor. Increased developmental rates owing to elevated temperatures may result in a higher frequency of anatomical anomalies (changes in numbers of vertebrae, pug-headedness, etc.). These anomalies seldom are direct factors in mortality, but they may decrease swimming and feeding efficiency and render the affected fish more susceptible to predation. Anomalies may be under genetic control as well, and adult individuals exhibiting anomalies have been reported in the literature for several species. Increased developmental rates may also result in young hatching at an earlier stage of development than is normal; mortality rates of prematurely hatched young are higher than for normal young. Considering the area involved, approximately 5 percent of the reservoir surface area, it is judged that such effects will have an insignificant impact on fishery resources.

Under Condition II a greater, but undefinable, degree of acceleration of developmental rates can be expected. Egg mortalities may result if the combination of ambient temperature conditions near the upper lethal threshold, low riverflow, and high diffuser discharge occurs. Such occurrences will be infrequent and of short duration; mortalities which may occur are judged to be insignificant in terms of the entire reservoir.

Pelagic eggs which become entrained in the diffuser discharge stream will be subject to rapid thermal shock as they pass through the jet mixing zone. The degree to which mortality is caused by the thermal shock will depend on the magnitude of the shock, the maximum temperature experienced by the eggs, the developmental stage of the eggs, and the duration of exposure to elevated temperature. Data on these effects are scanty, and no quantitative estimates of adverse effects can be made, but some increase in egg mortality may occur. Incomplete analysis of meter-net samples indicates that egg concentrations in the river channel near Browns Ferry (TRM 293) varied from 0 to $0.5/m^3$ in May 1971; from 0.004 to $2.5/m^3$ in June 1971; and from 0.003 to $0.4/m^3$ in July 1971. Presumably, the eggs taken were pelagic, buoyant eggs, most probably of the drum, *Aplodinotus grunniens*, and some fraction of these would have been exposed to the conditions noted above. Available information indicates that only two species common to the reservoir produce buoyant eggs: drum and mooneye (*Hiodon tergisus*); one other species, the skipjack herring (*Alosa chrysochloris*) may also have bouyant eggs. It is not anticipated that egg mortalities owing to entrainment will have a significant impact on populations of these species in Wheeler Reservoir.

(2) *Early life stages* - Preliminary results of the first year of sampling for young fish* in the vicinity of the plant are shown in figure 2.7-1. The methods and stations established for sampling for young fish are shown in figure 19 of Volume 2. While a complete analysis of the species composition and

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*For convenience, larval and young-of-the-year fish not exceeding the 1" to 2" size class are combined and referred to as young fish, unless further specified in the text.

relative species abundance is not yet available, some general observations can be made. Throughout the period in which young fish are vulnerable to the sampling gear, shad (Dorsoma spp.) dominate the catch, and gizzard shad appear to be more abundant than threadfin shad. The percentage of nonshad species, which never exceeds 10 percent of the total, increases somewhat in July. The downward trends of the curves in late June and July are the result of several processes--mortality, migration from inshore to pelagic areas, and gear avoidance due to a larger size and increased swimming ability. For these reasons the curves underestimate the abundance of fish and may overestimate the proportion of species other than shad. A list of species identified thus far is given in Table 2.7-1.

The data in figure 2.7-1 represent inshore samples only; population densities of young fish in the pelagic area (channel) at the same location are approximately one-tenth as great, and population densities at the 5m depth in the channel are somewhat lower than at the surface. The extent to which population densities noted at TRM 293 are typical of the entire reservoir is not known, but examination of a limited number of samples taken approximately 4 miles upstream from the plant has yielded equal or somewhat higher numbers, although the peak observed at TRM 293 on June 17 may not be reached.

The dynamics of populations of young fish are not clearly understood. The effects of adverse impacts on young fish as ultimately reflected in adult stocks and the reservoir ecosystem are unknown. The magnitude of the projected losses of larval fish as discussed in subsequent pages does, however, suggest the possibility of a significant adverse impact. To provide assurance that the operation of the Browns Ferry plant is not adversely affecting fish populations in Wheeler Reservoir, larval fish monitoring will continue following plant startup. Should there be significant adverse effects due to plant operation, corrective action will be taken.

(a) Thermal discharges - The effects of thermal discharges on young fish are largely unknown at present. Increased temperatures which remain below incipient lethal thresholds will accelerate metabolism, thereby accelerating growth if other factors, e.g., dissolved oxygen and food concentrations, are not limiting. Evidence has been presented of faster growth of young fish in a discharge embayment as compared to other areas of Lake Norman.[1] However, the extent to which this is a result of accelerated growth rates as opposed to increased growth due to earlier hatching has not been resolved. Since increased temperatures increase maintenance level food requirements, the effects of temperature are likely to operate in conjunction with available food supplies.[6]

Young fish subject to Condition I will experience slight increases in temperature; however, the effects on growth of a 1.4 deg C increase in water temperature may not be measurable. Increased predation may occur if significant numbers of predators are attracted to the warmer areas. Under Condition II temperatures of up to 5.6 deg C may be experienced. Increased growth may occur if food is not limiting; increased predation may also result, but it will be offset somewhat by the shorter period of vulnerability due to increased growth.

It is judged that the effects of thermal discharges on larval fish, whether adverse or beneficial, will not be of a measurable level. However, mortality of young fish resulting from plant operations may be caused by three distinct but related factors: (1) entrainment in the jet mixing zone; (2) impingement on intake screens; and (3) passage through the condenser cooling system.

(b) Entrainment - The number of larval fish entrained in the jet mixing zone will vary considerably over time. Based on (1) the volume of the jet mixing zone of 203.6 x 10^3 cubic meters (165 acre-feet) under 3-unit open-mode operation and (2) mean concentration of larval fish obtained from surface tows in the channel, the ranges of the numbers of larval fish in the zone under normal flow conditions are: April (1 date only), 653 x 10^3; May, 179 x 10^3 to 383 x 10^3; June, 20.2 x 10^3 to 1.88 x 10^6; July, 2.2 x 10^3 to 12.8 x 10^3. Assuming a turnover rate for the volume in the mixing zone of 20 times per hour, an estimated 11.99 x 10^9 larval fish would have passed through the jet mixing zone in the 91-day period from April 27 through July 27 in 1971.

Fish thus entrained will be subjected to a gradient of increased temperature from approximately 13.9 deg C at the diffuser ports to 1.4 deg C at the downstream edge of the mixing zone. Temperature data from 1971 indicate that, of the 11.99 x 10^9 fish noted above, 5.8 x 10^9 would have been subjected to temperatures in excess of 40°C (104°F) for short durations. No data are available to enable assessment of the effects of short-term exposures of larval fish to temperatures above 40°C; similarly, the length of exposure to the highest temperatures is not known. Any mortality occurring will probably be the result of increased predation on temporarily stunned fish.

These data probably overestimate the magnitude of entrainment in the jet mixing zone owing to (1) use of surface concentrations of larval fish; (2) rough approximations of the volume of the mixing zone and its rate of turnover under 3-unit, open-mode operation; and (3) step integration of the complex curve for numbers of fish in the meter-net samples versus time. The values of 11.99×10^9 and 5.8×10^9 given above probably represent the upper limit for the 91-day period. Based on limited data from samples taken at the 5m depth in the channel, lower limits would be approximately 60 percent of upper limits, or 7.2×10^9 and 3.5×10^9 respectively, given the same assumptions of operation, volume, and rate of turnover.

(c) Impingement - Young fish entering the intake forebay will be subjected to current velocities of up to 54 cm/s (1.8 ft/s). Those fish which are unable to withstand this current and which will not pass through the approximate 1-cm square (3/8 by 3/8 inch) mesh of the traveling screens, will be impinged. The literature on sustainable swimming speeds of fish is limited; moreover, published accounts often are not comparable in terms of experimental design and objectives of the study. The sustained swimming speed of young smallmouth bass (2.2 cm in length) has been estimated to be from 2 to 13 body lengths per second (3.6 to 30 cm/s) depending on acclimation temperature.[7] It is difficult to estimate the duration over which these speeds can be maintained since tests cited were continued for a maximum of only about 15 minutes. One-hour sustained swimming speeds for walleye and yellow perch larvae have been reported to approach maximum values of 5 cm/s for 1.6-cm fish.[8] Similar results with largemouth bass larvae have shown that 30-minute sustained swimming speeds were 4 to 5 body lengths per second (4 to 5 cm/s).[9] Assuming a commonly accepted value of 4 to 6 body lengths per second as a maximum sustained swimming speed for periods of 30 to 60 minutes, the intake velocity of 54 cm/s is likely to trap and expose to possible impingement most fish of less than 8 to 12 cm (3 to 4.5 inches) in length. Mechanical injury owing to impingement and the high velocity cleaning jets will result in high mortalities of fish so trapped.

However, experience at operating TVA steam plants indicate that the number and severity of fish captures on the traveling screens vary from plant to plant and from season to season. Shad minnow runs are normally experienced in the spring and fall, and the number of minnows captured on the screens varies from just a few to several thousand. Captured fish range up to 6 inches in length, but very few larger fish are captured on the screens. Occasionally, game fish are captured on the screens; however, this is not a common occurrence, and at some downriver plants no game fish have been noted on the screens.

Table 2.7-2 shows channel dimensions and water velocities in the channel and across the traveling screens for major TVA steam plants. The channel velocities were calculated using the cross-sectional area of the channel and assuming normal water levels. Calculations are based on all units of a plant being in operation. The screens at these plants have 3/8-inch openings, the same as at Browns Ferry.

(d) Condenser passage - Young fish which pass through the Browns Ferry intake screens will be subjected to a temperature increase of 13.9 deg C (25 deg F). Total duration of passage is estimated at from 7 to 11 minutes, assuming open-mode operation; of this, 5 to 9 minutes will be spent in heated water. Figure 2.7-2 gives estimates of the number of young fish which would have been subjected to condenser passage during the period noted in 1971. Integration of the areas under the curves O-3, H-3, and C-3 yields estimates of 12.5×10^9, 10.5×10^9, and 6.5×10^8 fish, respectively, for continuous 3-unit operation under open, helper, and closed modes, respectively. Mortality owing to condenser passage is presently considered to be a product of absolute temperature rise and duration of exposure to increased temperatures, but no data are available to establish limits on these parameters.[2] Data obtained at the Connecticut Yankee Atomic Power Plant showed no surviving warmwater fish larvae or juveniles at 35°C (95°F) immediately below the plant discharge.[10] Presumably these fish all passed through the condensers and were subject to a 12.5 deg C increase. Assuming that these data are extrapolable to the Browns Ferry plant and using available temperature records obtained at Wheeler Dam tailrace in 1971, nearly total mortality would have been experienced during the period from May 17 to the end of the sampling period. On the basis of the above estimates of numbers withdrawn, this would amount to a mortality of 11.8×10^9 fish under open-mode, 3-unit operation. Fish withdrawn before May 17 (amounting to 6.31×10^8) would have been subject to mortalities ranging from approximately 30 to 100 percent. Mortalities under helper- and closed-mode operation are expected to be 100 percent.

The assessment of condenser passage on larval fish must be made with the following limitations and considerations in mind:

1. Estimates are based on one year of sampling, comprising the 91-day period from April 27 through July 27, 1971; no estimates of yearly variation are available.
2. It was assumed that concentrations (and hence total numbers) of fish available to the plant intake were equal to those noted in the inshore-surface samples below the plant (TRM 293). Preliminary analysis of the upstream samples (TRM 298) indicates that the total numbers available here may in fact be higher, although the extreme peak concentration (see figures 2.7-1 and 2.7-2) may not have been reached. To the extent that this is true, total condenser passage may be underestimated. In addition, the data do not represent intake of species present as larvae before April 27.
3. It was assumed that all water taken in by the plant would come from the inshore area. Recent 3-dimensional model studies have verified this assumption at flows of 40,000 ft^3/s. The validity of this assumption for other flows is unknown.

4. The estimates of condenser passage assume continuous 3-unit operation by the specified mode only for the entire 91-day period observed in 1971. Actual passage would vary with changes in mode of operation and number of units employed.
5. It was assumed that concentrations of larval fish would be continuously available to the plant intake, i.e., the supply of fish to the intake would not be exhausted during the 91-day period of interest.
6. The data presently available do not allow estimation of the total population of young fish in the reservoir. Therefore, no definitive judgments of the significance to the reservoir of the estimated total losses are possible, beyond the comment that the exploitation of subadult age classes of fish is judged generally to be inadvisable where commercial and sport populations are concerned.

Under open-mode operation the larval fish will be returned to the reservoir and will be available as food to those organisms not requiring or selecting for live food. Fish withdrawn during helper-mode operation will presumably pass through the cooling towers; the degree to which these will serve as a food resource on being returned to the reservoir is unknown. Under closed-mode operation any fish withdrawn from the reservoir will constitute a total loss.

The significance of these losses to the fishery resource of the reservoir is not clear. Applying a survival coefficient of from 1×10^{-4} to 1.9×10^{-4} between the larval stage and recruitment to the adult population, operation of the plant (3-unit operation) would have in effect removed between 1.2×10^6 and 2.4×10^6 adults under open-mode; between 1.1×10^6 and 2.0×10^6 adults under helper-mode; and between 0.6×10^5 and 1.2×10^5 adults under closed-mode operation. Based on an estimated adult standing stock of 32.6×10^6 fish in Wheeler Reservoir, this reduction amounts to from 3.8 to 7.3 percent of the harvestable (adult) population under open-mode; from 3.2 to 6.1 percent under helper-mode; and from 0.2 to 0.4 percent under closed-mode operation.

Approximately 90 percent of these losses would be borne by gizzard and threadfin shad; it is estimated that 5 percent would be commercial and sport species and that the remainder would be other forage species.

The above calculations are based on the assumption that mortality caused by plant operations is additive to natural mortality. However, little is known regarding the mechanisms involved in establishing total mortality rates in fish populations. Mortality of young fish passing through the plant's cooling system is obviously density-dependent; natural mortality of the same fish may or may not be.[11,12] Whether the plant-induced mortality will be compensated for and, if so, to what extent is not known.

If compensation does not occur to any significant extent, several changes in the characteristics of the fishery resource may result. Decreased spawning stocks may result in lower production of young. Compensation for this has been shown to occur in some cases and not in others.[13] Thinning of the populations may lead to increased growth.[12,14] This would be advantageous in the case of commercial and sport species but disadvantageous in the case of the shads and other forage species. If commercial and sport species are adversely affected by noncompensated mortality, fishing success and therefore fishing mortality may be decreased.

The most important aspect of plant-induced mortality is likely to revolve around the effects of such mortality on shad and other forage species, and the resulting effects on species which rely on these forage species as a food source. The principal value of shad to the total fisheries resource is that of a prey species. Gizzard shad, because of their rapid growth rate, serve as forage only during their first year of life; threadfin shad grow more slowly and probably remain within the range of predation for most of their life span. Other forage species, i.e., small cyprinids, are preyed upon during their entire life span.

At present Wheeler Reservoir appears to support a surplus population of gizzard shad. The magnitude of this apparent surplus is unknown; it is difficult, therefore, to judge the significance of plant-induced mortality of this species in terms of the fishery resource of the reservoir. Reduction of the gizzard shad population may reduce the total amount of forage fish or other forage species may increase as a result. Any significant reduction of the total forage resource would have adverse effects on growth and production of desirable commercial and sport species, but a shift to a forage resource less dominated by gizzard shad would be beneficial, provided the other forage species can withstand the pressure of increased predation. On the balance, for the reservoir ecosystem, it is judged that local reductions of forage fishes will not affect reservoir food chains.

In summary, knowledge on entrainment cause and effect relations is limited, especially on the scale needed to judge the Browns Ferry impact questions. However, classic work with systems ecology and population dynamics, plus knowledge of the Tennessee River system, indicates that several phenomena are likely to occur. It is expected that condenser passage of larval fish will produce a profound local depression of larval populations which may be reflected locally in reduced numbers of juveniles and adult fishes. While several unknowns exist in terms of the total reservoir ecosystem, the impact of entrainment and condenser passage of larval fish is not expected to be significant, although immigration into depopulated areas will undoubtedly occur and may result in changes in relative abundance of some species.

The extent to which condenser passage of phytoplankton and zooplankton will adversely affect food supplies of young fish is unknown. Planktonic organisms, especially phytoplankton, copepods, and small cladocerans, which are killed during condenser passage, may still serve as a source of particulate food for young fish. Furthermore, it is conceivable that the concentration of particulate food will increase in the area below the discharge diffusers owing to withdrawal from the highly productive inshore waters. Young fish which survive entrainment in the jet mixing zone or condenser passage may have available conditions ideal for accelerated growth, i.e., elevated temperature and abundant food. If condenser-passed organisms are disintegrated, the area below the jet mixing zone may have a lower concentration of particulate food relative to that of the unaffected reservoir.

(3) Juveniles and adults - Effects of plant operations on juvenile and adult fish will be attributable to (1) impingement on intake screens, (2) discharge of heated water, (3) concentration or changes in abundance of food organisms below the discharge diffusers, and (4) effects of plant-induced mortality on eggs and young fish which may be transferable to subsequent age classes. This latter aspect has been discussed above. Discussion of items (1) through (3) appears in Volumes 2 and 3. The following represents a brief review of previous discussion and additional considerations.

Construction and operation of mechanical draft cooling towers has necessitated construction of a multiple-gate structure in the intake basin. The proposed design has three intake gates; the velocity through each of these gates is estimated to be 48 cm/s (1.6 ft/s), assuming equal hydraulic efficiency for all gates. Under these conditions juvenile and adult fish should have freedom of movement in and out of the intake basin, and there should be no significant losses due to impingement.

Possible changes in distribution of juvenile and adult fish owing to the thermal discharges are discussed in Volume 2 and are based largely on studies by TVA and others.[15] Significant increases in numbers of forage fish (including shad), largemouth bass, white bass, carp, and gar in a steam plant discharge cove relative to a control cove have been noted on Lake Norman.[1] Bluegill, black crappie, white crappie, and redhorse were found in significantly fewer numbers in the same comparison. The extent to which these differences are solely attributable to thermal preferences is not clear; dissolved oxygen concentrations, establishment and destruction of reservoir stratification, and currents may also have been factors.

Changes in distribution of fishes below the jet mixing zone will occur, owing to differing thermal preferenda among species. Although the extent of this occurrence and the particular species involved cannot now be positively identified, the changes should not constitute a significant adverse effect on fish species or their utilization by man.

Growth of juveniles and adults may be increased in those species having a positive preference for the thermally enriched zone owing to increased temperatures and to possible increased food concentration.

Concentrations and relative abundances of food organisms are likely to change in the area below the jet mixing zone for at least the following reasons:

1. When the intake water demand is satisfied by upstream overbank water, the organisms collected by the intake and dispersed to a more limited area of the old channel will result in a higher concentration within the jet mixing zone and downstream.

2. When riverflow exceeds diffuser discharge by less than a factor of 10, all riverflow is hydraulically demanded by the diffusers; thus, all planktonic organisms will pass over the diffusers and through the jet mixing zone in the old river channel.
3. The mixing of condenser-passed organisms with bypassing riverflow will change the total concentration per unit volume.
4. At riverflows less than ten times diffuser discharge, the physical changes produced by the diffuser demand will concentrate all planktonic organisms from the channel and left overbank upstream in the downstream old river channel where they will mix with the higher density of similar organisms dispersed from the right overbank by the diffuser.

Within this framework it is expected that zooplankton and phytoplankton will increase in abundance due to reproduction under potentially more favorable conditions resulting from increased temperatures and increased availability of nutrients. Larval fish will be concentrated physically due to hydraulic action of the diffusers.

Populations of benthic macroinvertebrates in the thermally enriched zone may be stimulated in growth and development. Some observers have noted that increased temperatures resulted in earlier emergence times of aquatic insects.[16] This may result in emergence when atmospheric conditions are not suitable for reproduction.

Although this food resource may be diminished, the adverse impacts on aquatic insects will not significantly decrease the total food resource available to fish because of the high productivity of Wheeler Reservoir. The extent to which increased thermal regimes accelerate rates of turnover, i.e., decrease generation times, in such organisms has not been thoroughly studied.

(4) Effects on sauger and smallmouth bass -

(a) Sauger - Sauger are neither commonly nor widely distributed in shallow overbank silted areas or in shallow embayments. They prefer and select areas of moderate current over rock, gravel, and mixed rubble in streams and tailraces or about reefs in deep water zones of lakes and reservoirs. They may move between or among the various types of habitat and substrate zones but apparently do not spend much time in the areas indicated as not being preferred zones. To our knowledge no reefs exist in the deep pool water above Wheeler Dam (TRM 275-287), and sauger are seldom caught there. Most netting and cove rotenone records indicate less than 1 percent of all fish captured by these methods are sauger. In the Wheeler Reservoir transition zone between pool and river channel (TRM 287-308) a few sauger are captured by netting or by electrofishing near heated water outfalls in the fall and winter. Nearly all efforts by sport fishermen are expended between TRM 308.0 and Guntersville Dam at TRM 384.8.

Sauger, especially maturing individuals, may be spread throughout the reservoir, but sampling indicates relatively few individuals downstream of the plant site. Water warmed 10 deg F above ambient in the late fall and early winter appears to attract sauger rather than act as a barrier to the movements.[17] When sauger begin moving on spawning or early winter runs, they generally move in such a way that by November or early December they concentrate near dams and near existing municipal, industrial, and steam plant thermal discharges. These concentrations are documented and are of such common occurrence that sauger fishermen in the Tennessee Valley begin concentrated efforts below the dams and in and about steam plant discharge basins in November and continue these efforts through April and even early May.

Spawning in suitable habitats occurs downstream of Guntersville Dam between 15 and 50 miles upstream of the nuclear plant. Most spawning occurs 40 to 50 miles upstream. Eggs adhere to the bottom substrates. The eggs hatch in 10 days to 2 weeks, and the fry drift downstream. The fry live on reserve food from the yolk sac for 5 to 7 days. Travel time from the spawning area to Browns Ferry varies due to separate and combined operation of Guntersville and Wheeler Dams. A simple or most common travel time is difficult to realistically compute because of dam operations and the complex topography. The average flows and velocities have been computed for a number of dam operation schedules. With all schedules the larvae could begin feeding by the time they reach the heated water area where zooplankton are expected to be more abundant in the heated water wedge. The thermal effect during March to May is expected to improve survival of larval fish which do not pass through the condensers because of lower stress resulting from an increased food supply.

(b) Smallmouth bass - Smallmouth bass are distributed in two distinct, well separated zones of Wheeler Reservoir, neither of which should experience much effect from the Browns Ferry Nuclear Plant's warmwater effluent. The upstream population appears to prefer the tailrace and river channel below Guntersville Dam (TRM 348.8-308.0). The downstream population is associated with the limestone bluffs from TRM 288.0 to Wheeler Dam, TRM 274.9, and Elk River, the main Wheeler Tributary, from mouth (TRM 284.5) to source. Elk River is principally a smallmouth bass-rock bass stream.

Smallmouth bass generally are not migratory; they are considered resident fish in an area. Usually they move locally in a vertical plane along shoreline features and show a seasonal response to temperature. Estimates of their exposure to thermal impact during the interim period can be made by examining the calculated linear temperature die-away curves for Browns Ferry shown in Appendix IV of this volume.

4. Effects on plankton, periphyton, and benthic fauna - Normal intake velocity through the 3/8-inch-square mesh traveling screens will be 1.8 ft/s. At this velocity most zooplankton and phytoplankton in the vicinity will be entrained.

In early summer *Hexagenia* leave their burrows at night and swim up into the water column where they drift with the current. Their cross-sectional diameter is less than the 3/8-inch by 3/8-inch mesh opening on the traveling screens. If caught crosswise, they appear to be flexible enough to bend and pass through the mesh openings.

Chaoborus and chironomid midges are capable of similar flexing. Spring populations of the predaceous crustacean plankter *Leptodora kindtii* would pass through the openings as would all other normal planktonic forms.

The effect on these organisms of passage through the condensers has been discussed in Volume 2, section 5.6, and Volume 3, section 3.3.

5. Effect of entrainment on dissolved oxygen - Essentially all plankton and fish larvae will be killed in passing through the plant cooling water system during periods of time when temperatures in the condensers exceed 95-100°F, and the organic waste load resulting will tend to depress concentrations of dissolved oxygen in the reservoir water downstream from the plant. To obtain an estimate of the maximum oxygen depression resulting from discharge of this organic waste load, it was assumed that the maximum concentrations of phytoplankton, zooplankton, and fish larvae found during all the biological sampling done to date in the vicinity of the Browns Ferry plant occurred in the intake water simultaneously, and furthermore, it was assumed that this simultaneous occurrence coincided with a period of time when the cooling water from all three generating units in the plant was being discharged through the diffusers while operating in the open mode. It was also assumed in making this estimate that the riverflow was 22,000 ft^3/s (minimum streamflow for 3-unit operation) and that a 5 degree rise, from 81°F to 86°F, was produced in the entire flow of the Tennessee River.

Based on the low streamflows the resulting extended time of water travel in lower Wheeler Reservoir dictates that the organic load would exert its ultimate biochemical oxygen demand in the lower end of the reservoir. In these calculations it was assumed that no reaeration or reoxygenation of the water would take place in the reservoir either through surface absorption of oxygen or by photosynthesis.

Based on all these very conservative assumptions--each of which tends to maximize the calculated DO depression--the greatest depression in concentration of dissolved oxygen was calculated to be about 0.2 milligrams per liter. Actual DO depression resulting from discharge of organic waste load is expected to be much less. As regards growth of heterotrophic slimes, such growths may result from organic enrichment, but unless DO concentrations are depressed to essentially zero for a significant percentage of the time, they do not result from DO depression.

As shown in figure 2.6-2 of this volume, the DO concentrations of the Wheeler Dam tailrace vary from a maximum of 12 mg/l in the winter to a minimum of about 5.5 mg/l in the summer. Only on infrequent occasions have concentrations less than 6 mg/l been noted. Thus, it is concluded that even when using conservative assumptions the organic waste load on the river produced by passing plankton and fish larvae through the plant cooling system will not result in the violation of water quality criteria or produce any significant water quality problems.

6. Monitoring programs - Concern has been expressed regarding the efficacy of the proposed postoperational monitoring program in determining effects of thermal discharges. The program, as described in Volume 2, is subject to the limitations as noted by TVA biologists and others.[18,2] Site studies are sensitive only to relatively large-scale changes in abundance and distribution of fishes owing to (1) the size of the body of water usually involved; (2) constraints placed on sampling methods by substrates, currents, and submerged topography; (3) limitations of time, money, and personnel; and (4) the dynamic nature (temporal and spatial) of populations of aquatic organisms. However, certain methods of data collection and analysis have been used with varying degrees of success; among these are the use of catch/effort statistics,[15] diversity indices,[19] and relative abundance. These methods will be employed, together with the results of meter-net sampling for young fish, population inventories, creel censuses, and tag-recapture studies, to provide a reasonably comprehensive overview of the fishery resource both before and after commencement of plant operations. The monitoring program for benthic fauna and plankton has been described in Volume 2 and discussed in Volume 3. All aspects of the monitoring program are under continuous reappraisal and other methods may be employed as they prove effective and feasible.

There is a critical need for studies to elucidate thermal effects at the level of individual organism or species. Two recently developed approaches appear promising and will, if feasible in this instance, be incorporated in the postoperational phase of monitoring. The first of these is the electrophoretic analysis of serum protein components in the blood of fishes. Changes in thermal regimes have been shown to change the amounts of various components. While all of the physiological implications of these changes are not known, implications involving antibody production and disease resistance have been drawn.[20]

The correlation of changes in growth rates with changes in thermal regimes has proved difficult if not impossible in natural systems when the usual methods of analysis are employed.[11] However, recent studies have shown that ratios of RNA to DNA content in fishes[21] and RNA concentrations in invertebrates[22] may be used as indicators of recent growth. These methods appear to have the advantage of being able to detect changes over short periods of time; furthermore, the results obtained in the field can be compared with results obtained under controlled conditions in the laboratory.

The environmental radiation monitoring program for the Browns Ferry Nuclear Plant is described in section 5.6 of Volume 2 and the locations of sampling sites are shown in figures 17 and 18 of the same volume.

At present TVA is reviewing its overall approach to environmental radiation monitoring in respect to the proposed guide for environmental monitoring now being prepared by the Environmental Protection Agency. TVA is in the process of moving one of the remote monitoring stations to the point of maximum predicted concentrations. This move will be completed prior to plant operation. TVA has considered including waterfowl in the environmental sampling program. It is known that most of the ducks hunted in north Alabama are migratory, moving great distances in the winter and spring. It would be almost impossible to identify the source of any radionuclides found in migratory waterfowl. TVA is presently sampling those vectors which will give the first indication of increased radioactivity levels in the environment. If increases are seen in those vectors being sampled, consideration will then be given to expanding the sampling program to include other biological specimens.

TVA is continuing to carry out a quality control program with the Environmental Protection Agency's Eastern Environmental Radiation Laboratory and the states of Alabama and Tennessee in which samples of soil, vegetation, milk, and air particulate filters are exchanged and analyzed to assure accuracy of the analytical program. This program will assure unbiased results of sample analyses.

Table 2.7-1

SPECIES OF FISH IDENTIFIED FROM METER-NET SAMPLING FOR YOUNG FISH

Gizzard shad	Dorsoma cepedianum
Threadfin shad	D. petenense
Freshwater drum	Aplodinotus grunniens
Skipjack herring	Alosa chrysochloris
Carp	Cyprinus carpio
Mooneye	Hiodon tergisus
Channel catfish	Ictalurus punctatus
Blue catfish	I. furcatus
Flathead catfish	Pylodictus olivaris
Crappie	Pomoxis spp.
White (and yellow?) bass	Morone spp.
Bluegill	Lepomis macrochirus
Longear sunfish	L. megalotis
Green sunfish	L. cyanellus
Gar	Lepisosteus (prob. osseus)
Emerald shiner	Notropis atherinoides
Logperch	Percina caprodes
Cyprinid	Pimephales (vigilax?)

Other than shad, freshwater drum and emerald shiner are most abundant

Table 2.7-2

INTAKE CHANNEL DIMENSIONS AND VELOCITIES

MAJOR STEAM PLANTS

Plant	Channel Length (feet)	Channel Width (feet)	Channel Velocity (ft/s)	Velocity Across Screens (ft/s)
Allen	-	-	1.0±	1.7
Bull Run	600	60	0.9	2.3
Colbert	100	300	1.0	2.1
Gallatin	2,700	70	1.5	1.8
John Sevier	1,000	150	1.0	2.0
Johnsonville	1,600	250	1.0	2.0
Kingston	4,500	60	2.0	2.0
Paradise	200	100	1.5±	2.0
Shawnee	2,000	120	2.0	2.0
Widows Creek A	1,100	150	1.0	1.7
Widows Creek B	200	50	1.0	2.5

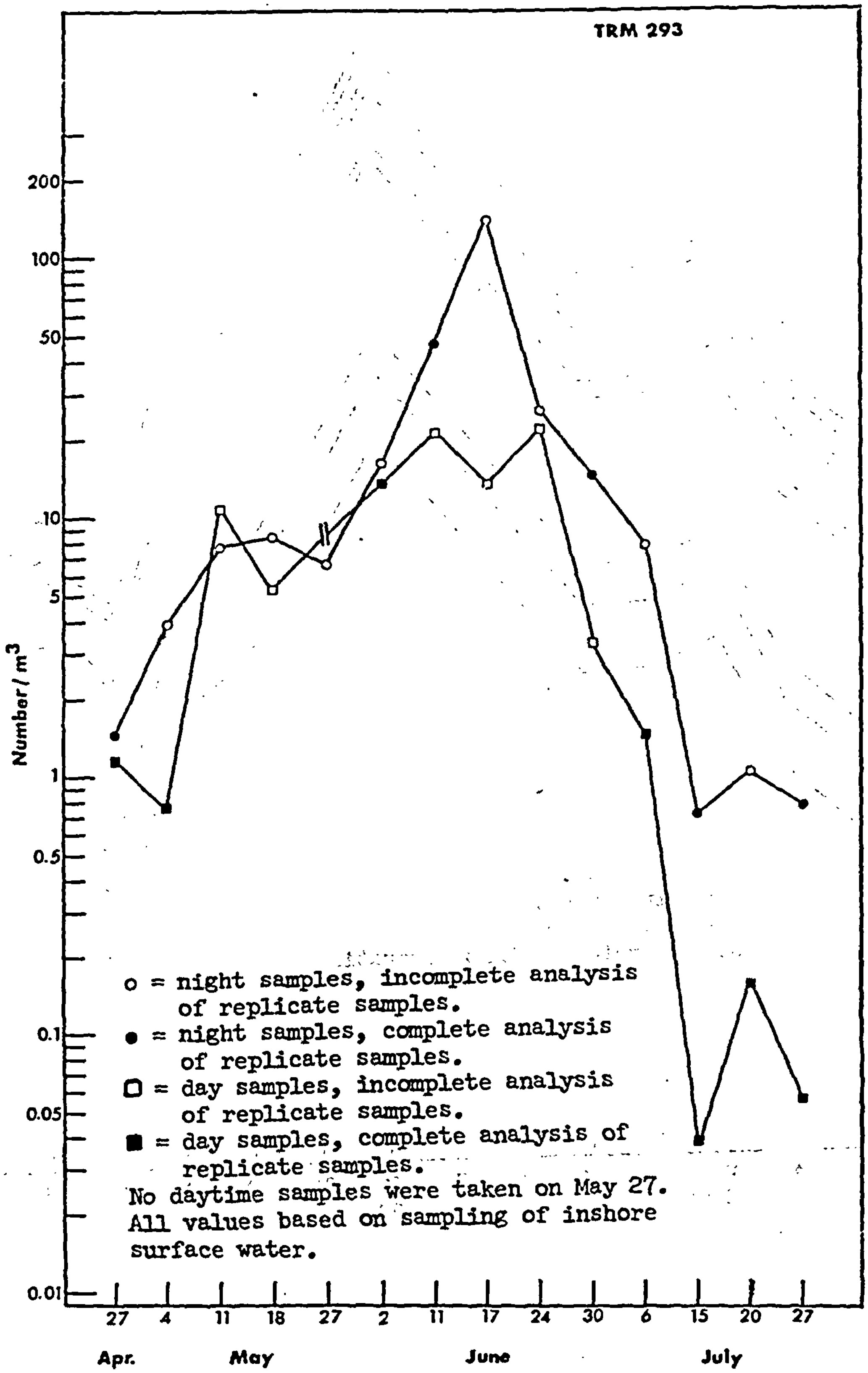

Figure 2.7-1
Catch of Young Fish by
Meter-net Sampling,
Vicinity of
BROWNS FERRY NUCLEAR STEAM PLANT

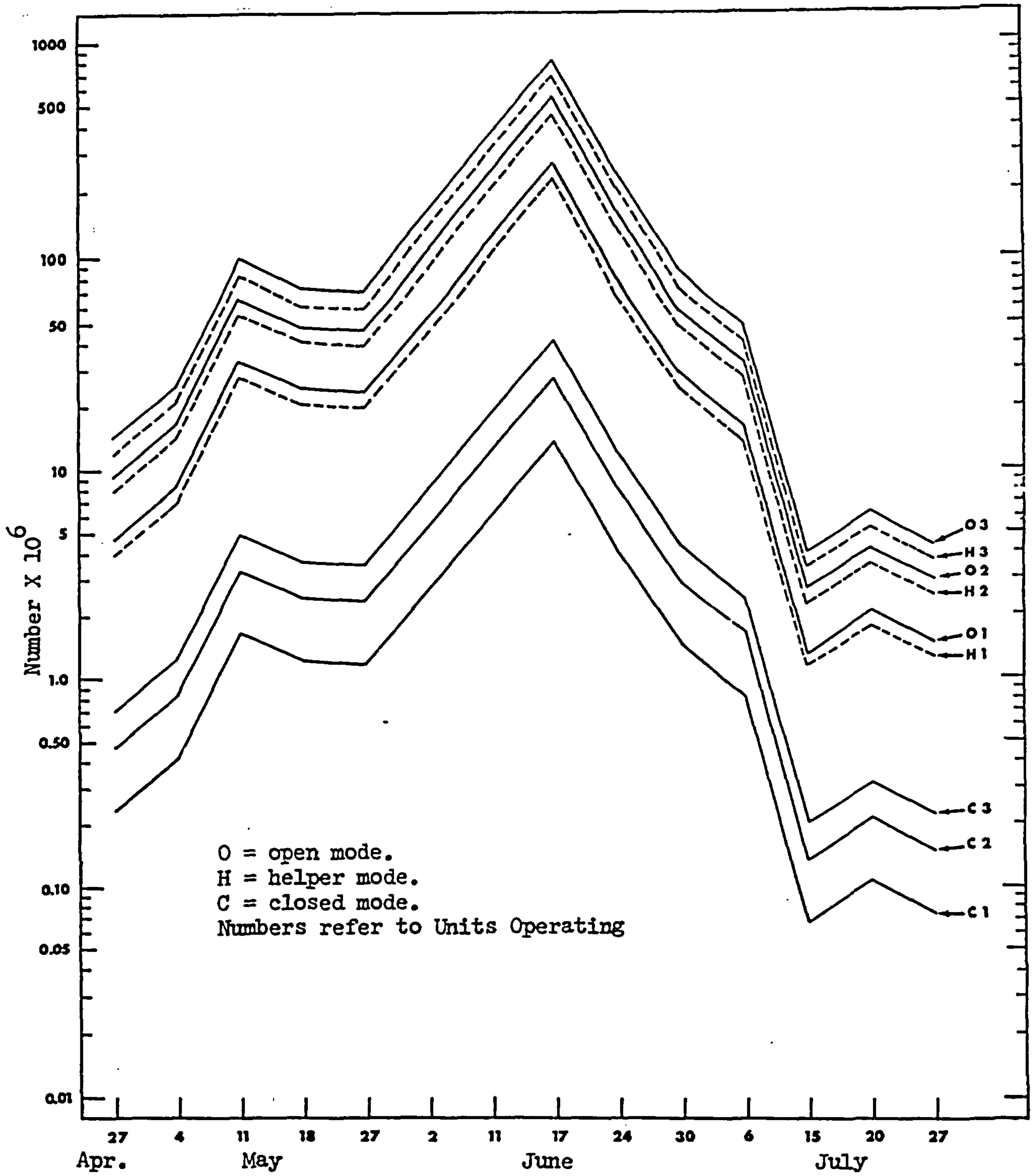

Figure 2.7-2

Estimated Daily Withdrawal and Passage of Young Fish through Condensers at BROWNS FERRY NUCLEAR STEAM PLANT

2.8 Other Impacts - The following potential environmental impact sources have been considered in addition to those discussed elsewhere in this statement.

1. Condenser cooling water intake - debris removal - The greatest portion of material collected on the travelling screens in the condenser cooling water intake structure consists of leaves, twigs, and other similar floating debris. Because of the nature of this material, it is nontoxic and generally compatible with the reservoir environment. Relatively small amounts are accumulated by the screens and very little benefit to the environment could be attributed to its collection. It is TVA's position that the cost of collection of the material would exceed the benefit it would yield to the environment.

2. Environmental effects of delays - As stated in Volume 3, adverse effects on the environment because of delays in operation of the plant will include increased emissions of particulates, sulfur dioxide, and other materials to the atmosphere at other plant sites. In addition, it was stated that delays would result in reduced system reliability, possibly resulting in the necessity to reduce loads in the TVA service area.

No specific health effects have been identified which can be attributed directly to either of these consequences. However, minimizing environmental impacts associated with the operation of power facilities and providing an adequate level of reliability in power supply minimizes the potential for any health effects which may exist.

3. Impacts on local geology - The construction and operation of the Browns Ferry plant will have no significant impact on the geology of the area.

No valuable mineral resources have been identified in the vicinity of the plant. Should resources such as gas or oil be discovered in the vicinity, the plant does not present an obstacle which would make these resources irretrievable. Data compiled[1] on wells in the vicinity show that because of the substantially high ground water profile in close proximity to the reservoir impacts on ground water usage are negligible.

4. Historical significance of site - Construction of the Browns Ferry plant required relocation of a cemetery and removal of a few structures. The relocation of the cemetery, done in 1966 and involving movement of over 50 graves, was done with considerable care and included a detailed investigation, a part of which was an exhaustive search for relatives of the interred. Complete records of all grave relocation activities were filed. The cemetery is not of large historical significance, and it has been estimated that a maximum of 2,000 visitors per year would be attracted to it. The structures which were torn down were not of major interest to preservationists or tourists.

Future construction will include preparation of the site for the mechanical draft cooling towers. This area has been investigated for historical and archaeological significance and none has been identified. However, should artifacts be discovered during any future construction operations, all appropriate agencies will be notified.

The Alabama Historical Commission has been consulted regarding these matters and has given its concurrence.

5. Impact of plant stack on air traffic - To properly disperse radioactive gaseous effluents a 600-foot stack has been incorporated into the design of the plant. Appropriate coordination with the Federal Aeronautics Administration has been made to assure that the stack would not be a hazard to aviation.

On December 15, 1966, TVA made application for a 325-foot stack to the Air Space Procedures Section, Air Traffic Branch, Federal Aeronautics Administration in Memphis, Tennessee. This application set forth the proposed location, height, painting, lighting, and other necessary information for evaluation by the FAA. Due to the addition of another generating unit and other considerations, an addendum to the original application containing the appropriate information for a 600-foot stack was filed on May 2, 1968. After review and coordination by the FAA, approval was issued on June 26, 1968, in the form of "Notice of Determination of No Hazard, Aeronautical Study No. MEM-OE-68-202."

3.0 AGENCY REVIEW COMMENTS

Responses to agency review comments are included in the topical discussions of this volume. The numbers noted in the margins of the agency comments indicate the sections in which the questions are answered.

Environmental Protection Agency
Department of Transportation
Alabama Development Office, State of Alabama
  Alabama Department of Conservation
  Alabama Historical Commission
  State of Alabama, Department of Public Health
  Comprehensive Health Department
  Bureau of Environmental Health
  Alabama Water Improvement Commission
  North Central Alabama Regional Planning and Development Commission
  Top of Alabama Regional Council of Governments
  Alabama Development Office Coordinator
Department of Commerce
Department of Agriculture
Department of Health, Education, and Welfare
Department of the Interior
Atomic Energy Commission
Federal Power Commission
Department of Housing and Urban Development
Department of the Army

AGENCY REVIEW COMMENTS KEYED TO TOPICAL DISCUSSION

Review Comment			Topical Discussion	
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	2	3.1-6	2.1.1	2.1-2
	3	3.1-6	2.1.2(1)	2.1-5
			2.1.2(2)	2.1-6
	4	3.1-6	2.1.2(3)(a)	2.1-10
			2.1.2(4)(a)	2.1-14
	5	3.1-6	2.1	2.1-1
			2.1.2(4)(b)	2.1-16
	6	3.1-6	2.1.1	2.1-2
	7	3.1-6	2.1.2(3)(b)	2.1-12
	8	3.1-6	2.1.3(3)(b)	2.1-26
	9	3.1-7	2.4	2.4-1
	10	3.1-7	2.4.2(1)	2.4-5
	11	3.1-8	2.4.1(1)(a)	2.4-2
	12	3.1-8	2.4.1(1)(b)	2.4-2
	13	3.1-9	2.4.1(2)	2.4-4
	14	3.1-9	2.4.2(2)	2.4-6
	15	3.1-9	2.4.1(2)	2.4-4
	16	3.1-9	2.4.2(2)	2.4-6
	17	3.1-10	2.1.2(2)	2.1-6
	18	3.1-10	2.1.2(2)	2.1-6
	19	3.1-11	2.4.3(3)	2.4-11
	20	3.1-11	2.4	2.4-13
	21	3.1-11	2.3.3	2.3-3
	22	3.1-11	2.4	2.4-13
	23	3.1-11	2.4	2.4-13
	24	3.1-11	2.4	2.4-13
	25	3.1-12	2.3	2.3-9
	26	3.1-13	2.5.3	2.5-10
	27	3.1-13	2.2	2.2-1
	28	3.1-13	2.5.2	2.5-10
	29	3.1-14	2.5.1(3)	2.5-5
			2.5.1(7)	2.5-9
	30	3.1-14	2.5.1(1)	2.5-2
	31	3.1-14	2.8.1	2.8-1
	32	3.1-15	2.7.6	2.7-26
	33	3.1-15	2.7.6	2.7-26
	34	3.1-16	2.6.5	2.6-7
	35	3.1-17	2.7.3(4)	2.7-21

AGENCY REVIEW COMMENTS KEYED TO TOPICAL DISCUSSION

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			2.7.3(2)	2.7-8
			2.7.3(2)(a)	2.7-9
			2.7.3(2)(d)	2.7-13
	37	3.1-18	2.7.5	2.7-25
	38	3.1-19	2.7.3(2)(c)	2.7-12
	39	3.1-19	2.7.5	2.7-25
	40	3.1-20	2.6.1	2.6-1
			2.6.3	2.6-3
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	42	3.1-20	2.6	A IV-9
	43	3.1-21	2.6.3	2.6-3
			2.6.7	2.6-18
	44	3.1-21	2.6.7	2.6-18
	45	3.1-21	2.6.3	2.6-3
	46	3.1-22	2.6.7	2.6-18
	47	3.1-22	2.6.6(3)(c)	2.6-15
	48	3.1-22	2.6.6(3)(e)	2.6-18
	49	3.1-22	2.6.6(3)(a)	2.6-13
	50	3.1-22	2.6.6(3)(b)	2.6-15
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	52	3.1-24	2.3.3	2.3-3
	53	3.1-24	2.3.3	2.3-3
	54	3.1-24	2.3.3	2.3-3
	55	3.1-25	2.3.3	2.3-3
	56	3.1-25	2.3.3	2.3-3
	57	3.1-26	2.5.5	2.5-12
	58	3.1-27	8.0	8.0-1
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DOT	60	3.2-1	2.8.5	2.8-3
DOT	61	3.2-3	2.2.2	2.2-7
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			2.7-3(1)(b)	2.7-6
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ALA	67	3.3-12	2.5.3	2.5-10
			2.5.4	2.5-12
ALA	68	3.3-12	2.5.4	2.5-12
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			2.3.3	2.3-3
DOA	70	3.5-3	2.7.6	2.7-26
DOA	71	3.5-4	2.7-6	2.7-26
DOA	72	3.5-4	2.4	2.4-1

AGENCY REVIEW COMMENTS KEYED TO TOPICAL DISCUSSION
(continued)

Review Comment			Topical Discussion	
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			2.1.1(3)	2.1-4
			2.1.2(2)	2.1-6
DOA	74	3.5-5	2.5-3	2.5-10
DOA	75	3.5-6	2.6.6(3)(c)	2.6-15
DHEW	76	3.6-2	2.8.2	2.8-1
DOI	77	3.7-1	2.8.3	2.8-2
DOI	78	3.7-1	2.6.7	2.6-18
DOI	79	3.7-2	2.6	A IV-3
DOI	80	3.7-2	2.3.3	2.3-3
DOI	81	3.7-3	6.0	6.0-1
			7.0	7.0-1
DOI	82	3.7-3	2.5.1	2.5-1
DOI	83	3.7-3	7.0	7.0-1
DOI	84	3.7-3	2.6.6	2.6-10
			2.6.6(3)(d)	2.6-17
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AEC	86	3.8-3	2.4.2(2)	2.4-6
AEC	87	3.8-3	2.4.3(2)	2.4-9
AEC	88	3.8-3	2.4.3(1)	2.4-8
AEC	89	3.8-3	2.4.3(2)	2.4-9
AEC	90	3.8-3	2.4.3(2)	2.4-9
AEC	91	3.8-3	2.7.6	2.7-26
AEC	92	3.8-3	2.3.3	2.3-3

ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

JAN 4 1972

OFFICE OF THE ADMINISTRATOR

Mr. Lynn Seeber
General Manager
Tennessee Valley Authority
Knoxville, Tennessee 378022

Dear Mr. Seeber:

We have reviewed the Draft Environmental Statement and Supplement for the Browns Ferry Nuclear Plant, Units 1, 2, and 3, and are pleased to provide you with the enclosed report which contains our comments. Our review was performed in accordance with the requirements placed on Federal agencies by the National Environmental Policy Act of 1969.

Our review of the impact statement revealed several deficiencies which made it impossible to verify all of the conclusions reached in the draft. These deficiencies are listed in the conclusions and are described fully in our enclosed review. Before a final review can be completed, we must have access to the additional information required.

On the basis of the information presented in the Draft Environmental Statement, we believe that the major potential environmental impact of the proposed operation of the Browns Ferry plant involves the release of significant quantities of waste heat to the Wheeler Reservoir. We understand that TVA intends to comply with the applicable water temperature standards; however, we do not believe that the plant, as presently designed for once-through cooling, will meet proposed water quality standards. We question the effectiveness and feasibility of the special control measures proposed; namely, stream-flow regulation and/or reducing power level.

We believe that TVA should describe in greater detail the proposed methods of stream-flow regulation and power generation that will be used during the initial period of plant operation in order to meet water quality standards. TVA should also make a definite commitment and outline plans, including timetables, for constructing auxiliary or alternate cooling systems required to insure compliance with proposed Federal and state standards. We would appreciate the opportunity to evaluate these plans before the final environmental impact statement is filed with the Council on Environmental Quality or before fuel loading operations commence. AEC has agreed to consult with EPA before issuing a partial operating license.

Page 2 - Mr. Lynn Seeber

Additional information on these issues and other comments are contained in the enclosed report. We would be pleased to discuss any of these comments. If we can assist you further in this matter, please let us know.

Sincerely yours,

Robert W. Fri
Deputy Administrator

Enclosure

EPA D-TVA-06018-23

ENVIRONMENTAL IMPACT STATEMENT COMMENTS

Browns Ferry Nuclear Plant Units 1, 2, and 3

ENVIRONMENTAL PROTECTION AGENCY
Washington, D.C. 20460

December 1971

TABLE OF CONTENTS

INTRODUCTION AND CONCLUSIONS

The Environmental Protection Agency has reviewed the draft environmental impact statement for the Browns Ferry Nuclear Plant, Units 1, 2, and 3, prepared by the Tennessee Valley Authority and issued on November 8, 1971.

The following are our major conclusions:

1. On the basis of the information provided in the draft environmental statement, it is not possible to support the conclusions presented in the statement. Additional information is needed on accident analyses, thermal effects, air quality, and solid waste disposal.

2. The plant cooling water system will not allow present and proposed water temperature standards to be met without additional control measures. The statement does not present the information needed to evaluate the compatibility of the proposed control measures with other streamflow and power generation requirements.

3. We suggest that TVA follow AEC guidance in cost/benefit analysis. Such guidance is being prepared by the AEC and is in the proposed rule making stage or in final draft form.

4. We commend TVA for the decision to employ extended radioactive waste treatment systems for both gaseous and liquid effluents. Additional information on the capacity of these proposed systems to handle the waste from all three reactor units should be made available.

2

RADIOLOGICAL ASPECTS

Transportation of Fuel and Solid Wastes

Some 350 truck shipments per year may be required to deliver fuel assemblies and remove spent fuel and radioactive solid wastes from the Browns Ferry site. The conclusion that there will be no undue hazard to the public or adverse environmental effect from potential transportation accidents should be supported by the following information:

2.1.1 a. the most probable shipping routes between the plant and the spent fuel reprocessing plant or waste burial ground;

2.1.1 b. the major cities or other population centers enroute;

2.1.2(1) 2.1.2(2) c. the estimated radionuclide inventory per fuel assembly at the time of shipment;

2.1.2(3)(a) 2.1.2(4)(a) d. the calculated maximum dose received by an individual as well as the integrated population dose;

2.1 2.1.2(4)(b) e. the estimated probabilities of accidents.

2.1.1 In estimating the population dose due to transportation accidents, it is more appropriate to use the maximum population density of any area through which the shipment must pass rather than the average population density for the entire route. 2.1.2(3)(b) The assumption of a 100-foot minimum approach may be valid only for normal conditions and may not be realistic in the event of a serious rail accident which could attract crowds.

2.1.3(3)(b) It is important to discuss the procedures and equipment employed to transfer the spent fuel shipping cask from the vehicle used for transport from the plant to the rail car used for shipment to the reprocessing plant. This is an off-site operation which increases the potential effect of accidents which may occur during or as a result of the transfer operation.

Waste Treatment and Effluent Discharge

2.4 The commitment of the Tennessee Valley Authority to employ extended radioactive waste treatment systems for both gaseous and liquid wastes is consistent with the need to reduce radioactive emissions to the lowest practicable level and is commended. Achievement of the lowest practicable effluent discharge requires effective administrative waste routing procedures as well as equipment installation. (We recommend that the TVA make every effort to establish procedures that will minimize radionuclide releases to the environment.)

2.4.2(1) Review of this facility indicated that additional capacity to treat high-conductivity liquid wastes was required. The proposed addition of evaporative treatment should provide sufficient capacity for routine effluents. The radionuclide reductions assumed for the operation of this equipment appear to be satisfactory and achievable in practice, providing there is no appreciable liquid carry-over in the evaporator. Recent experience with reactors of this type indicates that water leakage into the pressure suppression torus can produce appreciable volumes of contaminated liquid. The capability of the waste treatment system to handle this liquid should be discussed.

The proposed extended gaseous waste system will employ a hydrogen recombiner to reduce off-gas volume and six charcoal beds to retain noble-gas fission products; the decayed effluent will be discharged through a 600 foot stack. The stated holdup times of this system are 7.7 days for xenon radioisotopes and 16.5 hours for krypton isotopes. Based upon these retention times, the calculated reductions in gaseous effluent emission rates appear to be reasonable. It is estimated that the period of full-power reactor operation with only a 30-minute gaseous effluent holdup would be approximately nine months for Unit 1 and two months for Unit 2. These systems are expected to be operative prior to the startup of Unit 3.

We agree with the decision of the Tennessee Valley Authority to reduce potential off-site radiation doses; however, it is not clear that the proposed system represents selection of equipment to obtain the lowest practicable levels of discharge. Other boiling water reactor plants are installing up to eight charcoal beds for each unit, but TVA proposes to use six for three units. Insufficient information is provided on the gas volumes and flow rates in the proposed extended gaseous holdup system to indicate the basis for the proposed design to process the effluents from three reactors.

2.4.1(1)(a) Additional information on aging characteristics and degradation of the charcoal beds should be provided and periodic testing of the
2.4.1(1)(b) retention characteristics should be performed. Estimates of the buildup of radionuclides on the charcoal beds, particularly the particulates formed from noble gas precursors, should be provided and the consequences of their possible presence on the ultimate disposal of the charcoal should be discussed.

Discharges of radioactive materials to the environment are highly dependent on the integrity of the fuel cladding. The estimates of

2.4.1(2) annual discharges found in the environmental statement (Table 19) are based on cladding perforations existing in 0.8% of fuel rods. Similar estimates of releases (prior to evaporation and/or demineralization) are provided in Table 3.1-4 of the supplement to the environmental statement, but the associated annual dose estimates (Table 3.1-5 and 3.1-6) are based on 0.5% failed fuel. Similar design releases are also found in the reply to question 9.2 in supplement 15 to the final safety analysis report but 0.25% failed fuel is assumed. In addition to these estimates, a value of 0.2% failed fuel is assumed for estimating coolant radionuclide inventories for the accident evaluation. Although different values could be accepted for design purposes and for estimates of probable releases, insufficient information is provided on actual operating experience to substantiate any of these values.

Based on Dresden I operating experience, it would appear that

2.4.2(2) the routine liquid effluents from one reactor unit would correspond with that discussed in the environmental statement for three units without the additional demineralizers or evaporator. Estimates of gaseous radionuclide release rates prior to the operation of the extended

2.4.1(2) holdup system, when compared to those released by Dresden I, are also in disagreement by a similar factor. These discrepancies may be due to the applicant's estimate of fuel cladding defects and should be resolved.

Estimates of annual discharges for individual radionuclides in

2.4.2(2) liquid effluents differ from extrapolations based on a limited number of measurements at the Dresden plant. These differences may be partially due to reliance on theoretical decontamination efficiencies rather than on operating experience or due to differences in the design and operation of waste treatment systems between the two facilities. Existing information on specific radionuclide levels in the effluents from currently operating reactors is too limited to resolve these discrepancies. The radionuclides which may be underestimated are cesium-134, cesium-137, strontium-89, strontium-90, cobalt-58, and cobalt-60. Periodic analysis of the effluent as proposed by the Atomic Energy Commission should be employed to confirm the predicted values.

Information provided in the environmental statement supplement
2.1.2(2) (p. 2-14) indicates that the reactor coolant cleanup system sludge will have an average concentration of 8.7 curies per cubic foot while the final safety analysis report (section 9.3) indicates that the average concentration after a 60-day decay period will be 16 curies per cubic foot. It is not clear whether this reduction is due to an increased cooling time or to newer information. This difference appreciably affects the overall quantity of radioactive materials disposed of as solid waste for burial and should be discussed in greater detail.

The containers which will be used for shipment of high-level solid waste have been changed from 55 gallon drums (holding approximately
2.1.2(2) 7 cubic feet) as stated in the final safety analysis report (section 9.3) and the draft environmental statement (p. 5-46) to casks holding approximately 150 cubic feet (p. 2-14 of the environmental statement supplement). These casks are recoverable and the container used for the

burial operation is not specified or described. The integrity of this latter container is important to prevent radionuclide release from spent demineralizer resins and other materials as a result of leaching or other processes. A description of the burial container and the procedures for transferring wastes between the shipping and burial containers should be described.

Dose Assessment

The models and assumptions used to determine the radiation exposure to the surrounding population due to normal operation should be described or referenced to the appropriate sections of the final
2.4.3(3) safety analysis report. In particular, it is not clear whether the following sources of exposure were considered:

a. direct external radiation exposure from the reactor and turbine buildings;

2.4 b. radionuclides released to the atmosphere as a result of containment venting;

2.3.3 c. potential releases from coolant leakage through the reactor heat removal system;

2.4 d. radionuclides released from the condenser vacuum pumps during startup when the condenser vacuum must be re-established;

2.4 e. gland-seal leakage;

2.4 f. auxiliary building ventilation system.

Because of the addition of extended radioactive waste treatment systems which should significantly reduce the normal sources of effluents, these usually minor sources of radiation exposure may become of primary importance in determining the ability of this facility to meet the proposed discharge criteria of the Atomic Energy Commission.

Table 2.3-2 of the environmental statement supplement indicates that the total integrated whole body dose at the site boundary for
2.3 40-year operation of three units with 0.5% failed fuel is 233 millirems (mrem). The same table indicates that operation with one unit having 1% failed fuel and two units with 0.5% failed fuel would result in an annual dose of 3.7 mrem. This would be equivalent to 148 mrem over 40 years. Because the percentage of failed fuel is higher in the latter case, it is not clear why the associated dose estimate is lower. This discrepancy should be resolved.

NON-RADIOACTIVE WASTES

The draft environmental statement indicates (p. 9-1) that about 2 million gallons of fuel oil will be burned per year for the operation

2.5.3 of auxiliary boilers and generators. Assuming that low sulfur (0.2%) fuel oil will be burned, this source could produce the following effluents:

Particulates	8 tons/year
Sulfur oxides	32 tons/year
Carbon monoxide	0.04 tons/year
Hydrocarbons	5 tons/year
Nitrogen oxides	105 tons/year

The impact of these releases on regional air quality should be discussed.

It is suggested that consideration be given to the quantity of ozone produced by transmission facilities, especially the 500 kV lines,

2.2 and the related impact on the environment as outlined in recent National Ambient Air Quality Standards for oxidants. The technical literature since the late 1950's contains much information on the effects of ozone on animal and human tissues and the similarity of ozone damage to that of ionizing radiation in producing chromosome aberrations. Direct extension of these animal data to the human case (with the concurrent possibility of considerable error) indicates that presently permitted industrial ozone exposure limits (up to 0.1 ppm or 4 ppm hr/week for a 40 hour work week) would be expected to result in break frequencies that are orders of magnitude greater than those resulting from permitted radiation exposure.

Sanitary waste treatment utilizing two parallel extended aeration

2.5.2 plants with effluent chlorination appears adequate during the

construction period. However, during plant operation when only operating personnel and visitors are contributing wastes, underloading of the facility (even with one unit out of service) may result in inadequate treatment of the wastes. This possibility should be considered. Consideration should also be given to providing organic
2.5.1(3) waste treatment, in addition to filtration, of detergent (equipment
2.5.1(7) cleaning and decontaminating, laundry, shower, handwash, etc.) and ammonia wastes.

Procedures for handling and treating chemical wastes as described
2.5.1(1) in the environmental statement (section 5.4) are generally adequate. Sludge from the water treatment plant should not be discharged to the river but should be disposed of by landfill or some other acceptable method. Material removed from the moving screens on the condenser
2.8.1 cooling water intake should not be discharged to the reservoir. Estimates of this discharge should be provided.

MONITORING AND SURVEILLANCE

2.7.6 The applicant's preoperational and operational radiation monitoring programs appear to be generally adequate in terms of scope, sample locations, sampling frequency, media sampled, and types of analyses performed. The maximum concentrations of iodine and particulates are predicted to occur at 2200 meters within the northwest sector which also contains the largest population group within two miles of the site. Therefore, consideration should be given to the relocation of a monitoring station to this area.

2.5.3 Although background sampling has been conducted in the vicinity for several years, there is no mention of current air quality in the area. The TVA air quality monitoring program should be extended to cover the Browns Ferry site so that contributions of the emissions of the oil-fired generators and boilers to the over-all air quality of the region can be assessed.

2.7.6 Whether changes in the population structure of aquatic biota can be detected by the proposed ecological monitoring programs is highly questionable. Experience has shown that drastic changes in the population structure, in the order of 25 to 50 percent, are required before current census techniques can detect population changes in reservoirs of this size; therefore, it is unlikely that monitoring programs will detect other than gross changes in the reservoir populations.

THERMAL EFFECTS

Waste heat will be removed by a condenser cooling water flow of 1,890,000 gallons per minute taken from Wheeler Reservoir. The water

2.6.5 will undergo a 25°F temperature rise during passage through the steam condenser. The design thermal criteria for the Browns Ferry Facility are based on the original Alabama Standard of 93°F maximum and a maximum rise of 10°F over ambient, which were excepted from approval by EPA predecessor agencies. Accordingly, no supplemental cooling is provided and the heated condenser water is discharged directly to Wheeler Reservoir through a diffuser system designed to provide rapid mixing of the heated condenser water with water in the reservoir. However, it is anticipated that Water Quality Standards for the Tennessee River in Alabama when promulgated by the Administrator of EPA, will provide for a maximum temperature limit of 86°F with a 5°F maximum rise criterion.

Table 3.2-1 of the supplement indicates that the facility, as presently designed, will exceed existing thermal standards during critical periods of water temperature and flow. Anticipated thermal standards will be exceeded with greater frequency. It appears, therefore, that some type of auxiliary cooling facilities will be necessary, at least for critical periods.

The supplement states (pp. 3-89, 3-90) that TVA will comply with whatever thermal standards are ultimately adopted and, until any needed auxiliary cooling facilities can be provided, will operate the Browns Ferry plant and regulate the flow of water through Wheeler Reservoir so as to meet applicable thermal standards. It is not clear from the information provided in the statement that these proposed actions would be compatible with other power generation and streamflow requirements.

Biological Effects

Although we recognize that other agencies will provide specific comments relative to the effects of thermal discharges on important

2.7.3(4) aquatic species, EPA reviewers have identified general areas of concern.

During the period from March through May most of the important species in the reservoir will spawn. Only minor temperature rises can be tolerated by eggs that are incubating. The National Technical Advisory Committee on Water Quality Criteria in 1968 recommended provisional maximum temperatures compatible with the well-being of various species of fish and associated biota. Based on these recommendations, it appears that the sauger and small-mouth bass would be adversely affected by the thermal discharge resulting from the proposed once-through cooling system. Other game fish could also be at a disadvantage in their competition with more thermally tolerant species.

Sauger, white bass, and shad (grizzard and threadfin), three important species of fish in Wheeler Reservoir, move upstream into headwater areas and tributaries to spawn. It is questionable whether these species can move through a thermal barrier of up to 10°F above ambient without experiencing a thermal shock. Both shad and white bass move upstream to spawn in April when, according to data presented (p. 5-22 of the statement), the temperature for a distance of two miles downstream could be raised as much as 8.1°F above ambient. Also, based on the historic low flow of 10,000 cfs, temperature increases four miles downstream could be as high as 10-[illegible]°F over ambient. It should be noted that the two species of shad found in Wheeler Reservoir are particularly susceptible to temperature fluctuations.

2.7.3(1)(b) 2.7.3(2) 2.7.3(2)(a) 2.7.3(2)(d) Spawning, egg development, and egg hatching under undisturbed conditions are synchronized with the availability of food for the developing fry and fingerlings. Early hatching as a result of elevated temperatures will probably result in starvation and high mortality of fry, particularly of nest-building species such as large-mouth and small-mouth bass, crappie, and sunfish that spawn in the shallow over-bank areas.

Wheeler Reservoir has been recognized as a reasonably mature aquatic system and has probably reached an equilibrium in terms of total biomass.
2.7.5 Biomass within given food chains may also have reached equilibrium although the abundance of certain species may fluctuate widely. Thermal enrichment, within certain limits, may increase the total biomass. The increased temperature will also reduce the water's capacity for absorbing oxygen and increase the biological activity which will approximately double for each 10°F temperature rise. The combined effects of lower dissolved oxygen capacity, increased biomass, and increased respiration will be most severe in early morning just before sunrise when the dissolved oxygen concentration is at its daily minimum.

The Alabama water quality standards for interstate waters specify that the dissolved oxygen concentration of Wheeler Reservoir and waters protected for fish and wildlife shall be at or above 4 mg/l at all times. EPA has proposed that Alabama adopt somewhat more restrictive criteria (minimum of 5 mg/l) and these are under negotiation. The environmental impact statement should discuss the effect of elevated temperatures and oxygen depletion on the aquatic biota in Wheeler Reservoir and on the ability of the reservoir to meet water quality standards after the facility reaches full operation.

Power plant cooling system intake structures and travelling 2.7.3(2)(c) screens can have a significant adverse effect on fish and other aquatic life. An evaluation of these effects at the Browns Ferry plant is not presented.

The high intake velocity of the cooling water may sweep in plankton and fish larvae and then expose them to a thermal shock

2.7.5 of 25°F. Most of these plankton and larvae will be killed and add to the organic load downstream. If the dissolved oxygen concentration decreases sufficiently, heterotrophic slime growth could be stimulated. This might be a source of taste and odor problems for public water supplies downstream, especially during summer low-flow and high temperature conditions. This situation should be discussed.

It is not always possible to predict accurately biological changes as a result of entrainment of the plankton population. The reservoir is currently highly productive, and it is conceivable that the kill of plankton through entrainment in the plant cooling water might have a beneficial effect in reducing the productivity of the reservoir, thereby also reducing the algal blooms.

Thermal Modeling

The estimates of the number of days that thermal criteria would
2.6.1
2.6.3
have been equaled or exceeded are low for several reasons:

a) Average daily releases at Wheeler Dam were used. Flow at the site is subject to variations due to hydroelectric generation at both Wheeler and Guntersville Stations, and periods of low or no flow may exist for varying periods of each day.

b) Temperatures from Wheeler Dam were used. These temperatures will tend to be below average for the water body during periods of stratification in the reservoir.

c) Proposed thermal criteria include maximum values for each month -- from a high of 86°F in the summer to a low of 51°F in January and February.

d) Figure 3.2-6 shows the heat wedge moving upstream above the
2.6 plant intake area during the low flow conditions ($Q_r < 40{,}000$ cfs). Stream flow data for water years 1960-1964 indicated an average flow of about 32,000 cfs during summer months. This means that heat will be recycled through the plant which will result in a heat build up in the reservoir between the plant intake and outlet points.

e) Downstream surface temperature calculations are developed from
2.6 equilibrium temperatures and exchange coefficients based on monthly average meteorological data. While this provides some indication of downstream cooling trends, similar projections should be developed under both high and low flow conditions to estimate the distances from the discharge required to dissipate the heat load added to the river.

Equilibrium temperatures and exchange coefficients for critical weekly meteorological conditions should be utilized in such calculations.

Discussions of thermal characteristics of the reservoir and associated environmental effects presented in the statement and
2.6.3
2.6.7 supplement are generally based on steady-state physical modeling. However, the hydraulics and flow patterns of Wheeler Reservoir are presently controlled by the operations of the Guntersville and Wheeler Hydroelectric Stations. It would appear that steady-state conditions are seldom achieved and that periods of low or no flow probably exist frequently with varying duration. No information is presented on frequency and duration of these low or no flow occurrences, or for the resultant temperature patterns in the reservoir. Therefore, it is difficult to completely assess the associated thermal and biological effects of Brown Ferry discharges.

A minimal total river flow of 33,000 cfs is required to meet a 5°F rise criterion for three-unit operation assuming complete
2.6.7 mixing in the river. However, stratification, should it occur, will prevent total mixing unless flows are very much greater than 40,000 cfs. The estimated frequency and duration of flows at or below 33,000 cfs should be presented.

2.6.3 Temperature data for the period 1938 through 1943, summarized in

Table 12, do not provide adequate background temperature data for evaluation. Data from 1966 and 1967, as well as other available temperature data, should be included. Statistical evaluation of the 1966
2.6.7 through 1970 temperature data from Wheeler Dam also should be provided.

While the statement considers the interaction of all three Browns Ferry units, it does not provide information on possible thermal interactions between Browns Ferry and other TVA stations. Such information in the final environmental impact statement would allow a better understanding of the thermal interactions between existing power plants on the river. Estimates of plant load factors and seasonal demand curves in various future years should be included.

Alternative Cooling Methods

The evaluation of cooling towers and other alternatives for meeting
2.6.6(3)(c) thermal standards presented in the supplement would be improved if the following environmental considerations were included:

a) Upland locations for cooling towers in order to minimize siltation and further damage to the shoreline areas;

b) Diapers or other control techniques to minimize siltation during any future construction;

2.6.6(3)(e) c) Specific noise levels for mechanical draft cooling towers;

2.6.6(3)(a) d) The effects of diminished cooling water discharge on the concentrations of radioactive and chemical waste releases;

e) Supportive information on the techniques for minimizing
2.6.6(3)(b) plume drift from cooling tower operation.

COST/BENEFIT EVALUATION AND ANALYSIS OF ALTERNATIVES

8.0 The quantification of damage to the environment from a proposed or actual action is presently a relatively inexact science. Subtle changes in the surrounding ecosystems may not be readily recognized, and the conversion of a potential or real environmental effect into a dollar value is often a subjective judgement. Yet, there are techniques to quantify certain aspects of a facility's impact which can be related to a monetary value. Applicable techniques have been described in a recent draft guide issued by the Atomic Energy Commission. To this extent, a cost/benefit analysis should be provided. Effort already has been provided in the draft environmental statement supplement to quantify the costs of certain alternative radioactive waste treatment systems and cooling systems.

ABNORMAL SITUATIONS

Although TVA has addressed the possible consequences of postulated accidents at the Browns Ferry plant which could release radioactive
2.3.3 materials to the environment, the probabilities of occurrence of these accidents have not been adequately discussed. Consideration must be given to quantifying these probabilities, where possible, because the expected environmental risk due to potential accidental radionuclide releases is determined by the consequence of the release and the associated probability of occurrence. For the less severe accidents, the probability might be estimated by combining the observed probabilities of the component events as obtained from operating experience. In the case of the more serious accidents, where there is no applicable experience, reliability analysis could be employed to estimate the probability of occurrence.

Class 1 accidents are almost certain to occur and, in the case of volatile fission products which will ultimately be purged to the atmos-
2.3.3 phere, the consequences can be considered trivial only if an upper limit on the quantity of radioactive material involved is specified. The consequences of a class 9 accident are serious enough that probability-of-occurrence estimates should be investigated to strengthen the assumption that the expected environmental impact is negligible.

There appear to be inconsistencies between the assumptions employed for the estimation of radiation doses from potential accidents in the
2.3.3 final safety analysis report and the draft environmental statement supplement. The assumptions and models used for accident analysis

should be referenced to the applicable portions of the safety analysis report or otherwise described. Among the discrepancies which should be resolved are the following:

a. An iodine partition factor of 10,000 is assumed in the draft environmental statement for the control rod drop accident; in the final safety analysis report (Table 14.9-2) a value of 100 is assumed.

2.3.3 b. A value of 0.2% for the number of fuel rods which have defective cladding is used to predict the coolant radionuclide inventory for accident evaluations. This value is less than the value of 0.5% assumed for the estimation of effluents under normal conditions.

2.3.3 c. The adverse meteorological conditions assumed in the draft environmental statement supplement appear to produce radiation doses which differ by only a factor of seven or eight from dose estimates calculated using annual average meteorological conditions. The use of the most limiting meteorological conditions for both annual average and short-term dispersion indicates that this ratio should be greater than 100. The assumptions used for the adverse condition should be explicitly stated.

The list of agencies consulted by TVA in the preparation of an emergency plan for both on-site and transportation accidents indicates that TVA has consulted the appropriate Federal, state, and local agencies required to implement protective action in the event of a radiological emergency. It is important that the final emergency plan be approved by the participating state agencies prior to initial fuel loading.

2.5.5 Storage and transportation methods and procedures to prevent the contents or a ruptured tank or accidental leakage or spillage of oil or other hazardous materials from reaching surface watercourses should be presented. Discussions should include an analysis of the possibility and probable quantities of materials which could be discharged due to earthquake, flood, tornado, plant malfunction, human error, or other abnormal occurrences.

8.0 GENERAL DEVELOPMENT IMPLICATIONS

As a result of the additional electrical power provided by this plant it is anticipated that there will be increased population and industrial growth in this region. This growth, should it occur, will place additional demands on the available water supply and may contribute to air and water quality degradation and other environmental problems.

TVA, as a regional planning agency with considerable experience and knowledge on the relationship between social and natural systems, should take steps to help develop, through interaction with municipal, state, and Federal agencies, a land and water use plan for the region. This plan should be designed to achieve a balance between population and resource use of the region which will permit a high standard of living and a quality environment.

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

MAILING ADDRESS:
U.S. COAST GUARD (WS)
400 SEVENTH STREET SW.
WASHINGTON, D.C. 20590
PHONE: 202 426-2262

27 AUG 1971

Dr. F. E. Gartrell
Director of Environmental
Research and Development
Tennessee Valley Authority
Chattanooga, Tennessee 37401

Dear Dr. Gartrell:

This is in response to your letter of 15 July 1971 addressed to Mr. Herbert F. DeSimone, Assistant Secretary for Environment and Urban Systems, Department of Transportation, concerning the draft environmental impact statement for the Browns Ferry Nuclear Plant, Units 1, 2 and 3, located on the North Shore of Wheeler Reservoir on the Tennessee River, Limestone County, Alabama. 3.2

2:6(A-IV-2) The concerned operating administrations and staff of the Department of Transportation have reviewed the draft statement. It is the determination of this Department that the impact of this project upon transportation is minimal. Page 5-5 of the draft statement states that navigation channel markers will indicate the location of safe water depths over the diffuser piping. Since the U. S. Coast Guard is charged with the responsibility for installation, maintenance and operation of aids to navigation upon the navigable waters and in view of the lack of an indication in the draft statement of any coordination with the Coast Guard on this aspect of the project, it is requested that this matter be taken up with the Commander, 8th Coast Guard District in New Orleans, Louisiana.

2.8.5 Figure 4 under the list of figures shows the artist's concept of the Browns Ferry Nuclear Facility. A large stack is depicted. Nowhere in the report is there an indication of the height of this stack and it may possibly be a hazard to air navigation and should be discussed with the Federal Aviation Administration Regional Office in Atlanta, Georgia. Page 7-4 of the draft statement discusses future alternatives and the possible use of cooling towers. This Department would have some concern should cooling towers be planned, especially as it concerns air navigation hazard (height) and possible fog and icing of highways and bridges. It is assumed that should cooling towers be seriously considered in the future, the environmental impact statement will address itself to these possible adverse effects.

This Department recommends completion of the project. The environmental impact statement appears to address itself to those possible problem areas that may represent a concern to the Department of Transportation.

The opportunity to review and comment on the draft environmental impact statement for the Browns Ferry Nuclear Plant, Units 1, 2 and 3 is appreciated.

Sincerely,

W. M. BENKERT
Captain, U. S. Coast Guard
Acting Chief, Office of Marine
Environment and Systems

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

MAILING ADDRESS:
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WASHINGTON, D.C. 20590
PHONE: (202) 426-2262

14 December 1971

Dr. F. E. Gartrell
Director of Environmental
Research and Development
Tennessee Valley Authority
Chattanooga, Tennessee 37401

Dear Dr. Gartrell:

This is in response to your letter of 8 November 1971 addressed to Mr. Herbert F. DeSimone, Assistant Secretary for Environment and Urban Systems concerning the supplement and additions to the draft environmental impact statement of the Browns Ferry Nuclear Plant Units 1, 2 and 3 located on the north shore of Wheeler Reservoir on the Tennessee River, Limestone County, Alabama. The original draft statement for this project was previously reviewed by the Department of Transportation as indicated in our letter to you of 27 August 1971.

The supplement and additions to the draft statement for the Browns Ferry Nuclear Project were reviewed by both the staff and concerned operating administrations of the Department of Transportation.

The following is noted from the review of the Federal Railroad Administration:

2.2.2 "We are pleased to see the environmental impact of new transmission lines discussed in such detail. However, the question of inductive coupling or direct faulting with the signal and communication lines of railroads is not addressed. We would suggest that the statement reflect that there are neither railroads involved or that satisfactory protection has been mutually agreed upon with any railroad company involved."

Noted in the review of the Department's Office of Hazardous Materials was the following:

> "Although we have no specific comment on the supplement or the additions, we do note, however, that the supplement discusses the transport of nuclear materials in significantly greater detail than any of the other environmental impact statements which have been seen previously. While it is difficult to evaluate the content of the statement relative to transport, the supplement is not inconsistent with existing AEC and DOT regulatory requirements or industry practices."

The supplement and additions also address themselves to those transportation concerns which were pointed out to you in our letter of 27 August 1971.

The Department of Transportation concurs in the project and recommends early completion.

The opportunity to review and comment on the supplement and additions to the draft environmental impact statement on the Browns Ferry Nuclear Project Units 1, 2 and 3 is appreciated.

Sincerely,

J M Austin

J. M. AUSTIN
Deputy Chief, Office of Marine
Environment and Systems
By direction of the Commandant

STATE OF ALABAMA

ALABAMA DEVELOPMENT OFFICE

R. C. "RED" BAMBERG, Director

GEORGE C. WALLACE
Governor

September 8, 1971

9/10/71
CC: M. I. Foster
A. J. Gray
R. H. Marquis, 629 NSB-K
T. H. Ripley, FOR, Norris
F. E. Gartrell, 720 EB-C, (original)
C. M. Stephenson
J. E. Watson, 818 PRB-C
ND&RS Files, 604 AB

TO: Mr. M. I. Foster, Director
Division of Navigation Development & Regional Studies
Tennessee Valley Authority
Knoxville, Tennessee 37902

H. P. K. Walmsley

FROM: H. P. K. Walmsley
Administrator
Grant and Reference Services
State Clearinghouse

P-4 Browns Ferry Nuclear Plant
E-11 Units 1, 2 & 3

3.3

SUBJECT: DRAFT ENVIRONMENTAL IMPACT STATEMENT

Applicant: Tennessee Valley Authority

Project: Draft Environmental Statement – Brown's Ferry Nuclear Plant Units 1, 2 & 3

State Clearinghouse Control Number: ADO-84-71

The Draft Environmental Impact Statement for the above project is in the process of review by the appropriate State agencies in accordance with Office of Management and Budget Circular A-95, Revised.

The comments received to date from the reviewing agencies are attached. Additional comments will be forwarded as they are received.

Please contact us if we may be of further assistance. Correspondence regarding this proposal should refer to the assigned Clearinghouse Number.

Attachments

A-95/05: DE

STATE OF ALABAMA

ALABAMA DEVELOPMENT OFFICE
R. C. "RED" BAMBERG, Director

GEORGE C. WALLACE
Governor

September 24, 1971

TO: Mr. M. I. Foster, Director
Division of Navigation Development & Regional Studies
Tennessee Valley Authority
Knoxville, Tennessee 37902

FROM: H. P. K. Walmsley
Administrator
Grant and Reference Services
State Clearinghouse

P-4 Browns Ferry Nuclear Plt. Units 1, 2, & 3
E-11

SUBJECT: DRAFT ENVIRONMENTAL IMPACT STATEMENT

Applicant: Tennessee Valley Authority

Project: Draft Environmental Impact Statement Browns Ferry Nuclear Plant Units (1), (2) and (3)

State Clearinghouse Control Number: ADO-84-71

The Draft Environmental Impact Statement for the above project has been reviewed by the appropriate State agencies in accordance with Office of Management and Budget Circular A-95, Revised.

All of the comments received from the reviewing agencies have now been forwarded for your consideration.

Please contact us if we may be of further assistance. Correspondence regarding this proposal should refer to the assigned Clearinghouse Number.

Attachments

A-95/05:DE
cc: Department of Conservation
Historical Commission
Comprehensive Health Department
Bureau of Environmental Health
Mr. Gary Volketz - North Central Alabama Regional Planning & Development Commission
Mr. Dean Matthews - Top of Alabama Regional Council of Local Governments
Mr. Richard Dowdy - Alabama Development Office Coordinator
Mr. Ed Hudspeth - Alabama Development Office Coordinator

REQUEST FOR REVIEW OF PROJECT NOTIFICATION

TO:

Mr. Reynolds Thrasher
Conservation Department

CH Number ADO-84-71

Applicant Tennessee Valley Authority

Program Environmental Impact Statement
Browns Ferry Nuclear Plant — Units 1,2 & 3

DATE: August 3, 1971

Return Prior to: August 16, 1971
Date

Please review the attached notification of intent to apply for Federal funds, and indicate your comment below. Consideration should be given to conformance with other plans or projects proposed or in effect.

ALABAMA DEVELOPMENT OFFICE
AUG 27 1971
STATE CLEARING HOUSE

Comments: (Please check one block.)

- ☐ No Interest
- ☐ Concur
- ☐ Need More Information (explain below)
- ☐ Cannot Concur (explain below)

Additional Comments:

See attached comments from the Game and Fish Division.

R. Thrasher
Signature

Please Return Original to:
Alabama Development Office
Office of State Planning
State Clearinghouse
State Office Building
Montgomery, Alabama 36104

FORM CH-2
9/70

ALABAMA DEPARTMENT OF CONSERVATION

64 North Union Street - Montgomery, Alabama 36104

CLAUDE D. KELLEY
DIRECTOR
SIDNEY E. BLEDSOE
ASSISTANT DIRECTOR

August 25, 1971

DIVISION OF GAME & FISH
CHARLES D. KELLEY, CHIEF

MEMORANDUM TO: Mr. Reynolds W. Thrasher, Chief
Bureau of Outdoor Recreation

FROM: Ralph H. Allen, Jr., Chief
Game Management Section

Ralph H. Allen Jr

SUBJECT: Environmental Impact Statement On Browns Ferry Nuclear Plant - TVA

Game and Fish personnel have reviewed the TVA's Environmental Impact Statement on the Browns Ferry Nuclear Plant and offer the following comments.

TVA states several times in the report that they will meet any future applicable temperature standards. They apparently used the figures of 95° F. maximum and 93° F. average cross section and a 10° F. rise in designing the plant. They state (Page 5-10) that "These temperature limits have been used in design and are in line with those accepted by the Alabama Water Improvement Commission". A temperature maximum of 95° F. has not been accepted by the Alabama Water Improvement Commission. These figures are not in line with the temperatures recommended by the National Technical Advisory Committee for waters supporting populations of largemouth bass, smallmouth bass, crappie, bluegill, walleye and sauger. On Page 3-14 TVA states that "Investigations have shown the following fish to be important to sport use: largemouth bass, smallmouth bass, spotted bass, white bass, crappie, bluegill and sauger". Why didn't TVA use this outstanding report to design their plant so as to prevent damage to the valuable sport fishery resources rather than design for the maximum temperatures expected to be approved by the Alabama Water Improvement Commission? On Page 4-1 is the statement that TVA has consulted with several Federal, State and local agencies and officials since 1966 in the planning and construction of the Browns Ferry Plant. The Alabama Department of Conservation is listed as one agency with which they consulted. It is sufficient to say that they did not follow our advise concerning water temperatures maximums which we recommended. Mr. Churchill and Mr. Derryberry have attended several meetings where the Game and Fish Division officially recommended water temperature maximums of 90° F. for fish and wildlife waters and a maximum of 86° F. for waters containing sauger, walleye, or smallmouth bass. All three of these species are found in Wheeler Reservoir.

Memo to: Mr. Reynolds W. Thrasher
August 25, 1971
Page Two

TVA's temperature data listed in Tables 10, 11 and 12 support our recommendations of 86° F. maximum for the Tennessee River. Table 12 lists only one surface temperature reading (at Mile 305) above 86° F. for the period of 1938 through 1943. Table 11 lists the highest observed temperature reading at
2.7.3(1)(a) Mile 300.3 as 83.1° F. during the period May, 1964 to May, 1965. Table 10 shows 84° F. as the maximum (at 1 ft.) temperature recorded at Mile 277.0 for 1964-65. On Page 3-18 TVA states that "Temperature data at Tennessee River Mile 305.0, collected by TVA's Hydraulic Data Branch during 1938 through 1943 indicates the temperature pattern observed one year is very similar to that observed in other years". On Page 7-3 is the statement that "TVA's experience at all of its steam plants, and particularly at Paradise, indicates that a maximum temperature of 93° F. and a 10° F. rise should adequately protect aquatic life in the Tennessee River". This statement, of course, does not agree with the National Technical Advisory Committee's recommendations for the fish species found in the Tennessee River. There is no scientific research that I know of which indicates 93° F. is suitable for game fish such as largemouth bass, smallmouth bass, sauger, crappie and walleye.

The Browns Ferry Plant is designed to have a 25° F. rise in the condensers. TVA admits that this will kill fish larva and other desirable organisms. The report attempts to rationalize this with statements such as the following one found on Page 5-27; "However, since only ten percent of the water passing the site at mean annual flow passes through the condensers, any adverse effects are not expected to be significant." The three units pump 1,980,000 gallons per minute. This amounts to about 360 ac. ft. of water per hour and 8,640 ac. ft. of lake water per 24 hour day. I doubt that the destruction of fish larvae and desirable fish food organisms in 8,640 ac. ft. of Wheeler Reservoir water each day is insignificant.

On Page 5-16 of the report, mention is made of the use of a polymer which will be discharged to the river. No data is given that indicates studies
5.1(1) have been made that insure no toxicity or fish residue problems will result from such discharges. I think the following question requires an answer from TVA: Will the construction and operation of Browns Ferry Nuclear Plant result in any fish contamination problem such as we are not experiencing with mercury and PCB?

On Page 5-3 is the statement that "There is little likelihood that the warm water discharges would result in any adverse effect on water-contact recreation in Wheeler Reservoir". On Pages 4 and 13 of the National Technical Advisory
2 6.1 Committee report is the recommendation that "In primary contact recreation waters, except where caused by natural conditions, maximum water temperatures should not exceed 30° C. (85° F.)". TVA designed this plant to raise the water temperature up to 93° F. As a professional fishery biologists this is somewhat out of my field. My only purpose for mentioning this is to point out one other area where TVA's statements conflict with the recommendations of such groups as the National Technical Advisory Committee.

Memo to: Mr. Reynolds W. Thrasher
August 25, 1971
Page Three

On Page 5-4 TVA states that "Although during some months fish may avoid the immediate area of the plant discharges, in the winter the fish are likely to be attracted to the warm water". It appears that this statement is intended to imply that the benefits of heat for attracting fish in winter offset any summer damage while actually this abnormal concentration may pose a greater danger to the future abundance of certain desirable species. Certain important sport species that spawn in winter or early spring such as walleye and sauger will be attracted to the heated area during the time of year when they should be on their spawning migration. It is still unknown what effect this exposure to heated water will have on the development of sexual products of such fish. I do not believe TVA's biological studies are designed to answer this important question. If this exposure hinders or prohibits successful reproduction of sauger or walleye, then a series of such heated discharges could eventually eliminate a fishery for such species. 2.7.3(1)(a) 2.7.3(1)(b)

Several statements in the report indicate that TVA is concerned over the amount of radioactive material that will be released from the plant into the environment. Apparently this concern over the release of materials from nuclear plants is shared by such renown nuclear experts as Dr. George L. Weil, Nuclear Consultant of Washington, D. C., as indicated by the enclosed clipping which appeared in the Montgomery Advertiser on August 22, 1971.

RHA:jcb

Approved:

Charles D. Kelley

Charles D. Kelley, Chief
Game and Fish Division

cc: Mr. Sam Spencer

A-Plants Are Called 'Dangerous'

SEATTLE (AP) — A nuclear energy consultant says the Atomic Energy Commission and utility companies are misleading the public about the risk involved in nuclear power plants.

Dr. George L. Weil, a nuclear energy consultant from Washington, D.C., said nuclear power plants are dangerous, expensive and are only a short-term solution to power needs.

He said nuclear power plants contain "monumental amounts" of radioactive materials which must be contained. AEC studies have shown that accidents at some nuclear facilities could kill "Tens of thousands of people, cause many billion dollars worth of damage and make the area uninhabitable," Weil said.

"If the public wants to take the risks involved with nuclear power," Weil said, "they should know what the risks are — but they are being totally misled by the Atomic Energy Commission, the utility companies and others."

3.3-8

9/

REQUEST FOR REVIEW OF PROJECT NOTIFICATION

TO:

Mr. W. Warner Floyd
Historical Commission

CH Number ADO-84-71

Applicant Tennessee Valley Authority

Program Environmental Impact Statement
Browns Ferry Nuclear Plant -- Units 1,2 & 3

DATE: August 3, 1971

Return Prior to: August 16, 1971
Date

Please review the attached notification of intent to apply for Federal funds, and indicate your comment below. Consideration should be given to conformance with other plans or projects proposed or in effect.

ALABAMA DEVELOPMENT OFFICE
SEP 10 1971
STATE CLEARING HOUSE

Comments: (Please check one block.)

- ☐ No Interest
- ☐ Concur
- ☐ Need More Information (explain below)
- ☐ Cannot Concur (explain below)

Additional Comments:

The Alabama Historical Commission cannot accurately appraise the environmental impact of the Brown Ferry project upon the historic resources of this area because our agency had no opportunity to review the project until the demolition of old structures and the construction of the project had been completed. 2.8.4

W. Warner Floyd
Signature

Please Return Original to:
Alabama Development Office
Office of State Planning
State Clearinghouse
State Office Building
Montgomery, Alabama 36104

FORM CH-2
9/70

STATE OF ALABAMA

ALABAMA HISTORICAL COMMISSION
305 SOUTH LAWRENCE STREET
MONTGOMERY, ALABAMA 36104

W. WARNER FLOYD
EXECUTIVE DIRECTOR

TELEPHONE NUMBER
269-6839

March 16, 1972

P-4 Browns Ferry Nuclear Plant
E-11 Units 1, 2 & 3

Mr. George R. DeVeny
Regional Planner
Division of Navigation Development
and Regional Studies
Tennessee Valley Authority
Knoxville, Tennessee 37902

Dear Mr. DeVeny:

We have consulted with local preservations in the area of the Brown's Ferry Nuclear Plant and have found nothing which will be adversely affected by the addition to the plant.

The original construction of the plant required the relocation of an old cemetery which contained the graves of several early pioneers. Properly restored and preserved the cemetery would have attracted only approximately 2,000 visitors a year. While complete restoration of the cemetery would not have been feasible, it is our opinion that the cemetery was relocated with considerable care.

Structures located on Tract 13, several of which are over 50 years old, were, in our judgement, not of major interest to preservationists and tourists.

Sincerely,

W. Warner Floyd

W. Warner Floyd

WWF/jan

ALABAMA DEVELOPMENT OFFICE
SEP 22 1971
STATE CLEARING HOUSE

REQUEST FOR REVIEW OF PROJECT NOTIFICATION

TO:

Mr. Preston Blanks
Comprehensive Health

CH Number ADO-84-71

Applicant Tennessee Valley Authority

Program Environmental Impact Statement
Browns Ferry Nuclear Plant — Units 1,2 & 3

DATE: August 3, 1971

Return Prior to: August 16, 1971
Date

Please review the attached notification of intent to apply for Federal funds, and indicate your comment below. Consideration should be given to conformance with other plans or projects proposed or in effect.

Comments: (Please check one block.)

- ☐ No Interest
- ☒ Concur
- ☐ Need More Information (explain below)
- ☐ Cannot Concur (explain below)

Additional Comments:

Concur subject to questions raised in memorandum from Mr. Arthur Beck, State Health Department, to ADO, this subject.

C. Preston Blanks, Jr.
Signature

Please Return Original with Draft Statement to:
Alabama Development Office
Office of State Planning
State Clearinghouse
State Office Building
Montgomery, Alabama 36104

FORM CH-2
9/70

REQUEST FOR REVIEW OF PROJECT NOTIFICATION

TO:

Mr. A. N. Beck, Director
Bureau of Environmental Health

CH Number ADO-84-71

Applicant Tennessee Valley Authority

Program Environmental Impact Statement
Browns Ferry Nuclear Plant — Units 1,2 & 3

DATE: August 3, 1971

Return Prior to: August 16, 1971
Date

Please review the attached notification of intent to apply for Federal funds, and indicate your comment below. Consideration should be given to conformance with other plans or projects proposed or in effect.

Comments: (Please check one block.)

☐ No Interest

☒ Concur

☐ Need More Information (explain below)

☐ Cannot Concur (explain below)

Additional Comments:

See attached statements

Signature

Please Return Original to:
Alabama Development Office
Office of State Planning
State Clearinghouse
State Office Building
Montgomery, Alabama 36104

FORM CH-2
9/70

State of Alabama
Department of Public Health
State Office Building
Montgomery, Alabama 36104

IRA L. MYERS, M. D.
STATE HEALTH OFFICER

August 31, 1971

M E M O R A N D U M

TO: Alabama Development Office

FROM: Mr. A. N. Beck

SUBJECT: ADO-84-71, Environmental Impact Statement Browns Ferry Nuclear Plant

As a result of the review by the members of the Bureau of Environmental Health the following questions need resolving prior to completing our determinations:

1. In order to determine if any air pollution or pollution effects may be generated by the operation of this plant we need to know what types of fuel oil or fuel gas is to be burned in the auxiliary boilers along with the quantities and the altitude of the stack through which these boilers discharge. Further, if there is an incinerator proposed for the site we need to know the type, the amount of material to be burned in the incinerator, and the number of chambers in the incinerator. 2.5.3 2.5.4

2. A review of the Environmental Statement and the final Safety Analysis Report does not indicate how normal solid waste materials are to be disposed of. We request the applicant supply this information so that we can determine the effects of solid waste on the environment. 2.5.4

3. Although the applicant has indicated that he is going to put in "An advanced rad waste system". This system will not be operational when Unit I becomes operational. Further, the applicant indicates a tentative time schedule for the gaseous radwaste system, but does not indicate a time schedule for the completion of the liquid "Advanced rad waste system". We request a time schedule from the applicant for this liquid advanced rad waste system. It should be noted that projected radiation doses to the environs will be in excess of those in the proposed Appendix I to 10 CFR Part 50 until the "Advanced rad waste systems" are in operation.

STATE OF ALABAMA

WATER IMPROVEMENT COMMISSION

ROOMS 324-326
STATE OFFICE BUILDING
MONTGOMERY 4, ALABAMA

IRA L. MYERS, M. D.
CHAIRMAN

ARTHUR N. BECK
TECHNICAL SECRETARY

September 2, 1971

MEMORANDUM

TO: Alabama Development Office

FROM: Arthur N. Beck, Technical Secretary, Water Improvement Commission

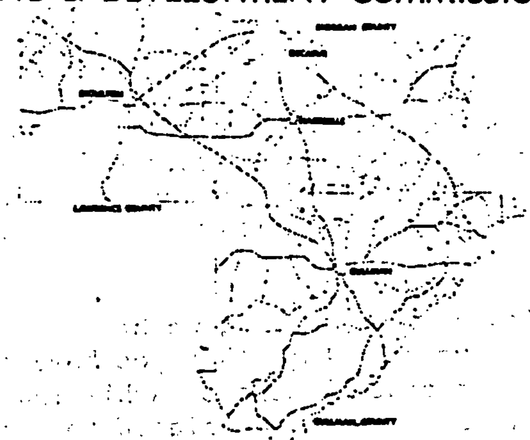
SUBJECT: CH No. ADO-84-71, Draft Environmental Statement by Tennessee Valley Authority on Browns Ferry Nuclear Plant, Units 1, 2 and 3

A review of the Tennessee Valley Authority's Draft Environmental Statement, Browns Ferry Nuclear Plant, reveals that the impact of the operation of this plant on water quality will be principally limited to thermal effects with other factors being inconsequental. The method for handling the discharge of condenser cooling waters, that of dispersion through diffusers, was selected by TVA on the basis of water quality standards adopted by the Alabama Water Improvement Commission and considerable investigation into the efficiency of diffusion of heated water within Wheeler Reservoir of the Tennessee River. Water quality standards adopted by the Alabama Water Improvement Commission in 1967 as related to thermal discharges permitted a maximum temperature in waters receiving cooling water discharges of 93°F after reasonable mixing. These standards further limited the temperature rise to not more than 10°F. The above standards were not approved by the appropriate Federal agency as indicated in TVA's environmental statement. Furthermore, the Environmental Protection Agency held a water quality standards conference for interstate waters within Alabama on April 5-7, 1971, during which conference the Environmental Protection Agency recommended that the maximum temperature rise resulting from the discharge of heated water shall not exceed 5°F in streams and 3°F in the surface waters of lakes and reservoirs. The recommendations of EPA also limited the maximum temperatures for streams and reservoirs supporting smallmouth bass, sauger and walleye to 86°F during the summer months. Subsequent discussions regarding temperature standards have led to the tentative proposal of a temperature standard limiting the maximum temperature rise to 5°F and the maximum temperature to 86°F in waters supporting smallmouth bass, sauger and walleye. The above restrictions would apply after reasonable mixing of heated waters with the receiving stream or reservoir. Since the Tennessee River is regarded as a smallmouth bass, sauger and walleye fishery, the above temperature standards, if adopted by the State and Federal Government, would apply to that portion of the Tennessee River into which cooling waters from the Browns Ferry Nuclear Plant would be discharged.

The Tennessee Valley Authority recognizes the probability of revisions in temperature standards originally adopted by the Alabama Water Improvement Commission and states that it will meet any future applicable standards for the Tennessee River as it may be affected by the discharge of cooling waters from the Browns Ferry Nuclear Plant. In view of the fact that definitive temperature standards are yet to be officially adopted by either the State or the Environmental Protection Agency, the commitment of TVA to meet any future applicable temperature standards is satisfactory to the Alabama Water Improvement Commission.

ANB/cbw

NORTH CENTRAL ALABAMA REGIONAL
PLANNING & DEVELOPMENT COMMISSION



5th Floor
City Hall Tower
402 Lee St.,N.E.
Decatur, Alabama 35601
P.O. Box 1069

GARY L. VOKETZ
EXECUTIVE
DIRECTOR

August 6, 1971

Mr. M. I. Foster, Director
Division of Navigation Development
and Regional Studies
Tennessee Valley Authority
Knoxville, Tennessee 37902

p-4 Browns Ferry Nuclear Plant,
E-11 Units, 1, 2 + 3

Dear Mr. Foster:

This is to inform you that the North Central Alabama Regional Planning and Development Commission, functioning in its role as the "Regional Clearinghouse", has completed the review of TVA's Draft Environmental Statement for Browns Ferry Nuclear Plant Units 1, 2 and 3.

The review was conducted in accordance with the Bureau of the Budget's Circular A-95 and took into consideration the consistency of the project with regional plans and the environmental aspects that the project has as related to the North Central Alabama Region.

In regard to the review of the project, I wish to make the following comments:

1. The project and the environmental impact it will have will not have any adverse affect on regional land use plans of the NCARP & DC.

2. TVA, as has been the case for many years, is concerned with planning and development throughout the Tennessee Valley. This concern has remained evident as related to the Browns Ferry Nuclear Plant project. Consultation with the regional planning agencies of north Alabama concerning the project has been held since the beginning of the project. TVA continues to maintain an effective continuing working relationship with these agencies, always considering their concerns.

Mr. M. I. Foster
Page 2
August 6, 1971

3. The project, as described in the Environmental Impact Statement you furnished this office, is in conformity with comprehensive plans of the North Central Alabama Regional Planning and Development Commission.

4. Upon the review of the project, we have determined to the best of our knowledge that you have considered and incorporated means of achieving state, regional and local objectives related to a project of this nature, as specified in Section 401(a) of the Intergovernmental Cooperation Act of 1968.

If we may be of further assistance, please advise.

Yours truly,

Scott Maples

Scott E. Maples
Planner

for

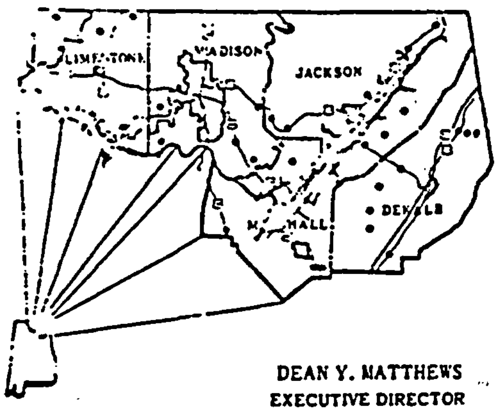
Gary L. Voketz
Executive Director

SEM:lm

cc: Director
Division of Radiological
and Environmental Protection
Atomic Energy Commission
Washington, D. C. 20545

Mr. Dean Y. Matthews, Director
Top of Alabama Regional ~~Council~~
of Governments
Huntsville, Alabama 35801

Mr. H. P. K. Wamsley
Alabama Development Office
Montgomery, Alabama 36104



Top of Alabama Regional Council of Governments

A NON-PROFIT CORPORATION

P. O. BOX 308
HUNTSVILLE, ALABAMA 35804

6th FLOOR - CITY HALL
TELEPHONE 205/536-3388

DEAN Y. MATTHEWS
EXECUTIVE DIRECTOR

LARRY W. RAYBON
DIRECTOR OF PLANNING

August 11, 1971

ALABAMA DEVELOPMENT OFFICE
AUG 13 1971
STATE CLEARING HOUSE

Mr. M. I. Foster, Director
Division of Navigation Development
and Regional Studies
Tennessee Valley Authority
Knoxville, Tennessee 37902

ADO-84-71

Dear Mr. Foster:

This is to advise that we have reviewed the Environmental Impact Statement Draft of the Tennessee Valley Authority regarding the Browns Ferry Nuclear Plant Units 1, 2, and 3.

We are quite impressed with the extensive attention given to all aspects of the Browns Ferry facility and its effects on the environment.

We concur wholeheartedly in the continued construction and operation of this facility.

It is our belief that the Browns Ferry Nuclear Plant is a national asset costing 1/2 billion dollars which will help supply a critical demand for power. The generation of electric power through nuclear energy is, in our opinion, much less damaging to the environment than through the use of fossil fuels.

It is further noted that there has been little or no adverse public reaction to the Browns Ferry Nuclear Plant within our region. We subscribe to 9 area newspapers.

Sincerely,

Dean Y. Matthews

Dean Y. Matthews
AIA, Director

DYM/vgp
cc: Mr. H. P. K. Walmsley
Director, Atomic Energy Commission

REQUEST FOR REVIEW OF PROJECT NOTIFICATION

TO:

Mr. Dick Dowdy
ADO

CH Number ADO-84-71

Applicant Tennessee Valley Authority

Program Environmental Impact Statement
Browns Ferry Nuclear Plant -- Units 1,2 & 3

DATE: August 3, 1971

Return Prior to: August 16, 1971
Date

Please review the attached notification of intent to apply for Federal funds, and indicate your comment below. Consideration should be given to conformance with other plans or projects proposed or in effect.

ALABAMA DEVELOPMENT OFFICE
AUG 9 1971
STATE CLEARING HOUSE

Comments: (Please check one block.)

- ☐ No Interest
- ☑ Concur
- ☐ Need More Information (explain below)
- ☐ Cannot Concur (explain below)

Additional Comments:

Concur provided TVA continues to try and minimize adverse environmental effects.

RW
Signature

with Draft Statement

Please Return Original to:
Alabama Development Office
Office of State Planning
State Clearinghouse
State Office Building
Montgomery, Alabama 36104

FORM CH-2
9/70

REQUEST FOR REVIEW OF PROJECT NOTIFICATION

TO:

Dr. Ken Johnson
ADO

CH Number ADO-84-71

Applicant Tennessee Valley Authority

Program Environmental Impact Statement
Browns Ferry Nuclear Plant — Units 1,2 & 3

DATE: August 3, 1971

Return Prior to: August 16, 1971
Date

Please review the attached notification of intent to apply for Federal funds, and indicate your comment below. Consideration should be given to conformance with other plans or projects proposed or in effect.

Comments: (Please check one block.)

- [ ] No Interest
- [x] Concur
- [ ] Need More Information (explain below)
- [ ] Cannot Concur (explain below)

ALABAMA DEVELOPMENT OFFICE
AUG 18 1971

Additional Comments:

Kenneth E. Johnson
Signature

Please Return Original to:
Alabama Development Office
Office of State Planning
State Clearinghouse
State Office Building
Montgomery, Alabama 36104

FORM CH-2
9/70

THE ASSISTANT SECRETARY OF COMMERCE
Washington, D.C. 20230

September 20, 1971

Dr. Francis E. Gartrell
Director of Environmental Research
and Development
Tennessee Valley Authority
Chattanooga, Tennessee 37401

Dear Dr. Gartrell:

Please refer to the draft environmental impact statement prepared by TVA for Browns Ferry Nuclear Plant, Units 1, 2 and 3.

The enclosed comments, prepared by the National Oceanic and Atmospheric Administration of the Department of Commerce, are presented for your consideration in preparing the final environmental impact statement. You will note that NOAA has attached a copy of an earlier set of comments developed in 1966 by the Institute for Atmospheric Sciences with reference to the Design and Analysis Report (Volumes I and II) of the same Browns Ferry Project.

Sincerely,

Sidney R. Galler

Sidney R. Galler
Deputy Assistant Secretary
for Environmental Affairs

Enclosure

3.4

Comments on

Draft Environmental Statement

by
Tennessee Valley Authority
for
Browns Ferry Nuclear Plant Units 1, 2 and 3

Prepared by

Air Resources Environmental Laboratory
National Oceanic and Atmospheric Administration
August 13, 1971

At the request of the U. S. Atomic Energy Commission, Division of Reactor Licensing, comments on the meteorological aspects of the Preliminary Safety Analysis Report for the Browns Ferry facility were prepared by this Laboratory and transmitted to the AEC on September 27, 1966, a copy of which is attached. Currently, again at the request of the AEC, the Final Safety Analysis Report (FSAR) is under evaluation by this Laboratory.

As pointed out in the attached comments, the controlling diffusion condition for the routine effluent emission from the 183-meter stack is one of rapid rather than poor diffusion. From the onsite meterological data presented in the FSAR, we have calculated the maximum average annual concentration at the ground to be 2×10^{-8} curie m^{-3} per curie sec^{-1} released at a distance of 1200 m from the stack. This agrees with the value used by the applicant to arrive at an annual average release limit listed on page 5-50 of the Environmental Statement.

Although in our evaluation of the FSAR we are considering the effect of inadverbent radioactive releases to the atmosphere as a result of
2.3 the so-called maximum credible accident, no metnion of this is made
2.3.3 in the Environmental Statement.

Attachment

Environmental Science Services Administration
Washington, D.C. 20235

September 27, 1966

Mr. Walter C. Belter, Chief
Environmental & Sanitary Engineering Branch
Reactor Development & Technology Division
U. S. Atomic Energy Commission
Washington 23, D.C.

Dear Mr. Belter:

This refers to the letter of July 26, 1966 from Edson G. Case Assistant Director of the Division of Reactor Licensing requesting comments of the following:

Browns Ferry Nuclear Power Station
Tennessee Valley Authority
Design and Analysis Report, Volumes 7 and 11
Dated July 13, 1966

These comments are attached, and we would appreciate your including them with other Reactor Development & Technology Division comments or forwarding copies to the Division of Reactor Licensing.

Sincerely yours,

Isaac Van der Hoven, Chief
Environmental Meteorology Branch
Air Resources Laboratory

Attachment
As stated

cc: J. Newell, AEC
bcc: Dr. Gifford, ATDL
IVH:hmm

Comments on

Browns Ferry Nuclear Power Station
Tennessee Valley Authority
Design and Analysis Report, Volumes I and II
Dated July 13, 1966

Prepared by

Environmental Meteorology Branch
Institute for Atmospheric Sciences
September 27, 1966

The Browns Ferry site is on the southwestern edge of the Appalachian Mountain region and as such is influenced by the frequent occurrence of the stagnant, anticyclonic flow characteristic of the Southeastern United States. As shown by Hosler [1] the site is within a maximum region of low nighttime wind speeds and cloudiness which is conducive to surface-based radiational inversions. This condition is exemplified by the nearby Colbert Steam Plant inversion frequency data given in the Design and Analysis Report (page II-3-5) from which one would conclude an almost 100% occurrence of surface inversions at night.

In the computation of downwind surface concentrations and dosages of radioactivity the most sensitive parameter, besides the source strength, is the assumption of a 100 m high release point. The maximum ground concentration or dosage from an elevated source will be higher during unstable condition than during stable regimes since, during periods of instability over reasonably level terrain, the stack effluent reaches the ground much closer to the stack location than is the case during stable conditions. As a consequence the controlling atmospheric condition at the site boundary is one of more rapid vertical dilution rather than poor vertical dilution. This is evident from the relative concentrations shown in Table XIV-13 of the report and is graphically shown in figure 7 of Slade [2], where for a 100 m stack height and a wind speed of 1 m/sec a maximum surface concentration of 1.4×10^{-5} Ci/m^3 per Ci/sec results under type C (slighly unstable) diffusion at the site boundary distance of 1200 m. This compares well with the N-2 category (neutral stability, 1 m/sec) shown in Table XIV-13.

Locally high concentrations can occur during fumigation conditions, that is, at the time the radiational inversion is destroyed. The fumigation condition which presumably can occur at the site boundary could cause relative surface concentrations of 7×10^{-5} Ci/m^3 per Ci/sec released assuming a mixing depth of 100 m, a wind speed of 1 m/sec and a σ_y value of 60 meters. This could be a controlling situation with regard to radioactive doses except that fumigation of this type is associated with the propagation in the vertical of the effect of surface heating after sunrise and as such would last about an hour as a maximum. The high frequency of nocturnal surface inversions coupled with the lack of marked patchiness in the wind direction distribution would indicate frequent morning fumigations but with no one area subject to repeated fumigation episodes.

In the accident case of a radioactive superheated steam cloud issuing from the turbine building after portions of the roof and siding were blown out, the model used to predict the height of rise of the centerline of the cloud does not seem appropriate for the conditions being considered. The reference by Singer, Frizzola and Smith [3] cited in the report points out the empirical nature of the height of the plume centerline prediction equation, the meagerness of the data and the narrow range of observed centerline heights. A summary of their test data shows a maximum observed rise of 160 feet and a wind speed range of from 2 to 11 miles per hour. An extrapolation of a rise to 5,000 feet and of a wind speed of 50 mph, as was done in the hazard analysis, would seem a questionable procedure.

In summary, the general diffusion climate of the site seems somewhat below average with regard to the probability of slow dilution rates. However, because of the assumption of a 100 m stack release the controlling atmospheric condition for concentrations at the site boundary is one of rapid rather than poor dilution in the vertical.

References

[1] Hosler, C. R., 1961: "Low-level Inversion Frequency in the Contiguous United States". Monthly Weather Review, Vol. 89, pp. 319-339.

[2] Slade, D. H., 1966: "Estimates of Dispersion from Pollutant Releases of a Few Seconds to 8 Hours Duration". ESSA Technical Note 39-ARL-3, 26 pp.

[3] Singer, I. A., Frizzola, J. A., and Smith, M. E., 1964: "The Prediction of the Rise of a Hot Cloud from Field Experiments". APCA Journal, Vol. 14, No. 11, pp. 455-458.

DEPARTMENT OF AGRICULTURE
OFFICE OF THE SECRETARY
WASHINGTON, D. C. 20250

SEP 15 1971

Mr. F. E. Gartrell
Tennessee Valley Authority
Chattanooga, Tennessee 37401

Dear Mr. Gartrell:

We have had the draft environmental statement for TVA's Browns Ferry Nuclear Plant Units 1, 2, and 3 reviewed by the relevant agencies in the Department of Agriculture and comments from three USDA agencies are attached.

Three copies of the environmental statement are returned herewith.

Sincerely,

T. C. Byerly

T. C. BYERLY
Assistant Director
Science and Education

Enclosures

3.5

Environmental Statement

Browns Ferry Nuclear Plant, Units 1, 2, and 3 - TVA

The subject environmental statement has been carefully reviewed by the Agricultural Research Service as pertains to the agricultural use of soil and water.

This report is well prepared and most informative. TVA's policy of keeping the discharge of all wastes at the lowest practicable level by using the best and highest degree of waste treatment available under existing technology, within reasonable economic limits, is most commendable. However, in the past the lowest practicable levels of waste disposal, with the passage of time, have turned out to not be low enough.

2.7.6 As envisioned, the monitoring programs established by TVA, including the quality control procedures, should reveal any possible impairment of soil and water resources for agricultural use. The monitoring program should be continued even though results are negative in any one particular year. Long term incidents might otherwise be missed. Divatent cations move slowly and therefore accumulate slowly and for that reason, the monitoring should be continuous. The monitoring program, for reasons of bias, not necessarily those of TVA, might ought to be conducted by a State or Federal agency.

Sept. 7, 1971

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
WASHINGTON, D.C. 20250

IN REPLY REFER TO
1920

August 23, 1971

Tennessee Valley Authority Draft Environmental Statement
Browns Ferry Nuclear Plant Units 1, 2 and 3

We have reviewed the draft environmental statement prepared by the Tennessee Valley Authority for the construction and operation of a three-unit nuclear power generating station in Limestone County, Alabama.

The plant is located on an 840-acre tract on the north shore of Wheeler Reservoir on the Tennessee River. It will consist of a reactor containment building, turbine, radwaste and service buildings, transformer and switch yards, a stack and sewage treatment plant. There is no indication that TVA is providing any public recreation facilities at the site.

The statement indicates that TVA has closely coordinated its
2.7.6 activities with concerned Federal, State and local agencies in
all phases of project planning, construction, and monitoring
relating to radiological and biological factors that can be affected
by the operation of the plant. The statement sufficiently describes
the environmental radioactivity monitoring program; however, we
would recommend that it be more specific as to distance of sampling
sites from the plant site.

The statement does not mention possible effects of accidental
radioactive releases on the environment. Unless an accident can
2.4 be ruled out as impossible, the statement should discuss potential
consequences. In this connection the possible need for alternate
or supplementary waste treatment facilities should be considered.
In addition, the establishment of higher water quality standards
and the detection of unanticipated adverse environmental effects
may require additional waste treatment facilities. It would seem
important that radioactive disposal processes be provided sufficient
flexibility in order that additional controls can be added.

SOIL CONSERVATION SERVICE, USDA, COMMENTS

Draft Environmental Statement Prepared by

Tennessee Valley Authority for

Browns Ferry Nuclear Plant Units 1, 2 and 3, Alabama

2.6.6(3)(c) This statement fails to discuss the measures, if any, to be undertaken to minimize soil erosion during construction of the facilities.

DEPARTMENT OF AGRICULTURE
OFFICE OF THE SECRETARY
WASHINGTON, D. C. 20250

December 27, 1971

VIA AIR MAIL

Mr. F. E. Gartrell
Tennessee Valley Authority
Chattanooga, Tennessee 37401

Dear Mr. Gartrell:

We have had the supplement to the draft environmental statement for the Browns Ferry Nuclear Plant Units 1, 2, and 3 reviewed in the relevant agencies of the Department of Agriculture. Comments from the Forest Service and the Soil Conservation Service are enclosed. Also enclosed are three copies of the statement.

Sincerely,

T C Byerly DJW

T. C. BYERLY
Assistant Director
Science and Education

Enclosures

USDA-Forest Service Comments

Browns Ferry Nuclear Plant, Units 1, 2, and 3
Supplement to Draft Environmental Statement

We have reviewed the subject supplemental statement prepared by the Tennessee Valley Authority for the construction and operation of a three-unit nuclear power generating station in Limestone County, Alabama.

Since no new information on the monitoring program is presented, our comments of August 11, 1971, on this phase of the project are still valid.

Beginning on page 2-14, the supplemental statement discusses radio-
2.1.1(2) active waste shipment to an offsite burial ground. The statement
2.1.1(3) sufficiently describes shipping safeguards, but is not clear as to
2.1.2(2) how waste containers are shielded to prevent radioactive contamination to subsurface and groundwater at the disposal site. The report might also provide more specific information on the location and site characteristics of the burial ground.

We note that all transmission lines for the Browns Ferry Nuclear Plant, including 70 miles of new construction, have been completed. Environmental considerations involved in the location, construction and maintenance of the transmission systems are clearly presented except that the statement is silent on methods used for disposal of waste vegetation cleared from land acquired for new lines. We trust that TVA in future statements will report its intentions with respect to utilization of non air polluting practices alternative to open burning in disposing of vegetation cleared from rights-of-way.

The supplementary statement indicates that TVA has studied the expected releases from Browns Ferry Nuclear Plant and investigated the alternative
2.5.3 thoroughly for keeping the radioactivity in effluents to unrestricted areas as low as practicable. In connection with gaseous radioactive wastes, the report describes a decay process and four alternative ways to reduce radioactive gaseous discharges at the Plant. However, no mention is made of the amount and contents of the disradioactive gases which would be released. The environmental statement should give consideration to what these emissions would contain and discuss any effects they would have on the environment.

SOIL CONSERVATION SERVICE, USDA, COMMENTS

Draft Environmental Statement Prepared by

Tennessee Valley Authority for

Browns Ferry Nuclear Plant Units 1, 2, and 3, Alabama

Supplements and Additions

Construction of these facilities will necessitate the disturbance of soil and vegetative cover. Assistance in minimizing soil erosion and the resultant sedimentation is available from the Soil Conservation Service through local soil and water conservation districts.

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20201

SEP 1 0 1971

F. E. Gartrell, Dr. P. H.
Director of Environmental
Research and Development
Tennessee Valley Authority
Chattanooga, Tennessee 37401

Dear Dr. Gartrell:

The draft environmental statement, Browns Ferry Nuclear Plant - Units 1, 2, and 3, sent with your memorandum of July 15, 1971, has been reviewed within this Department. On the basis of information contained in the draft statement, it appears that this facility can be operated without undue impact on the environment or an unacceptable hazard to the public health and safety.

Sincerely yours,

Merlin K. DuVal M.D.

Merlin K. DuVal, M.D.
Assistant Secretary for
Health and Scientific Affairs

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
WASHINGTON, D.C. 20201

OFFICE OF THE SECRETARY

JAN 21 1972

F. E. Gartrell, Dr. P. H.
Director of Environmental Research
and Development
Tennessee Valley Authority
Chattanooga, Tennessee 37401

Dear Dr. Gartrell:

Your draft supplements and additions to the draft environmental statement, Browns Ferry Nuclear Plant - Units 1, 2, and 3, transmitted with your memorandum of November 8, 1971, have been reviewed within this Department. Based on information contained in these statements, it does not appear that there will be unacceptable radiation exposures to the public nor other environmental health hazards resulting from construction and operation of the proposed nuclear generating station.

2.8.2 In part 3.7 of the supplements and additions to the report, Electric Power Supply and Demand, you may wish to include a discussion in subpart 2, Consequences of Delays, a statement concerning health effects which could result from such delays. This might include both an estimate of the health impact of utilizing alternate sources of power as well as that which could result from power shortages due to a reduction in the reliability of the region's power supply.

Sincerely yours,

Merlin K. DuVal, M.D.

Merlin K. DuVal, M.D.
Assistant Secretary for
Health and Scientific Affairs

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

JAN 18 1972

Dear Dr. Gartrell:

This is in response to your request that we review the draft environmental statement, and its supplement, prepared by your agency for the Brown's Ferry Nuclear Plant, Units 1, 2, and 3, AEC Docket Nos. 50-259, 50-260, and 50-296. We have reviewed these and other materials available on the project and offer the following comments for your consideration:

The statement adequately documents the fish and wildlife, recreational, and mineral resources of the project area, together with the ongoing and planned studies designed to determine the impact of all three units of the project on these resources and the environment. The project will not adversely affect any existing or known potential unit of the National Park System or properties eligible or potentially eligible for registration as National Natural Landmarks or National Historic Landmarks. Archaeological surveys conducted revealed that no Indian mounds, town sites, artifacts, or any other items of archaeological significance occur at the 840-acre plant site. Although we do not anticipate that the project will affect the geologic environment significantly, some consideration of this impact should be
2.8.3 included in the statement.

We are pleased that recreation areas and facilities, including a visitor lobby, will be provided at the project. The numerous res-
2.6.7 ervoirs on the Tennessee River and tributaries provide high quality recreation for the public. Although the Brown's Ferry project alone will not affect water-oriented recreation adversely, construction of additional units could have a cumulative, adverse effect on this activity. For example, if the quantity of heated water added to Wheeler Reservoir becomes great enough to cause algal blooms, undesirable decay byproducts would detract from the value of water-oriented public use of the area. Any plans TVA has for adding units to this project or for constructing additional nuclear or fossil-fueled plants at Wheeler Reservoir should be discussed in the statement.

About 4,200 cfs of condenser cooling water will be pumped from Wheeler Reservoir, passed through the condensers where it will be heated 25° F., and discharged back to the reservoir through a diffuser system

3.7

designed to dissipate the waste heat as rapidly as possible. We understand that, at times, special streamflow regulation, reduction of power production, or both would be necessary to meet the proposed Alabama water quality standards. Those standards, which would require that the temperature of the receiving waters not be increased by more than 10° F. nor raised above 93° F. after reasonable mixing, have not been approved by the Environmental Protection Agency. The EPA has recommended to the State of Alabama that it adopt standards that specify a maximum rise of 5° F., with a maximum allowable water temperature at 86° F.

A special 5-year (1966-1970) study of climatic and hydraulic conditions indicated that with all three units operating at full capacity, the proposed standards would have been exceeded on 9.0 percent and the recommended standards on 48.5 percent of the days of the 5-year study period. During the spring and summer months this added heat would raise the temperature in the receiving waters above 96° F.--the lethal temperature for most fish larvae and plankton. Many fish spawn in the reservoir throughout the discharge area during this period. It is obvious that operating the project with the planned once-through cooling-diffuser system will violate the proposed and recommended water quality standards and will cause significant damage to important aquatic resources of Wheeler Reservoir.

The supplement to the environmental statement discusses four alternative heat dissipation methods that could be used independently or in conjunction with the present diffuser design. Each alternative could be added to the project at some later time, if required to cool the project effluent to comply with more stringent water quality standards and protect aquatic life from significant thermal damage. However, a complete analysis of the spray canal alternative was not made because large-scale operating experience with this system is lacking. The TVA concluded that the mechanical draft cooling tower system probably would be the most attractive alternative for the project.

2.6(AIV-3) The water from the diffuser pipes will be discharged into the reservoir through downstream oriented 2-inch holes. The continual hydraulic disturbance of the reservoir bottom downstream from the diffuser will cause excessive entrainment of silt, which may damage the important aquatic habitat. This probable effect should be discussed in the statement.

2.3.3 The supplement presents a preliminary analysis of the consequences of nuclear accidents in response to recent AEC guidelines. Our review of this analysis indicates that the consequences of the most serious type of accident (Class 9 - breakdown of the containment structure and release of radionuclides from the core) has not been considered. Such consequences were not considered, because the probability of occurrence in terms of environmental risk is negligible compared to that of the other classes of accidents. Also, the supplement indicates that it is not possible to quantify the probability of occurrence of any accident at this time. This indicates that the evaluation of risks associated with accidents cannot be considered reliable. Even if the probability of a Class 9 accident is extremely low, this does not justify calling the associated environmental risk "negligible" when the environmental consequences of Class 9 accidents have not been considered. The failure to evaluate the probable consequences of Class 9 accidents is a glaring omission that should be treated in some detail to allay public concern for safety of the project, even though the probability of such an accident is remote.

Additional wording is needed in the statement to demonstrate that
6.0 all short-term and long-range uses and the irreversible and irretriev-
7.0 able commitments of resources have been considered and that the best possible plan for protecting the environment has been developed.

We recognize that the comprehensive monitoring studies scheduled or underway may satisfy the relationship between short-term uses of the
2.5.1 environment and the maintenance and enhancement of long-term productivity. However, we believe the statement concerning chemical discharges on pages 3-103 of the supplement that, "Those concentrations are not expected to have a significant adverse environmental impact on water quality in the Wheeler Reservoir." is premature at best and likely untrue. This section of the statement should include a detailed discussion of the effects the project will have on the production of living natural resources, including fish and wildlife.

The section on irreversible and irretrievable commitments of resources should be expanded to describe and identify the extent that construc-
7.0 tion and operation of the project will destroy living natural resources, including fish and wildlife and their habitats, and foreclose the natural production from these habitats. These are irretrievable losses. The once-through cooling system will have an adverse impact on the important fish and wildlife resources of Wheeler Reservoir. The TVA has recognized that it is economically and engineeringly feasible
2.6.6 to construct adequate cooling facilities at the project, and that it
2.6.6(3)(d) is inevitable that more stringent water quality standards will be adopted by Alabama and approved by the EPA in the near future. In view of the foregoing, and the Administration's emphasis on clean waters and abating all forms of pollution at the source, TVA should

be required to proceed with the necessary detailed studies to more carefully review the possibility of incorporating the spray canal cooling alternative into the project. Also, TVA should carefully reexamine its conclusion that mechanical draft cooling towers would be the more expeditious installation for the project. The visual aesthetic impacts of the cooling facilities selected should be discussed in the statement.

In any event, some type of supplemental cooling facility is definitely needed at the project and can be justified on the grounds that natural resources of this magnitude must be protected from significant damage for the overall benefit and enjoyment of the public.

Government agencies should be leaders striving to demonstrate that major power facilities can be constructed and operated without significantly damaging the basic natural resources.

The environmental statement and its supplement are incomplete and should be revised to treat the suggestions discussed above.

We appreciate the opportunity to comment on this statement and its supplement.

Sincerely yours,

S. S. Lyons

Deputy Assistant Secretary of the Interior

Dr. F. E. Gartrell
Director of Environmental
Research and Development
Tennessee Valley Authority
Chattanooga, Tennessee 37401

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

FEB 10 1972

Docket Nos. 50-259,
50-260
and 50-296

Dr. Francis Gartrell
Director of Environmental Research
and Development
Tennessee Valley Authority
720 Edney Building
Chattanooga, Tennessee

Dear Dr. Gartrell:

This is in response to Mr. James E. Watson's letter of November 5, 1971 transmitting the Supplements and Additions to the Draft Environmental Statement for the Browns Ferry Nuclear Plant, Units 1, 2, and 3. We have reviewed the Draft Environmental Statement, as well as the Supplements and Additions, in accordance with the requirements placed on Federal Agencies by the National Environmental Policy Act of 1969.

Consistent with the letter from Mr. Harold L. Price, to Mr. Watson dated June 30, 1971, we have concentrated our review on the radiological impact of normal plant operation and the impact of radiological accidents.

While we agree with your conclusion that "no significant environmental effects should result from planned radioactive releases----," we believe that the document should be strengthened as indicated in enclosure 1. Many of the suggested changes are based on models and calculational techniques that we are applying to other nuclear plants.

Enclosure 2 represents our analyses of the Environmental Impact of Radiological Accidents Utilizing the uniform models and calculations mentioned above. We believe the guide for accident analyses issued by the Commission as a proposed amendment to Appendix D of 10 CFR Part 50 December 1, 1971 should be used by TVA in preparing its final statement.

If we can assist you further in this matter, please let us know.

Sincerely,

Lester Rogers

Lester Rogers, Director
Division of Radiological and
Environmental Protection

Enclosures:
1. Comments on Radiological Impact Section
2. Environmental Impact of Accidents

COMMENTS ON RADIOLOGICAL IMPACT SECTION

2.4.2(2) 1. The relative abundance of the various isotopes, reported by TVA in the liquid waste, prior to any processing, does not agree with information developed by the AEC, based on experience with operating boiling water reactors.

2.4.2(2) 2. TVA has assumed credit for operation at design efficiencies of waste treatment equipment such as demineralizers, evaporators, recombiners, and charcoal beds. Our experience has been that these systems may not operate as efficiently as specified by the equipment manufacturer. Thus, TVA's activity releases may be less conservative than indicated in the statement.

2.4.3(2) 3. Even taking into account comments 1 and 2 above, we are unable to reconcile the calculated doses from liquid wastes with AEC methods and results. That is, using a higher release activity and a mix which should yield a higher dose, our calculations yield whole body dose results lower than those in the TVA statement.

2.4.3(1) 4. The statement does not include any information on estimated amounts of the radioiodines and particulates in the gaseous wastes. Since the general area is agricultural, there are milk cows and possibly dairy herds in the area. We believe, at the very least, the dose to the infant thyroid via the milk route should be considered.

2.4.3(2) 5. There is no information in the statement concerning estimated GI Tract dose. It has been AEC practice to include this information when it is significant.

2.4.3(2) 6. There is no information in the statement concerning radiation doses to species other than man. Some statement concerning this radiological impact is normally included in an AEC-developed statement.

2.7.6 7. Since the area is an important waterfowl habitat, and considerable waterfowl hunting takes place, we believe it would be appropriate to consider including waterfowl in the environmental sampling program.

2.3.3 8. We believe a map of the site with the boundary of the exclusion area clearly marked would improve the statement.

If TVA desires to meet with the regulatory staff to discuss items 1 through 3 we are ready to meet with you at your convenience.

ENVIRONMENTAL IMPACT OF ACCIDENTS

Protection against the occurrence of postulated design basis accidents in the Browns Ferry Nuclear Power Station is provided through the defense in depth concept of design, manufacture, operation and testing, and the continued quality assurance program used to establish the necessary high degree of assurance for the integrity of the reactor primary system. These aspects will be considered in the Commission's Safety Evaluation for the Browns Ferry Station. Off-design conditions that may occur are limited by protection systems which place and hold the power plant in a safe condition. Notwithstanding this, the conservative postulate is made that serious accidents might occur, even though unlikely, and engineered safety features are installed to mitigate the consequences of these postulated events. The probability of occurrence of accidents and the spectrum of their consequences to be considered from an environmental effects standpoint have been analyzed using estimates of probabilities and realistic fission product release and transport assumptions. For site evaluation in our safety review, extremely conservative assumptions were used for the purpose of evaluating the adequacy of engineered safety features and for comparing calculated doses resulting from a hypothetical release of fission products from the fuel, against the 10 CFR Part 100 siting guidelines. The computed doses that would be received by the population and environment from actual accidents would be significantly less than those presented in our Safety Evaluation. The Commission issued guidance to applicants on September 1, 1971, requiring the consideration of a spectrum of accidents with assumptions as realistic as the state of knowledge permits. TVA's response was contained in the "Tennessee Valley Authority Draft Environmental Statement Supplements and Additions," received by the Commission on November 8, 1971.

TVA's report has been evaluated, using the standard accident assumptions and guidance issued by the Commission as a proposed amendment to Appendix D of 10 CFR Part 50 December 1, 1971 (Federal Register, Vol. 36, No. 231).

Nine classes of postulated accidents and occurrences ranging in severity from trivial to very serious have been identified by the Commission. In general, accidents in the high potential consequence end of the spectrum have a very low occurrence rate, and those on the low potential consequence end are characterized by a higher occurrence rate. The Commission's and TVA's examples for these classes of accidents are shown in Table I. Our examples are based on the proposed amendment to Appendix D, entered in the Federal Register on December 1, 1971, whereas TVA's are not. The examples given are reasonably homogeneous in terms of probability within each class.

Certain assumptions made by TVA, such as the assumption of an iodine partition factor in the suppression pool during a loss-of-coolant accident and the efficiency assigned to the charcoal filters in the standby gas treatment system, in our view, are unduly optimistic; but the use of alternative assumptions does not significantly affect the overall environmental risk.

Our estimates of the dose which might be received by an assumed individual standing at the site boundary in the windward direction, using the assumptions in the proposed Annex to Appendix D, are presented in Table II. Our estimates of the integrated exposure in man-rem that might be delivered to the population within 50 miles of the site are also presented in Table II. TVA's estimates were based on the 1970 population density figures, and 60 mile distance from the site, whereas our man-rem estimates were based on the projected population around the site for the year 2010.

To establish a realistic annual risk, the calculated doses in Table II should be multiplied by estimated probabilities of their occurrences. In general, we consider the events in Classes 2 through 5 as improbable, i.e., not likely, during the 40-year life of the plant. Accidents in Classes 6 through 7 are relatively less probable, but still are possible. The probability of occurrence of Class 8 accidents is very small. Accidents in this class are considered design basis accidents and are conservatively evaluated in the AEC's safety review.

The postulated occurrences in Class 9 involve failures more severe than those required to be considered for the design basis of protection systems and engineered safety features (i.e., Class 8 accidents). Their consequences could be severe; however, the probability of their occurrence is so small that their environmental risk is extremely low. Defense in depth (multiple physical barriers), quality assurance for design, manufacture, and operation, continued surveillance and testing, and conservative design are all applied to provide and maintain the required high degree of assurance that potential accidents in this class are, and will remain, so small in probability that the environmental risk is negligible and therefore need not be considered in our summary of radiological consequences to the population.

The information given in Table II indicates that the realistically estimated radiological consequences of the postulated accidents would result in exposures of an assumed individual at the site boundary to concentrations of radioactive materials within or comparable to the Maximum Permissible Concentrations (MPC) of 10 CFR Part 20, Table II. The tabulated information also shows that the estimated integrated exposure of the projected population within 50 miles of the station from each postulated accident would be orders of magnitude smaller than that from the naturally occurring radioactivity, which corresponds to approximately 137,200 man-rem/yr based on a natural background level of 0.115 rem/yr. When multiplied by the probability of occurrence, the annual potential radiation exposure of the population from all the postulated accidents is an even smaller fraction of the exposure from natural background radiation and, in fact, is well within naturally occurring variations in the natural background. It is concluded from the results of the "realistic" analysis that the environmental risks due to postulated radiological accidents at the Browns Ferry Station are exceedingly small and need not be considered further.

TABLE I

CLASSIFICATION OF POSTULATED ACCIDENTS AND OCCURRENCES

of Class	Description	AEC Examples 1/	TVA Example(s)
1	Trivial incidents	Routine releases	Small spills, small leaks inside containment.
2	Small releases outside containment	Steamline relief valves releases and small spills and leaks.	Spills, leaks, and pipe breaks.
3	Radwaste system failures	3.1 Equipment leakage or malfunction. 3.2 Release of waste gas storage tank contents. 3.3 Release of liquid waste storage tank contents.	Equipment failure, serious malfunction or human error.
4	Fission products to primary system	4.1 Fuel cladding defects. 4.2 Off-design transients that induce fuel failures above those expected.	Fuel failures during normal operation. Transients outside expected ranges of variables.
5	Fission products to primary and secondary system (PWR)	Not applicable	Class 4 and heat-exchanger leak.
6	Refueling accidents	6.1 Fuel bundle drop. 6.2 Heavy object drop onto fuel in core.	Dropping fuel element. Drop heavy object onto fuel. Mechanical malfunction or loss of cooling in transfer tube.
7	Spent fuel handling accident	7.1 Fuel assembly drop in fuel storage pool. 7.2 Heavy object drop onto fuel rack. 7.3 Fuel cask drop.	Transportation incident on site. Drop fuel element. Drop heavy object onto fuel. Drop shielding cask--loss of cooling to cask.

1/ Numerical values of radiological releases shown in Table II.

of Class	Description	AEC Examples[1/]	TVA Example(s)
8	Accident initiation events considered in design basis evaluation in the Safety Analysis Report	8.1 Loss of coolant accidents. 8.1 (a) Break in instrument line from primary system that penetrates the containment. 8.2 Rod drop accident. 8.3 Steamline breaks.	Reactivity transient. Rupture of primary piping. Flow decrease-steamline break.
9	Hypothetical sequences of failures more severe than Class 8	None	Successive failures of multiple barriers normally provided and maintained.

[1/] Numerical values of radiological releases determined by the AEC shown in Table II.

TABLE II

SUMMARY OF RADIOLOGICAL CONSEQUENCES OF POSTULATED ACCIDENTS DETERMINED BY THE A.E.C.

Class	Event	Estimated Fraction of 10 CFR Part 20 Limit at Site Boundary 1/	Estimated Dose to Population in 50 mile Radius, man-rem
1.0	Trivial incidents	2/	2/
2.0	Small releases outside containment	2/	2/
3.0	Radwaste system failures		
3.1	Equipment leakage or malfunction	.003	0
3.2	Release of waste gas storage tank contents	0.011	1.23
3.3	Release of liquid waste storage tank contents	Neg.	Neg.
4.0	Fission products to primary system		
4.1	Fuel cladding defects	2/	2/
4.2	Off-design transients that	0.003	0.38
5.0	Fission products to primary and secondary systems (PWR)	N.A.	N.A.
6.0	Refueling accidents		
6.1	Fuel bundle drop	<.001	0.033
6.2	Heavy object drop onto fuel in core	.0025	0.0288
7.0	Spent fuel handling accident		
7.1	Fuel assembly drop in fuel storage pool	<.001	0.033
7.2	Heavy object drop onto fuel rack	<.001	0.013
7.3	Fuel cask drop	0.002	0.263

1/ Represents the calculated whole body dose as a fraction of 500 mrem (or the equivalent dose to organ).

2/ These releases will be comparable to the design objective indicated in the proposed Appendix I to 10 CFR Part 50 for routine effluents (i.e., 5 mrem/yr to an individual from all sources).

Class	Event	Estimated Fraction of 10 CFR Part 20 Limit at Site Boundary 1/	Estimated Dose to Population in 50 mile Radius, man-rem
8.0	Accident initiation events considered in design basis evaluation in the safety analysis report		
8.1	Loss-of-coolant accidents		
	Small break	<.001	0.071
	Large break	<.001	0.404
8.1 (a)	Break in instrument line from primary system that penetrates the containment	<.001	0.004
8.2	Rod drop accident	0.004	0.41
8.3	Steamline breaks		
	Small break	<.001	0.094
	Large break	0.05	5.85

1/ Represents the calculated whole body dose as a fraction of 500 mrem (or the equivalent dose to organ).

2/ These releases will be comparable to the design objective indicated in the proposed Appendix I to 10 CFR Part 50 for routine effluents (i.e., 5 mrem/yr to an individual from all sources).

FEDERAL POWER COMMISSION
WASHINGTON, D.C. 20426

IN REPLY REFER TO:
PWR-ER

December 22, 1971

Dr. F. E. Gartrell
Director of Environmental Research
and Development
Tennessee Valley Authority
Chattanooga, Tennessee 37401

Dear Dr. Gartrell:

This is in response to your letter of November 8, 1971, requesting the comments of the Federal Power Commission on the Draft Environmental Statement for the Browns Ferry Nuclear Plant - Units 1, 2 and 3, Supplement and Additions.

The enclosed staff report, prepared by the Commission's Bureau of Power, sets forth specific information relative to the projected load and power supply conditions for the Applicant and for the Southeastern Electric Reliability Council of which the Applicant is a member. The report illustrates the need for the three units at the peak load period following their currently scheduled commercial service dates.

Very truly yours,

T. A. Phillips
Chief, Bureau of Power

Enclosure
Report on the Browns Ferry Nuclear Plant
Supplemental Environmental Statement

FEDERAL POWER COMMISSION
BUREAU OF POWER

Report on the Browns Ferry Nuclear Plant
Supplemental Environmental Statement

In his letter dated November 8, 1971, the Director of Environmental Research and Development, Tennessee Valley Authority, requested the comments of the Federal Power Commission on need for power to be supplied by the three 1,065 megawatt Browns Ferry nuclear electric generating units. We understand that the environmental aspects of this plant are currently undergoing supplemental analysis and that the Atomic Energy Commission wishes to consider such factors as: the effect of delays in facility operation upon the public interest, particularly "the power needs to be served by the facility; the availability of alternative sources, if any, to meet those demands on a timely basis; and delay costs to the licensee and to consumers." Thus our comments are directed to these points in a review of the need for the facilities as concerns the adequacy and reliability of the Applicant's electric system and the systems of the Southeastern Electric Reliability Council area, the regional reliability council which includes the Applicant. This is in accordance with the National Environmental Policy Act of 1969, and the Guidelines of the President's Council on Environmental Quality dated April 23, 1971.

The Browns Ferry Nuclear Plant has three 1,065 megawatt electrical units in various stages of construction. The Applicant states it now expects authorization for full power operation for Unit No. 1 in October 1972, Unit No. 2 in July 1973, and Unit No. 3 in February 1974. These dates recognize already suffered delays in the initially planned full power operation dates of five months, four months, and one month respectively for the three units. The Applicant states its system experiences winter and summer peaks with the highest annual peak loads in its service area usually occurring between November and March. However, due to seasonal firm power exchange agreements with other power systems, the total loads which its generating capacity must actually serve during the remainder of this decade will be greater in the summer than in the preceding winter. This is to say that the already suffered delay of five months for Unit No. 1 will affect the concerned systems in meeting their 1972 summer peak demands, and the four month delay for Unit No. 2 likewise will be of concern in meeting early summer 1973 demands. The one month delay experienced to date for Unit No. 3 is not likely to be at great consequence unless further slippage should affect the availability of the unit for service during the summer of 1974.

The following report of the Bureau of Power considers the needs for Unit No. 1 to meet the 1972-73 winter peak load responsibility and for both Units No. 1 and No. 2 to meet the 1973 summer peak load responsibility. It also shows the situation that could obtain in the 1972 summer and the 1973-74 winter peak demand periods since the Applicant has advised that Unit No. 1 is not expected to be in commercial operation until after the projected 1972 summer peak, and Unit No. 3 until after the projected 1973-74 winter peak.

In preparing this report, the staff of the Bureau of Power has considered the Applicant's Draft Environmental Statement -- Supplements and Additions -- Browns Ferry Nuclear Plant Units No. 1, No. 2, and No. 3; related reports made in response to the Commission's April 1970 Statement of Policy on Adequacy and Reliability of Electric Service (Order No. 383-2), and the FPC staff's independent analyses of these documents together with related information from other FPC reports.

Need for the Facilities

The following tabulation shows the load to be served by the Applicant and the systems of the Southeastern Electric Reliability Council, including the Applicant, and the relationship of the Browns Ferry units to their expected available reserve margins at the times of the 1972 summer, 1972-73 winter, 1973 summer, and 1973-74 winter peaks. These are the anticipated initial service periods of the new units, but the life of these units is expected to be some 35 years, and they are expected to constitute a proportionate part of the Applicant's total generating capacity throughout that period. Therefore, they will be depended upon to supply power to meet future demands over a period of many years beyond the initial service needs discussed in this report.

The Applicant states that, in addition to the Browns Ferry nuclear units, its net capability forecasts reflect 660 megawatts of new gas-turbine capacity scheduled for May 1972, Cumberland No. 1 (1,275 megawatts) fossil-fired unit scheduled for July 1972, and Cumberland No. 2 (1,275 megawatts) fossil-fired unit scheduled for April 1973. In addition to the Applicant's 2,130 megawatts of nuclear capacity (Browns Ferry No. 1 and No. 2) included in the evaluation period, other members of the Southeastern Electric Reliability Council are including ten[1/] nuclear units aggregating approximately 8,000 megawatts in their forecasted net capability for the same period. Of these ten units, only Robinson No. 2 is currently operating. Some of the remaining nine have already experienced delays which have prevented their meeting initially forecast operating dates, and there is no absolute certainty that any

1/ To meet 1972 Summer peak: Turkey Point No. 3 (728 MW), Turkey Point No. 4 (728 MW), Surry No. 1 (788 MW), Surry No. 2 (788 MW), Robinson No. 2 (700 MW), and Oconee No. 1 (885 MW).
To meet 1972-73 Winter peak: Oconee No. 2 (885 MW)
To meet 1973 Summer: Crystal River No. 3 (855 MW), Hatch No. 1 (786 MW), and Oconee No. 3 (885 MW).

TVA SYSTEM RESERVE MARGIN

	1972 Summer Peak	1972-73 Winter Peak	1973 Summer Peak	1973-74 Winter Peak
Without Browns Ferry Units				
Net Capability - Megawatts	20,746	20,540	22,021	21,810
Load Responsibility - Megawatts 1/	18,040	18,140	20,120	19,715 6/
Reserve Margin - Megawatts	2,706	2,400	1,901	2,095
Reserve Margin - Percent of Load Responsibility	15.0	13.2	9.4	10.6
With Browns Ferry Units				
Net Capability - Megawatts	20,746	21,605 3/	24,151 4/	23,940 5/
Load Responsibility - Megawatts 1/	18,040	18,140	20,120	19,715 6/
Reserve Margin - Megawatts	2,706	3,465	4,031	4,225
Reserve Margin - Percent of Load Responsibility	15.0	19.1	20.0	21.4
Percent of Reserve Represented by These Units	2/	30.7	52.8	50.4

3.9-4

SOUTHEASTERN REGION SYSTEMS RESERVE MARGIN

	1972 Summer Peak	1972-73 Winter Peak	1973 Summer Peak	1973-74 Winter Peak
Without Browns Ferry Units				
Net Capability - Megawatts	75,768 7/	76,508 8/	84,915 9/	85,455
Load Responsibility - Megawatts 1/	65,471	63,211	72,941	69,590 6/
Reserve Margin - Megawatts	10,297	13,297	11,974	15,865
Reserve Margin - Percent of Load Responsibility	15.7	21.0	16.4	22.8
With Browns Ferry Units				
Net Capability - Megawatts	75,768 7/	77,573 3/ 8/	87,044 4/ 9/	87,585 5/
Load Responsibility - Megawatts 1/	65,471	63,211	72,941	69,590 6/
Reserve Margin - Megawatts	10,297	14,362	14,103	17,995
Reserve Margin - Percent of Load Responsibility	15.7	22.7	19.3	25.9
Percent of Reserve Represented by These Units	2/	7.4	15.1	11.8

1/ System load plus net of firm receipts and deliveries.
2/ Units not available.

3/ Includes Browns Ferry No. 1.
4/ Includes Browns Ferry No. 1 and No. 2.
5/ Includes Browns Ferry No. 1 and No. 2, but not No. 3 which is now delayed beyond assumed January peak.
6/ Could be 625 megawatts greater, if AEC load increase is supplied.
7/ Includes as in service for this and subsequent peak periods: Turkey Point No. 3, Turkey Point No. 4, Surry No. 1, Surry No. 2, Robinson No. 2, and Oconee No. 1 nuclear units.
8/ Includes as in service for this and subsequent peak periods: Oconee No. 2 nuclear unit.
9/ Includes as in service for this and subsequent peak periods: Crystal River No. 3, Hatch No. 1, and Oconee No. 3 nuclear units.

will meet currently forecast operating dates. Very recent information indicates that Oconee No. 1 unit will be delayed at least three additional months from March to June 1972 because of equipment problems which will require factory repair. There are also indications that some of the other scheduled units will likely suffer further delay.

The Applicant states "With the exception of the summer of 1972 (reserve margin 15.0 percent), the margins shown in the above tabulation (19.1 percent, 20.0 percent, and 21.4 percent) are expected to be adequate if the currently projected schedules of capacity additions are achieved." Without the timely installation of the Browns Ferry units, the Applicant's acceptable levels of reserve margin of 19.1 percent for 1972-73 winter, 20.0 percent for 1973 summer, and 21.4 percent for 1973-74 winter are reduced to 13.2 percent, 9.4 percent, and 10.6 percent respectively. The Applicant lists among its presently operating thermal electric generating units one of 1,150 megawatts, one of 950 megawatts, two of 704 megawatts, one of 575 megawatts, and two of 550 megawatts. To these medium to large units will be added the two Cumberland units of 1,275 megawatts each and two of the three Browns Ferry units of 1,065 megawatts each by the time of the 1973-74 winter peak. At that time, the integrity of the 4,225 megawatts of reserve margin the Applicant deems acceptable will be rested in four large units, the smallest being 1,065 megawatts capacity. The preceding 1973 summer's reserve margin of 4,031 megawatts, also deemed acceptable by the Applicant, is almost satisfied by the three largest units. Because of the relative efficiencies and economies of scale in the operation of these large units, it would not be normal to expect these units to be scheduled out for routine or normal maintenance during these periods, consequently the forced outage of any of these units during these periods has a proportionally large effect upon the system's ability to withstand second or third contingencies. The reserve margins indicated in the foregoing tabulations are gross in that they include allowances for scheduled maintenance, forced outages, errors in load forecasting, and spinning reserve requirements, and recent experience with new large generating units indicates frequent forced outages of such units during the initial months of their operation.

If the same implied reserve margin criterion is applied to the load responsibilities of the Southeastern Electric Reliability Council regional resources as to the TVA system, the analysis indicates the 1972 summer to be a critical period and similarly the 1973 summer without the first Browns Ferry unit. However, the region is dependent upon a little more than 10,000 megawatts of nuclear capacity, including two of the Browns Ferry units, being in timely service over this period to meet the levels of reserve margin shown. This 10,000 megawatts represents approximately 72 percent of the total reserve margin shown for 1973 summer, and the delay of more than one of these units from their presently scheduled dates is a real possibility with a resulting undesirable deterioration of the reserve margins shown.

Transmission Facilities

Because of the proximity of the plant to the Applicant's existing 500-kilovolt EHV transmission grid, all new transmission line construction was within a 20-mile radius of the plant, and totaled approximately 70 miles. Two existing 500-kilovolt lines were looped through the plant, yielding four line terminals, and two new 500-kilovolt lines, each approximately ten miles in length, were constructed from the plant site to a nearby industrial load center. In addition to these six 500-kilovolt lines whose main function is to deliver power from the plant into the bulk power transmission system, two 161-kilovolt lines were constructed into the plant site from the existing 161-kilovolt network. In addition to furnishing construction power to the site, these two lines will provide backup station service to the nuclear plant for emergency operation. This transmission construction program is complete.

The Applicant states that in the design, routing, and construction of these transmission facilities measures were employed to minimize land-use impact. These included multiple use of existing rights-of-ways, selection of aesthetically designed materials and structures, and routing to reduce visual exposure.

Alternates for the Proposed Facilities

Within the time available, there are no known alternate additions of base load generating capacity which could be substituted for these units. Although some utilities have found it possible under somewhat special circumstances to meet a shorter time schedule, the Applicant states that the lead time, from the decision to purchase gas turbines until their commercial operation, is about 18 months. On this basis, immediate decision to substitute this type of normally considered peaking generation for any part of the Browns Ferry generation would not be productive in meeting loads any sooner than the mid-summer of 1973.

The regional reliance upon the timely operation of the ten nuclear generating units noted above, not including the three Browns Ferry units, provides percentages of reserve margins as shown in the earlier table of 15.7, 21.0, 16.4, and 22.8 respectively for the four critical load periods tabulated. With the possibility of further delays affecting some of these ten units, the Applicant cannot rely upon substantial aid from other utilities within the region. The Applicant states that another 600 megawatts of seasonal exchange power from the South Central Electric Companies for the 1972-73 winter appears to be the only likely source of firm power from outside the region. To obtain this, notice must be given by February 1972.

The relatively few miles of transmission lines added, for a plant of this size, are already constructed.

Conclusions

The staff considers that the 2,130 megawatts of capacity represented by Browns Ferry No. 1 and No. 2 units is needed to assist in meeting the Applicant's 1972 summer, 1972-73 winter, 1973 summer, and 1973-74 winter peaks and provide reasonable reserve margins for adequacy and reliability of electric service. Prudent and responsible operations include provisions for loss of capacity due to forced outages of generating capacity, occurrence of loads higher than those forecast, operating margins required to fulfill obligations to participants in the interconnected systems, and operating margins to provide for flexibility in the allocation of load to generating resources because of abnormal bulk power system conditions. Also, in systems with significant hydroelectric generation, such as the Applicant's, provisions must be made for capacity in thermal generation to meet the contingencies inherent in hydroelectric resources under varying seasonal hydro conditions.

The Applicant estimates the energy costs from these units during the 1973-75 period to be about 1.8 to 1.9 mills per kilowatt hour, and replacement energy which would be used in lieu of this nuclear energy to cost from 3.5 to 10.0 mills per kilowatt hour, depending upon its source -- older TVA units, purchases, or gas turbines. The staff has examined these cost ranges and finds them to be reasonable. Using these costs, the Applicant conducted a computer study which indicated that each month's delay on these three units would result in increased production expenses on the TVA system of approximately $4 million. The Applicant states that if construction were to be suspended, an additional construction cost of approximately $3 million per month of suspension would be incurred, not including a substantial interruption cost. These costs must ultimately be borne by the consumer.

T. A. Phillips

T. A. Phillips

12/16/71

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
AREA OFFICE
DANIEL BUILDING, 15 SOUTH 20TH. STREET, BIRMINGHAM, ALABAMA 35233

August 16, 1971

REGION IV
REGIONAL OFFICE
ATLANTA, GEORGIA

IN REPLY REFER TO:
4.1SQ

Mr. F. E. Gartwell
Director of Environmental
Research and Development
Tennessee Valley Authority
Chattanooga, Tennessee 37401

Re: Brown's Ferry Nuclear Plant - Units 1, 2, and 3.

Dear Mr. Gartrell:

SUBJECT: Request for HUD Comments on Draft Environmental Impact Statement

We are pleased to acknowledge receipt of the above referenced request for HUD comments under the requirements of the National Environmental Policy Act of 1969 (PL 91-190).

We have reviewed the information submitted along with your referral and, to the extent of our available staff resources, have investigated the environmental impact, adverse effects, alternatives, short term uses of the local environment and long term productivity and irreversible and irretrievable commitment of resources which the project involves. From the information available to us, we find no basis for comment because of special HUD interest or expertise. However, we would call your attention to the areas indicated on the attached "HUD Comments on Draft Environmental Impact Statement" which we feel would assist your agency in the evaluation and execution of this project.

We were unable to determine if this proposal has been submitted to the Area-wide Regional Planning Agency as required under OMBA-95(revised effective April, 1971).

Please advise your field staff that if they were to indicate such submission within the body of the Environmental Statements submitted to this agency it would materially assist and expedite your requests for our comments.

Should further clarification of our review be deemed necessary, please contact Mr. Peter Field, Director, Production Division, 15 South 20th Street, (Daniel Building - Sixth Floor), Birmingham, Alabama 35233 at 205-325-3697.

Sincerely,

Raymond M. Sherry

Raymond M. Sherry
Special Assistant to Area Director
(Planning Requirements)

DHUD COMMENTS ON DRAFT ENVIRONMENTAL IMPACT STATEMENT

Project Identification:
Brown's Ferry Nuclear Plant, Units 1, 2, and 3

Project Location:
Limestone County, Alabama

The following includes the general caveats and remarks which we feel should be brought to the attention of any State, local or Federal agency which has requested DHUD review of and comment on a draft Environmental Statement under the Environmental Policy Act of 1969 and the CEQ Guidelines. We have checked those comments which seem to be particularly applicable to the draft statement identified above; however the letter of transmittal will amplify these general comments if appropriate.

COMMENTS

[X] Inasmuch as HUD has no direct program involvement in Historic sites or structures effected by the subject project, we defer to the Advisory Council on Historic Preservation with respect to Historic Preservation matters.

[ ] HUD has direct program involvement in the Historic Preservation aspects of the proposed project and appropriate comment is included in the transmittal letter.

[ ] The subject project effects an urban park or recreational area and appropriate comment is included in the transmittal letter.

[X] The subject project effects only rural parks and recreational areas and HUD therefore defers to the Forest Service of the Department of Agriculture, the Bureau of Outdoor Recreation, Bureau of Land Management, National Park Service and the Bureau of Sports Fisheries and Wildlife with respect to comments on the Parks, Forests and Recreational effects thereof.

[ ] This project will probably involve a statutorily required HUD review under Section 4(f) of the Transportation Act of 1966. Therefore, we defer comment on the parks and recreational aspects of the project pending request by D.O.T. for such a review.

☒ This review covers the HUD responsibilities under Section 4(f) of the Transportation Act of 1966.

☐ The Draft Environmental Statement fails to reflect clearance or consultation with the appropriate local planning agency which is: ______________________________.

☐ The Draft Environmental Statement fails to reflect consultation or clearance with the appropriate areawide planning agency which is: ______________________________.

☐ The Draft Environmental Statement fails to reflect consultation or clearance with the appropriate State Clearinghouse as required by Circular A-95, Office of Management and Budget. The A-95 Clearinghouse of jurisdiction is: ______________________________.

☐ The project apparently requires the displacement of businesses or residences. The Draft Environmental Statement does not reveal full consideration of the requirements of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (Public Law 91-646). If relocation assistance is desired, please contact Mr. Peter Field, Director, Production Div., Daniel Bldg., 15 So. 20th Street, Birmingham, Ala. at 205-325-3697. In the local community the person or office most familiar with relocation resources is: ______________________________.

☐ The draft statement does not discuss apparently feasible alternatives which may have a more beneficial effect on the urban environment. See letter of transmittal for possibly overlooked alternatives.

☒ In general, HUD defers to other agencies with respect to establishing and enforcing air and water quality standards, thermal pollution standards, radiation and general safety standards. We have no formal jurisdiction over such matters and no comments contained herein should be construed as assuming such responsibility or jurisdiction.

[X] Since this project raises issues involving radiation safety, we recommend consultation with: Dr. Joseph Lieberman, Radiation Office, E.P.A., 5600 Fishers Lane, Parklawn Building, Rockville, Maryland 20852.

[ ] We recommend that you write or call the Office of Management and Budget for a copy of "Directory of State, Metropolitan and Regional Clearinghouses under B.O.B. Circular A-95," and consult with such clearinghouses as appropriate.

August 13, 1971
DATE

Carlton L. Lowe
PREPARED BY
(FIELD REPRESENTATIVE)

August 16-1971
DATE

John D. Page, Jr.
CONCURRED IN
(PROGRAM MANAGER)

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
AREA OFFICE
DANIEL BUILDING, 15 SOUTH 20TH. STREET, BIRMINGHAM, ALABAMA 35233

November 22, 1971

REGION IV
REGIONAL OFFICE
ATLANTA, GEORGIA

IN REPLY REFER TO:
4.1SQ

Mr. F. E. Gartrell
Tennessee Valley Authority
Chattanooga, Tennessee 37401

Re: Brown's Ferry Nuclear Plant
Units 1, 2, and 3

Dear Mr. Gartrell:

SUBJECT: Request for HUD Comments on Draft Environmental Impact Statement

We are pleased to acknowledge receipt of the above referenced request for HUD comments under the requirements of the National Environmental Policy Act of 1969 (PL 91-190).

We have reviewed the information submitted along with your referral and, to the extent of our available staff resources, have investigated the environmental impact, adverse effects, alternatives, short term uses of the local environment and long term productivity and irreversible and irretrievable commitment of resources which the project involves. From the information available to us, we find no basis for comment because of special HUD interest or expertise. However, we would call your attention to the areas indicated on the attached "<u>HUD Comments on Draft Environmental Impact Statement</u>" which we feel would assist your agency in the evaluation and execution of this project.

We were unable to determine if this proposal has been submitted to the Area-wide Regional Planning Agency as required under OMBA-95(revised effective April, 1971).

Please advise your field staff that if they were to indicate such submission within the body of the Environmental Statements submitted to this agency it would materially assist and expedite your requests for our comments.

Should further clarification of our review be deemed necessary, please contact Mr. Peter Field, Director, Production Division, 15 South 20th Street, (Daniel Building - Sixth Floor), Birmingham, Alabama 35233 at 205-325-3697.

Sincerely,

Raymond M. Sherry

Raymond M. Sherry
Special Assistant to Area Director
(Planning Requirements)

DHUD COMMENTS ON DRAFT
ENVIRONMENTAL IMPACT STATEMENT

Project Identification:
Browns Ferry Nuclear Plant
Units 1, 2 + 3

Project Location:
15 miles N.W of Decatur, ALA.
on the Tennessee River

The following includes the general caveats and remarks which we feel should be brought to the attention of any State, local or Federal agency which has requested DHUD review of and comment on a draft Environmental Statement under the Environmental Policy Act of 1969 and the CEQ Guidelines. We have checked those comments which seem to be particularly applicable to the draft statement identified above; however the letter of transmittal will amplify these general comments if appropriate.

COMMENTS

/_/ Inasmuch as HUD has no direct program involvement in Historic sites or structures effected by the subject project, we defer to the Advisory Council on Historic Preservation with respect to Historic Preservation matters.

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/✓/ The subject project effects only rural parks and recreational areas and HUD therefore defers to the Forest Service of the Department of Agriculture, the Bureau of Outdoor Recreation, Bureau of Land Management, National Park Service and the Bureau of Sports Fisheries and Wildlife with respect to comments on the Parks, Forests and Recreational effects thereof.

/_/ This project will probably involve a statutorily required HUD review under Section 4(f) of the Transportation Act of 1966. Therefore, we defer comment on the parks and recreational aspects of the project pending request by D.O.T. for such a review.

/ / This review covers the HUD responsibilities under Section 4(f) of the Transportation Act of 1966.

/ / The Draft Environmental Statement fails to reflect clearance or consultation with the appropriate local planning agency which is: ____

____.

/ / The Draft Environmental Statement fails to reflect consultation or clearance with the appropriate areawide planning agency which is: ____

____.

/ / The Draft Environmental Statement fails to reflect consultation or clearance with the appropriate State Clearinghouse as required by Circular A-95, Office of Management and Budget. The A-95 Clearinghouse of jurisdiction is: ______________________

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/ / The project apparently requires the displacement of businesses or residences. The Draft Environmental Statement does not reveal full consideration of the requirements of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (Public Law 91-646). If relooation assistance is desired, please contact Mr. Peter Field, Director, Production Div., Daniel Bldg., 15 So. 20th Street, Birmingham, Ala. at 205-325-3697. In the local community the person or office most familiar with relocation resources is: ______________________

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/ / The draft statement does not discuss apparently feasible alternatives which may have a more beneficial effect on the urban environment. See letter of transmittal for possibly overlooked alternatives.

/✓/ In general, HUD defers to other agencies with respect to establishing and enforcing air and water quality standards, thermal pollution standards, radiation and general safety standards. We have no formal jurisdiction over such matters and no comments contained herein should be construed as assuming such responsibility or jurisdiction.

/X/ Since this project raises issues involving radiation safety, we recommend consultation with: Dr. Joseph Lieberman, Radiation Office, E.P.A., 5600 Fishers Lane, Parklawn Building, Rockville, Maryland 20852.

/ / We recommend that you write or call the Office of Management and Budget for a copy of "Directory of State, Metropolitan and Regional Clearinghouses under B.O.B. Circular A-95," and consult with such clearinghouses as appropriate.

11/22/71 — DATE

Donald R. Janne — PREPARED BY (FIELD REPRESENTATIVE)

DATE

CONCURRED IN (PROGRAM MANAGER)

DEPARTMENT OF THE ARMY
NASHVILLE DISTRICT, CORPS OF ENGINEERS
P. O. BOX 1070
NASHVILLE, TENNESSEE 37202

IN REPLY REFER TO
ORNED-P

18 January 1972

Dr. F. E. Gartrell
Director of Environmental Research
and Development
Tennessee Valley Authority
Chattanooga, Tennessee 37401

Dear Dr. Gartrell:

Your letter of 8 November 1971 forwarding a copy of the Supplement and Additions to the draft environmental statement for Browns Ferry Nuclear Plant - Units 1, 2 and 3, to Dr. Louis M. Rousselot, Assistant Secretary for Defense (Health and Environment), was referred to this office for reply.

The areas discussed in the Supplement and Additions in which the Corps of Engineers has special expertise or jurisdiction appear to have been adequately covered. Since the navigational aspects of this project were coordinated with this agency in previous years, there should be no conflicts with any present or projected programs of the Corps of Engineers.

Line maintenance operations were discussed on page 2-28 of the Supplement and Additions, and did not indicate the use of chemicals of any kind. Excluding "brownouts" from transmission line rights-of-way, maintenance is considered appropriate and will definitely lessen the visual impact of these cleared areas.

The opportunity to review the Supplement and Additions to the draft environmental statement for Browns Ferry Nuclear Plant is appreciated.

Sincerely yours,

WM. F. BRANDES
Colonel, Corps of Engineers
District Engineer

CF:
Dir, Div of Radiological & Env.
Protection, AEC, WASH, DC
Mr. Charles R. Ford, Chief, Ofic
of Civ Functions, OUSA, WASH, DC
Mr. John A. Busterud, OASD (Env
Qlty) WASH, DC

ENVIRONMENTAL PROTECTION AGENCY

REGION IV

1421 Peachtree St., N.E., Atlanta, Georgia 30309

May 22, 1972

Dr. F. E. Gartrell
Director, Environmental Research
and Development
Tennessee Valley Authority
Chattanooga, Tennessee 37401

Subject: Browns Ferry Nuclear Plant Final Environmental Impact Statement

Dear Doctor Gartrell:

In regard to the TVA-EPA meeting of March 5, 1972 and the previous comments, telecommunications, and meeting of December 9, 1971 concerning the Final Environmental Impact Statement on the Browns Ferry Nuclear plant, we offer the following further comments:

As to TVA's present position on thermal criteria, we believe that EPA has satisfied the conditions of Section 4(b) of Executive Order 11507 by our letter of December 17, 1971, which defines the thermal criteria applicable to Browns Ferry Nuclear Plant: "Temperature shall not be increased more than 5°F above the natural prevailing background temperature, nor exceed a maximum of 86°F."

On this basis, we encourage TVA to use all environmentally acceptable methods 2.6.5[a]
in an attempt to meet the foregoing criteria during the interim period prior 2.6.7[b]
to completion of the cooling tower system rather than the proposed 10°F rise/ 2.7.1
93°F maximum temperature. 2.7.2

Since it appears that applicable criteria can be met with minimal effort when 2.6.5[a]
only one unit is in operation by regulating releases from upstream and down- 2.6.7[b]
stream dams and/or reduction in power levels during critical periods we rec- 2.7.2
commend this course of action. Table 2.6-3

When two or three units are in operation, however, these methods of control 2.6.1
will be harder to maintain, especially during peak power demand periods. 2.6.5[a]
Therefore, it is recommended that during the estimated eighteen-month 2.7.2
operational period prior to completing the cooling towers, all environmentally
acceptable methods be used in an attempt to meet applicable water quality Table 2.6-3
standards, including controlled releases from impoundments, reduced power levels, continuous use of completed cooling towers in the closed cycle mode, etc. Completion of the cooling towers should be expedited to the maximum degree feasible.

a. pp. 2.6-7 thru 2.6-10
b. p. 2.6-20

EPA recognizes that a reduced power level at the Browns Ferry Plant will necessitate the use of existing fossil fueled plants to provide needed power, which in turn will result in degradation of water, air and land at these sites. Further, it is understood that a balancing by TVA will be necessary to minimize total environmental effects from the TVA power system during this interim period. 2.6.5[a] 2.7.1

Studies of fish predation by traveling screens are recommended as soon as practicable at existing power stations and at Browns Ferry when the first unit begins operation and continued through three-unit operation. Such studies should determine numbers and weights of fish killed by species throughout the year during diurnal collection periods. Sampling should be conducted monthly except during critical periods, which it should be increased to weekly. 2.7.3(2)(c)

Studies are also recommended to determine alternate design configurations and parameters and auxilliary structures and equipment which could significantly reduce or eliminate fish mortality. Items to be investigated should include, but not be limited to, horizontal travel of screens, increased screen area, skimmer walls, air curtains, reduced pressure of screen wash sprays, sluicing of trapped fish back to the water at some point away from the screens, and frequency of screen operation (continuous versus intermittent). 2.6.2

Under present analysis techniques it appears that no zone of passage will exist when flow in the Tennessee River is less than ten times the condenser flow. Such a condition is in conflict with the recommendations of the National Technical Advisory Committee on Water Quality Criteria. We feel that a zone of passage must be provided at the Browns Ferry site to assure that migration of fish is not impeded, especially during critical spawning periods. We therefore recommend that the far section of the diffuser pipe (adjacent to the shallow overbank area) not be used and that closed cycle cooling be provided for the Unit discharging to that section of the diffuser pipe. 2.6.4 2.7.3(1)(a) IV.3

Sincerely yours,

Jack E. Ravan

Jack E. Ravan by: JRW
Regional Administrator

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a. p. 2.6-10

TVA RESPONSE TO COMMENT FROM

ENVIRONMENTAL PROTECTION AGENCY (MAY 22, 1972)

The May 22, 1972, letter from the Environmental Protection Agency was received when the environmental statement was in the final stages of preparation. Sections of the statement which cover several of the points raised by EPA are referenced in the margins of the letter, and additional response is made as follows.

TVA's plans for installing mechanical draft cooling towers and the interim operation of the Browns Ferry Nuclear Plant prior to their completion were discussed with representatives of EPA at a meeting on March 16, 1972. EPA's letter is in regard to that meeting.

EPA makes the important observation that for plant operation prior to the availability of cooling towers, a balancing is necessary to minimize total adverse environmental effects from the TVA power system as a whole. TVA agrees, and on that basis has concluded that the plant should be operated to meet the 10°F rise and 93°F maximum temperature criteria during the interim period.

Meeting the proposed thermal standards of a 5°F rise and 86°F maximum would involve the regulation of upstream reservoirs to provide additional streamflow at Browns Ferry, the reduction of generation by the Browns Ferry units, or a combination of the two.

Although it is feasible to use limited regulation by the TVA reservoir system to meet the 10°F rise and 93°F maximum criteria, the greater regulation which would be required to meet the more stringent criteria would result in drawdowns of upstream reservoirs so large that

TVA does not consider this approach to be practicable. Furthermore, the natural temperature of Wheeler Reservoir exceeds the 86°F on many occasions, in which case the proposed standards could not be realized even with upstream regulation.

TVA considers that the adverse impacts to the environment from increased generation by fossil-fueled plants as a result of reducing generation at Browns Ferry would exceed the questionable environmental benefit to aquatic life, particularly in view of the small percentage of time the proposed 5°F rise and 86°F maximum temperature standard would be exceeded during the interim period due to plant generation. TVA does not consider the interruption of service to power consumers to be an acceptable alternative in this case.

After taking the overall system requirements and environmental impacts into account, it is judged that the operation of the Browns Ferry plant to meet the 10°F rise and 93°F maximum temperature criteria during the interim period represents the best method of operation.

4.0 ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED

The CEQ guidelines require a discussion of any probable adverse environmental effects which cannot be avoided, such as water and air pollution, damage to life systems, urban congestion, threats to health, or other consequences adverse to the environmental goals set out in Section 101(b) of NEPA.

1. Water pollution - Large quantities of waste heat will be rejected to the waters of Wheeler Reservoir. Mechanical draft cooling towers will be installed to meet thermal standards. Extensive studies on the effects of heated water on aquatic life will be conducted in order to detect significant adverse effects. Both nonradioactive and radioactive wastes will of necessity be discharged to Wheeler Reservoir. Prior to being discharged, however, various treatment is provided to ensure that all applicable standards are met and the quantities and concentrations released are small enough to ensure that any probable adverse environmental effects are insignificant or undetectable. Additional processing of liquid radwaste will be instituted to keep releases as low as practicable.

Some siltation of the reservoir due to the construction of the mechanical draft cooling towers will occur. All reasonable efforts will be made to minimize siltation due to erosion, dredging, etc.

Water, aquatic life, and life systems will be monitored to assure that no significant adverse environmental impacts will occur due to water pollution.

2. Air pollution - Radioactive releases in the form of gaseous wastes will be discharged into the air. Installation of hydrogen recombiners and charcoal beds will assist in holding these releases to the lowest practicable levels. This should avoid significant adverse environmental effects. Careful monitoring will be conducted to ensure this result.

The operation of the cooling towers and diffusers will result in some additional air pollution in the form of heat rejection and releases of significant quantities of water vapor. This water vapor will, during certain atmospheric conditions, result in increased formation of fog and ice.

Small quantities of nonradioactive gaseous discharges to the air will result from operation of the auxiliary boilers and diesel generators. The quantities discharged are small, and comparison of the discharges to ambient standards show that these emissions will have negligible environmental impacts.

3. Impacts on land use - Construction of the base plant buildings, the cooling water diffuser system, and the transmission facilities for Browns Ferry have been completed. Environmental impacts from these activities have occurred.

Approximately 130 acres of land will be graded or excavated for the installation of the cooling towers. This land will be on the 840-acre plant site, and no additional purchase of land will be required.

The base plant will be essentially noiseless and aesthetically pleasing. Addition of the mechanical draft cooling towers will result in increased noise levels and some expense to the aesthetics of the project and surrounding environment. However, noise levels will be within acceptable limits, and the cooling towers will be made visually acceptable so that their presence and operation should cause no significant impact.

4. Damage to life systems - When cooling water passes through the traveling screens en route to the condensers, fish larvae will be drawn into the intake water. At this time it is not known the extent to which fish larvae are present near the condenser cooling water intake. Studies are under way to determine this and, as operating experience is gained, to develop steps which could reduce the intake of fish larvae. Plankton present in the condenser cooling water will also be destroyed, in the sense that it is changed as a source of food when seasonally subjected to temperatures in excess of 96.8°F in passing through the condensers. This effect may be reduced by the addition of cooling towers since operation with the towers results in smaller quantities of water intake. At the time when the most adverse conditions exist for plankton damage, a maximum of about 25 percent of the total riverflow passes through the condensers. Based on TVA's experience with other large thermal plants, rapid reseeding of plankton populations downstream of the condenser outfall would be expected. To the extent that this plankton serves as a food source to aquatic life, its destruction is an adverse effect which cannot be avoided.

There may be some loss of existing river bottom fauna and habitat in the immediate vicinity of the diffuser pipes.

There will be a loss of 13 acres of this habitat within the cooling water return channel. These are adverse effects which cannot be avoided.

While these effects cannot be avoided, they are not expected to damage significantly any life system. Extensive studies are designed to detect significant adverse effects.

5. Threats to health - The facility is being designed and constructed and will be operated in accordance with all applicable Federal and state regulations in order to assure that the health and safety of the public will be safeguarded.

Significant accidental releases of radioactive products at the plant or during transportation of radioactive materials are very improbable. Should such a release occur, implementation of the radiological emergency plans would mitigate the potential risk to the public.

6. Socioeconomic effects - The primary and secondary social and economic impacts were covered in section 5.0 of Volume 2. As indicated, the total magnitude of these impacts is large; however, the distribution of residences and local material supply sources occurs over a 40-mile radius of the plant site. While this may produce temporary stress on the social infrastructure (schools, roads, housing, and similar services), it will also provide a stimulus to area economical development (jobs, attraction of visitors, etc.). There should be no severe social or economic dislocation as the project construction phases out.

7. Conclusion - The operation of Browns Ferry will result in some adverse environmental effects which cannot be avoided. However, these effects are not expected to conflict with the environmental goals set out in Section 101(b) of NEPA. If any significant adverse effects attributable to operation of the plant become evident through the various environmental monitoring programs, appropriate steps will be taken to correct the situation.

5.0 ALTERNATIVES

Section 102(2)(C) of NEPA requires a discussion of alternatives to the proposed action, and Section 102(2)(D) requires an agency to "study, develop, and describe appropriate alternatives to recommend courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources."

The Browns Ferry Nuclear Plant was initiated before NEPA became effective, and the TVA Board of Directors has determined that it is not practicable to reassess the basic course of action in the design and construction of the plant. The environmental statement considers the ways in which the plant will interact with the environment by reevaluating environmental consequences considered at the outset of the project and minimizing any further adverse environmental consequences that would affect the overall balance of environmental costs and benefits by studying and adopting appropriate alternatives.

1. Alternative heat dissipation methods - The systems which were given consideration as alternative heat dissipation methods include mechanical draft cooling towers, natural draft cooling towers, a spray canal system, and a cooling lake. These alternatives were considered using feasibility, environmental impact, and cost as factors in the analyses.

As described in section 3.4 of Volume 3, the spray canal and cooling lake alternatives were not considered feasible for this site. Consequently, detailed cost analyses were made only on the two types of cooling towers. The results of these studies indicated that the mechanical draft cooling tower alternative was the best choice.

The decision to incorporate this alternative into the plant design and the associated environmental impacts are described in section 2.6 of this volume.

2. Alternative systems for reductions of radioactive discharges - Analyses of alternative systems for the reduction of radioactive discharges include consideration of subsystems for both liquid and gaseous radioactive discharges. These systems were considered using feasibility, environmental impact, and cost as factors in the analyses.

(1) Liquid radwaste alternatives - Systems considered for the reduction of liquid radioactive effluents include demineralizers and evaporators.

As shown in section 3.1 of Volume 3, the evaporator alternative gives greater reductions in radioactive releases and has a considerable cost advantage. Consequently, TVA has concluded that an evaporator along with its associated buildings and equipment should be installed at the Browns Ferry Nuclear Plant.

No other feasible alternatives have been identified which would further reduce liquid radioactive discharges.

(2) Gaseous radwaste alternatives - The system originally designed for treatment of gaseous radioactive discharges included 30-minute holdup and elevated stack release. Four additional systems have been evaluated as alternative methods for reduction of these discharges: hydrogen recombiners, hydrogen recombiners and charcoal adsorbers, hydrogen recombiners and solvent absorption, and hydrogen recombiners and cryogenic distillation. A summary description

of each alternative system considered, the timing of the installation, its cost, and its potential environmental benefit is given in section 3.1 of Volume 3. Of these systems only the hydrogen recombiner with charcoal adsorbers have been proven in this type of service.

The analyses of these alternatives show that balancing the reductions in environmental impacts and costs of each of the feasible systems leads to the conclusion that a system utilizing a hydrogen recombiner in combination with six charcoal beds per unit is the best selection and reduces environmental impacts due to gaseous radioactive releases to the minimum practicable level.

6.0 SHORT-TERM USES VERSUS LONG-TERM PRODUCTIVITY

The local short-term uses of the environment are those required to construct and operate the facility. These include preparation of the site and construction of buildings, the use of the ambient air for the dispersion of gaseous effluents and heat, and the use of Wheeler Reservoir for the dissipation of waste heat, liquid radioactive effluents, and chemical discharges.

Most of the short-term use of the site will result in no significant effect on the long-term productivity of the land affected since only that portion occupied by the reactor systems buildings will be affected for a period much longer than the useful life of the plant. The long-term productivity of no other land will be irreparably damaged.

The operation of the plant will not result in any significant long-term environmental degradation. All effluents discharged to the air and water will be well within levels which are considered acceptable for short-term use, and no long-term effects are expected to occur as a result of these uses. Comprehensive monitoring programs will be carried out to assure detection of the existence of any such effects.

7.0 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

The CEQ guidelines call for a discussion of any irreversible and irretrievable commitments of resources which would be involved in the construction and operation of Browns Ferry. This requires identifying the extent to which operation of the facility curtails the range of beneficial uses of the environment.

The Browns Ferry plant is located in a rural, relatively isolated and sparsely populated area. The plant will not curtail the beneficial use of land, air, water, or living natural resources in the area.

In addition to those commitments described in section 9.0 of Volume 2, some by-products which result from the operation of the plant must also be considered as irreversible and irretrievable commitments of resources. These include damaged components which are radioactive, solid radwaste materials such as spent demineralizer resins, and various chemicals which are used in the plant processes. Chemicals used in plant processes will be widely dispersed to the environment and in most cases will have changed forms and will have lost their value. Reclamation of these chemicals after discharge from the plant is impractical.

The commitments of natural resources associated with this plant's construction and operation are small when compared to the benefits gained.

8.0 BENEFIT-COST WEIGHING AND BALANCING

This section provides an overall assessment of the economic, technical, and other benefits of the Browns Ferry Nuclear Plant weighed against the environmental costs, with the alternatives considered which would affect the balance of values.

While various benefits and environmental costs have been quantified, some are necessarily expressed in qualitative terms. For example, the effect of mechanical draft cooling towers on aesthetics is treated qualitatively, as is the specific contribution of electricity generated at Browns Ferry to the overall resource development of TVA; that is, advancement of physical, social, and economic development cannot reasonably be quantified. Moreover, of those factors subject to quantification, all cannot reasonably be expressed in monetary values. Although the number of fish larvae killed passing through the condensers can be quantified in terms of numbers, translation of that number to a monetary value is not reasonable in view of the wide range of variables influencing the significance of the impact. Environmental impacts, therefore, are quantified in commonly used terms such as numbers of fish, gallons of water, and tons of earth.

The decisions leading to the plans to construct the Browns Ferry facility were made in 1965-66, four to five years prior to the passage of the National Environmental Policy Act, and the Tennessee Valley Authority has determined that it is not practicable to reassess the basic course of action of designing and constructing the plant. The environmental review was limited to an analysis of the alternatives for limiting environmental impacts during the completion of construction of the project and the environmental impacts which will result from operation of the plant. During this environmental review, significant changes have been made to the plant to minimize the environmental impacts as summarized below:

<u>Gaseous Radwaste</u> - The original system which included 30-minute holdup has been reevaluated and is being modified to include hydrogen recombiners and six charcoal beds per generating unit.

<u>Liquid Radwaste</u> - The original system which included filtration and demineralization has been reevaluated and the system design modified to include an evaporator.

<u>Cooling Water</u> - The original system which included diffusers for dispersing the heat rejected to Wheeler Reservoir is being augmented with mechanical draft cooling towers.

With these modifications the Browns Ferry Nuclear Plant approaches a minimum impact plant. With normal operation from the plant the maximum radiation dose to the hypothetical individual is 1.5 percent of that received from natural background radiation and the dose to the population within 50 miles of the plant in the year 2010 is projected at 0.013 percent of the dose from natural background radiation. Therefore, radiation resulting from operation of the Browns Ferry Nuclear Plant will result in no undue risk to the health and safety of the public.

With the addition of cooling towers to the plant, the plant will operate so as to meet proposed water quality criteria of $5^{\circ}F$ temperature rise and a maximum temperature of $86^{\circ}F$.

TVA from its very inception has been deeply committed to the tasks of environmental improvement. The President in transmitting to Congress in 1933 the bill that became the TVA Act said that TVA ". . . should be charged with the broadest duty of planning for the proper use, conservation, and development of the natural resources of the Tennessee River drainage basin and its adjoining territory for the general social and economic welfare of the Nation." It is on the basis of these principles that TVA plans and conducts all its activities, be they planning, constructing, and operating a nuclear power plant; planning, building, and operating a water control project; providing research to develop a new fertilizer; setting aside areas for fish and wildlife; developing improved hardwood tree strains; or seeking ways to utilize the rugged scenic qualities of some of the region's natural streams. In all of these and TVA's many other varied resource development programs, its management and staff are deeply conscious of their responsibilities to all of the six million people in the TVA region and, more generally, to the 200 million people in the Nation.

This invariably calls for a balancing of the requirements and hopes of a variety of interests, and finally, decision and action in which differences are reconciled insofar as possible to best serve the needs of the greatest number over the longest possible time. Inherent in this is the requirement of finding a balance between the needs of man, including his need for useful employment, and the safeguarding of his physical environment.

In TVA, electric power is regarded as a tool for economic development. Its use has been encouraged as a means for improving the quality of life in the region. Fitted into a comprehensive, unified development program, it has helped ease the burdens of drudgery, provide more jobs and more productive employment, bring the amenities of life to an ever increasing number of people, and improve the health, education and living conditions of the people generally.

An abundant supply of low cost electric energy, integrated with a total resource development program, has been a major factor in the progress achieved by the TVA region since 1933. Employment, income, and productivity have all increased with a shift from a primarily agricultural to an industrial economy.

The uses of electricity are many. To the residential user it provides lighting, refrigeration, cooking, washing and drying of clothes, heating, air-conditioning, and education and entertainment via radio and television, to name but a few. Most stores, banks, and other commercial ventures are dependent upon electricity for conducting business. In industry it is an essential element by which productivity has been increased with an attendant improvement in living standards. While in most industrial activities the cost of electric power is a small fraction of the total cost of production, without electricity modern industry could not provide the Nation with the goods and services it demands. In the aluminum, electro-chemical, and metallurgical industries, electricity is a significant component required in the manufacture of these essential products.

The addition of the Browns Ferry Nuclear Plant to the TVA system will enable TVA to continue to carry out its responsibility to provide an abundant supply of electricity for the TVA region. The benefits of the plant include the value of the electrical power to be generated, the potential for reduction of releases of combustion products to the atmosphere at fossil-fired stations, the recreational and educational value to visitors to the plant, a stimulant to the economic growth of the region through an abundant supply of electrical power, increased payments to local governments of in lieu of tax payments, and increased employment potentials.

The costs of the plant include the commitment of 840 acres of land and 13 acres of reservoir area for the lifetime of the plant; the rejection of 2.44×10^{10} Btu/h to the air either directly or via Wheeler Reservoir, depending upon the mode of operation of the cooling towers; the consumption of 110 ft^3/s of evaporated water; minor releases of radioactivity to the air and to Wheeler Reservoir; erosion of soil during construction; a very low probability of releasing radioactivity due to an accident in the plant or an accident during the transport of radioactive materials; and the monetary costs to construct, operate, and maintain the plant.

At the end of March 1972, a total of $473 million had been expended on the construction of the Browns Ferry Nuclear Plant of the estimated project cost of over $650 million.

TVA has attempted, insofar as practicable, to detail those items covered in the Atomic Energy Commission's proposed guide for benefit-cost analyses for completed or partially completed nuclear facilities in sections 8.1 and 8.2. The weighing and balancing of benefits and costs of subsystems is presented in section 8.3.

Conclusion - This environmental review has reevaluated environmental impacts considered at the beginning of the project; evaluated those not considered earlier; considered alternatives which would lessen environmental impacts; and considered the need for power from the project. After weighing the environmental costs and the technical, economic, environmental, and other benefits of the project, and adopting alternatives which affect the overall balance of costs and benefits by lessening environmental impacts, TVA has concluded that the overall benefits of the project far outweigh the monetary and environmental costs.

8.1 <u>Benefits</u> - The benefits of the Browns Ferry plant are detailed below and are summarized in Table 8.1-1.

1. <u>Electric power produced and sold</u> - Browns Ferry Nuclear Plant includes three units with a dependable capacity of 1,065 MW electrical each, or a total plant capacity of 3,195 MW electrical. The units are scheduled for commercial operation as follows: unit 1 - March 1973; unit 2 - December 1973; and unit 3 - July 1974. Since capacity is planned for on a system basis and TVA has additional generating capacity scheduled for commercial operation during this time period, it is not possible to identify the specific loads which the Browns Ferry nuclear units will serve. For the purpose of the benefit analysis, it has been assumed that the plant serves loads based on the incremental increase in loads for each class of customers estimated between F.Y. 1972 and F.Y. 1980. The estimated peak load and sales for these years are identified in the following table:

	F.Y. 1972		F.Y. 1980		Increase	
	Load	Percent of Total	Load	Percent of Total	Load	Percent of Total
Estimated Peak Demand (MW)	17,326		30,300		12,974	
Estimated Sales (million kWh):						
Residential	28,072	30.8	45,833	28.2	17,761	24.8
Commercial	11,901	13.1	22,667	13.9	10,766	15.0
Industrial	32,908	36.2	55,907	34.4	22,999	32.1
Government	13,815	15.2	30,873	19.0	17,058	23.8
Other Sales	4,249	4.7	7,320	4.5	3,071	4.3
TOTAL SALES	90,945	(100)	162,600	(100)	71,655	(100)

The value of a unit of electric energy to the user varies widely depending on the availability and cost of alternative energy sources. No attempt was made to identify such values in this analysis. However, the price customers pay for electric energy presumably establishes a minimum value to the user. Based on the present rate structures of TVA and the distributors of TVA power, the following average prices to the ultimate consumer are estimated for F.Y. 1972:

Residential	1.413 ¢/kWh
Commercial	1.337 ¢/kWh
Industrial	0.727 ¢/kWh
Government	0.622 ¢/kWh
Other	1.023 ¢/kWh

For the purpose of estimating the present value of the revenue received from the sale of this energy it has been assumed that the Browns Ferry plant will operate as shown in the following table during its 35-year life:

Years	Capacity Factor	Net Generation (million kWh)	Total Transmission and Distribution Losses (million kWh)	Energy Available For Sale (million kWh)
1-15	80%	22,391	1,533	20,858
16-25	55%	15,394	1,053	14,341
26-35	40%	11,195	767	10,428

Using the energy available for sale and the average price paid for electricity shown above, and a discount rate of 8 percent, a present value of the sales from the plant was established and is presented in the benefit description form.

The results are summarized below:

ELECTRIC POWER PRODUCED AND SOLD - BROWNS FERRY NUCLEAR PLANT

Levelized Annual Energy Generation (kWh)	$20,178 \times 10^6$
Levelized Total Losses (kWh)	$1,409 \times 10^6$
Levelized Energy Available for Sale (kWh)	$18,769 \times 10^6$

	Energy Available For Sale - kWh	Present Value of Sales During Plant Life - Dollars
Energy Sold:		
Residential	$4,652 \times 10^6$	766,000,000
Commercial	$2,820 \times 10^6$	439,000,000
Industrial	$6,024 \times 10^6$	510,000,000
Government	$4,468 \times 10^6$	324,000,000
Other	805×10^6	96,000,000
Total Sold[a]	$18,769 \times 10^6$	2,135,000,000

a. Before cooling tower additions. Average tower power requirements are 9,525 kW.

Historically, electricity rates have declined during most of the past 40 years. Events of the more recent years have caused this trend to reverse. Higher prices for fuels, increases in construction costs, and costs of pollution control equipment have been significant factors causing the increases in rates for electric utilities. It was necessary for TVA to increase its rate schedules in 1967, 1969, and 1970. The effect of these rate increases has resulted in the average cost of electricity to the consumer increasing by 49.0 percent. Thus, the use of current rates could significantly understate the present value of the future sale price.

2. System Reliability - Capacity requirements on the TVA system are determined by the loss of load probability method using a monthly reliability index equivalent to an annual index of 0.1 day per year failure to meet firm loads. Each of the alternatives considered for the Browns Ferry plant meets this criteria. While differences in the reliability of the subsystems associated with the various Browns Ferry alternatives might conceivably affect the unit forced outage rate, thereby slightly changing the reliability index for that particular alternative, it is not feasible to make this determination without actual operating experience with each alternative.

3. Recreation - The recreational benefits of the Browns Ferry plant are estimated at 8,000 visits per year. This estimate of recreational visits is exclusive of the estimate of educational visits to the plant, which is given below. At a value of $0.75 per visit, the present value of these visits is estimated to be $69,930.

4. Air Quality - Since the Browns Ferry plant is a baseload plant approximately 7.4 billion kWh will be available during the baseload period to replace coal-fired generation which would otherwise have consumed about 3 million tons of coal per year. This will result in annual reductions in particulate emissions of 13,800 tons, SO_2 emissions of 194,000 tons, and NO_x emissions of 26,000 tons when based on replacing coal-fired generation with coal of the quality presently being burned.

5. Education - The educational benefits of the Browns Ferry plant are estimated to be 98,000 visits per year. The present value of these visits, at $0.75 per visit, is $856,600. The latter value does not consider the educational visits by persons to the plant during its construction. However, the number of such visits has been used in estimating the 98,000 visits per year.

6. Research - A 3.1 million dollar biothermal research project is to be constructed at Browns Ferry to objectively determine the effect of changes in temperature regimes on warmwater aquatic communities. The natural warm water reservoir communities will be exposed to different controlled temperatures. The resulting effects on growth, reproduction, and mortality will be observed.

This research facility is to be located at the Browns Ferry site for two primary reasons. First, the thermal rise (25°F) in the condenser water is high enough to permit concurrent experiments to be conducted for a wide range of temperatures. Second, since Browns Ferry will be operated as a base load plant with three generating units, it is expected that at least one unit will be operating at all times, thereby assuring a continuous supply of heated water for the research activity.

Accurate determination of the effects on aquatic life from thermal discharges would have nation-wide benefits. If the results show that the thermal criteria being adopted by regulatory agencies is excessively restrictive, a considerable savings in expenditures for auxiliary cooling facilities at power plants and other industrial operations could be realized. If the results of the studies show the presently proposed thermal criteria to underestimate the protection needed, then large environmental benefits would result if the adoption of more stringent thermal controls is needed to protect aquatic life.

7. Regional Gross Product - Benefits of the Browns Ferry plant to regional gross product cannot be exactly quantified monetarily. However, a correlation has been made of the average annual dollar flow of gross product with the use of the Browns Ferry electrical power in the TVA power service region. This correlation is based on using the average power generation and relationships between gross product and kilowatt hours equivalent of all energy consumed. The industrial gross product factor was obtained as a product of the relationship between value added and kWh equivalent (Census of Manufacturers, 1967) and the relationship between gross product from manufacturing and value added by manufacturing (Census of Manufacturers, 1967 and Survey of Current Business). The numerical value of the industrial gross product factor was found by this method to be $0.0649 per kWh. The commercial gross product factor was obtained by comparing gross product from commercial activities and an assumed electrical energy output of 25 percent of total energy input to the commercial

sector (<u>Energy in the American Economy, 1850-1975</u>, Schurr and Netschert). Numerical values of this factor were \$0.187 per kWh for 1967 and \$0.184 per kWh for 1969. Giving slightly more weight to the recent figure, \$0.185 per kWh was selected as the commercial gross product factor. Industrial power consumed was assumed to include government use of electrical energy. The resulting average annual dollar flow of gross product is estimated at \$1.203 billion.

As noted above, no additional quantification to arrive at a monetary benefit is considered possible. This is because the comparison of dollar value of products produced and energy consumed does not consider other variables in the production of products, such as wages of workers and efficiencies of individual production processes. It should be noted that a plentiful energy source has long been considered essential in the economic and industrial expansion of any region. As required by the TVA Act, as amended, TVA maintains an ample supply of electrical energy in the area in which it conducts its operations. A comparison of statistics in the TVA region with national statistics implies there is some beneficial effects of this plentiful energy source. In 1960 gross regional product was 2.26 percent of national; in 1970 this had increased to 2.69 percent. In 1960 personal income in the region was 64 percent of the national value; in 1970 this had increased to 75 percent. TVA considers that the availability of electricity as a plentiful energy source has helped realize these growth rates.

8. <u>Payments in lieu of taxes</u> - Estimates of payments in lieu of taxes includes estimates of payments to states and local governments by TVA and by distributors of TVA electricity. Estimates are based on current rates of payment related to the energy which will be generated by the plant.

9. Employment - Benefits to employment have been listed as the average annual number of workers whose jobs could be related to the consumption of electrical power produced by the Browns Ferry plant. An industrial employment factor, relating kWh equivalent consumed in manufacturing to employment in manufacturing was determined from national data from the Census of Manufacturers, 1967. A value of 5.4588 workers per million kilowatthours was obtained. A commercial employment factor was obtained by analysis of data from Energy in the American Economy, 1850-1975, by Schurr and Netschert. For 1967 this relationship was 14.83 workers per million kWh; for 1969, 13.39 workers per million kWh. The intermediate value of 14 was chosen for estimating the commercial portion of the employment value listed. Based on the portion of the Browns Ferry Nuclear Plant generation allocated to commercial and industrial use, the potential exists for expanding the number of new jobs by 96,750.

Table 8.1-1

BROWNS FERRY NUCLEAR PLANT - BENEFITS*

Alternative Plant Number**		1	2	3	4
Description		Base Plant	Minimum Water Impact	Minimum Land/Air Impact	Plant License Request
Electric Power Produced and Sold in Thousands of Dollars (present worth)	Industrial Commercial Residential Government Other Uses	766,000 439,000 510,000 324,000 96,000	***	766,000 439,000 510,000 324,000 96,000	***
Recreation Visits @ $.75 each-thousands of $ (present worth)		69.9	69.9	69.9	69.9
Air Quality - Potential to Reduce Pollutants in tons/yr	SO_2 NO_x Particulates	194,000 26,000 13,800	194,000 26,000 13,800	194,000 26,000 13,800	194,000 26,000 13,800
Educational Visits @ $.75 ea. thousands of $ (present worth)		856.6	856.6	856.6	856.6
Research		See Text			
Gross Regional Product Credit		See Text			
Payments in Lieu of Local Taxes in thousands of dollars (present worth)		144,505	***	144,505	***
Employment Benefits—potential jobs provided		96,750	***	96,750	***

*AEC Guide to Benefit-Cost Analyses followed in preparation of tables.
**Alternatives have the following subsystems:

Alternative	Heat Dissipation System	Gaseous**** Radwaste	Liquid Radwaste
1	diffuser	30-minute holdup	filtration and demineralization
2	Mechanical draft towers—closed cycle only	30-minute holdup	base plant and evaporator
3	diffuser	ORGDP or cryogenic	base plant and evaporator
4	mech. draft cooling towers--combined cycle	hydrogen recombiners and 6 charcoal beds	base plant and evaporator

***Reduced slightly from base to account for losses for cooling tower power.
****Base plant 30-minute holdup included in all alternatives.

8.2 Monetary and Environmental Costs - The monetary (generating) and environmental costs of the Browns Ferry plant for four alternative combinations of subsystems are detailed below and are summarized in Table 8.2-1. The four alternative combinations represent the base plant (at the start of the environmental review), the plant with minimum water impact, the plant with minimum air and land impacts, and the final plant (after environmental review). In addition, incremental generating costs and differences in environmental costs for alternatives for the liquid radwaste system, gaseous radwaste system, and heat dissipation system are summarized in Tables 8.2-2, 8.2-3, and 8.2-4, respectively.

Generating costs - The generating costs for the alternative combinations of subsystems have been computed using the following assumptions: current base plant capital cost estimates of \$610 million; a power generating cost of 1.9 mill/kWh (\$0.0019/kWh); a declining plant capacity factor as discussed in section 8.1-1; incremental generating costs for alternative subsystems as listed on Tables 8.2-2, 8.2-3, and 8.2-4; an 8 percent discount rate; and an assumed plant lifetime of 35 years. The results are summarized in Table 8.2-1.

1. Heat discharged to water body -

(1) Cooling capacity - The maximum total plant heat rejection to Wheeler Reservoir will be 2.44×10^{10} Btu/h on open-mode, 1.36×10^{10} Btu/h on helper-mode, and 4.5×10^{8} Btu/h on closed-mode cooling tower operation. The volumes of water in the mixing zone

for cooling water discharges have been estimated in Appendix IV to be about 165 acre-feet for open and helper modes and about 55 acre-feet for closed mode.

(2) Aquatic biota - It is TVA's judgement that there is no basis for assuming irretrievable loss of aquatic biota owing to thermal discharges of the plant. For comparative purposes the volume of water within the 5°F isotherm (165 acre-feet) is assumed to be affected; this 5°F isotherm represents the Alabama criterion for maximum temperature rise. This volume constitutes only 0.0165 percent of the volume of Wheeler Reservoir. The surface area bounded by the 5°F isotherm was calculated to be 8.3 acres. This area is only 0.0124 percent of that of the reservoir. In 1970 the commercial catch from Wheeler Reservoir had a value of $264,000. On the basis of the affected area, 0.0124 percent of this would have a cost of about $33. In 1970-71 the sport catch, based on a continuous 12-month creel census of approximately 60,000 acres of the reservoir, had a value of $314,016. Given the same area within the 5°F isotherm (8.3 acres) the area involved would be 0.0138 percent of the census area, and the monetary value would be about $43. The total annual commercial and sport value in the affected area would then be about $76.

Phytoplankton and zooplankton biomass estimates were made assuming the affected plankton were in the top meter of the reservoir in the estimated 8.3 acres of surface area bounded by the 5°F isotherm. Results varied in the various seasons as indicated below:

Season	Phytoplankton Biomass Total Pounds	Phytoplankton Biomass Pounds/Acre	Zooplankton Biomass Total Pounds	Zooplankton Biomass Pounds/Acre
Winter	830	100.0	40.7	4.9
Spring	888	107.0	10.8	1.3
Summer	1,096	132.0	38.2	4.6
Fall	486	58.6	45.7	5.5

The actual effects on these populations cannot be accurately assessed. In general, it is known that about 96°F constitutes a limit above which lethal effects are noted. Since this limit will be exceeded only in the diffuser mixing zone, and then only on certain occasions, mortality effects are considered negligible. There could even be increases of populations of these species due to the increased metabolism rates expected at higher temperatures.

It should be noted that the above estimates are based on interim plant operation without cooling towers.

(3) Migratory fish - It has been judged that a barrier, in the strict sense of preventing or significantly decreasing or retarding fish migration, will not result. A detailed discussion is provided earlier in Section 2.7, Biological Impact.

2. Effects on water body of intake structure and condenser cooling systems - Two primary areas for effects on Wheeler Reservoir due to removal of cooling water are in changes to fish and plankton populations. Estimates of these effects are presented below.

(1) Larval fish entrainment losses - Larval fish which pass through the plant in the cooling water flow will to a great extent be killed in this passage due to the temperature rise in the condensers and to mechanical shock. An accurate assessment of

the effects on larval fish populations cannot be made at this time. Studies made during the spawning season of 1971 gave preliminary results of the species composition and relative species abundance from which some general observations can be made. Throughout the sampling period shad dominated the catch (90 percent) and gizzard shad outnumbered threadfin shad. About half of the remaining fish in the samples were other rough or forage fish (5 percent) and the other half were sport fish (5 percent). Additionally, it was determined that larval fish concentrations in the overbank areas are orders of magnitude higher than in the channel area of the reservoir. Thus the actual concentration entering the Browns Ferry plant could vary widely depending on the ratio of channel to overbank water which enters the plant.

For purposes of analysis, the following assumptions have been made:

1. Larval fish concentrations in the intake at Browns Ferry are those noted in inshore-surface samples.

2. Survival rate from larval fish to adult is 1×10^{-4}.

3. The results from one sampling station, comprising replicate weekly day and night samples for a 91-day period, provides a representative case for analysis.

4. Condenser passage results in 100 percent mortality of larval fish.

5. Open mode cooling.

The data indicate that the quantity of water flowing through the Browns Ferry condenser cooling system during the representative time period would have contained 12.5×10^9 larval fish. Assumption 2 yields a representative mortality of 12.5×10^5 adults. The use of other modes (helper, closed) would reduce the above values by 16 percent and 95 percent, respectively, for the representative time period.

Very little is known regarding population dynamics of warmwater reservoir fishes, especially in a mixed fish population. The resulting impact of the projected larval fish mortalities cannot therefore be accurately estimated. The magnitude of the projected losses of larval fish as discussed in subsequent pages does, however, suggest the possibility of a significant adverse impact. To provide assurance that the operation of the Browns Ferry plant is not adversely affecting fish populations in Wheeler Reservoir, larval fish monitoring will continue following plant startup. Should there be significant adverse effects due to plant operation, corrective action will be taken.

(2) Plankton entrainment - Phytoplankton and zooplankton passing through the cooling water system should for the most part survive for a large portion of the year since the lethal temperature limits for plankton are higher than for larval fish. Estimates of total daily quantities (by weight) were made for the various tower operational modes based on concentrations indicated in quarterly samples taken in January, April, July, and October of calendar years 1969-71, estimates of the withdrawal volumes of the various modes, and the assumptions of uniform draw by the intake and uniformity of sample distributions in horizontal and vertical cross sections. Additionally, estimates of maximum phytoplankton standing crop were made by converting the chlorophyll a content to equivalent biomass.

Plankton entrainment estimates are summarized as follows:

Cooling System Operational Mode	Season	Phytoplankton (pounds/day)	Zooplankton (pounds/day)
open (on river)	winter	61,200	2,980
	spring	65,600	819
	summer	81,000	2,820
	fall	35,900	3,340
helper (on river plus towers)	winter	51,000	2,480
	spring	54,700	682
	summer	67,500	2,350
	fall	29,940	2,790
closed (on towers)	winter	3,050	149
	spring	3,270	41
	summer	4,040	141
	fall	1,790	167

Based on the expected amount of operation of the cooling towers in each mode, total estimated annual losses of phytoplankton are 4,182 tons; no estimate is available for zooplankton losses.

The inherent weaknesses in the estimates of plankton amounts are as follows:

1. The samples are "grab" samples that are not actually replicated at a point, only across a river transect.
2. Phytoplankton cell numbers may double in as short an interval as one day.
3. Zooplankton standing crop is estimated with day samples.
4. Zooplankton standing crop may change drastically within as short an interval as one week.
5. Communities of genera are measured and described--not species populations and/or size and age groups within species populations.
6. Only indirect biomass estimated have been made to date.
7. Seasonal trends develop within phytoplankton stocks as the result of changing solar energy values. The present monitoring program would underestimate these trends during the winter and spring quarters and overestimate in the fall quarter since samples

are taken during the first or second week of the quarter. However, present sample schedules fit existing flow or discharge cycles in the river.

3. Chemical discharge to water body - As discussed earlier in section 2.5 of this volume, the concentrations of chemicals to be discharged from the Browns Ferry plant will be within water quality standards prior to discharge. Thus there are no environmental costs associated with chemical discharges to Wheeler Reservoir.

4. Consumption of water - Although evaporation and drift loss rates of 110, 220, and 220 acre-feet per day are estimated in the open, closed, and helper modes of cooling tower operation, no significant effects on either downstream water supplies or irrigation supplies occur due to the insignificant size of these loss rates relative to average daily streamflow (89,000 acre-feet/day).

5. Chemical discharge to ambient air - Resulting ambient pollutant levels due to gaseous emissions from the plant's auxiliary boilers and diesel generators have been conservatively estimated assuming combustion of 5.3×10^6 gallons per year of fuel oil with 0.5 percent sulfur content. The maximum levels, as percents of the ambient air quality standards, are listed below:

Pollutant	Percent of Secondary Ambient Air Quality Standard
Particulates	0.19
Sulfur dioxide	0.68
Carbon monoxide	0.000014
Hydrocarbons	0.46
Nitrogen oxides	0.19

No odor originating from the plant should be perceptible at any point offsite.

6. Salts discharged in drift from cooling towers - The cooling water chemical content will be approximately double the chemical content of the makeup water. However, at these levels the cooling water will meet Public Health Service Drinking Water Standards. Thus, no significant effects are expected from drift discharges from the towers.

7. Chemical contamination of ground water - Chemicals discharged from the plant are at such concentrations when discharged that water quality standards are met. Thus, there exists no potential for chemical contamination of ground water.

8. Radionuclides discharged to water body - Doses are calculated according to the methods described in Appendix II and are derived from the numbers listed in Tables 3 and 6 of Appendix II by using scaling factors of 43.4, 5.42, and 0.434 for respective alternatives for liquid radwaste treatment. Maximum dose rates or dose commitments for each annual intake are reported.

(1) People - external - The maximum dose rates for an individual apply to skin exposure of a swimmer. Population dose rates are for skin doses and apply to both above-water activities and inwater activities.

(2) People - ingestion - Maximum dose commitments to the G.I. tract for the water and fish pathways are shown for both the individual and the population within 50 miles of the Browns Ferry Nuclear Plant.

(3) Primary producers and consumers - Dose rates (rads/year) are for internal and external exposure to green algae growing near the Browns Ferry diffusers.

(4) Fish - Dose rates (rads/year) are for total exposure to a fish living in the vicinity of the Browns Ferry Nuclear Plant.

9. Radionuclides discharged to ambient air -

(1) People - external - Individual and population external dose rates from the nuclides expected to be released to the air are computed as described in Appendix I. The maximum external dose to any organ, including the whole body, is the dose delivered to the skin. This dose rate is presented for all alternatives.

(2) People - ingestion - Individual and population thyroid doses from the ingestion of iodine released to the air are computed as described in Appendix I. This dose rate is presented for all alternatives.

(3) Plants and animals - The dose rate to plants and animals from radionuclides expected to be discharged to the air is assumed to be the same as the external dose rate to people.

10. Radionuclide contamination of ground water -

(1) People - Dose commitments for the annual intake of ground water are based on the calculations for the ingestion of Tennessee River water at the Browns Ferry site (Table 3 of Appendix II). It is assumed that the radioactivity concentration in ground water within 500 feet of the Tennessee River is 5 percent of

that present in the river below the Browns Ferry Nuclear Plant. A conservative estimate of the human population drinking ground water within 500 feet of the river is 7,300 persons between Browns Ferry and Pickwick Landing Dam. The maximum population dose commitment (thyroid) for an annual release of 1.0 Ci in the liquid effluent is:

$$\underset{\text{man}}{(7{,}300)} \quad \underset{\text{rem/yr}}{(0.05 \times 6.0 \times 10^{-6})} = \underset{\text{man-rem/yr}}{2.2 \times 10^{-3}}$$

Population dose commitments for the liquid radwaste alternatives are obtained by multiplying 2.2×10^{-3} man-rem/yr by 43.4, 5.42, and 0.434 for the respective cases. Individual dose commitments are obtained by multiplying 3×10^{-7} rem/yr by the same factors.

(2) Plants and animals - Calculations of doses to aquatic plants and animals living in the Tennessee River near the Browns Ferry Nuclear Plant are described in Appendix II. The maximum dose rate to any species is calculated to be 4.7×10^{-3} rad/yr for an annual release of 1.0 Ci. It is assumed that ground water within 500 feet of the Tennessee River contains a maximum of 5 percent of the radioactivity concentration present in the river below the Browns Ferry Nuclear Plant. Therefore, doses to plants and animals resulting from the radioactivity concentration in the ground water are expected to be very small.

11. Fogging and icing -

(1) Effects on local ground transportation - The analysis of effects on local ground transportation of fogging and icing of the heat dissipation alternatives is based on the procedural methods described in section 3.4 of Volume 3. As indicated in the same

volume, natural draft cooling towers and cooling ponds are not expected to have any effect on ground transportation. The analysis showed that spray canal plumes could affect ground transporation 385 hours per year. Closed cycle mechanical draft towers could affect ground transportation 445 hours per year. Combined cycle mechanical draft cooling towers could affect ground transportation 80 hours per year.

(2) Effects on air transportation - Analysis of Paradise power plant natural draft cooling tower plume behavior as described in section 3.4.3 of Volume 3 shows that the maximum extent of plumes or fogs from any of the six alternative cooling systems is about 5 miles. Since the nearest airport is located 11 miles east-southeast of the Browns Ferry site, no interference with commercial airport operation is anticipated.

(3) Local Effects on water transportation - The effects of river fogging (steam fogging) from diffuser releases were evaluated by relating dry bulb temperature, relative humidity, wind speed and water temperature to predict the frequency of occurrence of river fogging capable of affecting traffic. Analyses of the effects of mechanical draft towers and spray canals on river fogging are based on the procedural methods described in Section 3.4 of Volume 3. These analyses showed that river traffic could be affected 147 hours per year by fogging induced by use of the diffusers alone and 107 hours when operating combined cycle. Spray canals could affect river traffic 500 hours per year. Closed cycle mechanical draft cooling towers could interfere with river traffic 610 hours per year, and combined cycle mechanical draft towers could affect river traffic 110 hours per year.

(4) Effects on plants - Vegetation should not be damaged by fogs or plumes generated by any of the alternative cooling systems because daily exposure to excessive moisture should be of short duration (5 hours or less for all six alternative schemes) and should occur most frequently during predawn and postdawn hours, periods when vegetation is normally exposed to naturally occurring high relative humidities and dew.

12. Raising or lowering of ground water levels - Water withdrawals for the Browns Ferry plant should have no effect on local ground water levels since Wheeler Reservoir water levels are maintained according to TVA's reservoir operating guides. Normal fluctuations in water levels in the reservoir are from elevation 550 in winter to elevation 556 in late spring.

13. Ambient noise - Ambient noise levels due to operation of the Browns Ferry plant will be attributable to operation of the mechanical draft cooling towers. Noise levels from the towers are discussed in Section 2.6, Heat Dissipation. Operation of the base plant is essentially noiseless at the site boundary except for very infrequent operation of the air blast circuit breakers.

14. Aesthetics - Aesthetics cannot be quantified. The design of the Browns Ferry Nuclear Plant has as one objective the creation of harmony between plant and environment. The architectural design and site development should provide an aesthetically pleasing appearance and mitigate the transition in land use of the project area from agricultural to industrial. The addition of mechanical draft cooling towers will, to a certain extent, be an expense to the project aesthetics and surrounding environment, but careful design should make these cooling towers visually acceptable.

15. Permanent residuals of construction activity - Individual subtopics are discussed below.

(1) Accessibility of historical sites - No historical sites are affected by the plant or its transmission system additions.

(2) Accessibility of archaeological sites - No areas of known archaeological significance are affected by the plant or its transmission system additions.

(3) Setting of historical sites - Plant construction has not modified the local landscape at any historical site since none were affected.

(4) Land use - Site land requirements are about 840 acres for the base plant. Alternatives for heat dissipation have the following land requirements:

Heat Dissipation Alternative	Plant Land Area Required (acres)	New Land Area Required (acres)
Diffuser	—	-
Mechanical draft cooling towers	250	0
Natural draft cooling towers	70	0
Spray canal	135*	350
Cooling lake	135*	10,000

The additional land required for either spray canal or cooling lake would have had to be converted from farming or rural use to power plant use.

*Includes some reservoir shoreline area.

(5) Property -

(a) Impact of the plant site on property values - Browns Ferry Nuclear Plant site was acquired by TVA in December 1967 and construction began in 1968. Consequently, any impact of the plant on land values in the proximity should be evident by now. To ascertain the effects on property values in the area TVA investigated all real estate transactions occurring within a 5-mile radius of the plant site since 1965. In addition, information concerning 152 transactions occurring since 1962 within Limestone County as a whole have been analyzed to develop reference-point data. Since 1965 some 60 real estate transactions have taken place within the 5-mile zone. Twenty of these are residential lakefront lots; 25 are rural residential homesites near Athens, Alabama; and 15 are sales of farm properties.

The 20 residential lakefront lots investigated have risen in price from $2,500 in 1965 to $3,500 in 1972, an increase of approximately 5.7 percent per year. The prices of rural residential properties 3 to 5 miles away from the plant range from $200 to $3,150, depending primarily on location relative to Athens, Alabama, and the kind of road frontage serving the property.

The 15 farm property sales within the 5-mile zone have soils equal to or better than the county average. Almost all the land is row cropped and has a cotton allotment. In the impact study zone the farmland prices average $472 an acre with a median value of $489 an acre. Elsewhere throughout the country farmland averages $417 an acre with a median value of $381 an acre. Most of the agricultural land near the plant site is in large holdings, and many owners believe that the future highest and best use of their land will be industrial, although no pending location by industry is now known or contemplated.

Investigations revealed no adverse effect on real estate values within 5 miles of the Browns Ferry Nuclear Plant site. Sale prices for farmland and rural residential properties equal or exceed prices of comparable properties in other areas of Limestone County. Lakefront subdivision lots in the 5-mile zone apparently are not as desirable as those downstream on the Elk River embayment, and any difference in value is attributable to such factors as silt problems, prevailing winds, dock damage on the main channel, and poor road access. In no event did the investigations show any discernable effect, either adverse or otherwise, attributable to proximity to the nuclear plant site.

(b) Impact of transmission lines on property values - All transmission lines required for the Browns Ferry Nuclear Plant have been completed. Right of way acquisition began in 1963 and extended through 1967. Except for a corridor in the vicinity of Decatur, Alabama, most of the property traversed by the Browns Ferry transmission line system is farmland and low-density rural residential property.

Recent investigations by TVA revealed no discernable loss in value attributable to the transmission lines outside the right of way proper. The only measurable damage occurs within the right of way where buildings are prohibited. Investigations in other agricultural, residential, and industrial areas throughout the TVA power service area show similar land value behavior characteristics, and TVA anticipates no adverse effects by transmission lines on lands in the Browns Ferry Nuclear Plant site area. TVA can find no evidence that the presence of the transmission line system will inhibit orderly land development in the area and normal transition from agricultural use to residential, commercial, and industrial use should future demands require such transition.

(6) Flood control - The Browns Ferry project has no implication for flood control.

(7) Erosion control - The average amount of soil displaced by erosion due to construction activities at the Browns Ferry site is estimated to be 10,000 tons per year throughout the construction period. This estimate includes the effects of direct erosion of cleared land and also the displacement of dredge material in Wheeler Reservoir. Before the decision to add cooling towers at Browns Ferry, this estimate was only slightly less: 9,875 tons per year. Additions of other alternative cooling facilities could be expected to contribute approximately the same quantities of land erosion as the construction of mechanical draft cooling towers with the exception of a spray canal or a cooling lake. No exact estimates were made for these, but larger erosion rates would be expected.

16. Transportation - Browns Ferry will receive 18 truck shipments of new fuel in a normal year; 32 rail shipments of spent fuel will be made in a normal year; and about 53 shipments of radioactive waste will be made in a normal year. In addition, deliveries of fuel oil and chemicals will require receiving about 300 tank-truck shipments in a normal year. The

environmental review has demonstrated that the transportation shipments to and from the plant considering normal and accident conditions can be accomplished with a minimum impact.

17. Accidents - A spectrum of postulated accidents ranging in severity from trivial to very serious have been divided into 9 classes by AEC. This characterization of accident by classifications brackets the qualitative assessment of environmental costs and aids the development of the overall balancing of environmental costs and benefits. Table 2.3-2 of section 2.3 in this volume gives a summary of the radiological consequences of the postulated accidents. This environmental risk for the range of postulated accidents considering the probability of occurrence indicates that the annual potential exposure to the population from all postulated accidents is a very small fraction of the exposure of the same population from natural background radiation and, in fact, is well within naturally occurring variations in background radiation levels.

Table 8.2-1

BROWNS FERRY NUCLEAR PLANT
GENERATING AND ENVIRONMENTAL COSTS

Alternative (Defined at end of table)		1	2	3	4
Generating Costs - Thousands of Dollars		1,056,863	1,118,054	1,068,554	1,111,454
1. Heat Discharge to Water Body	1.1 Cooling capacity - Btu/hr heat rejection	2.44×10^{10}	3.6×10^{8}	2.44×10^{10}	2.44×10^{10} open 1.36×10^{10} helper 4.5×10^{8} closed
	acre-feet water affected ($5^{o}F$ isotherm)	165	55	165	165 open 165 helper 55 closed
	1.2 Aquatic biota - within affected area	see text			
	1.3 Migratory fish	no barrier	no barrier	no barrier	no barrier
2. Effects on Water Body of Intake Structure and Condenser Cooling Systems	2.1 Primary producers and consumers	varies seasonally - see text			
	2.2 Fisheries - larval fish mortality during 91-day sample period	12.5×10^{9}	6.5×10^{8}	12.5×10^{9}	12.5×10^{9} open 10.5×10^{9} helper 6.5×10^{8} closed
3. Chemical Discharge to Water Body	3.1 People - dilution volume to meet standards	0	0	0	0
	3.2 Aquatic biota - affected population	0	0	0	0
	3.3 Water quality - chemical dilution volume required to meet standards	0	0	0	0

Table 8.2-1 (contd.)

BROWNS FERRY NUCLEAR PLANT
GENERATING AND ENVIRONMENTAL COSTS

		1	2	3	4
Alternative (Defined at end of table)		1	2	3	4
Generating Costs - Thousands of Dollars		1,056,863	1,118,054	1,068,554	1,111,454
4. Consumption of Water	4.1 People - acre-feet of water evaporated per day	110	220	110	110 open 220 helper 220 closed
	4.2 Property - affects on irrigation supplies	none	none	none	none
5. Chemical Discharge to Ambient Air	5.1 Air quality - chemical - highest percentage of standard	0.68%	0.68%	0.68%	0.68%
	5.2 Air Quality - odor	none	none	none	none
6. Salts Discharged from Cooling Towers	6.1 People - gal/yr of affected water	0	0	0	0
	6.2 Plants affected	none	none	none	none
7. Chemical Contamination of Ground Water	7.1 People - gallons of water contaminated	0	0	0	0
	7.2 Plants affected	none	none	none	none
8. Radionuclides Discharged to Water Body	8.1 People - rem/yr External contact man-rem/yr	$2x10^{-6}$ $5x10^{-3}$	$2x10^{-8}$ $5x10^{-5}$	$2x10^{-8}$ $5x10^{-5}$	$2x10^{-8}$ $5x10^{-5}$
	8.2 People - ingestion rem/yr man-rem/yr	$1x10^{-3}$ 80	$1x10^{-5}$ 0.8	$1x10^{-5}$ 0.8	$1x10^{-5}$ 0.8

Table 8.2-1 (contd.)

BROWNS FERRY NUCLEAR PLANT
GENERATING AND ENVIRONMENTAL COSTS

Alternative (Defined at end of table)			1	2	3	4
Generating Costs - Thousands of Dollars			1,056,863	1,118,054	1,068,554	1,111,454
	8.3 Primary consumers	rad/yr	$2x10^{-2}$	$2x10^{-4}$	$2x10^{-4}$	$2x10^{-4}$
	8.4 Fish	rad/yr	$5x10^{-2}$	$5x10^{-4}$	$5x10^{-4}$	$5x10^{-4}$
9. Radionuclides Discharged to Ambient Air	9.1 People - External	rem/yr	0.170	0.170	$5x10^{-4}$	$1.6x10^{-3}$
		man-rem/yr	890	890	1.6	23
	9.2 People - ingestion	rem/yr	$2x10^{-4}$	$2x10^{-4}$	$1.8x10^{-4}$	$1.8x10^{-4}$
		man-rem/yr	0.79	0.79	0.73	0.73
	9.3 Plants and Animals	rad/yr	0.170	0.170	$5x10^{-4}$	$1.6x10^{-3}$
10. Radionuclide Contamination of Ground Water	10.1 People -	rem/yr	$1x10^{-5}$	$1x10^{-7}$	$1x10^{-7}$	$1x10^{-7}$
		man-rem/yr	0.1	$1x10^{-3}$	$1x10^{-3}$	$1x10^{-3}$
	10.2 Plants and animals		see text			
11. Fogging and Icing Hours/Year	11.1 Ground transportation		0	445	0	80
	11.2 Air transportation		0	0	0	0
	11.3 Water transporation		147	610	147	217
	11.4 Plants		0	0	0	0

Table 8.2-1 (contd.)

BROWNS FERRY NUCLEAR PLANT
GENERATING AND ENVIRONMENTAL COSTS

Alternative (Defined at end of table)		1	2	3	4
Generating Costs - Thousands of Dollars		1,056,863	1,118,054	1,068,554	1,111,454
12. Raising/Lowering of Ground Water Levels	12.1 People - Gal. Water affected	0	0	0	0
	12.2 Plants - acres affected	0	0	0	0
13. Ambient Noise	13.1 People	see text			
14. Aesthetics	14.1 Appearance	see text			
15. Permanent Residuals of Construction Activity	15.1 Accessibility of historical sites	see text			
	15.2 Accessibility of archeological sites	see text			
	15.3 Setting of historical sites	see text			
	15.4 Land use	see text			
	15.5 Property	see text			
	15.6 Flood control	none	none	none	none
	15.7 Erosion control tons/year	9,875	10,000	9,875	10,000
16. Transportation	16.1 Transport of radioactive material	see text			
17. Accidents	17.1 Radiological effects	see text			

Table 8.2-1 (contd.)

BROWNS FERRY NUCLEAR PLANT
GENERATING AND ENVIRONMENTAL COSTS

Alternatives have the following subsystems:

	Alternative	Heat Dissipation System	Gaseous* Radwaste	Liquid Radwaste
1.	Base plant	diffuser	30-minute holdup	filtration and demineralization
2.	Minimum water impact	mechanical draft towers--closed cycle only	30-minute holdup	base plant and evaporation
3.	Minimum land/ air impact	diffuser	ORGDP or cryogenic	base plant and evaporation
4.	Plant license request	mechanical draft cooling towers--combined cycle	hydrogen recombiners and 6 char-coal beds	base plant and evaporation

*Base plant 30-minute holdup included in all alternatives.

Table 8.2-2

BROWNS FERRY NUCLEAR PLANT

ALTERNATIVES FOR LIQUID RADWASTE SYSTEM

COSTS WHICH VARY FROM BASE PLANT

Alternative Liquid Radwaste System	Filtration and Demineralization	Additional Demineralization	Filtration Demineralization, and Evaporation
Incremental Generating Cost (thousands of dollars)	base	5,711	1,991
Dosage Rates to People due to Radionuclides Discharged to Water Body - External Contact			
(rem/yr)	2×10^{-6}	3×10^{-7}	2×10^{-8}
(man-rem/yr)	5×10^{-3}	6×10^{-4}	5×10^{-5}
Dosage Rates to People due to Ingestion			
(rem/yr)	1×10^{-3}	1×10^{-4}	1×10^{-5}
(man-rem/yr)	80	10	0.8
Dosage Rate to Primary Consumers (rad/yr)	2×10^{-2}	3×10^{-3}	2×10^{-4}
Dosage Rate to Fish (rad/yr)	5×10^{-2}	7×10^{-3}	5×10^{-4}
Dosage Rates to People due to Radionuclide Contamination of Ground Water			
(rem/yr)	1×10^{-5}	2×10^{-6}	1×10^{-7}
(man-rem/yr)	0.1	1×10^{-2}	1×10^{-3}

Table 8.2-3

BROWNS FERRY NUCLEAR PLANT

ALTERNATIVES FOR GASEOUS RADWASTE SYSTEM

COSTS WHICH VARY FROM BASE PLANT

Alternative Gaseous Radwaste System	30-Minute Holdup	Hydrogen Recombiners	Hydrogen Recombiner and Six Charcoal Beds per unit	Hydrogen Recombiner and Twelve Charcoal Beds per unit	ORGDP Systems	Cryo-genic
Incremental Generating Cost (thousands of dollars)	base	6,000	9,000	10,500	Not Esti-mated	9,700
Dosage Rates to People from External Contact						
rem/yr	0.170	1.6×10^{-2}	1.6×10^{-3}	6×10^{-4}	5×10^{-4}	5×10^{-4}
man-rem/yr	890	260	23	6.8	1.6	1.6
Dosage Rates to People from Inges-tion						
rem/yr	2×10^{-4}	1.8×10^{-4}	1.8×10^{-4}	1.8×10^{-4}	1.8×10^{-4}	1.8×10^{-4}
man-rem/yr	0.79	0.73	0.73	0.73	0.73	0.73
Dosage Rate to Plants and Animals						
rad/yr	0.170	1.6×10^{-2}	1.6×10^{-3}	6×10^{-4}	5×10^{-4}	5×10^{-4}

Table 8.2-4

BROWNS FERRY NUCLEAR PLANT
ALTERNATIVES FOR HEAT DISSIPATION SYSTEM
COSTS WHICH VARY FROM BASE PLANT

Alternative Heat Dissipation System	Mechanical Draft Towers Combined Cycle	Mechanical Draft Towers Closed Cycle	Natural Draft Cooling Towers	Diffusers	Spray Canal	Cooling Pond
Estimated Incremental Generating Cost (Thousands of Dollars)	43,600	59,200	54,200*	Base	None made	None made
Reservoir Heat Affected Volume (acre-feet/mode)	165 - open 165 - helper 55 - closed	55	165 - open 165 - helper 55 - closed	165	165 - open 55 - closed	165 - open 55 - closed
Reservoir Heat Input (Btu/hr-mode)	$2.44x10^{10}$ - open $1.36x10^{10}$ - helper $4.5x10^{8}$ - closed	$4.5x10^{8}$	$2.44x10^{10}$ - open $1.36x10^{10}$ - helper $4.5x10^{8}$ - closed	$2.44x10^{10}$	$2.44x10^{10}$ - open 4.5x10 - closed	$2.44x10^{10}$ - open $4.5x10^{8}$ - closed
Larval Fish Mortality due to Condenser Passage (fish-mode)	$12.5x10^{9}$ - open $10.5x10^{9}$ - helper $6.5x10^{8}$ - closed	$6.5x10^{8}$	$12.5x10^{9}$ - open $10.5x10^{9}$ - helper $6.5x10^{8}$ - closed	$12.5x10^{9}$	$12.5x10^{9}$ - open $6.5x10^{8}$ - closed	$12.5x10^{9}$ - open $6.5x10^{8}$ - closed
Water Consumed (acre-feet/day)	140	220	140	110	140	140
Transportation Affected (hr/yr) Ground -	80	445	0	0	385	0
Water -	217	610	0	147	500	0
Additional Land Required (acres)	0	0	0	0	350	10,000
Erosion (T/yr)	10,000	10,000	10,000	9,875	> 10,000	> 10,000

* For closed-cycle operation, $67,600 thousand.

8.3 <u>Environmental Cost-Benefit Weighing and Balancing of Alternative Subsystems</u> - Tables 8.2-2, 8.2-3, and 8.2-4 present the economic costs and environmental impacts for the alternative subsystems evaluated for liquid radwaste, gaseous radwaste, and heat dissipation respectively. This section presents weighing and balancing of the costs and benefits associated with each of these subsystems.

1. <u>Liquid radwaste system</u> - As discussed in section 3.1 of Volume 3, the liquid radwaste system as originally designed would have resulted in releases of approximately 40 curies per year of radioactivity (exclusive of tritium) into Wheeler Reservoir. Two alternatives were considered for reducing these releases: (1) modify the operation of the liquid radwaste treatment system to demineralize low conductivity liquid from the floor drain, or (2) install an evaporator to treat the liquid radwaste. The evaporator was estimated to have an installation cost of $1,000,000 with an annual operating cost of $85,000 for a total cost of $1,991,000. Demineralization of the floor drains was estimated to cost $490,000 annually for a total cost of $5,711,000. As indicated in Table 8.2-2, installation of the evaporator shows an economic advantage of $3.7 million and results in ad additional reduction factor over the demineralization of floor drain alternative. Based on this analysis TVA has concluded that an evaporator along with its associated buildings and equipment should be installed. TVA considers that there are no other feasible alternatives which would further reduce the liquid radioactive discharges. The system chosen for treatment of radioactive liquids yields a very low (0.00005 mrem) annual total body dose to any individual which is 0.001 percent

8.3

of the numerical guidance value provided by the proposed Appendix I to 10 CFR Part 50. The maximum annual dose to any body organ is only 0.01 mrem which is 0.2 percent of the numerical guidance value provided by the proposed Apendix I.

2. <u>Gaseous radwaste system</u> - As discussed in section 3.1 of Volume 3, the gaseous radwaste system as originally designed included 30-minute holdup and elevated stack release. Four alternative ways to reduce radioactive gaseous discharges at Browns Ferry were evaluated. These included:

1. Hydrogen recombiners
2. Hydrogen recombiners and charcoal absorber
3. Hydrogen recombiners and absorption by solvent (ORGDP system)
4. Hydrogen recombiners and cryogenic distillation

Table 8.2-3 presents an evaluation of hydrogen recombiners and hydrogen recombiners augmented with either 6 or 12 charcoal beds per unit, ORGDP system, or cryogenic distillation.

As shown in table 8.2-3, the original system (30 minute holdup) assuming a release rate of 100,000 μCi/s per unit resulted in a 170 mrem dose to people from external contact. The addition of hydrogen recombiners at an investment of $6 million resulted in reducing this dose from 170 mrem to 16 mrem for a reduction of 154 mrem. The augmenting of the hydrogen recombiners with 6 charcoal beds per unit at an incremental cost of $3 million (total cost of $9 million) resulted in a further reduction of 14.4 mrem to 1.6 mrem per year. Further augmentation of the hydrogen recombiner and 6 charcoal beds to include a total of 12 charcoal beds at an incremental cost of $1.5 million (total cost of $10.5 million) resulted in a further reduction of only 1 mrem to 0.6 mrem per year.

Both the ORGDP system and cryogenic system offered the potential for reducing the dose to people from external contact to a level of 0.5 mrem per year. A cost estimate was not developed for the ORGDP system; however, indications were that it would be considerably less expensive than the other alternatives being considered. The cryogenic system was estimated to cost $9.7 million. Neither of these systems have demonstrated performance and reliability in nuclear plant service. The only experience to date with the ORGDP system has been with bench and pilot size systems. The cryogenic distillation system, while proven for industrial applications, is a complex system compared to charcoal absorption systems and could experience operating problems and presents the potential for accidental release of concentrated waste to the environment.

Based on this analysis, TVA has concluded that the recombiner and six-charcoal bed (per unit) alternative which results in a dose reduction of 168.4 mrem per year to 1.6 mrem per year, represents the best balance of economic cost, reduction in environmental impact, and feasibility. TVA believes the benefits to be gained by further reducing the radioactive gaseous releases are not commensurate with the cost associated with the reduction. The proposed system results in a "fence post dose" of 1.6 mrem. This very low "fence post dose" is 16 percent of the numerical guidance provided by the proposed Appendix I. It also represents a very small percentage (about 1 percent) of the naturally occuring background dose.

3. Heat dissipation - The original plant design called for condenser waste heat dissipation by means of diffusers on

the bottom of Wheeler Reservoir. The original method was designed to permit a maximum 10°F temperature rise which was the proposed Alabama thermal water quality criteria at the time of initial plant planning. A recent change in the proposed Alabama thermal criteria limiting the temperature rise to a maximum of 5°F concurrent with the environmental review of Browns Ferry, prompted TVA to give further consideration to alternative methods of heat dissipation. The alternatives considered were mechanical and natural draft cooling towers, a spray canal, and a cooling lake. Details on these alternatives, including cost estimates, when deemed feasible, are given in Volume 3, section 3.4.

Analyses were performed using the following factors as a basis: feasibility, environmental considerations, and economic considerations. The analyses were carried to the extent required to determine the acceptability of each alternative when considering these factors. This resulted in a complete analysis of only the cooling tower alternatives.

Estimates of environmental impacts were made as discussed above in section 8.2. The results are summarized in Table 8.2-4.

The spray canal alternative would require a cooling canal approximately 5 miles in total length and 200 feet wide with 700 spray modules and would require the purchase of an additional 350 acres of land. The analysis of the spray canal alternative showed no significant reductions in environmental impacts that could not be accomplished with the cooling tower alternatives. Due to the limited operating experience with spray canals and the absence of any installations with a heat rejection of the magnitude of Browns Ferry, the spray canal was not considered a feasible alternative for this plant.

The cooling lake alternative would require a lake of approximately 5,000 acres and the purchase of an additional 10,000 acres of land. Due to the unfavorable topography at the Browns Ferry site, impoundment of a reservoir of this size would require many miles of canals and high dikes and would have resulted in a reservoir level 50-100 feet above the existing reservoir. Thus, it was concluded that a cooling lake is not a feasible alternative for this plant.

A comparison of the mechanical and natural draft cooling tower alternatives was made in the same operating mode. The principal disadvantages of the mechanical draft cooling towers when compared to natural draft cooling towers are the possible higher frequency for fogging and icing and higher noise levels. However, the mechanical draft cooling towers showed an economic advantage of $10.6 million and required approximately two years less to construct. The first set of mechanical draft towers can be in operation prior to commercial operation of Browns Ferry Unit 3. Based on the analysis of the feasibility considerations (including short construction time), environmental considerations and economic costs, TVA has concluded that the mechanical draft cooling towers offer the best balance of these factors for providing auxiliary cooling for the Browns Ferry plant.

The mechanical draft cooling towers to be installed can operate in the open, helper, or closed mode. The combined cycle information presented in Table 8.2-4 is based on making maximum use of the heat dissipation capability of the reservoir and reflects operation 7 percent of the time in the closed mode, 21 percent of the time in the helper mode, and 72 percent of the time in the open mode. When compared to mechanical draft tower closed cycle alternative, the combined cycle shows an economic advantage of $15.6 million. While the environmental impacts are greater for combined cycle operation, the only potentially significant impact is that resulting from larval fish mortality due to condenser passage. The significance of these larval fish mortalities is not known. Since the environmental costs of this impact cannot be determined at this time, TVA plans to utilize the combined cycle operating method due to the significant economic advantage. TVA has the capability to modify plant operation during critical periods should environmental monitoring indicate significant adverse effects on fish populations in Wheeler Reservoir.

9.0 CONCLUSION

The Browns Ferry Nuclear Plant was initiated before NEPA became effective, and the TVA Board of Directors has determined that it is not practicable to reassess the basic course of action in the design and construction of this plant. However, the environmental impacts considered at the outset of the project have been reevaluated so as to minimize adverse consequences. For example, extended radwaste treatment, additional chemical treatment facilities, and mechanical draft cooling towers have been provided.

The three-volume final detailed environmental statement traces the environmental considerations and manner in which they were incorporated into TVA's decision-making process. In addition, this process has identified the principal ways in which the plant will interact with the environment as (1) minute additions of radioactivity to the air and water, (2) release of large quantities of heat to the environment, and (3) change in land use from farming to industrial.

The addition of the Browns Ferry Nuclear Plant to the TVA system will enable TVA to continue to carry out its responsibility to provide an ample supply of electricity for the TVA region. After weighing the environmental costs and the technical, economic, environmental, and other benefits of the project and adopting alternatives which affect the overall balance of costs and benefits by lessening environmental impacts, TVA has concluded that the overall benefits of the project far outweigh the monetary and environmental costs.

It is concluded that the plant as now designed closely approaches a minimum impact plant and can be operated without significant risk to the health and safety of the public.

APPENDIX I

RADIOLOGICAL IMPACT OF GASEOUS EFFLUENTS

The following doses to humans living in the vicinity of the Browns Ferry Nuclear Plant (BFNP) are calculated for routine releases of radioactive gases:

1. external beta doses
2. external gamma doses
3. thyroid doses due to inhalation of radioactive iodine
4. thyroid doses due to reconcentration of radioactive iodine in milk produced near the site.

The doses which appear in the tables in this appendix are calculated assuming operation of three units with an average annual noble gas release rate of 100,000 μCi/sec/unit (after 30 minutes decay). The basic assumptions and calculational methods used in computing the doses due to gaseous effluents are described in this section.

Gaseous radionuclides will be released from the Browns Ferry Nuclear Plant through the 600-foot plant stack and from vents on top of various plant buildings. In calculating downwind, ground level air concentrations or radioactive gases from stack releases, an elevated, point source dispersion equation is used (see equation 1).

Stack Release

$$\chi_{km} = \sum_{i=1}^{3} \sum_{j=1}^{6} \frac{\sqrt{2}\, Q f_{ijk}}{\sqrt{\pi}\, \sigma_{zim} u_j \theta\, x_m} \exp \left[\frac{-h_j^2}{2\sigma_{zim}^2} \quad \frac{-\lambda x_m}{u_j} \right] \quad (1)$$

To calculate downwind, ground level air concentrations of radioactive gases resulting from releases from building vents, a ground level, volume source dispersion equation is used (see equation 2). The radioactive gases are assumed to be caught in the turbulent wake downwind of the building and mixed across the vertical building height.

Building Release

$$\chi_{km} = \sum_{i=1}^{3} \sum_{j=1}^{6} \frac{\sqrt{2\pi}\, \sigma_{yim} Q f_{ijk}}{(\pi \sigma_{yim} \sigma_{zim} + cA) u_j \theta x_m} \exp\left(-\lambda \frac{x_m}{u_j}\right) , \qquad (2)$$

where

χ_{km} = average annual, ground-level air concentration of a particular nuclide in sector k at distance x_m, (Ci/m^3),

f_{ijk} = fraction of the release period during which the wind blows in direction k, with speed j, and atmospheric stability condition i,

Q = release rate of nuclide, (Ci/sec),

σ_{yim} = horizontal standard deviation of the plume for stability condition i at distance x_m, (m),

σ_{zim} = vertical standard deviation of the plume for stability condition i at distance x_m, (m),

h_j = effective release height for wind speed j,(m),

cA = correction factor to account for initial mixing of the gases in the turbulent wake of the reactor building,(m^2),

x_m = downwind distance at which air concentration is calculated,(m),

u_j = wind speed j,(m/sec),

θ = sector width, (radians),

λ = radioactive decay constant for a particular nuclide, (sec^{-1}).

These equations are used to predict the average annual ground level air concentration of the gases over the width of a 22.5° sector. In equation 2, c is taken as 0.5 and A is taken as the minimum cross sectional area of the reactor building.

For these analyses, σ_{yim} and σ_{zim}, as measured by TVA,[1] are used. The frequencies, f_{ijk}, in equations 1 and 2 are obtained by TVA meteorologists using meteorological data measured at the BFNP site. The data are grouped for three stability conditions (very stable, moderately stable, and unstable) and for six wind speed ranges (0-3, 4-7, 8-12, 13-18, 19-24, ≥ 25 mph).

1. <u>External beta doses</u> - The individual beta doses are computed using an immersion dose model described by the equation:

$$D_\beta = 4.64 \times 10^9 \, \overline{E}_\beta \, \chi, \qquad (3)$$

where

D_β = external beta dose due to submersion in a cloud, (mrem/yr),

4.64×10^9 = a constant used in calculating external beta dose, $\left(\frac{\text{mrem/yr}}{\text{Ci-Mev/dis-m}^3}\right)$,

$\overline{E}_\beta$ = average beta energy of isotope being considered, (Mev/dis),

χ = average annual, ground level air concentration as calculated by equation 1 or 2, $\left(\frac{Ci}{m^3}\right)$.

In this equation, a geometry correction factor of 0.64 is included to account for the semihemispherical cloud and a geometry correction factor of 0.5 is included to account for self shielding by the human body.

The χ used in equation 3 is the same as χ_{km} in equations 1 and 2. To obtain the total beta dose derived from a mixture of several noble gases and radioiodines, equation 3 is applied for each isotope, and the resulting doses are summed. The average beta energies for the isotopes being considered are calculated from information contained in the reference.[2]

In computing the total population beta dose within 50 miles of the BFNP, the area is divided into 16 directional sectors and 11 concentric rings, i.e., the area within 50 miles of the plant is divided into 176 small area elements. A beta dose is computed at the center of each element and multiplied by the number of persons residing in that element. A summation of the element dose multiplied by element population over all elements gives the total population dose within 50 miles of the plant. In calculating the population dose, the projected population for the year 2010 is used.

For each source, the annual releases of the various isotopes considered in these analyses are given in Table 1, and the corresponding individual and population external beta doses are given in Table 2.

2. <u>External gamma doses</u> - The elevated release, immersion dose approach grossly underestimates the external ground level gamma dose at downwind distances where the bulk of the radioactive plume is above the ground. In this situation, the immersion dose approach predicts

a dose based on the very low ground level air concentration while the major contribution to the ground level gamma dose comes from the radioactive materials contained in the overhead plume.

For a very stable atmospheric condition, the bulk of a radioactive plume released from the 600-foot stack at BFNP will remain overhead for distances beyond the 50-mile radius within which population doses are calculated. To adequately assess the ground level gamma doses from an overhead plume, the plume must be divided into a finite number of volume elements (sources), and the dose contributions from all volume elements to each point on the ground under consideration must be calculated and summed. Such a model has been developed by TVA[3] for use in computing site boundary doses for the BFNP. This finite volume element model does not give a representative estimate of ground level gamma doses at downwind distances beyond 10 miles from the release point. Ground level gamma doses for both elevated and building releases were calculated using a "hybrid" computer model which executes the following sequence:

1. A ground level gamma dose is calculated at 1,200 m downwind from the release point using the finite volume element gamma dose model for an elevated or a building release (whichever is appropriate).
2. A ground level gamma dose is calculated at 100,000 m downwind from the release point using the building (ground level) release, immersion dose model.
3. A log-log interpolation is performed between these two end points to obtain gamma doses at intermediate points.

The TVA finite volume element model is described in detail in the references[3,4] and will not be discussed further in this appendix. The immersion dose model used to compute the ground level gamma dose at 100,000 m is given by equation 4.

$$D_\gamma = 7.21 \times 10^9 \, \overline{E}_\gamma \chi \qquad (4)$$

where

D_γ = external gamma dose due to submersion in a cloud, (mrem/yr),

7.21×10^9 = a constant used in calculating external gamma dose, $\left(\frac{\text{mrem/yr}}{\text{Ci-Mev/dis-m}^3}\right)$,

$\overline{E}_\gamma$ = average gamma energy of isotope being considered, (Mev/dis),

χ = average annual, ground level air concentration as calculated by equation 1 or 2, (Ci/m^3).

In this equation, a geometry correction factor of 0.5 is included to account for the semihemispherical cloud. The air concentration χ at 100,000 m is obtained using equation 2.

Where several isotopes contribute to the external gamma dose, the dose due to each isotope is computed and a summation (over all isotopes) is executed to obtain the total external gamma dose. The average gamma energies used in calculating external gamma doses were computed from data contained in the reference.[2]

The total population gamma dose within 50 miles of BFNP is calculated using the method described for the population beta dose. The annual individual and population external gamma doses, calculated for the releases shown in Table 1, are given in Table 2.

3. Thyroid doses due to iodine inhalation - The dose equation used in calculating inhalation doses for routine releases of radioiodine from BFNP is:

$$D = 8.76 \times 10^3 \chi(BR)\ (DCF), \qquad (5)$$

where

D = thyroid dose committed during release period, (mrem committed/yr),

8.76×10^3 = a constant representing the number of hours per year, $\left(\frac{\text{hr}}{\text{yr}}\right)$,

χ = average annual, ground level air concentration as calculated by equation 1 or 2, (Ci/m^3),

BR = breathing rate for person receiving dose, (m^3/hr),

DCF = dose commitment factor for iodine inhalation, (mrem/Ci inhaled).

The Federal Radiation Council[5] recommended a one-year-old child as the critical receptor for thyroid doses due to intake of radioiodine. In accordance with this recommendation maximum individual doses are calculated for a one-year-old child. Population doses are calculated using adult parameters and the same method described for beta doses.

The breathing rate used for a one-year-old child is 0.29 m^3/hr[6] and for an adult is 0.83 m^3/hr.[7] The inhalation dose commitment factors for the one-year-old child and for the adult are obtained for the five radioiodine isotopes considered using data from the reference.[8]

For each source, the annual radioiodine releases are shown in Table 1, and the calculated annual individual and population iodine inhalation doses are shown in Table 3.

4. <u>Thyroid doses due to iodine ingestion</u> - The equation used in calculating the thyroid doses to a receptor due to iodine ingestion through the milk food chain is:

$$D = 3.15 \times 10^7 (\chi) (v_g) (M) (CR) (DCF) \qquad (6)$$

where

D = thyroid dose committed during release period, (mrem committed/yr),

3.15×10^7 = a constant representing the number of seconds per year, $\left(\frac{sec}{yr}\right)$,

χ = average annual, ground level air concentration as calculated by equation 1 or 2, (Ci/m^3),

v_g = radioiodine deposition velocity, (m/sec),

M = empirically determined value of milk concentration of radioiodine per unit deposition rate, $\left(\frac{Ci/l}{Ci/m^2\text{-day}}\right)$,

CR = milk consumption rate, (l/day),

DCF = dose commitment factor for iodine ingestion, (mrem/Ci ingested).

In calculating milk ingestion doses due to routine releases of radioiodine from BFNP, only I-131 and I-133 isotopes are considered. The other iodine isotopes listed in Table 1 (I-132, I-134, and I-135) have short half lives ($<$7 hours) and will have essentially disappeared due to radioactive decay before significant reconcentration in the milk occurs.

The one-year-old child is assumed to be the critical receptor in calculating the maximum dose to an individual drinking milk produced at the nearest dairy farm (2.6 miles SSW of the plant). Population doses to persons within 50 miles of the plant are calculated using adult parameters. The assumption is made that all milk produced within 50 miles of the BFNP is consumed within the area. Cows are assumed to graze the pastures during the entire year. The numerical values used for the parameters v_g[9], M[10], CR[11], and DCF[11,8] were taken from the references indicated.

The individual and population milk ingestion doses are reported in Table 3.

5. <u>Maximum average annual radioiodine concentration</u> - The maximum average annual concentration of each radioiodine isotope released from the BFNP occurs in the NNW sector. These maximum concentrations (and the points at which they occur) are shown for each source in Table 4. These concentrations are calculated using equations 1 and 2.

Table 1

CALCULATED ANNUAL GASEOUS RELEASES DURING NORMAL OPERATION OF THREE UNITS WITH RELEASES CONSISTENT WITH A NOBLE GAS RELEASE RATE OF 100,000 μCi/sec/unit (after 30 minutes decay)

	Source of Release							
	Routine Release Sources				Alternate Waste Treatment Systems			
Isotope	Containment Purge[b] (E)[a] (Ci/yr)	Mechanical Vacuum Pump[b] (E) (Ci/yr)	Turbine Building[c] (B) (Ci/yr)	Waste Treatment 6 Charcoal Beds[d] (E) (Ci/yr)	Waste Treatment 30 Minutes Decay[d] (E) (Ci/yr)	Waste Treatment Recombiners Only[d] (E) (Ci/yr)	Waste Treatment 12 Charcoal Beds[d] (E) (Ci/yr)	Waste Treatment Gas Removal Systems[e] (E) (Ci/yr)
I-131	1.8 (-2)[f]		1.1 (-2)		6.5 (-3)g			
I-132	2.1 (-3)		1.0 (-1)		6.0 (-2)g			
I-133	1.4 (-2)		7.5 (-2)		4.5 (-2)g			
I-134			2.1 (-1)		1.2 (-1)g			
I-135			1.1 (-1)		6.5 (-2)g			
Kr-83m				9.3 (+2)	2.7 (+5)	2.2 (+4)	3.4 (+2)	3.4 (+2)
Kr-85m				4.3 (+4)	5.3 (+5)	1.9 (+5)	9.9 (+3)	7.7 (+2)
Kr-85				1.9 (+3)	1.9 (+3)	1.9 (+3)	1.9 (+3)	3.8
Kr-87				2.1 (+3)	1.4 (+6)	4.2 (+4)	1.9 (+3)	1.9 (+3)
Kr-88				3.2 (+4)	1.7 (+6)	3.2 (+5)	4.7 (+3)	2.2 (+3)
Kr-89								
Xe-131m	2.0			9.2 (+2)	1.4 (+3)	1.4 (+3)	6.1 (+2)	2.8
Xe-133m	4.0			2.8 (+3)	2.6 (+4)	2.5 (+4)	3.4 (+2)	5.2 (+1)
Xe-133	1.6 (+2)	5.8 (+3)		2.9 (+5)	7.8 (+5)	7.5 (+5)	1.1 (+5)	1.5 (+3)
Xe-135m	2.0 (+1)			2.5 (+3)	6.5 (+5)	2.5 (+3)	2.5 (+3)	2.5 (+3)
Xe-135	6.5 (+1)	8.6 (+2)		2.1 (+3)	2.1 (+6)	1.2 (+6)	2.1 (+3)	3.3 (+3)
Xe-137				1.4 (+4)	6.3 (+4)	1.4 (+4)	1.4 (+4)	1.4 (+4)
Xe-138				8.4 (+3)	2.0 (+6)	8.4 (+3)	8.4 (+3)	8.4 (+3)

a. (E) = stack release; (B) = building release
b. Release taken from the Browns Ferry Nuclear Plant FSAR
c. Based on 100 gal/day/unit leakage, a total DF of 2×10^3, and no decay
d. Based on air ejector flow rate of 18.5 scfm; includes release due to gland seal leakage
e. Assumes a DF of 1,000 for all isotopes; includes release of gland seal leakage
f. 1.8×10^{-2}
g. Assumes a DF of 100 due to washout

Table 2

CALCULATED ANNUAL EXTERNAL GAMMA AND BETA DOSES DURING NORMAL OPERATION OF THREE UNITS

WITH RELEASES CONSISTENT WITH A NOBLE GAS RELEASE RATE OF 100,000 μCi/sec/unit (after 30 minutes decay)

	Source of Release							
	Routine Release Sources				Alternate Waste Treatment Systems			
	Containment Purge	Mechanical Vacuum Pump	Turbine Building	Waste Treatment 6 Charcoal Beds	Waste Treatment 30 Minutes Decay	Waste Treatment Recombiners Only	Waste Treatment 12 Charcoal Beds	Waste Treatment Gas Removal Systems
Maximum Individual Gamma Dose (mrem)	2.1 (-4)[a] (1509m)	2.2 (-3) (1509m)	4.0 (-5) (1509m)	1.3 (1509m)	1.5 (+2) (1509m)	1.3 (+1) (1509m)	4.9 (-1) (1509m)	4.1 (-1) (1509m)
Maximum Individual Beta Dose (mrem)	2.0 (-4) (2400m)	4.5 (-3) (2400m)	2.0 (-5) (1509m)	3.4 (-1) (2400m)	2.2 (+1) (2400m)	3.3 (2400m)	1.6 (-1) (2400m)	8.0 (-2) (2400m)
Total Population Gamma Dose Within 50 miles (man-rem)	8.3 (-3)	1.8 (-1)	1.6 (-4)	1.5 (+1)	6.7 (+2)	1.9 (+2)	3.9	9.5 (-1)
Total Population Beta Dose Within 50 miles (man-rem)	5.3 (-3)	1.3 (-1)	7.9 (-5)	7.2	2.2 (+2)	7.1 (+1)	2.6	3.6 (-1)

a. 2.1×10^{-4}

Table 3

CALCULATED ANNUAL THYROID DOSES DUE TO IODINE INTAKE DURING NORMAL OPERATION OF THREE UNITS

WITH RELEASES CONSISTENT WITH A NOBLE GAS RELEASE RATE OF 100,000 μCi/sec/unit (after 30 minutes decay)

	Source of Release							
	Routine Release Sources				Alternate Waste Treatment Systems			
	Containment Purge	Mechanical Vacuum Pump	Turbine Building	Waste Treatment 6 Charcoal Beds	Waste Treatment 30 Minutes Decay	Waste Treatment Recombiners Only	Waste Treatment 12 Charcoal Beds	Waste Treatment Gas Removal Systems
Iodine Inhalation								
Maximum Individual Thyroid Dose (mrem)	6.3 (-4)[a] (2400m)	-	3.9 (-2) (1509m)	-	1.2 (-3) (2400m)	-	-	-
Total Population Thyroid Dose Within 50 miles (man-rem)	9.7 (-3)	-	1.0 (-1)	-	1.0 (-2)	-	-	-
Iodine Ingestion via Milk								
Maximum Individual Thyroid Dose at Nearest Dairy Farm (mrem)	3.3 (-2) (4200m)	-	1.5 (-1) (4200m)	-	1.3 (-2) (4200m)	-	-	-
Total Population Thyroid Dose Within 50 miles (man-rem)	1.5 (-1)	-	5.8 (-1)	-	5.6 (-2)	-	-	-

a. 6.3×10^{-4}

Table 4

CALCULATED MAXIMUM ANNUAL IODINE CONCENTRATIONS DURING NORMAL OPERATION OF THREE UNITS

WITH RELEASES CONSISTENT WITH A NOBLE GAS RELEASE RATE OF 100,000 μCi/sec/unit (after 30 minutes decay)

	Source of Release								
	Routine Release Sources					Alternate Waste Treatment Systems			
	Containment Purge	Mechanical Vacuum Pump	Turbine Building	Waste Treatment 6 Charcoal Beds	Total, All Routine Sources	Waste Treatment 30 Minutes Decay	Waste Treatment Recombiners Only	Waste Treatment 12 Charcoal Beds	Waste Treatment Gas Removal Systems
Max. Annual Conc. of I-131, μCi/cc	1.8 (-17)[a] (2400m)	-	2.3 (-16) (1509m)	-	2.4 (-16) (1509m)	6.6 (-18) (2400m)	-	-	-
Max. Annual Conc. of I-132, μCi/cc	2.0 (-18) (2400m)	-	1.9 (-15) (1509m)	-	1.9 (-15) (1509m)	5.6 (-17) (2400m)	-	-	-
Max. Annual Conc. of I-133, μCi/cc	1.4 (-17) (2400m)	-	1.5 (-15) (1509m)	-	1.5 (-15) (1509m)	4.5 (-17) (2400m)	-	-	-
Max. Annual Conc. of I-134, μCi/cc	-	-	3.7 (-15) (1509m)	-	3.7 (-15) (1509m)	9.7 (-17) (2400m)	-	-	-
Max. Annual Conc. of I-135, μCi/cc	-	-	2.2 (-15) (1509m)	-	2.2 (-15) (1509m)	6.4 (-17) (2400m)			

a. 1.8×10^{-17}

APPENDIX II

RADIOLOGICAL IMPACT OF LIQUID EFFLUENTS

The calculation of radiation doses to organisms that are exposed in a natural or incompletely controlled environment is a difficult task. Because of the complexity of biological functions and the interrelationship between organisms and their environments, it is necessary to develop simplified dose models that can predict the more important characteristics of the system under analysis. It is further necessary to apply assumptions that are descriptive of average behavior and average conditions of the ecosystems. While these models may be unable to follow the detailed variances of a system and while the results of an analysis may not be applicable to all members of a population, assumptions are chosen so that the radiation doses are conservative, i.e., overestimated. Only the basic assumptions are given in this appendix along with a brief outline of the models and methods of calculation.

Doses are calculated for the radionuclides listed in Table 1 which are expected to be released during normal operation of the Browns Ferry plant. For convenience, the activities are normalized to a total of 1.0 Ci with the assumption that the nuclides Y-90, Tc-99m, La-140, and Pr-144 are in equilibrium with their respective parents at the time of release. Inclusion of these daughter nuclides increases the total activity by 8.5 percent and the ratios between the activities in Table 1 and those in Table 2.4-2 of this volume are 43.4, 5.42, and 0.434 for the 40 Ci, 5 Ci, and 0.4 Ci values respectively. These activities correspond to the expected annual releases (1) from the system as designed, (2) for interim operation with demineralizers, and (3) for operation with the complete radwaste system including evaporator. Doses in Table 2.4-3 of this volume are derived from the normalized dose estimates listed in the tables of this appendix by the application of the factors 5.42 and 0.434 as appropriate. Tritium doses are considered separately and are based on a normalized release of 1 Ci per year. The annual tritium dose may be computed by applying the appropriate factor to this normalized value.

Calculations of doses to humans include estimates of the doses to bone, G.I. tract, thyroid, and skin tissues as well as the total body. Dose estimates for organisms other than man are not detailed by organs other than the total body because of a lack of applicable data.

1. Doses to man from the ingestion of water - Calculations of dose commitments from the consumption of Tennessee River water use data for the public and industrial water systems listed in Table 2. Projected populations for the year 2010 are used based on a uniform ratio of 1.77 x 1970 population within 50 miles of the Browns Ferry site. The plant effluent is assumed to be mixed with 65 percent of the riverflow at or near the outfall at Browns Ferry. Although natural water turbulence should increase the total dispersion (and reduce the activity concentration) in the 19.1-mile reach to the first water supply intake at Wheeler Dam, there are uncertainties, e.g., the degree of mixing of the main riverflow with the Elk River inflow at TRM 283. Therefore, it is assumed that complete mixing would not be effected until the water passes Wheeler Dam.

Dilution is calculated using average annual flow data for the Tennessee River as measured during 1899-1968. The average flow ranges from approximately 45,000 ft^3/s at the site to 54,000 ft^3/s at Pickwick Landing Dam. Radioactive decay and the buildup of daughter activity are based on estimates of the transport time using data for water velocities which vary between 0.2 and 2.6 ft/s within the reach from the nuclear plant site to Pickwick Landing Dam. No radioactive decay is considered between the time of intake in a water system and the time of consumption. It is assumed that each individual consumes 2,200 ml of water per day (the average daily adult ingestion from all sources including drinking water, food, bottled drinks, etc.).

Due to a lack of definitive data, no credit is taken for removal of activity from the water through adsorption on solids and sedimentation, by deposition in the biomass, or by processing within water treatment systems.

Internal doses, D_{ij}, for the j^{th} organ from the i^{th} radionuclide are calculated using the relation

$$D_{ij} = (DCF)_{ij} \times I_i, \tag{1}$$

where $(DCF)_{ij}$ = the dose commitment factor for an average adult assuming that the dose can be accumulated over a 50-year interval, (mrem/μCi),

I_i = the activity of the i^{th} radionuclide taken into the body annually via ingestion, (μCi).

The dose commitment factors were derived from data given in the references listed[1,2,3] and are defined in units of (mrem/μCi) by the equation

$$(DCF)_{ij} = \frac{51.2 \times 10^3 \, f_{wij} \, \varepsilon_{ij} \, (1-e^{-\lambda_{ij} T})}{m_j \, \lambda_{ij}}, \tag{2}$$

where $51.2 \times 10^3 = \left(\frac{\text{g-rad}}{\text{Mev}}\right)\left(\frac{\text{disintegrations}}{\mu\text{Ci-day}}\right)\left(\frac{\text{mrem}}{\text{rem}}\right)$

f_{wij} = fraction of the i^{th} radionuclide taken into the body by ingestion that is retained in the j^{th} organ, (dimensionless),

ϵ_{ij} = effective energy absorbed in the j^{th} organ per disintegration of the i^{th} radionuclide including daughter products, (Mev-rem/dis-rad),

λ_{ij} = the effective decay constant of the i^{th} radionuclide in the j^{th} organ, (day^{-1}),

T = integration time, (18,250 days),

m_j = mass of the j^{th} organ, (g).

Tables 3 and 4 show a detailed breakdown of the dose commitments at each public water supply intake.

For comparison, dose commitments are also calculated for a hypothetical individual whose entire yearly water supply is obtained from the plant discharge conduit prior to dilution in the Tennessee River. These estimates are upper limits based on a continuous discharge flow rate of 50,000 GPM which corresponds to the minimum flow rate with cooling towers operating in a closed-cycle mode.

Doses to humans from ingestion of Tennessee River water affected by slug releases can be estimated using the data in section A of Tables 3 and 4 provided (1) the distribution of activity is the same as for the dose estimates for normal operation, (2) the total activity of the slug release is known, and (3) the river velocities and dilution factors are not grossly different from the average values on which the routine dose estimates are based.

2. Doses to man from the consumption of fish - Calculations of the dose commitments from the consumption of fish assume a sport fish harvest[4] of 15.2 lb/acre and an edible commercial fish harvest[5] of 13.7 lb/acre taken from a total of 125,000 acres. It is assumed that the entire harvest of edible fish contributes to the estimated population dose commitment. The radioactivity levels in these fish are estimated by the product of the average concentration of water activity in the reach from TRM 294.0 to TRM 233.0 and a concentration factor for each radionuclide.[6,7] It is assumed that the maximum annual consumption of fish by an individual is 45 lbs. Radioactive decay is not considered between the time the fish is removed from the water and the time of consumption and the entire mass of the fish is assumed to be eaten. Shellfish consumption is assumed to be negligible.

Dose commitments are calculated with equations 1 and 2 which are discussed for water ingestion in the previous section, and the results are shown in Tables 3 and 4.

3. Doses to man due to water sports - Estimates of the doses from immersion in the Tennessee River are calculated for each radionuclide using the following relations:

For the dose rate to the skin,

$$R_i = 51.2 \times 10^3 \, C_{wi} \left(\bar{E}_\beta/2 + E_\gamma\right)_i \, \frac{\text{mrem}}{\text{day}} \tag{3}$$

For the dose rate to the total body,

$$R_i = 51.2 \times 10^3 \, C_{wi} \, E_{\gamma i} \, \frac{\text{mrem}}{\text{day}} \tag{4}$$

where 51.2×10^3 = (see equation 1),

C_{wi} = water concentration for the i^{th} radionuclide, ($\mu Ci/g$),

$E\gamma i$ or $(\bar{E}_\beta/2 + E_\gamma)i$ = average effective energy emitted by the i^{th} radionuclide per disintegration, (Mev-rem/dis-rad).

Dose rates for those activities such as boating are assumed to be given by equations 3 and 4 divided by 2.

Population doses are calculated for the reach from the Browns Ferry site (TRM 294.0) to Tennessee River mile 233.0 using estimates of 2,518,000 above-water visits and 480,000 in-water visits per year based on information given in reference 8 and 9. The maximum individual doses for above-water use of the river are estimated for a commerical fisherman who is not a water sport enthusiast but who might be exposed for 300 days per year at 5 hours per day. The maximum individual doses for in-water activities are estimated for a person who swims 918 hours per year (6 hours per day for the 5 warm months) at a location just below the Browns Ferry site. In order to estimate the maximum possible tritium dose to a swimmer, continuous immersion in the Tennessee River just below the Browns Ferry site is assumed.

4. Doses to organisms other than man - A comprehensive analysis of the radiation doses to species other than man would require many man-years of effort that could be justified only if a significant radiological impact on a particular species were anticipated. After consultation with professionals in the health physics and radioecology fields, a decision was made by TVA to restrict the analyses to those

organisms living on or near the Browns Ferry site that would most likely receive the greatest doses. These include terrestrial vertebrates, aquatic plants, aquatic invertebrates, and fish.

(1) Terrestrial vertebrates - Radioactivity contained in nuclear plant liquid effluents is reconcentrated in fish, invertebrates, and plants by factors that range from less than 1 to greater than 10^5 depending on interrelated physical, chemical, and biological factors. Terrestrial vertebrates will receive a radiation dose from liquid effluents if their food chain includes aquatic organisms that have reconcentrated radionuclides. In general, aquatic plants such as green algae concentrate trace elements to a greater extent than do fish and invertebrates.[6] Therefore, internal dose estimates have been made for ducks and muskrats with the conservative assumption that their diet consists entirely of green algae from algol masses growing near and affected by the Browns Ferry outfall. Equations 1 and 2 from section 1 are used for estimating internal dose. It is assumed that the duck or muskrat has a mass m of 1,000 g, an effective radius of 10 cm, and consumes 333 g of green algae per day. Long lived radionuclides such as Sr-90 can deliver significant portions of the total dose commitment long after the time of ingestion. Therefore, a period of 5 years was chosen for the integration of interval T. In the absence of data specifically applicable to ducks or muskrats, ICRP data[2] are used for the fractional uptake f_{wi} and for the biological half life of parent radionuclides. The use of human data for the biological half lives is conservative because, in general, warm-blooded vertebrates that are smaller than man exhibit

more rapid elimination rates. Equation 5 is a combination of the above assumptions with equations 1 and 2.

$$D_i = 6.23 \times 10^6 \, f_{wi} \, \varepsilon_i \, (1-e^{-\lambda_i T}) \, C_{wi} \, F_{pi}/\lambda_i \text{ mrad,} \qquad (5)$$

where T = 1,825 days,

C_{wi} = water concentration, (μCi/g),

F_{pi} = concentration factor[6,7] for aquatic plants, (dimensionless).

External doses are estimated with equation 4 using the conservative assumption that the duck and muskrat are exposed continuously by full immersion in the water.

Table 5 shows the estimates of the doses to a duck or muskrat.

(2) Aquatic plants, invertebrates, and fish - Radionuclide activity internally deposited in these organisms is estimated from the concentration in the water in the Tennessee River just below the liquid effluent outfall, assuming 65 percent mixing, multiplied by the applicable concentration factors.[6,7] Doses are estimated for organisms having effective radii of 3 cm and 30 cm. Although estimates for both geometries are reported, an effective radius of 30 cm could represent organisms weighing up to 250 pounds. This geometry probably results in overestimates of the doses. On the other hand, the increased doses to benthic invertebrates from radionuclides having higher concentrations in bottom sediments than in the water are not included in the calculations. In the absence of a detailed knowledge of the dynamic behavior of daughter products that are produced from internally deposited parents, the conservative assumption is made that all daughter products are permanently bound in the

organisms and contribute energy at the rate of one disintegration of every daughter in a decay chain for each disintegration of the parent. The doses from the i^{th} radionuclide are calculated using the relation:

$$D_i = 1.87 \times 10^7 \, C_{wi} \, F_i \, \varepsilon_i \text{ mrad.} \tag{6}$$

Table 6 lists the dose estimates for these organisms.

Table 1

ROUTINE RELEASES OF LIQUID EFFLUENTS[a]
(Normalized to 1.0 Curie)

Nuclide	Release[b] (microcuries)
Co-58	1.2 (4)[c]
Co-60	1.2 (3)
Sr-89	7.4 (3)
Sr-90	5.5 (2)
Sr-91	6.9 (4)
Y-90	5.5 (2)
Mo-99	4.8 (4)
Tc-99m	4.8 (4)
I-131	3.0 (4)
I-133	1.4 (5)
I-135	9.0 (4)
Cs-134	3.9 (2)
Cs-137	5.8 (2)
Ba-140	2.1 (4)
La-140	2.1 (4)
Ce-144	8.3 (1)
Pr-144	8.3 (1)
Np-239	5.1 (5)
Total	1.0×10^6 µCi

a. Tritium is not included
b. The following radioactive daughters are assumed to be in equilibrium with the respective parents at the time of release; Y-90, Tc-99m, La-140, Pr-144.
c. 1.2×10^4

Table 2

TENNESSEE RIVER DRINKING WATER SUPPLY INTAKES WITHIN A 50-MILE RADIUS DOWNSTREAM FROM BROWNS FERRY NUCLEAR PLANT

System	Location (TRM)	Distance (miles)	Populations Served 1970	2010
Wheeler Dam	274.9	19.1	50	90
Wilson Dam	259.4	34.6	2,500	4,400
Sheffield	254.3	39.7	16,000	29,000
Colbert Steam Plant	245.0	49.0	350	620
Cherokee	239.3	54.7	2,400	4,200

Table 3

DOSES[a] TO HUMANS FROM WATER CONTAINING A MIXTURE[b] OF RADIONUCLIDES

A. Ingestion of Tennessee River Water[c]

Location	Bone	G.I. Tract	Thyroid	Total Body
Browns Ferry Site (for comparison)	6.8 (-4)[d]	9.4 (-4)	6.0 (-3)	4.8 (-5) mrem
Wheeler Dam	6.0 (-4)	2.7 (-4)	1.7 (-3)	3.7 (-5) mrem
	5.3 (-5)	2.4 (-5)	1.5 (-4)	3.3 (-6) man-rem
Wilson Dam	3.7 (-4)	1.0 (-4)	7.2 (-4)	2.3 (-5) mrem
	1.7 (-3)	4.4 (-4)	3.2 (-3)	1.0 (-4) man-rem
Sheffield	3.7 (-4)	9.8 (-5)	7.0 (-4)	2.3 (-5) mrem
	1.1 (-2)	2.8 (-3)	2.0 (-2)	6.5 (-4) man-rem
Colbert Steam Plant	3.7 (-4)	9.4 (-5)	6.8 (-4)	2.2 (-5) mrem
	2.3 (-4)	5.8 (-5)	4.2 (-4)	1.4 (-5) man-rem
Cherokee	3.7 (-4)	9.2 (-5)	6.7 (-4)	2.2 (-5) mrem
	1.5 (-3)	3.8 (-4)	2.8 (-3)	9.3 (-5) man-rem
Total Population Dose Commitments	1.4 (-2)	3.7 (-3)	2.7 (-2)	8.6 (-4) man-rem

B. Ingestion of Nuclear Plant Effluent[e] Prior to Dilution in the Tennessee River

Individual Dose Commitments	0.18	0.25	1.6	0.013 mrem

C. Eating Fish Taken from Wheeler, Wilson, and Pickwick Lakes

Maximum Individual Dose Commitment	1.6 (-4)	2.2 (-2)	1.6 (-3)	4.4 (-5) mrem
Population Dose Commitment	1.3 (-2)	1.8	0.13	3.5 (-3) man-rem

a. Estimates for parts A, B, and C are internal dose commitments for each annual intake of radioactivity. Estimates for part D are external doses for each annual exposure.
b. Normalized to 1.0 Ci total annual release excluding tritium.
c. Based on the estimated population in the year 2010.
d. 6.8×10^{-4}
e. Assuming a continuous discharge of 50,000 GPM (minimum flow with cooling towers)

Table 3 (Continued)

D. Use of the Tennessee River for Water Sports

	Above Water[f]		In Water[g]		
	Skin	Total Body	Skin	Total Body	
Maximum Individual Dose	1.8 (-5)	1.4 (-5)	5.0 (-5)	3.9 (-5)	mrem
Population Dose	7.7 (-5)	6.0 (-5)	3.0 (-5)	2.3 (-5)	man-rem

f. Boating and fishing, for example
g. Swimming and water skiing, for example

Table 4

DOSES[a] TO HUMANS FROM WATER CONTAINING TRITIUM[b]

A. Ingestion of Tennessee River Water[c]

Location	Individual (mrem)	Population (man-rem)
Browns Ferry Site (for comparison)	3.9 (-6)[d]	-
Wheeler Dam	3.6 (-6)	3.2 (-7)
Wilson Dam	2.2 (-6)	9.9 (-6)
Sheffield	2.2 (-6)	6.5 (-5)
Colbert Steam Plant	2.2 (-6)	1.4 (-6)
Cherokee	2.2 (-6)	9.2 (-6)
Population Total		8.5 (-5) man-rem

B. Ingestion of Nuclear Plant Effluent[e] Prior to Dilution in the Tennessee River

Individual Dose Commitment	1.0 (-3) mrem

C. Eating Fish Taken from Wheeler, Wilson, and Pickwick Lakes

Maximum Individual Dose Commitment	6.5 (-8) mrem
Population Dose Commitment	5.2 (-6) man-rem

D. Use of the Tennessee River for Water Sports

Maximum Individual Dose[f]	7.1 (-6) mrem

a. Estimates are internal dose commitments for each annual intake of tritium
b. Normalized to 1.0 Ci total annual release
c. Based on the estimated population in the year 2010
d. 3.9×10^{-6}
e. Assuming a continuous discharge of 50,000 GPM (minimum flow with cooling towers)
f. Assuming continuous immersion

Table 5

DOSES[a] TO DUCKS AND MUSKRATS LIVING NEAR THE BROWNS FERRY NUCLEAR PLANT

	1.0 Ci Mixture	1.0 Ci Tritium
Internal	0.49 mrad	4.1 (-5)[b] mrad
External	3.7 (-4) mrad	0 mrad
Total	0.49 mrad	4.1 (-5) mrad

a. Internal dose commitments for each annual intake and external doses from each annual exposure
b. 4.1×10^{-5}

ible 6

DOSES TO AQUATIC ORGANISMS LIVING IN THE TENNESSEE RIVER

NEAR THE BROWNS FERRY NUCLEAR PLANT

A. Doses from an Annual Release of a 1.0 Ci Radionuclide Mixture[a]

	Internal (mrad) 3-cm	30-cm	External (mrad)
Plants	0.23	0.48	3.7 (-4)[b]
Invertebrates	3.3	4.7	3.7 (-4)
Fish	0.83	1.2	3.7 (-4)

B. Doses from an Annual Release of 1.0 Ci Tritium

Plants, invertebrates, and fish	7.1 (-6) mrad (internal)

a. Excluding tritium
b. 3.7×10^{-4}

APPENDIX III

RADIOLOGICAL IMPACT OF EXTERNAL EXPOSURE FROM SOURCES INSIDE THE REACTOR AND TURBINE BUILDINGS

A simplified model is utilized to estimate an upper bound for the external radiation dose at the site boundary from sources inside the reactor and turbine buildings. Direct radiation exposure from these sources is eliminated by shielding. Scattered radiation exposure is possible due to the scattering of gamma radiation which exits through the turbine building roof. The following assumptions are employed to establish an upper bound for the radiation dose from this source:

1. N-16 gammas dominant source.
2. Total source term (3 units) is 2.2×10^{12} photons/s.
3. Isotropic point source.
4. Unscattered gammas (6.13 Mev) exit turbine building vertically through a cone defined by the shield walls.
5. No credit is taken for shield effect of turbine building roof.
6. All gammas leaving turbine building are scattered at one scatter mean free path.
7. Fraction scattered toward offsite dose point is calculated from Compton scatter cross section considerations.
8. No further scattering is assumed although the path length from the first scattering point to the dose point is about $2\text{-}\frac{1}{2}$ scatter mean free paths of the once scattered gammas.

Based upon the above assumptions the dose at the site boundary due to scattered radiation from the turbine building is 0.6 mrem/yr. This dose is less than 0.5 percent of the dose from natural background radiation. Therefore, a more complex analysis, which would be expected to show that the dose is lower, is not warranted. The rapid reduction of this dose at increasing distances beyond the site boundary would limit the population dose from this source to a very low value.

APPENDIX IV

EXCERPTS FROM TVA REPORT 63-38:

Prediction and Control of Water Temperatures in Wheeler Reservoir During Operation of the Browns Ferry Nuclear Plant, April 1972

1. Hydraulic Design and Basic Studies of the Diffuser System - The manifold-type, multiport pipe system adapted for diffusion of the heated condenser water is similar to those used in marine outfalls. The discharged water will issue from the diffuser ports at a relatively high velocity, and the turbulence created by these jets will cause mixing of the heated discharge with the cooler reservoir water.

The diffuser system was designed to meet the following requirements:

1. Each pipe must handle a flow of 1,450 ft^3/s.
2. The total discharge from all three pipes must be uniformly distributed across the 1,800-foot wide main channel.
3. The jet velocity must be sufficiently high to create complete mixing of the condenser discharge with the reservoir flow available to the diffusers.
4. The total head at the entrance to the pipes should not exceed 4.5 feet of water.

A model study was performed at the TVA Engineering Laboratory in 1967 to determine the hydraulic characteristics of the jets issuing from the diffuser holes. The tests were performed at a scale of 1:2, thus providing realistically high model turbulence levels for the range of pipe diameters and hole sizes expected in prototype. The study showed that the flow will issue from the diffuser ports at nearly a 90° angle and with a discharge coefficient which is a function primarily of the ratio of velocity head to total energy in the pipe.

The design of the diffuser involved selection of a main pipe diameter and discharge port size which, for the design discharge flow, will produce a discharge distribution, jet velocity, and total entrance head as specified above in items 1 to 4. This procedure utilized the discharge coefficients determined by the model study and corrugated pipe friction factors measured at the U.S. Army Corps of Engineers Waterways Experiment Station at Vicksburg, Mississippi.[1] These data were inputs to an analytical model of the diffuser's hydraulic performance which calculated the distribution of the discharge and the energy grade line along the diffuser pipes. The final diffuser design shown in figure 1 was selected on the basis of these calculations.

(Editor's Note: The preliminary design and location of the steel-supported warning signs to mark the portion of the present navigation channel which will be over the diffuser pipes has been informally coordinated with the U.S. Coast Guard, Second District Office, St. Louis, and the Corps of Engineers, Nashville District Office. The signs will be about 1,200 feet apart, leaving a clear navigable width of channel of more than 1,000 feet. When the final design of the signs is completed, it will be formally sent to those two agencies for review and comment.)

(1) <u>2-Dimensional Model Testing of the Jet Mixing Region</u> - Based on the available state-of-the-art knowledge of submerged jets, it was expected that the design discharge velocity of about 9 ft/s would result in efficient mixing of the discharge flow with the ambient flow passing over the diffuser. A 2-dimensional model study was undertaken to examine the characteristics of the mixing induced

by the diffuser discharge and to determine the angle of discharge with the horizontal which would minimize bed scour downstream from the diffuser. These tests were performed at the MIT R. M. Parsons Laboratory for Water Resources and Hydrodynamics during 1967 and 1968. The model scales were 1:15 horizontally and vertically providing the undistorted model required for jet mixing zone studies. The principal results of the investigations were:

1. Mixing of the jets with that portion of the flow passing over the diffusers will occur rapidly. This is illustrated by figure 2 which shows the temperature distribution obtained from model tests in the immediate vicinity of the diffusers for a simulated steady reservoir flow of 20,000 ft^3/s. Within a matter of a few feet from the diffuser, the temperature was reduced to about 11°F above ambient. The maximum temperature at the reservoir bottom was about 6-7°F above ambient over an area extending a distance of about 30 feet from the diffuser. At distances greater than about 50 feet, the observed temperature agreed well with the theoretical fully mixed rise of 5.5°F. Figure 3 shows the temperature distribution for a flow of 26,000 ft^3/s.

   On the basis of the MIT tests, it is expected that the mixing will result in uniform temperature over the full depth within a distance of about 100-200 feet horizontally from the diffuser pipe. The zone of jet mixing will extend no more than 200 feet from the diffuser horizontally and no more than 5-10 feet above the top of the diffuser pipe.

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(2) <u>3-Dimensional Thermal Model</u> - The thermal regime induced in Wheeler Reservoir by the operation of Browns Ferry in either the open or helper modes will depend upon a complex interaction between the intake and discharge flows and the regulated flows in the reservoir. The purpose of the 3-dimensional thermal model study has been to assess the performance of the discharge configuration and to determine the relationship between the reservoir flow and the temperature distribution.

The model encompasses a 5-mile reach of Wheeler Reservoir with the Browns Ferry intake and diffuser situated near the center of this reach. The model (see figure 4) is distorted having a vertical scale ratio of 1:50 and a horizontal scale ratio of 1:250.

The 3-dimensional thermal model is designed to give information about the intermediate region between the jet mixing area, immediately adjacent to the diffusers, and the far field upstream and downstream regions. This region is of great importance in evaluating thermal effects because the highest temperatures outside of the mixing zone will occur here. In addition, the dynamics of the flow in the intermediate region may affect the magnitude of the mixing flow, Qm. Finally, the observed behavior of the heated layer provides the required starting boundary condition for downstream heat loss calculations.

The dominant physical phenomena in the intermediate region are the convection of mass and heat, the formation of stratified conditions, and to a lesser extent the loss of heat through the water surface. The scales of the 3-dimensional thermal model were chosen to ensure correct similitude of the convection, stratification, and surface heat loss. Field studies in the prototype have been conducted and are continuing with the purpose of determining the pattern of reservoir currents and the surface heat loss characteristics in the vicinity of the plant. In the model the distribution of the upstream reservoir flow may be adjusted to replicate prototype current conditions. A study of the surface heat exchange in the model has been made to facilitate the evaluation of surface heat loss upon model temperature data. Careful sensitivity testing is continuing to determine whether or not the upstream distribution of flow, surface heat loss, boundary roughness, and distorted diffuser configuration have any significant effects upon the observed flow and temperature structure. To date, it appears that the first three are not of major significance and probably the diffuser configuration is not either.

A series of steady reservoir flow tests have determined the 3-dimensional flow and temperature distributions in the modeled area for 1-, 2-, and 3-unit operation. These tests indicate the following pattern of behavior:

The intake flow will be withdrawn from the full depth and will consist of water which flows downstream from the shallow area on the plant side and from the righthand side of the main channel. This flow distribution will tend to minimize recirculation of heated water.

Recirculation will occur only in the low-flow situations when all of the upstream flow is being drawn into the mixing zone. It can be shown on theoretical grounds that the mixed temperature rise will be virtually independent of the degree of recirculation (see Equation (4)). The model data confirm this conclusion. (Editor's Note: After the cooling towers become operational they will be used during most of these low-flow situations.)

For reservoir flows of large magnitude, i.e., greater than 50,000-70,000 ft^3/s (case 1) the natural flow distribution in the reservoir will not be significantly altered by the mixing action of the diffusers. Velocities will be in the downstream direction over the full depth and over the entire width of the reservoir (see figure 5). No heated water will move upstream from the diffusers, thus preventing any recirculation (R = 0). The mixed flow at temperature Tm leaving the jet mixing region will form a heated surface layer downstream above a lower layer consisting of that portion of the ambient flow which does not pass through the mixing region. The mixing flow Qm will be determined by the amount of flow which passes over the diffuser naturally. Field measurements of currents in Wheeler Reservoir indicate that about 22 percent of the total reservoir flow passes over each of the three diffuser sections, making a total of about 65 percent in the deep river channel. The mixing flow Qm will depend upon how the flow downstream from the intake is redistributed across the channel during operation of the plant. However, the resulting mixed temperature is relatively insensitive to this factor and is given approximately by

$$Tm = Tr + \frac{167,000}{Qr} \qquad (2)$$

where Qr is the total reservoir flow. The value of Tm given by Equation (2) is for one, two, or three units and is shown in figure 8.

For reservoir flows greater than 7-10 times the diffuser flow but less than 50,000-70,000 ft^3/s (case 2) the sum of the intake flow and the mixing flow, Qm, demanded and diverted by the diffusers will be equal to about 7-10 times the condenser flow. The remainder of the riverflow Qr will pass by the side of the diffusers unmixed. The flow pattern in these cases is shown in figure 6. No eddy will be present in the subsurface flow as the portion of the ambient water which passes the diffusers without mixing will be an underflow over the shallow lefthand area. Downstream from the diffusers the ambient flow which did not mix will form a cooler bottom layer beneath an eddying surface layer of water at the mixed temperature. The surface layer will spread laterally across the shallow area and depending on the magnitude of the riverflow may have spread upstream from the diffusers. No recirculation occurs for these cases, making R = 0 in Equation (1).

$$Tm = Tr + \frac{25}{P} \qquad (3)$$

where P is about 7-10 as shown in figure 8. The resulting temperature rise is about 2.5-3.5°F.

For reservoir flows less than about 7-10 times the diffuser flow (case 3) all of the reservoir flow will be drawn into the jet mixing zone. The flow pattern in these cases is shown schematically in figure 7. A large eddy will occur over the total depth in the wide lefthand shallow area adjacent to the diffusers as a result of the diversion of the riverflow. Since no ambient water will pass by the diffusers without mixing, the entire downstream region will be at the mixed temperature over the full depth. A surface layer of water at the mixed temperature may extend upstream from the diffusers either because of the eddy currents or because of gravitational spreading.

For this case the mixing flow Qm is equal to the total reservoir flow Qr less the intake flow Qc(1 - R) and the mixed temperature is given by:

$$Tm = Tr + \frac{25Qc}{Qr} \qquad (4)$$

which is independent of the amount of recirculation. A plot of Equation (4) is also shown on figure 8.

<u>The upstream movement of a heated surface layer</u> is a highly 3-dimensional phenomena which is only qualitatively similar to the upstream wedge in a 2-dimensional channel. In the cases where the surface layer reaches the upstream boundary of the model, with our present understanding, it is not possible to predict how much further the warm water will extend in the prototype. However, it is expected that the vertical thickness of the layer will decrease in the upstream direction.

<u>The downstream flow of mixed water</u> at temperature Tm will initially be limited to the deep river channel just below the diffusers, but within a few miles of the diffusers it will spread over the full width of the reservoir. As previously discussed, the degree of vertical stratification will be dependent upon the magnitude of the reservoir flow. However, the downstream surface layer will lose heat to the atmosphere at a rate independent of the depth of the heated layer. This will be discussed below.

2. <u>Downstream Water Surface Temperature Predictions</u> - The changes in the downstream reservoir temperature resulting from the

operation of Browns Ferry were determined by routing the initial increase in temperature using the following 1-dimensional, steady-state equation:

$$\Delta Tx = \Delta To \exp\left[\frac{-K}{\rho c}\,\frac{XB}{Qm + Qc}\right] \qquad (5)$$

where ΔTx = the increase in surface temperature at the end of a routing reach

ΔTo = the increase in surface temperature at the beginning of a routing reach

X = length of routing reach

B = effective width of the reach

K = environmental heat exchange coefficient

Qm = the portion of the total riverflow that mixes with the diffuser discharge

Qc = the diffuser discharge

ρ = density of water

c = specific heat of water

For computational purposes the reservoir was divided into six reaches varying in length from 2.1 to 4.2 miles. Equation (5) was applied successively to each reach by using the temperature rise at the beginning of the reach, ΔTo, to obtain the temperature at the end of the reach, ΔTx, which then became the initial temperature rise for the following reach.

The effective width of the heated water for each reach was based on observations of the 3-dimensional model which showed that the main body of heated water flows downstream spreading laterally across the reservoir and that the full width of the reservoir will be covered at a distance of about 3 miles from the diffusers. Within the first 3 miles the effective width for heat dissipation will be about one-half of the average reservoir width. The formation of an eddy in the shallow area opposite the plant at low flows was previously described. It was assumed for the purpose of the temperature predictions that no heat will be transported from the main body of flow by the eddy. The effect of this assumption is that the downstream temperature predictions are slightly high when such an eddy exists.

The environmental heat exchange coefficient affects the rate at which the temperature decreases. An increase in the coefficient causes a more rapid die-off. This coefficient is a function of meteorological conditions; hence, it varies seasonally and from year to year. To account for the meteorological variations, temperature routings were made for each month of the 12-year period 1960 through 1971 based upon coefficients determined for the average meteorological conditions that existed during the middle week of the month. From these routings the mean and 95 percent confidence limits of the routed temperatures were computed.

The discharge Qm + Qc represents that portion of the reservoir flow that will be heated above ambient. As previously discussed Qm + Qc may be equal to or less than the total reservoir flow depending on the magnitude of the total reservoir flow. Qm + Qc affects the rate of temperature die-off and the initial temperature rise in the near field. As Qm + Qc increases the die-off rate and the initial temperature rise decreases.

Predictions were made for 1-, 2-, and 3-unit operation assuming initial temperature rises of 10, 5, and 3.5°F.

(Editor's Note: The complete results of these predictions for each month are included in TVA report 63-38, Prediction and Control of Water Temperatures in Wheeler Reservoir During Operation of the Browns Ferry Nuclear Plant, April 1972. Figures 9 through 20 summarize the results of these predictions for each season of the year for 1-, 2-, and 3-unit operation. The text has been modified slightly to reflect these changes.)

3. The Steady Thermal Regime in Wheeler Reservoir During Open-Mode Operation - Based upon the data in the previous section, the following discusses quantitatively the predicted steady flow and temperature distributions during operation of Browns Ferry plant in the open mode. One-unit operation is treated first followed by discussions of the 2- and 3-unit ones.

(1) 1-Unit Operation - The single-unit condenser flow of 1,450 ft^3/s will result in intake channel velocities of about 0.4 ft/s. Heated water will be discharged through the diffuser section of the active unit and will mix with the reservoir flow in the manner described in the previous sections. The jet mixing zone will be just downstream from the active diffuser section and will be approximately 20 feet high, 200 feet long, and 600 feet wide, thus occupying about 12,000 ft^2 (or 9 percent) of the total reservoir cross section and about 2,400,000 ft^3 of volume. The water leaving the mixing zone will be at the mixed temperature Tm which is dependent upon the reservoir flow Qr as shown in figure 8. For reservoir flows less than about 10,000 to 14,500 ft^3/s the entire reservoir flow will be drawn into the jet mixing zone, either from behind the diffusers or from along the sides of the mixing region.

Predictions of the downstream temperature increase above ambient are shown on figures 9 through 12 for the middle week of each month shown. Predictions were made for the following cases:

1. A reservoir flow of 3,600 ft^3/s and its associated temperature rise of 10^oF
2. A reservoir flow of 7,200 ft^3/s and its associated temperature rise of 5^oF
3. A reservoir flow greater than 10,200 ft^3/s but less than about 50,000 ft^3/s which gives a temperature rise of 3.5^oF

The relationship between reservoir flow and temperature was taken from figure 8. Complete mixing of the reservoir flow and the condenser flow occurs for the first two cases. For case 3 only 10,200 ft^3/s of the reservoir flow mixes with the condenser flow and the remainder flows as a cooler underflow.

(2) <u>2-Unit Operation</u> - The 2-unit condenser flow of 2,900 ft^3/s will result in intake channel velocities of about 0.9 ft/s. The location of the mixing zones will depend upon which two units are operating. The total mixing zone will be about 1,200 feet wide and occupy 18 percent of the total reservoir cross sectional area and a volume of 4,800,000 ft^3. The mixed temperature rises in the intermediate zone are shown in figure 8 as a function of the reservoir flow. Complete mixing of the reservoir flow with the discharge will occur for flows of less than 20,000-29,000 ft^3/s.

Predictions of the downstream temperature increase above ambient are shown on figures 13 through 16 for the middle week of each month shown. Predictions were made for the following cases:

1. A reservoir flow of 7,200 ft^3/s and its associated temperature rise of 10^oF

2. A reservoir flow of 14,500 ft^3/s and its associated temperature rise of 5°F
3. A reservoir flow greater than 20,300 ft^3/s but less than about 50,000 ft^3/s which gives a temperature rise of 3.5°F

The relationship between reservoir flow and temperature was taken from figure 8. Complete mixing of the reservoir flow and the condenser flow occurs for the first two cases. For case 3 only 20,300 ft^3/s of the reservoir flow mixes with the condenser flow and the remainder flows as a cooler underflow.

(3) <u>3-Unit Operation</u> - The condenser flow of 4,350 ft^3/s will result in intake channel velocities of about 1.3 ft/s. The discharge will occur over the full 1,800-foot diffuser structure resulting in a mixing zone which will occupy 27 percent of the reservoir cross sectional area and a volume of 7,200,000 ft^3. The mixed temperature rise is shown in figure 8. Complete mixing of the reservoir flow with the discharge will occur for reservoir flows less than 30,000 to 43,500 ft^3/s.

Predictions of the downstream temperature increase above ambient are shown on figures 17 through 20 for the middle week of each month shown. Predictions were made for the following cases:

1. A reservoir flow of 10,900 ft^3/s and its associated temperature rise of 10°F
2. A reservoir flow of 21,800 ft^3/s and its associated temperature rise of 5°F
3. A reservoir flow greater than 30,500 ft^3/s but less than about 50,000 ft^3/s which gives a temperature rise of 3.5°F

The relationship between reservoir flow and temperature was taken from figure 8. Complete mixing of the reservoir flow and the condenser flow occurs for the first two cases. For case 3 only 30,500 ft^3/s of the reservoir flow mixes with the condenser flow and the remainder flows as a cooler underflow.

4. Helper-Mode Operation - The construction of cooling towers at Browns Ferry will make possible the operation of the condenser cooling system in a helper mode where a portion of the heat will be removed from the condenser water by the towers before it is discharged into the river. Although the details of the design are not final, it will involve a somewhat lower condenser waterflow (1,223 ft^3/s) for each unit, a higher condenser rise (31.7°F), and a lower temperature rise in the discharged water than in an open-mode operation. In addition, the flow from a single unit, if it is shown to provide more desirable mixing characteristics, may be discharged through all three diffuser sections. These differences from open-mode operation will result in a different relationship between the reservoir flow magnitude and the temperature rises in the reservoir, but operations in general should result in similar flow and temperature patterns as described for the open mode of operation.

As the designs are firmed up, model tests and field investigations after the units are in operation will be used to predict the 3-dimensional flow and temperature distributions for helper-mode operation as they were predicted for open-mode operation and to determine the most appropriate operating method for achieving the desired temperature standards.

5. <u>Unsteady Reservoir Flows</u> - The temperature rises described above are steady-state values reached asymptotically after a change in flow conditions. If the reservoir flow is constantly changing, the temperature and flow distribution may never be in a steady-state condition. It is clear that if the reservoir flow remains greater than a certain magnitude, the mixed temperature rise in the reservoir will never exceed the steady-state value corresponding to that minimum flow. If the reservoir flow fluctuates below the minimum value for some short length of time, the temperature rise may not increase significantly. A continuing program of testing in the 3-dimensional thermal model has as its objective the determination of what unsteady flow regulations will be required to keep the induced temperature rises in Wheeler Reservoir below the desired value.

6. <u>Field Measurements</u> - The operation of Browns Ferry Nuclear Plant and the regulations of Wheeler Reservoir flows will be determined by the readings from a system of continuously recording fixed temperature monitors (see figure 21). There will also be intensive surveys by boat and airborne techniques to measure the details of the temperature distribution in the vicinity of the plant. This information will begin to be available as soon as the plant commences 1-unit operation. The field data will be compared with model results to verify and refine the predictions presented in this report and to develop the final required operating procedures.

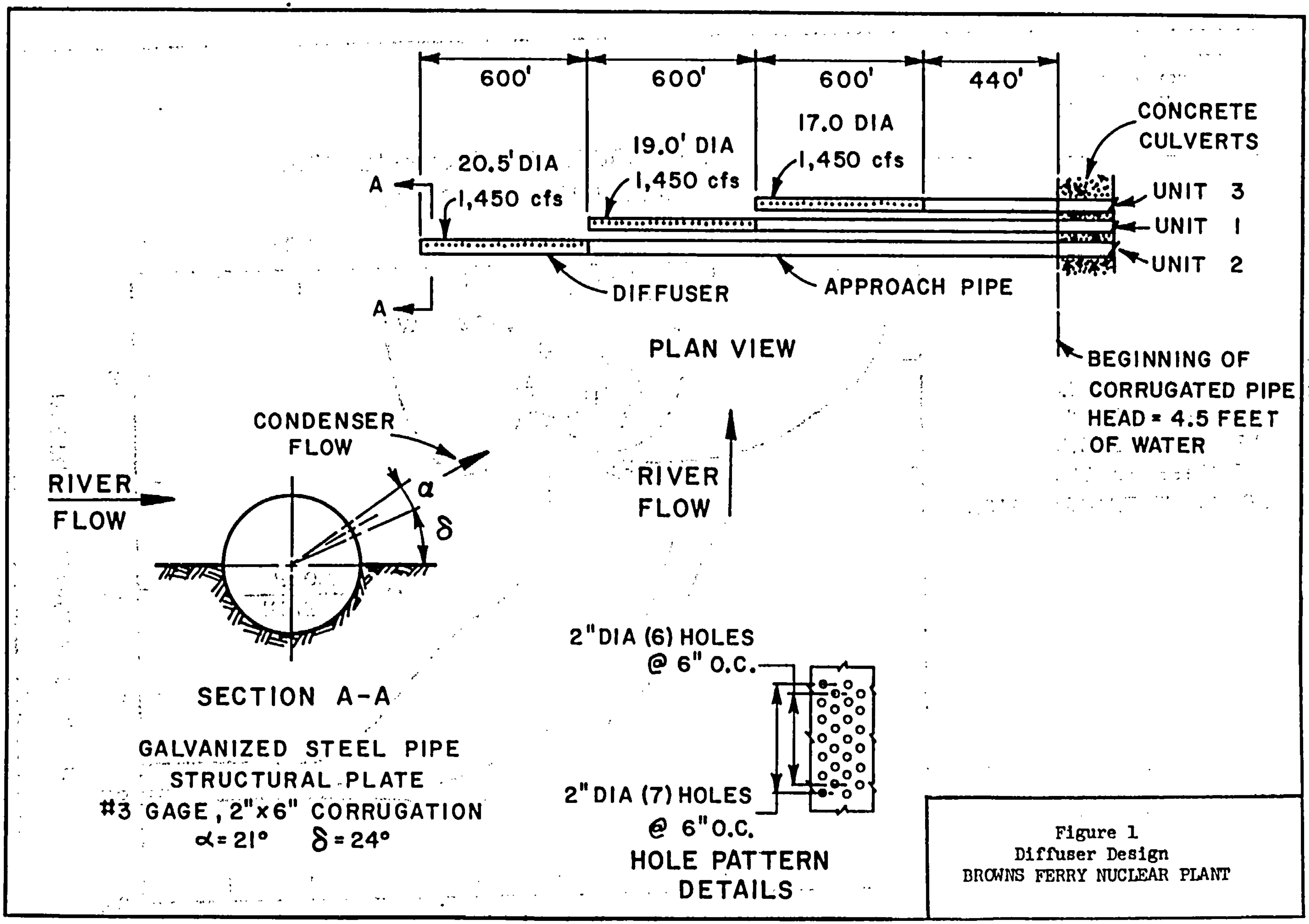


Figure 1
Diffuser Design
BROWNS FERRY NUCLEAR PLANT

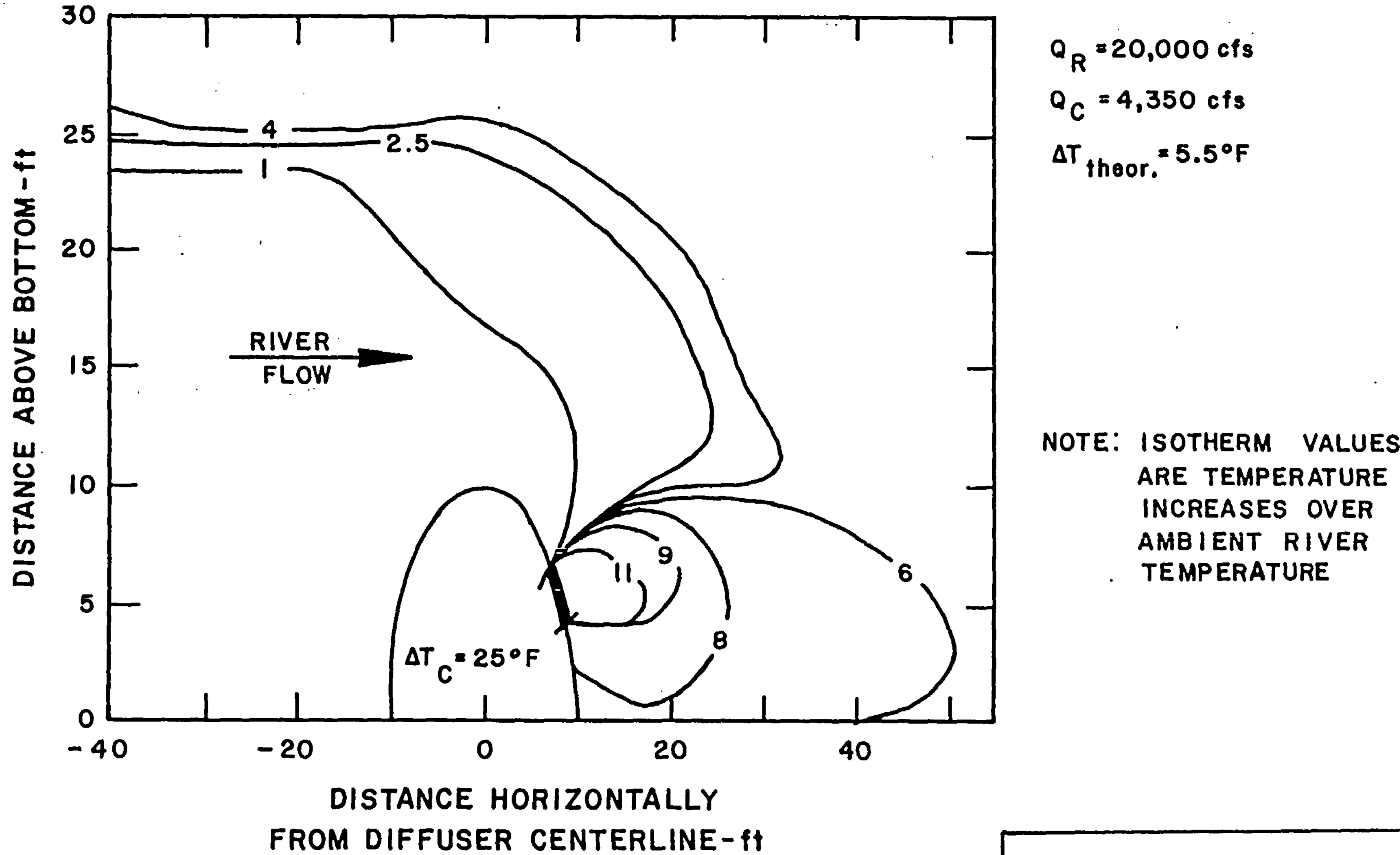
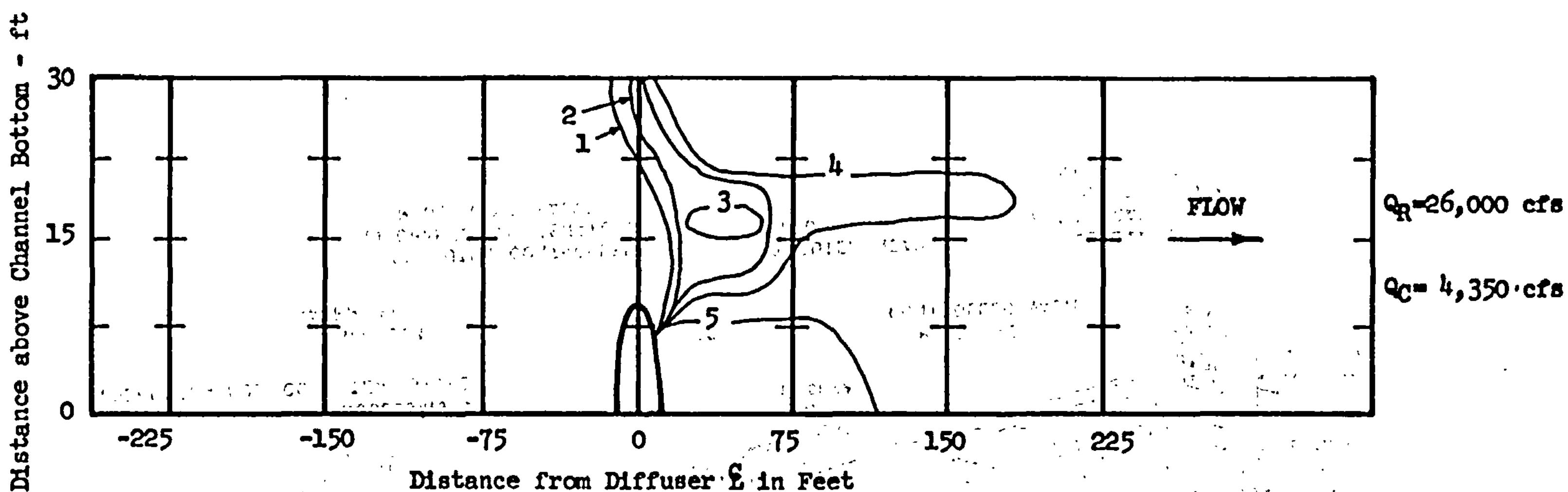


Figure 2
Structure of the
Jet Mixing Region
BROWNS FERRY NUCLEAR PLANT



Note: Isotherm values are temperature increases over Ambient River Temperature

Figure 3
Temperature Rise in the
Jet Mixing Region

BROWNS FERRY NUCLEAR PLANT

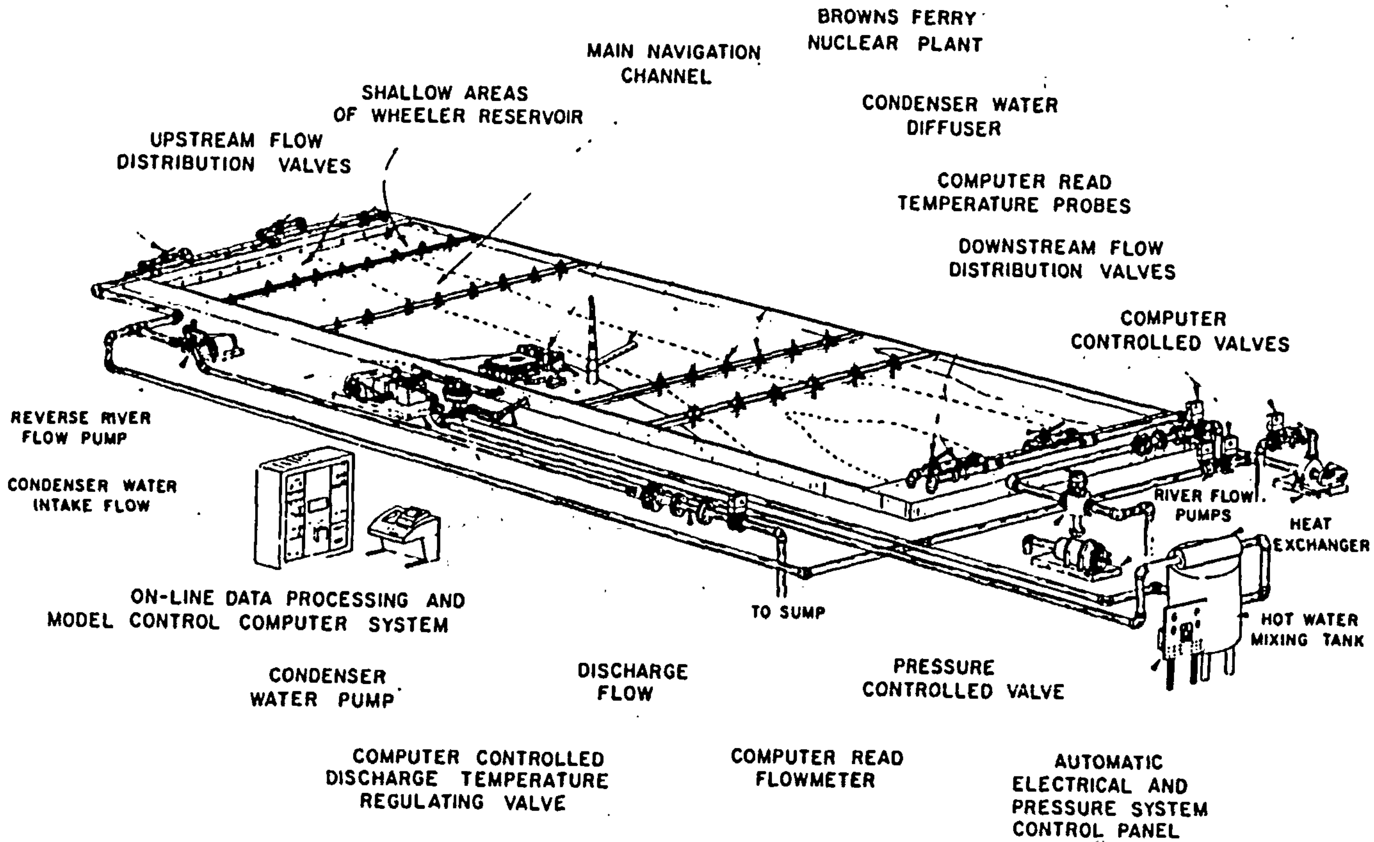


Figure 4
Three Dimensional
Thermal Model

BROWNS FERRY NUCLEAR PLANT

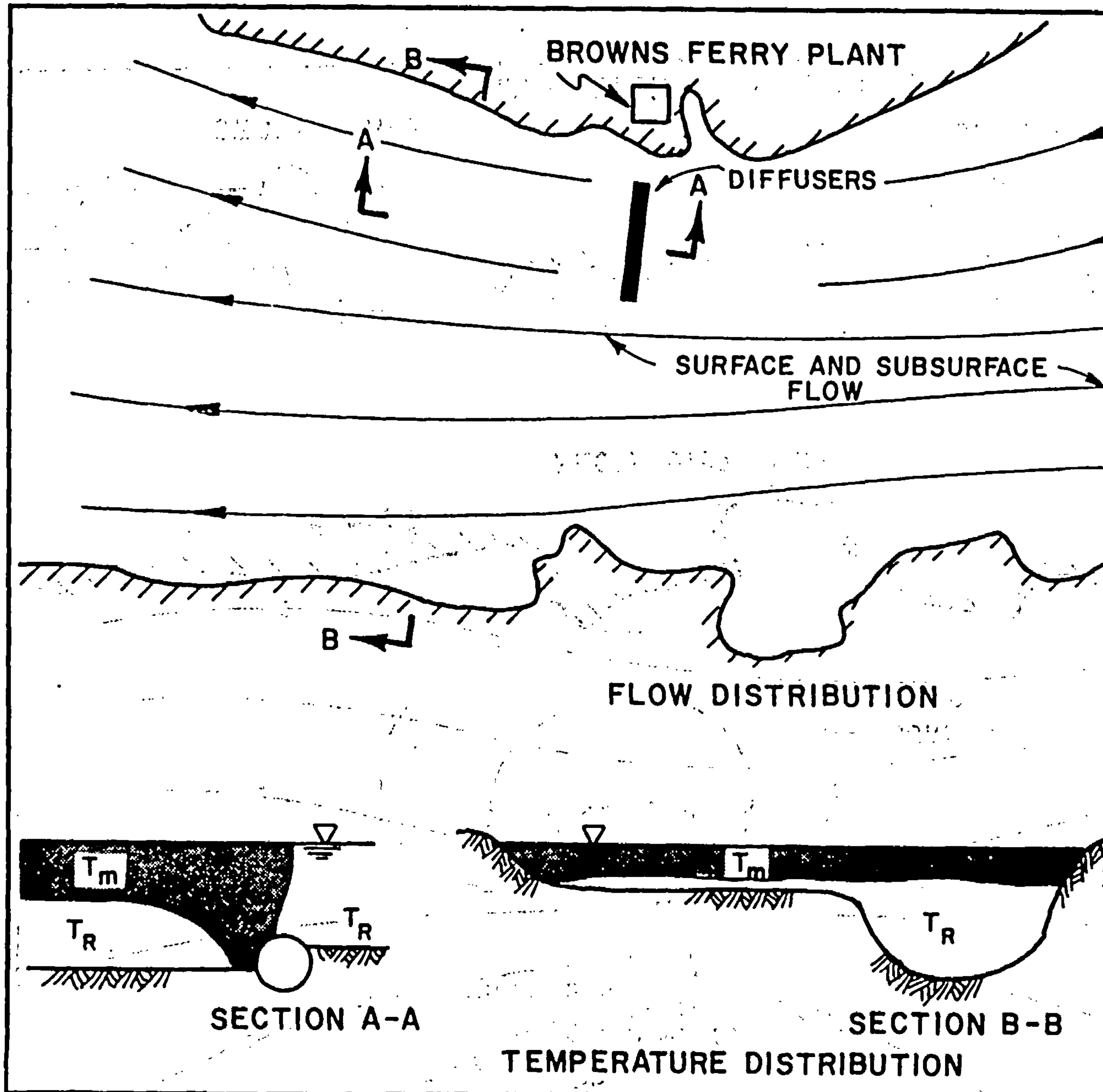


Figure 5
Case 1
BROWNS FERRY NUCLEAR PLANT

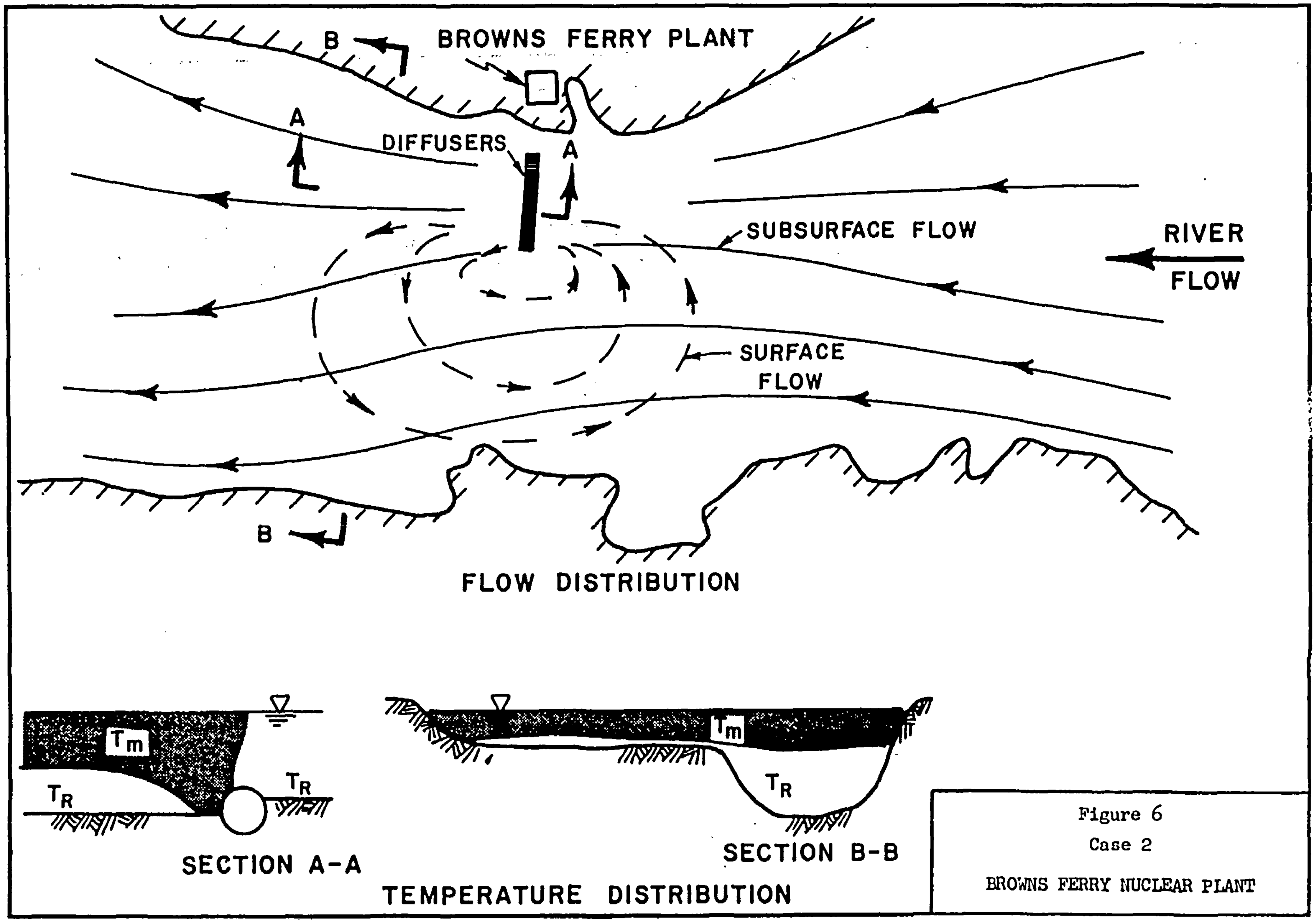


Figure 6
Case 2
BROWNS FERRY NUCLEAR PLANT

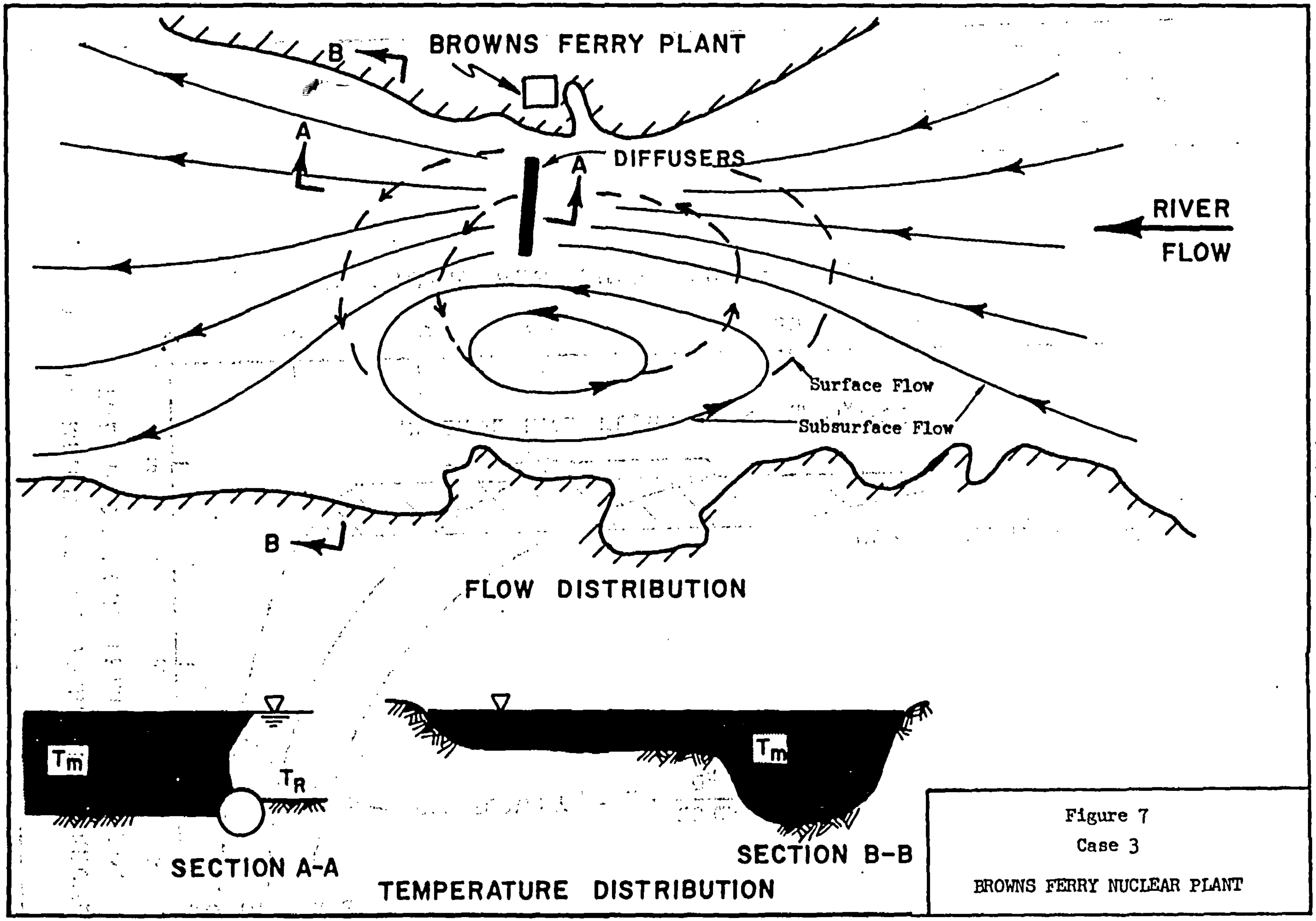


Figure 7
Case 3
BROWNS FERRY NUCLEAR PLANT

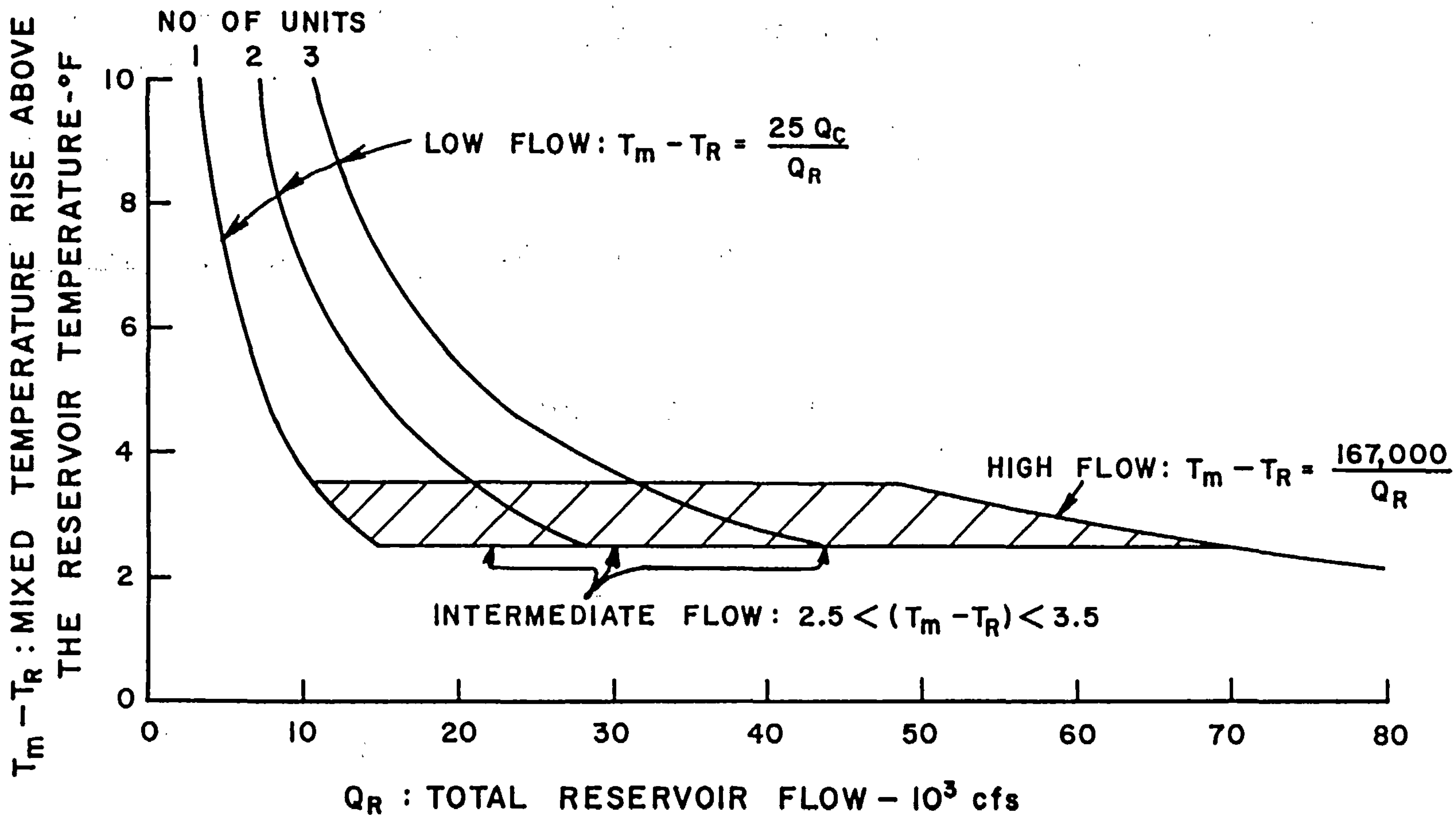


Figure 8
Temperature Rise Outside of
the Jet Mixing Region

BROWNS FERRY NUCLEAR PLANT

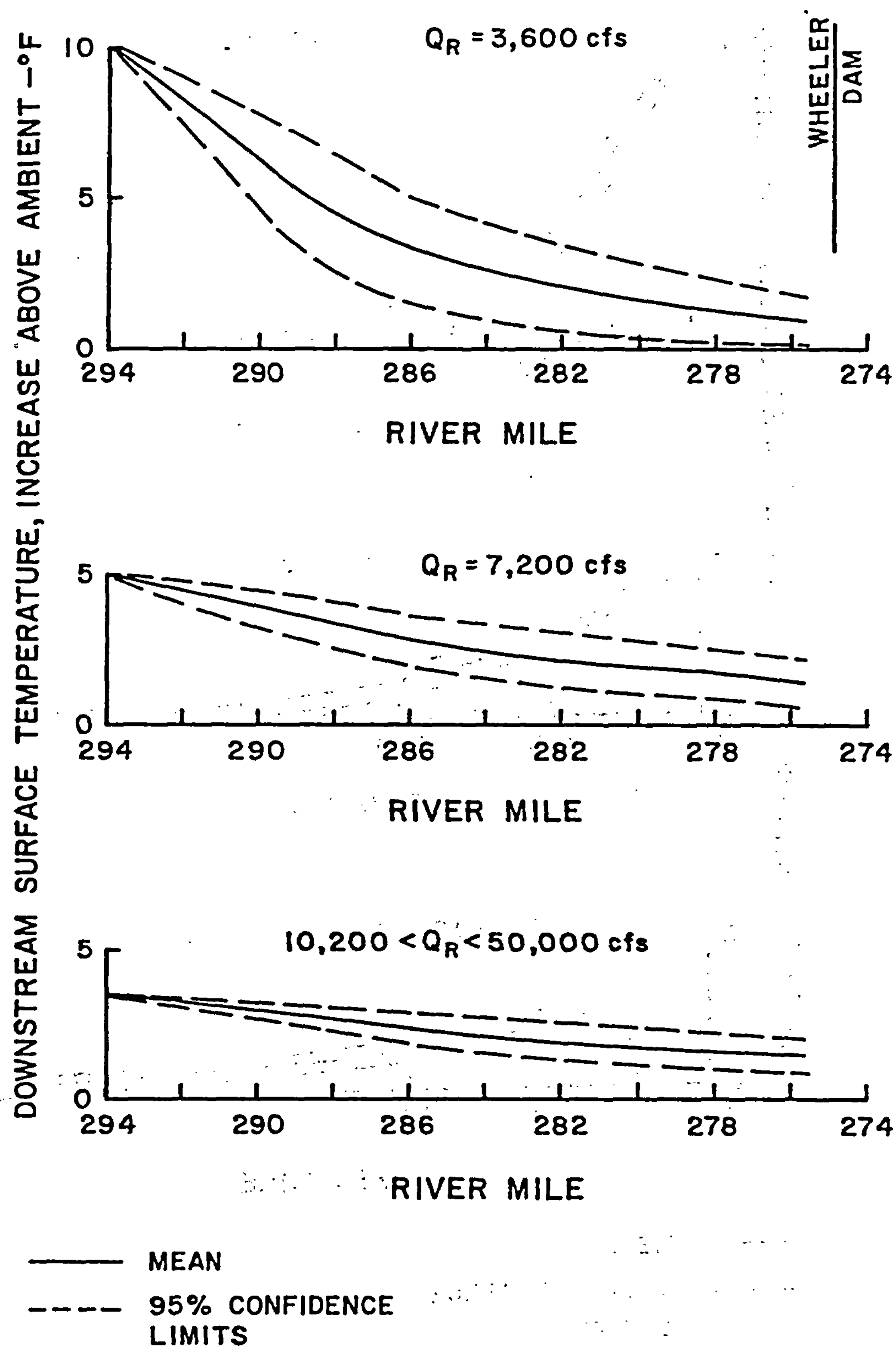


Figure 9
Effect of Plant on Downstream Temperature
January, 1 Unit
BROWNS FERRY NUCLEAR PLANT

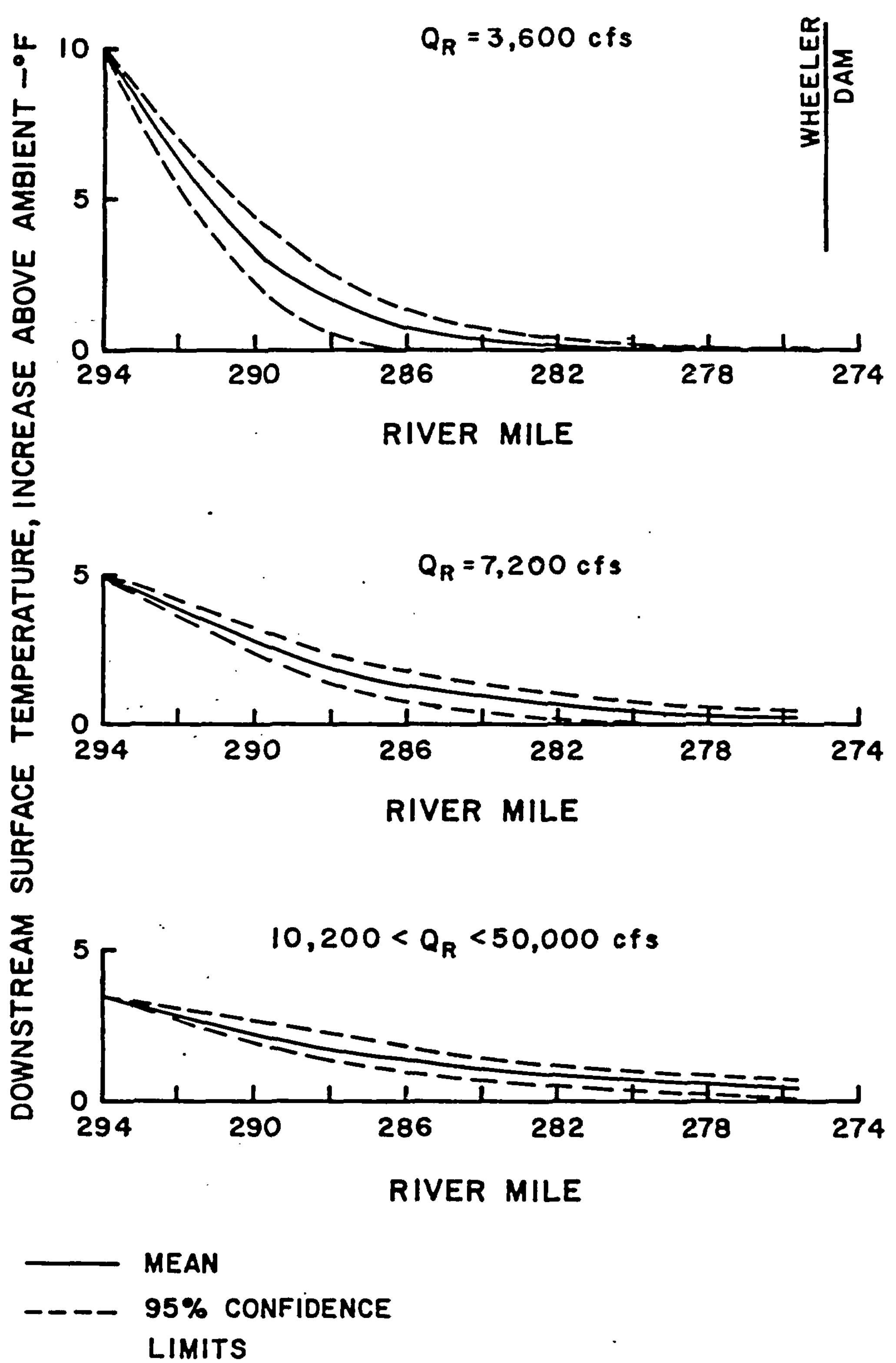


Figure 10
Effect of Plant on Downstream Temperature
April, 1 Unit
BROWNS FERRY NUCLEAR PLANT

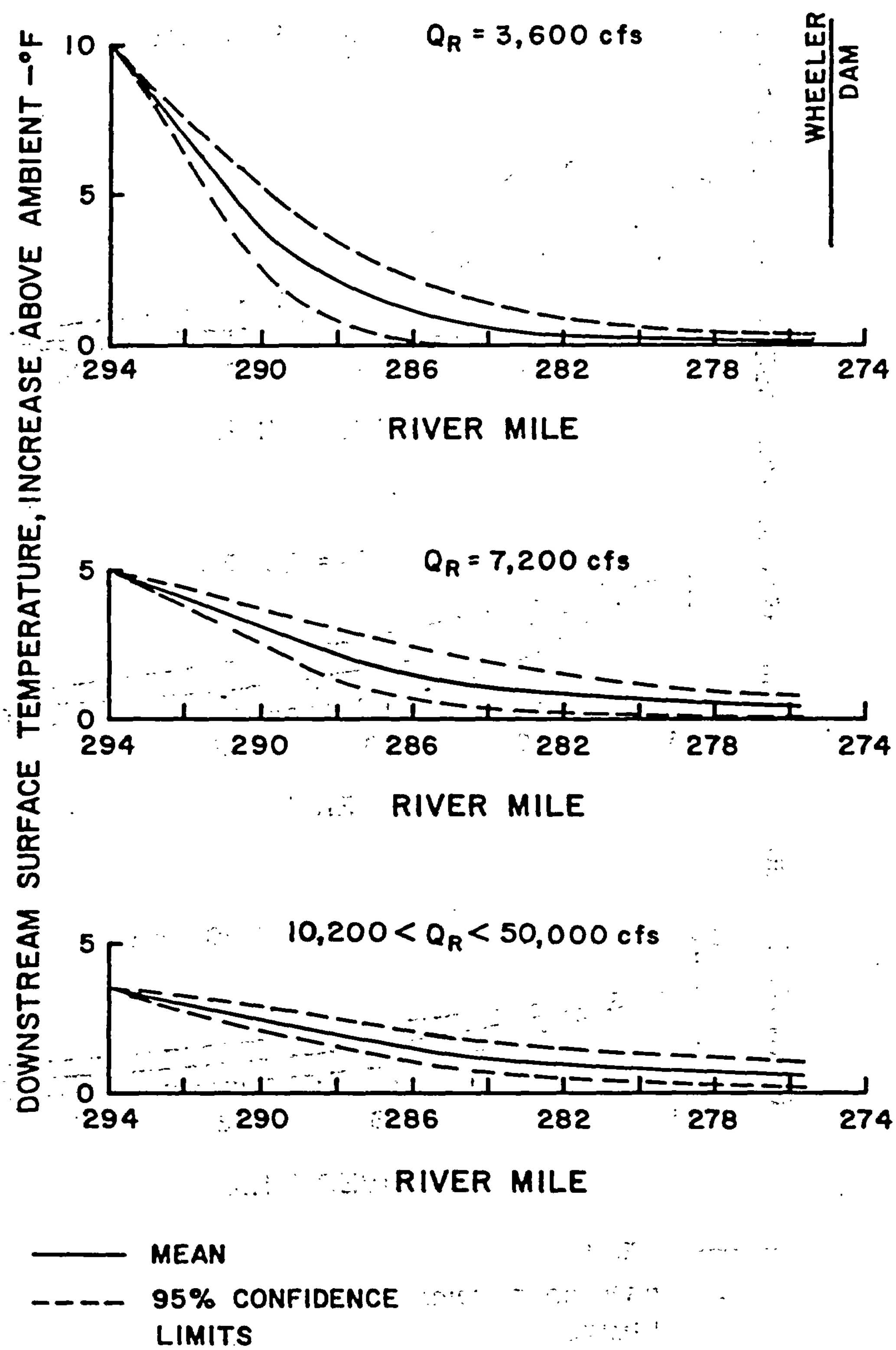


Figure 11
Effect of Plant on Downstream Temperature
August, 1 Unit
BROWNS FERRY NUCLEAR PLANT

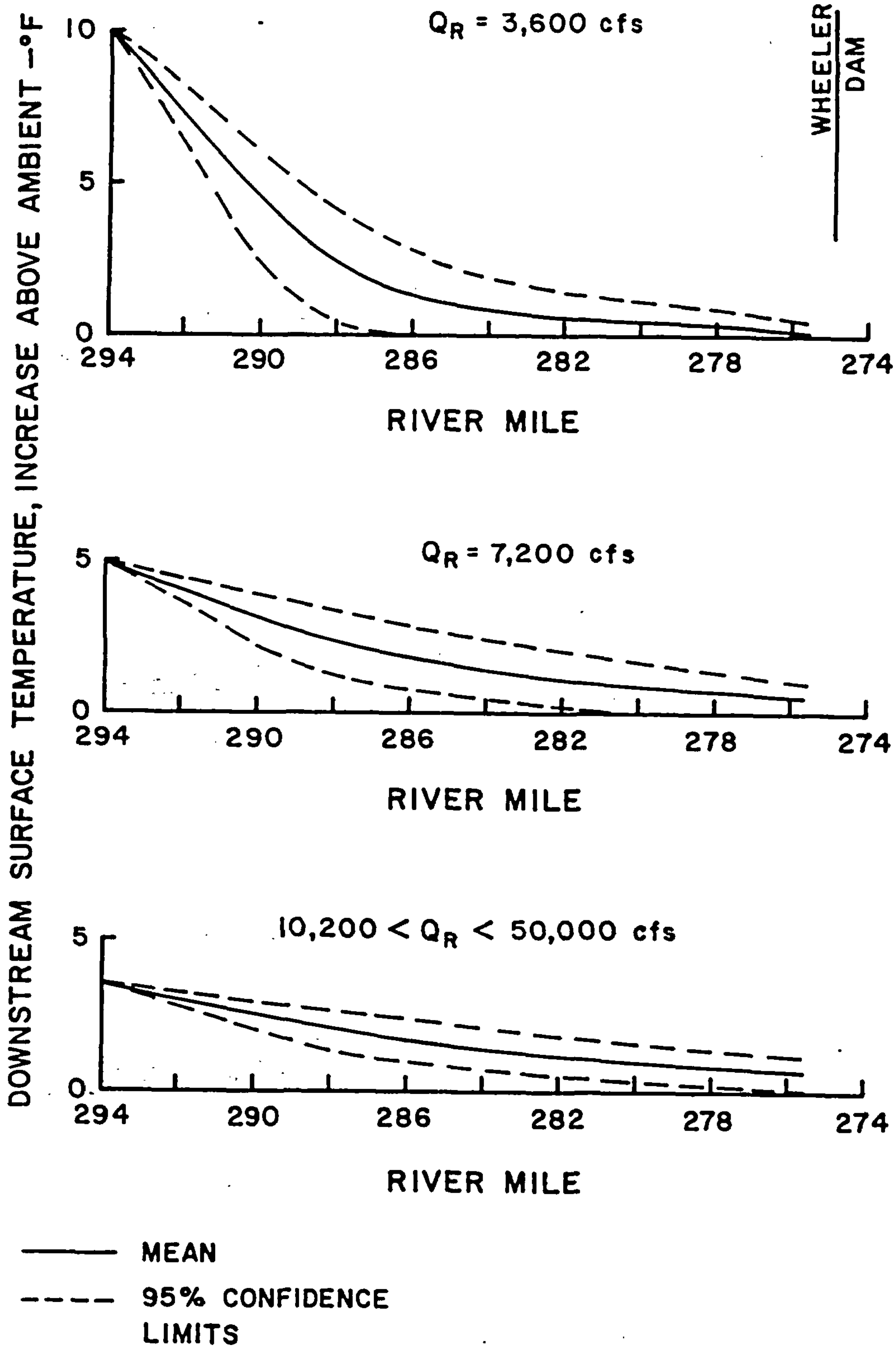


Figure 12
Effect of Plant on
Downstream Temp.
October, 1 Unit
BROWNS FERRY NUCLEAR PLANT

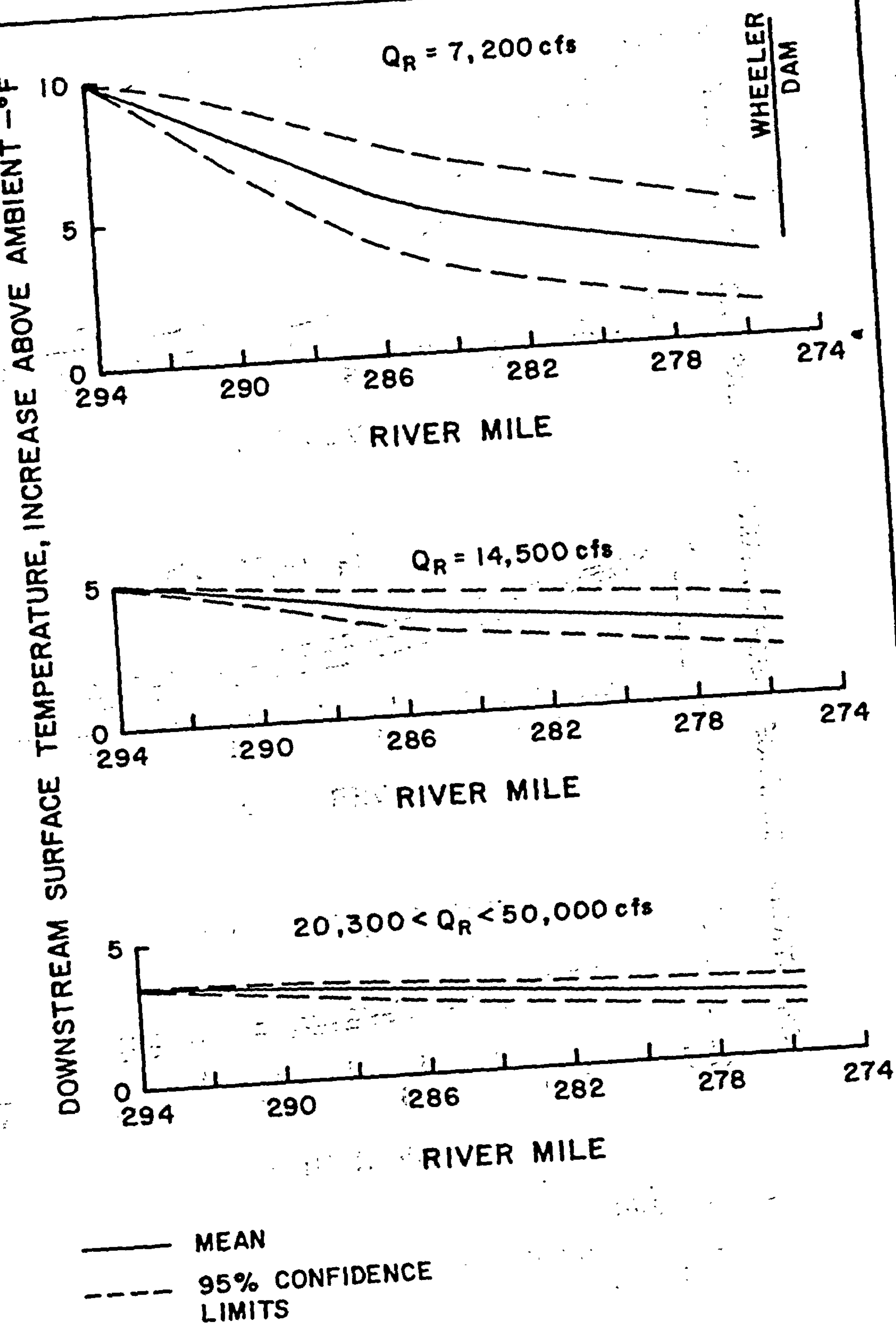


Figure 13
Effect of Plant on Downstream Temperature
January, 2 Units

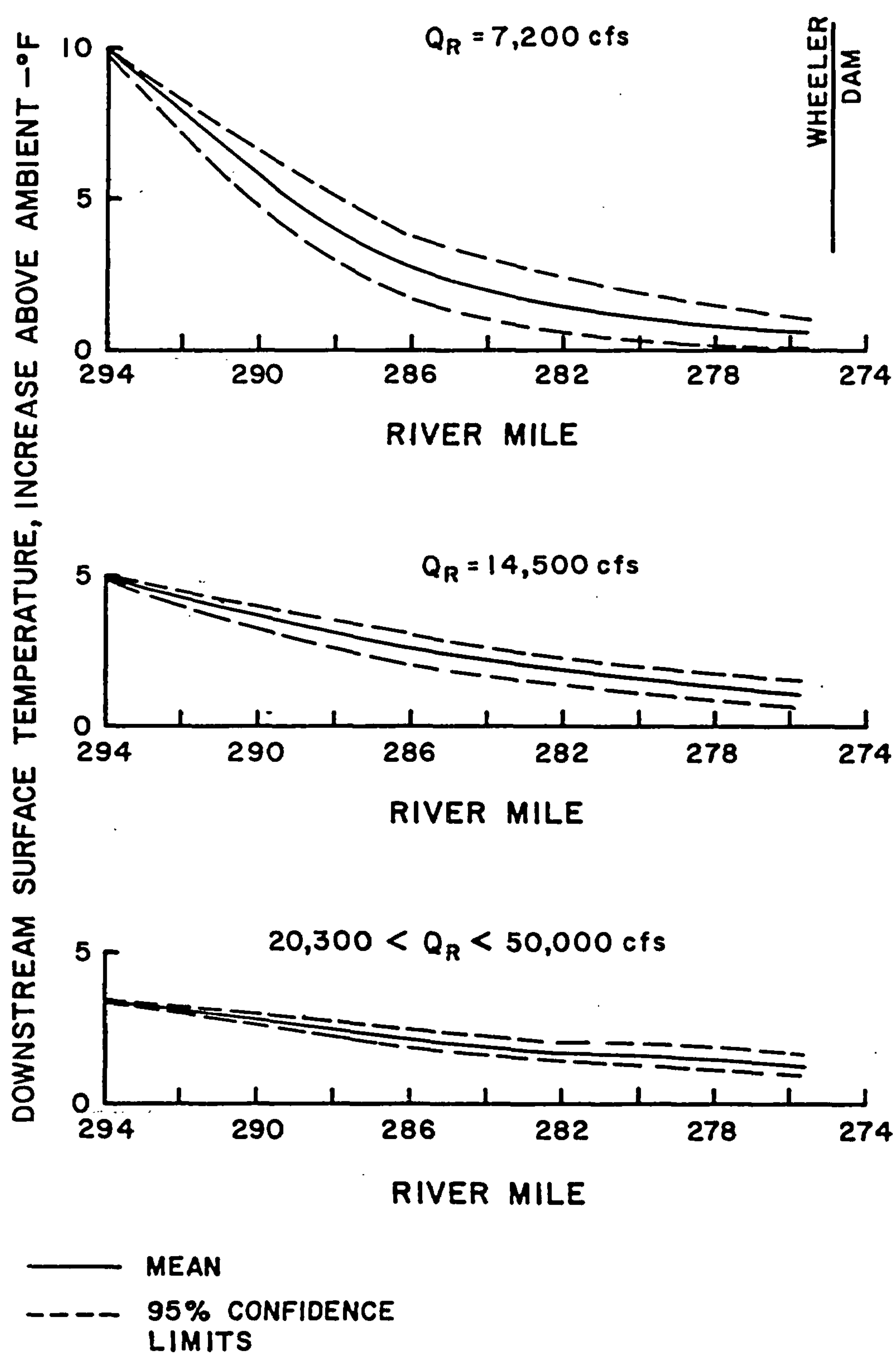


Figure 14
Effect of Plant on
Downstream Temp.
April, 2 Units
BROWNS FERRY NUCLEAR PLANT

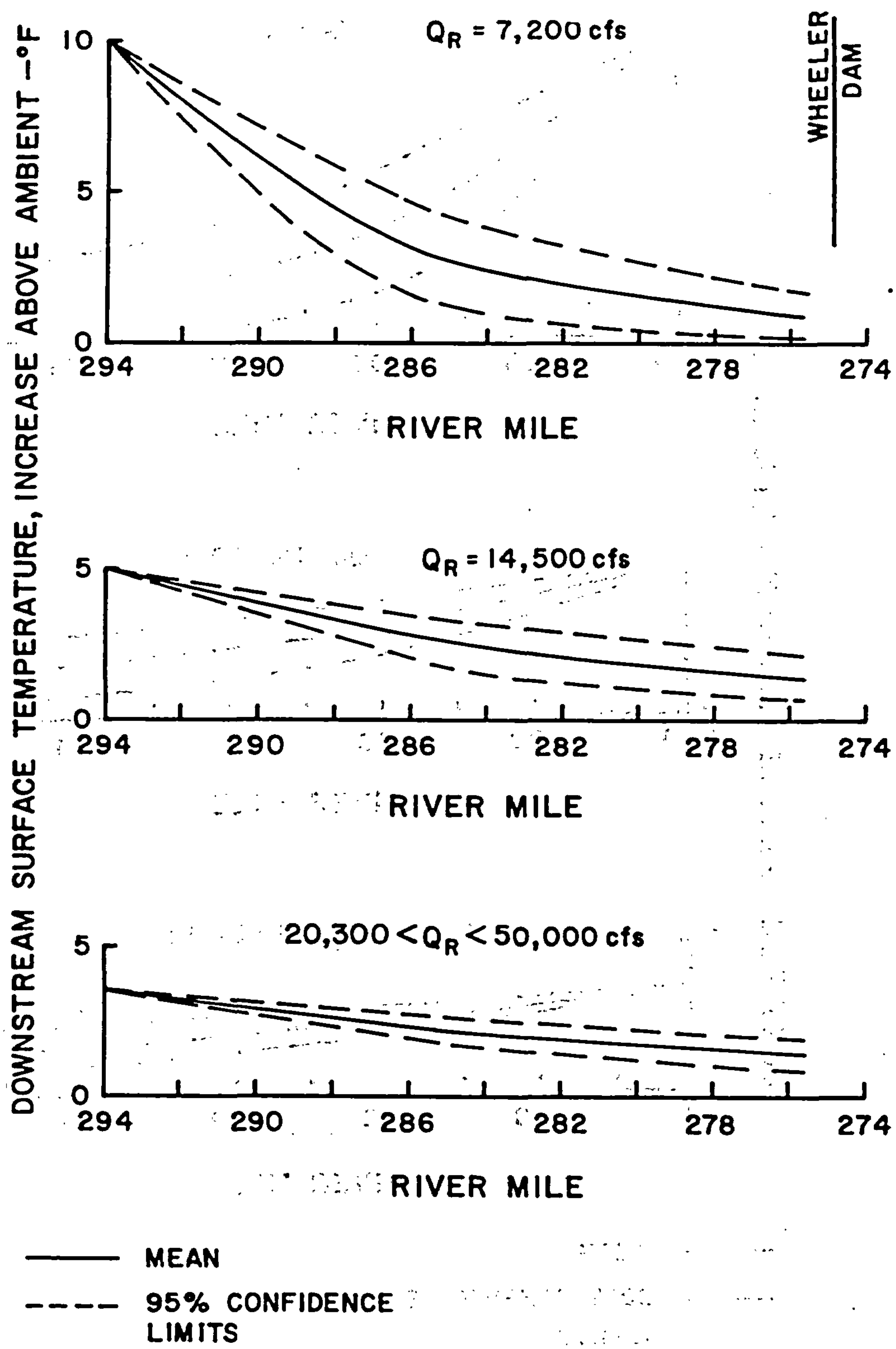


Figure 15
Effect of Plant on
Downstream Temp.
August, 2 Units
BROWNS FERRY NUCLEAR PLANT

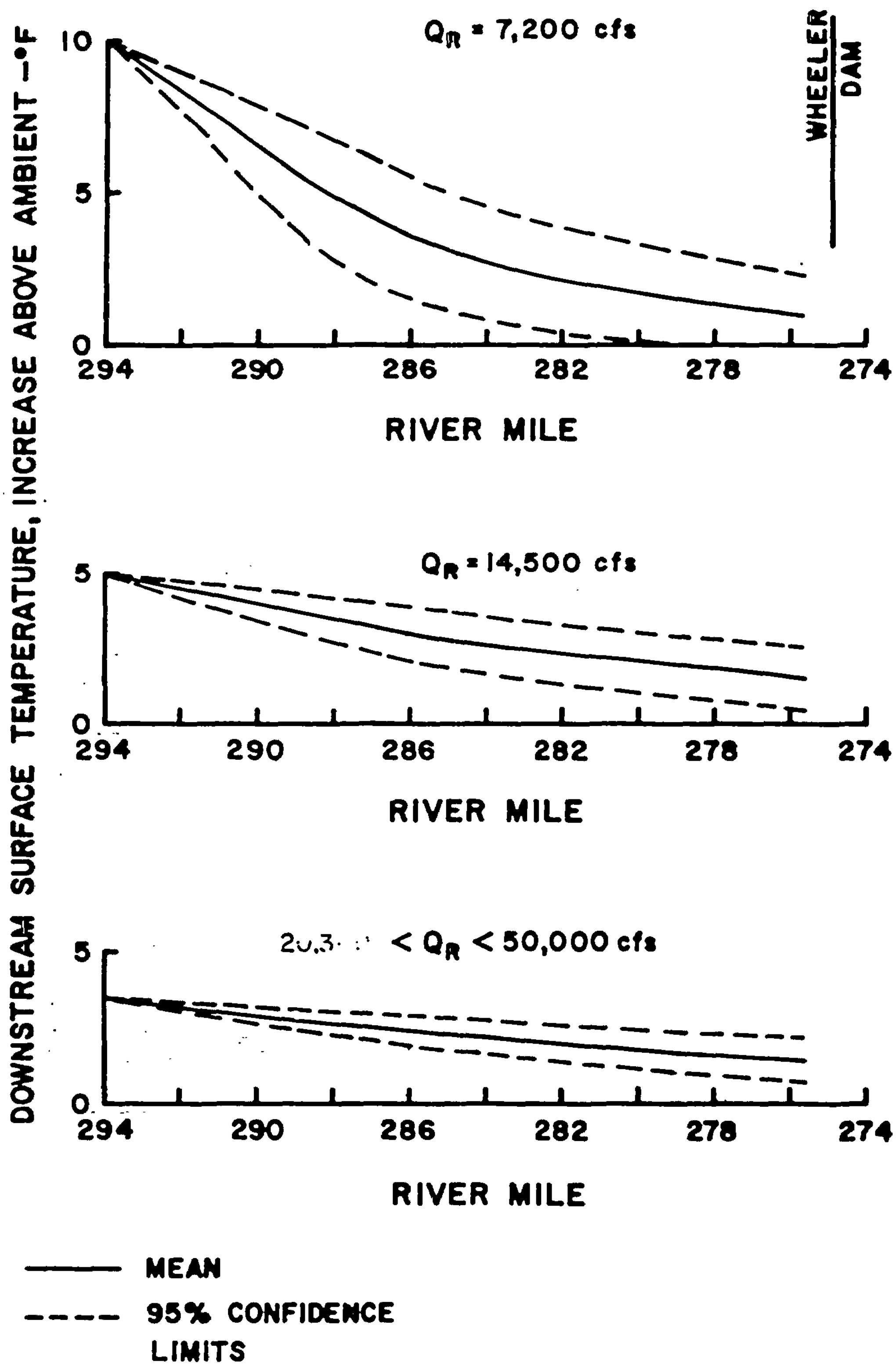


Figure 16
Effect of Plant on
Downstream Temp.
October, 2 Units
BROWNS FERRY NUCLEAR PLANT

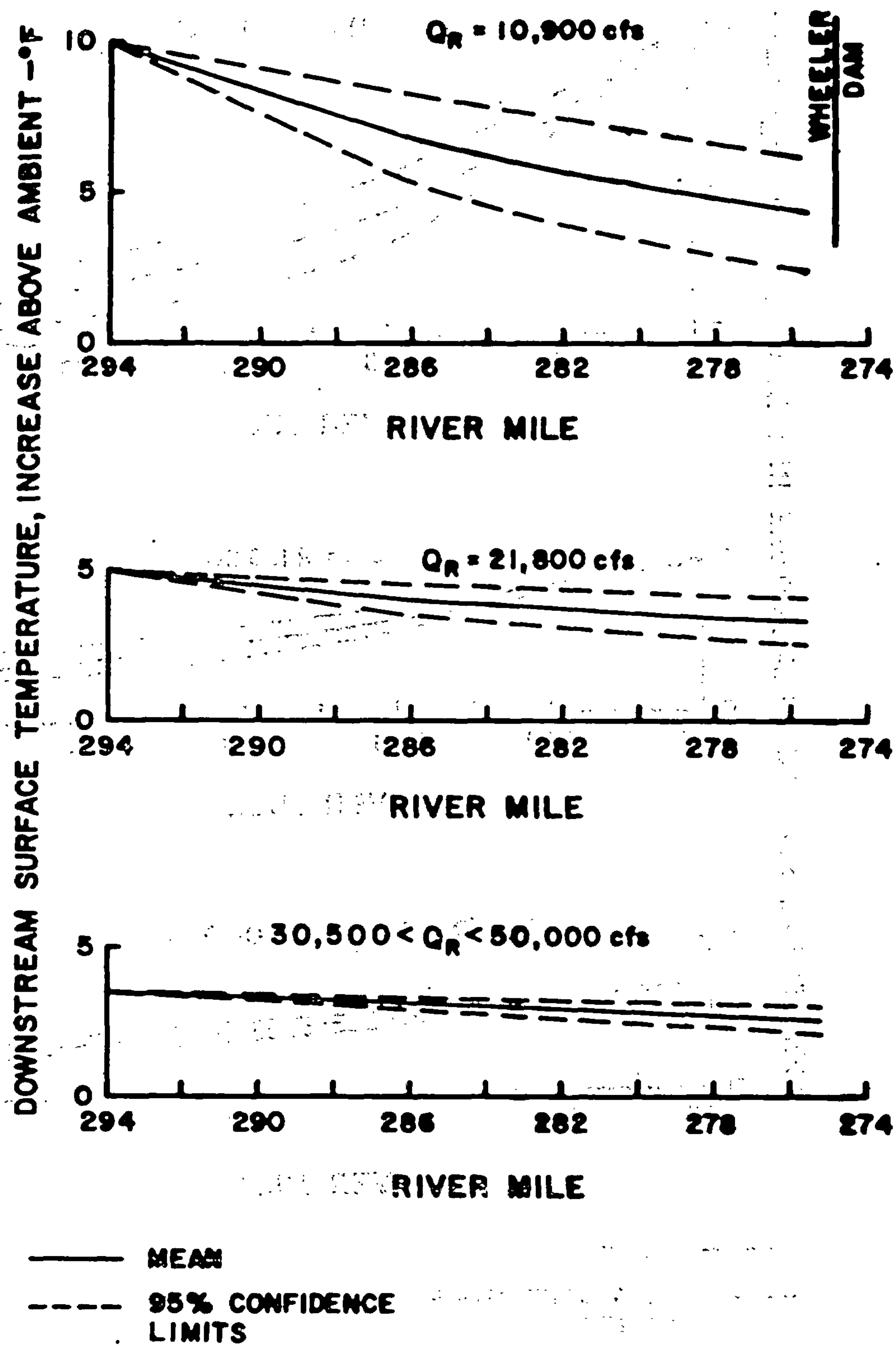


Figure 17
Effect of Plant on
Downstream Temp.
January, 3 Units
BROWNS FERRY NUCLEAR PLANT

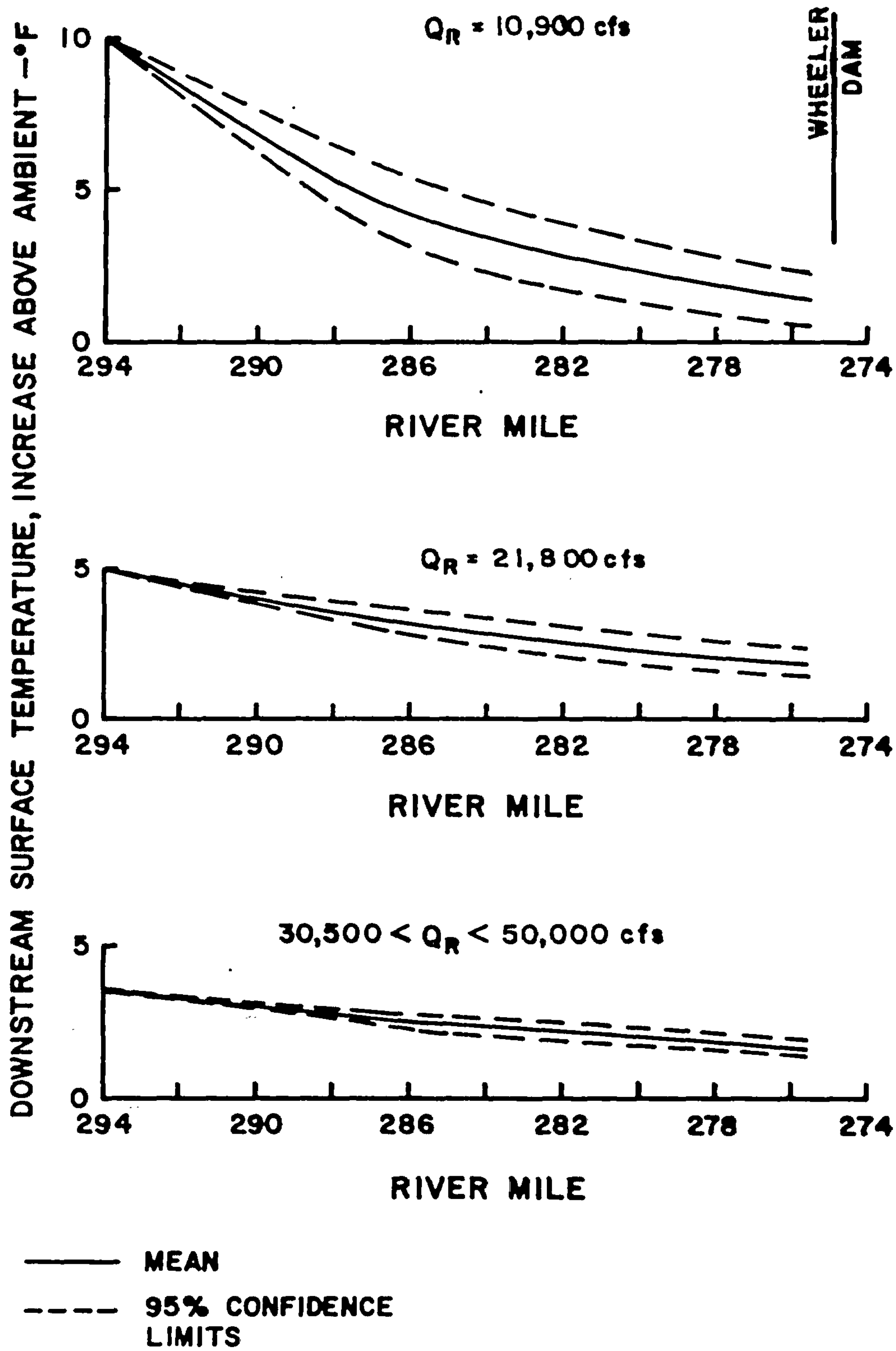


Figure 18
Effect of Plant on
Downstream Temp.
April, 3 Units
BROWNS FERRY NUCLEAR PLANT

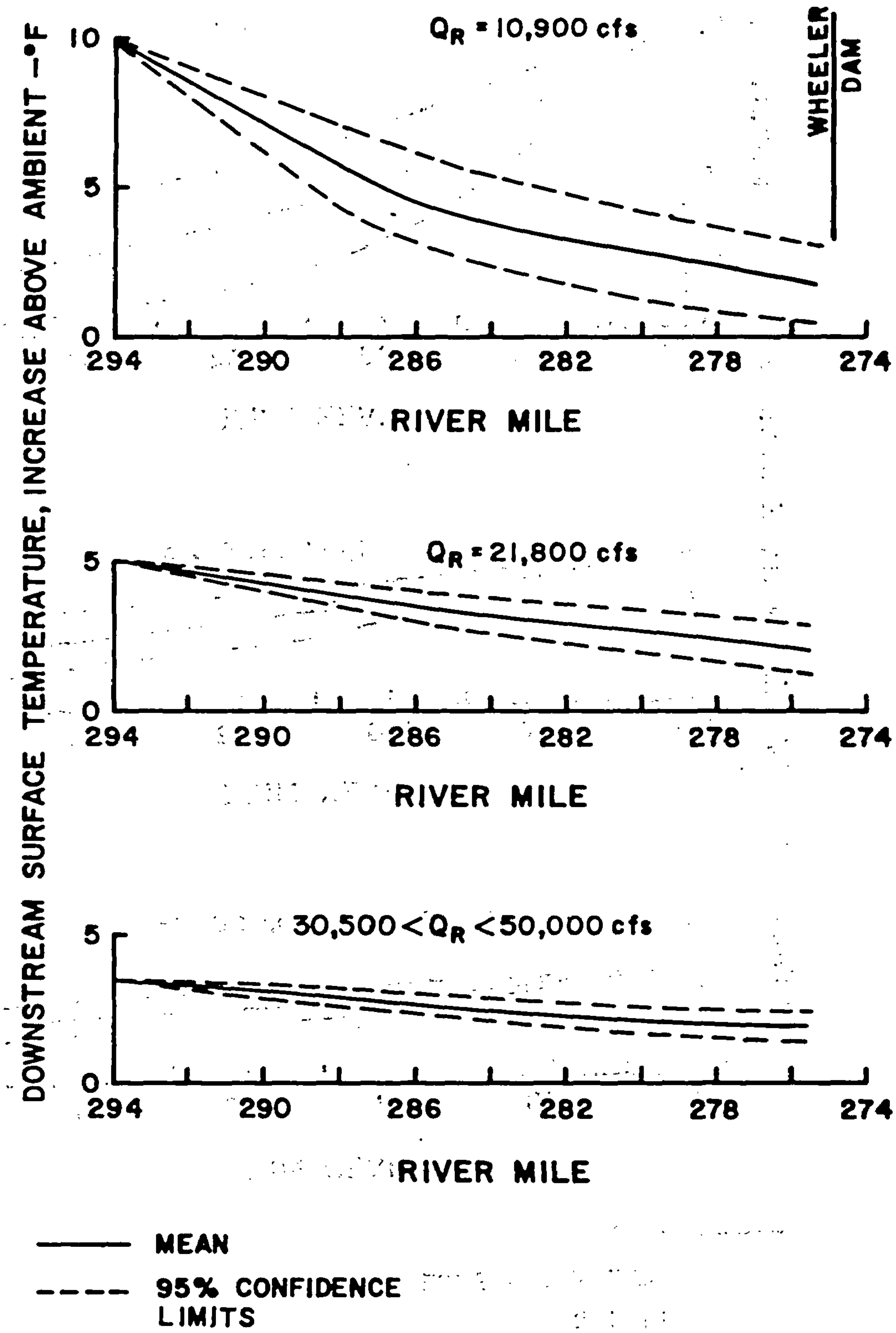


Figure 19
Effect of Plant on
Downstream Temp.
August, 3 Units
BROWNS FERRY NUCLEAR PLANT

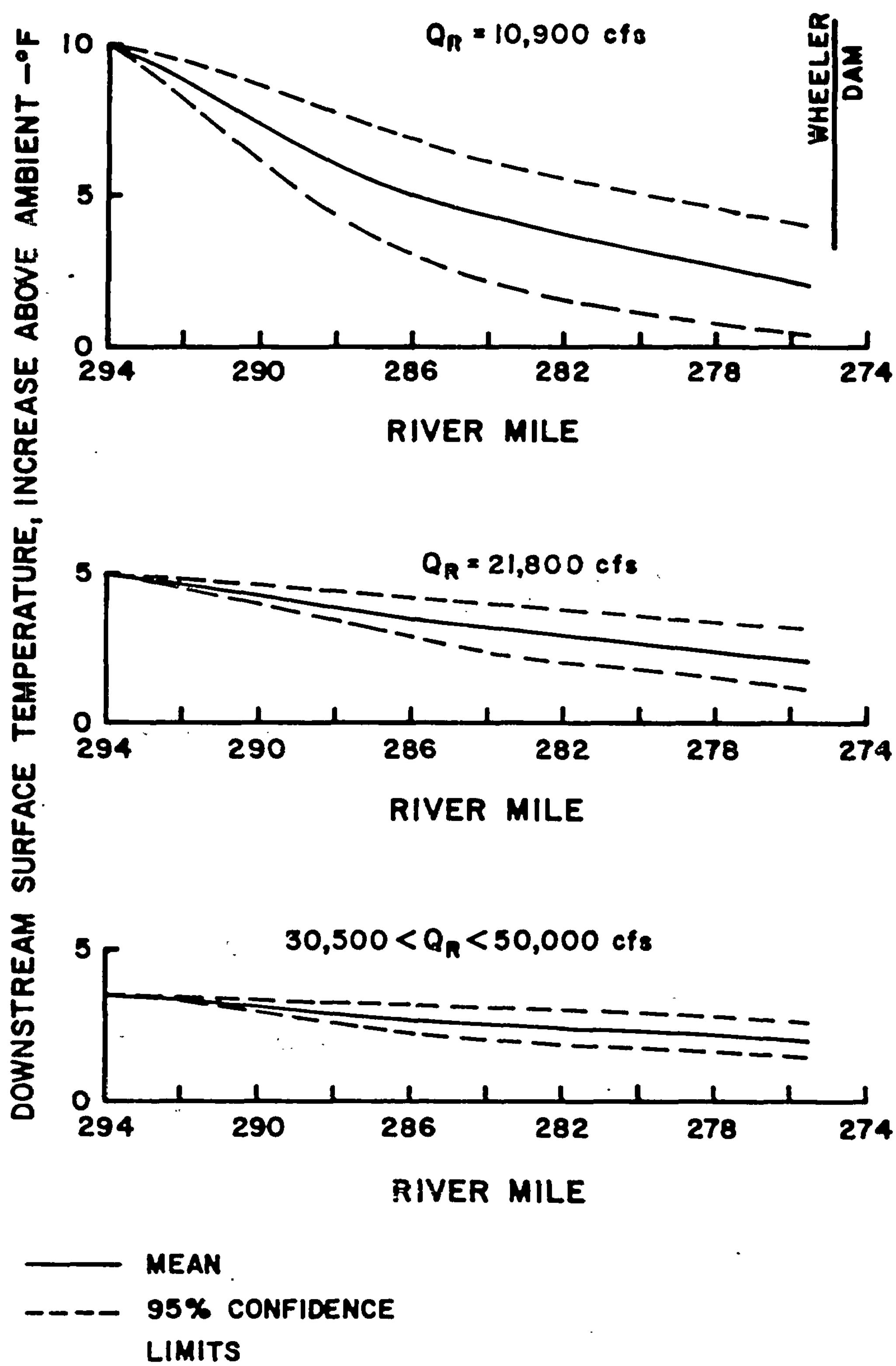


Figure 20
Effect of Plant on
Downstream Temp.
October, 3 Units
BROWNS FERRY NUCLEAR PLANT

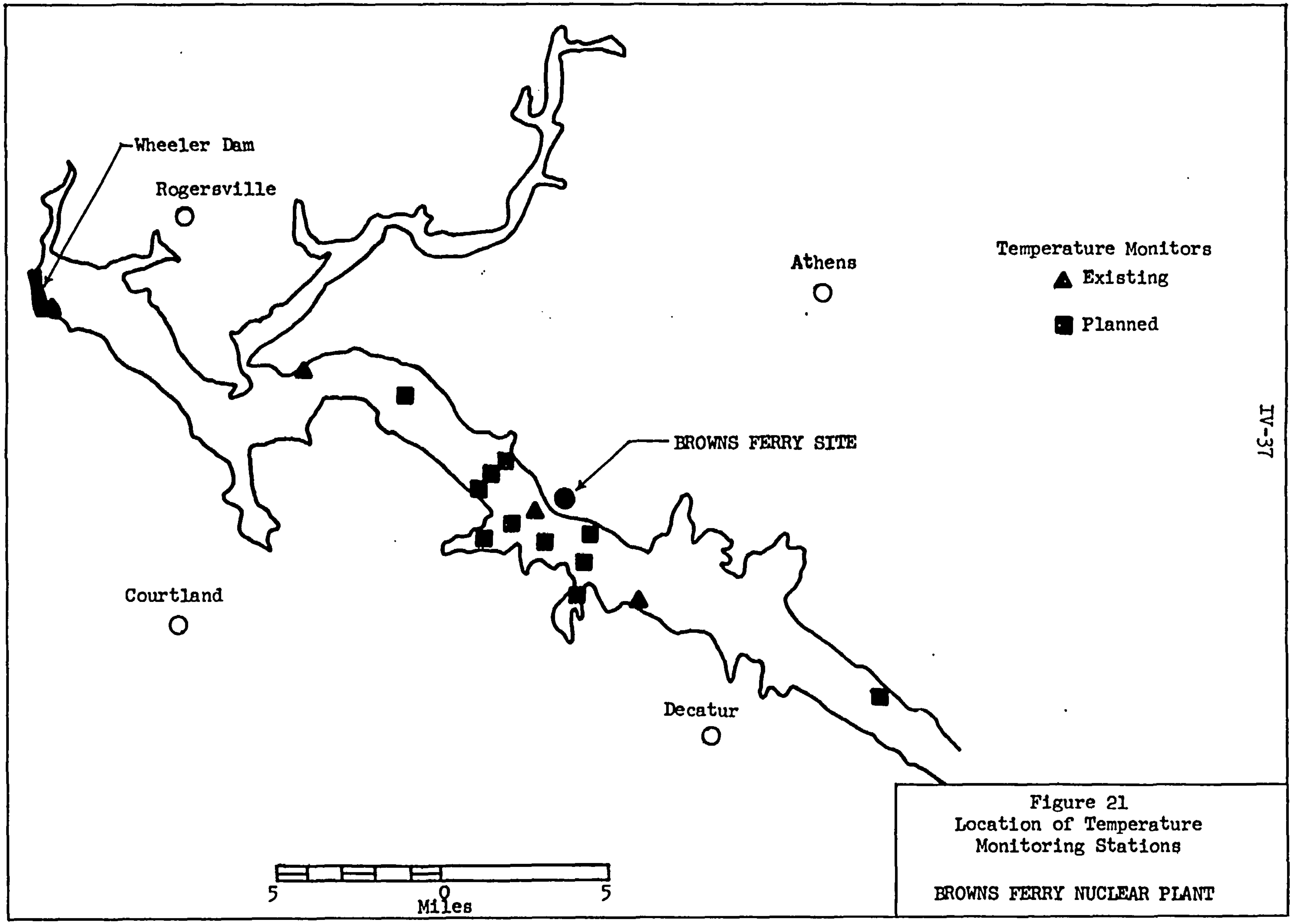


Figure 21
Location of Temperature
Monitoring Stations

BROWNS FERRY NUCLEAR PLANT

APPENDIX V

NOISE LEVEL CALCULATIONS - BROWNS FERRY

MECHANICAL DRAFT COOLING TOWERS

Sound pressure levels were calculated for four points 1,000 feet from the perimeter of the six Browns Ferry cooling towers. The basic equation[1]

$$L_{p\theta} = L_w + DI - f(r) \pm K$$

where $L_{p\theta}$ = sound pressure levels at distance and angle

L_w = sound pressure level

DI_θ = directivity index

$f(r)$ = an attenuation factor based on geometry and distance

K = constant associated with units and spherical directivity

was modified to fit the specific situation of the Browns Ferry cooling towers. The design parameters used were:

1. Tower dimensions of 600-foot length, 50-foot width, and 50- to 60-foot height.
2. Layout as shown in figure 2.6-8.
3. Sixteen fan motors of 200 horsepower each arranged linearly along the major dimensional axis of each cooling tower.

Because fan noise is dominant over water noise in mechanical draft cooling towers, fan noise was used as the design basis in the evaluation. The relationship used to calculate the sound power level of the source was:

$$L_w = 95 + 10 \log (\text{horsepower}),$$ an empirically derived equation.[2]

Appendix V

Empirical data from one major manufacturer of towers listed sound pressure levels for a similar cooling tower in two directions at a 200-foot distance, the correction constant K in the derived equations was calculated by making the modified equation fit that data at 200 feet. This factor is a sum of several correction factors, i.e., the correction factor for a hemispherical calculation, the directivity index factor, the unit conversion factor, and the octave band power level distribution factor. It was assumed that once K has been determined for any distance in one direction, it remains constant, independent of change in distance as long as the direction outward is not changed.

The sound level spectra calculated 1,000 feet from the tower complex along the facility centerlines (the long axis runs approximately parallel to the shoreline, see figure 2.6-8) are shown below:

Predicted Noise Spectrum, Six Mechanical Draft Cooling Towers, 1,000 Feet from Towers, Corrected for Air Absorption at 80°F and 70 Percent RH

Center Frequency, Hz	63	125	250	500	1,000	2,000	4,000	8,000	dB(A)
Listening Stations									
Along centerline of short axis of tower complex (NE by SW)	61	56	53	51	49	44	42	38	54
Along centerline of long axis of tower complex (NW by SE)	55	31	48	44	38	30	15	7	44

It is expected that these theoretical values are well on the high side because the calculated model was based on worst case conditions and there should be further attentuation caused by environmental factors such as building obstruction, shrubbery, trees, wind, temperature gradients, ground profile, etc. These were not included in the model. These factors can be taken into consideration later once the design parameters and layout configuration are firmly resolved.

The predicted dB(A) noise levels at 1,000 feet may be used to calculate noise levels more distant from the towers by assuming a 6 dB decrease in noise level with each doubling of distance and correcting for air absorption at $80^{\circ}F$ and 70 percent RH. Again, attenuation by structures, topography, and vegetation was ignored, thereby leading to conservatively high predictions. A background noise survey was performed by TVA industrial hygienists in November 1971 at nine locations outside the Browns Ferry Nuclear Plant reservation boundary. Background data were taken after midnight to minimize construction noise from the site. These data provide a basis for comparison with predicted operational cooling tower noise.

Comparison may also be made with nonaircraft noise criteria developed by the U.S. Department of Housing and Urban Development (HUD).[1] Noise levels were estimated in the direction of the short axis of the tower complex at locations where excessive noise might become significant to residents of the community. Predicted noise levels were corrected for background noise influence where applicable. The predicted operational noise levels, the measured background noise, and the acceptablitiy of the operational noise with respect to HUD criteria are shown below for the short axis (NE by SW) listening points.

BFNP MECHANICAL DRAFT COOLING TOWER NOISE COMPARISON

NE BY SW DIRECTIONS

Listening Station	Dist. from Source	Dir. from Source	Bkgd Night 11/5/71 dB(A)	Predicted Noise Level Bkgd Corrected, dB(A)	Acceptability by HUD Recommended Noise Criteria
At plant boundary	4,200'	NE	33	38	Normally Acceptable
Outside plant boundary	1 mi	NE	33	37	Normally Acceptable
Nearest residence	2 mi	NE	32	33	Normally Acceptable
Far shore, Wheeler Reservoir	1.9 mi	SW	34	35	Normally Acceptable

Noise levels in the direction of the long axis will be less than that at corresponding distances in the direction of the short axis as shown by the predicted noise spectrum at 1,000 feet from the towers.

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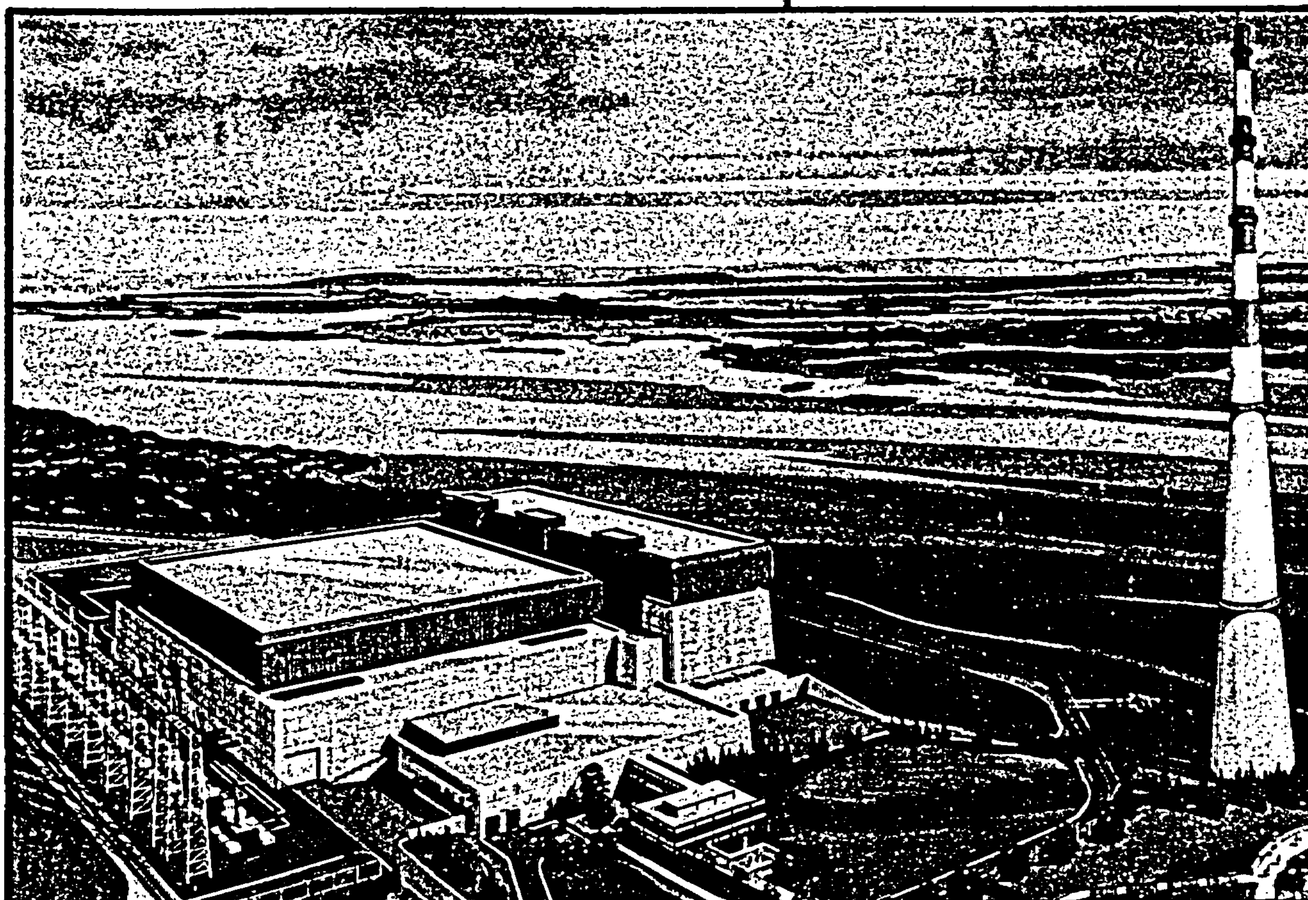
TENNESSEE VALLEY AUTHORITY

DRAFT

ENVIRONMENTAL STATEMENT



Browns Ferry Nuclear Plant Units 1, 2 and 3

VOLUME 2

1.0 SUMMARY: Browns Ferry Draft Environmental Statement
STATEMENT DATE: July 14, 1971
RESPONSIBLE FEDERAL AGENCY: Tennessee Valley Authority
TYPE OF PROPOSED ACTION: Administrative

Description of Action - This action is the construction and operation of a three-unit nuclear power generating station in Limestone County, Alabama.

Environmental Impact - The plant will interact with the environment in five principal ways: (1) It will require relatively minor adjustments in land use; (2) It may produce temporary stress on social infrastructure (schools, roads, housing, and similar services); (3) It will provide a stimulus to area economical development (jobs, attraction of visitors, etc.); (4) Small amounts and concentration of low-level gaseous and liquid radioactivity will be discharged; and (5) Possible minor influences from thermal discharges.

Adverse Environmental Effects Which Cannot be Avoided - The plant will release small quantities of radioactivity in low-level concentrations to the environment during normal operation. The best and highest degree of waste treatment available under existing technology within reasonable economic limits will be utilized in keeping radioactive wastes to the lowest practicable level. Heated water discharged into Wheeler Reservoir will produce a small temperature rise in a portion of the reservoir. Alternate cooling methods are being studied and will be implemented in the event Alabama Water Quality criteria are revised. In all cases, the systems chosen will be consistent with applicable Federal and state regulations. No significant environmental effects should result from these low-level radioactive releases and thermal discharges under these conditions. Certain short-term local environmental effects will result from construction activities of the Browns Ferry facility (reservoir turbidity, excavation, congestion). These will be minimized.

Alternatives to the Proposed Action - To meet the 1971-1972 winter peak load, TVA considered the following alternatives: (1) Base-loaded coal-fired units, and (2) Nuclear-fueled units. The second alternative provides the lowest cost of generating power and the least environmental impact. The purchase of power in the quantities needed is not a realistic alternative. TVA is considering alternative heat dissipation methods and will use the cooling method which keeps the thermal discharges well within applicable standards. TVA has also decided to provide extended treatment for liquid and gaseous radwaste.

Federal and State Agencies to Review

Atomic Energy Commission
Council on Environmental Quality
Environmental Protection Agency
Federal Power Commission
Department of Agriculture
Department of Commerce
Department of Defense
Department of Health, Education, and Welfare
Office of Economic Opportunity
Department of Housing and Urban Development
Department of the Interior
Department of Transportation
Appalachian Regional Commission
Alabama Development Office
Top of Alabama Council of Local Governments
North Central Regional Planning Development Commission

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2.0 INTRODUCTION

TVA is a corporate agency of the United States created by the Tennessee Valley Authority Act of 1933 (48 Stat. 58, as amended, 16 U.S.C. §§ 831-831dd (1964; Supp. V, 1965-69)). In addition to its responsibilities for flood control, navigation, and regional development, TVA operates a power system supplying the power requirements for an area of approximately 80,000 square miles containing about 6 million people. Except for direct service by TVA to certain industrial customers and Federal installations with large or unusual power requirements, TVA power is supplied to the ultimate consumer by 160 municipalities and rural electric cooperatives which purchase their power requirements from TVA. TVA is interconnected at 26 points with neighboring utility systems.

The TVA generating system consists of 29 hydrogenerating plants and 11 fossil-fueled steam-generating plants now in operation. In addition, power from Corps of Engineers' dams on the Cumberland River and dams owned by the Aluminum Company of America on Tennessee River tributaries is made available to TVA under long-term contracts. Figure 1 shows the location of TVA's present generating facilities and those under construction, as well as the location of the above Corps and Alcoa dams. The approximate area served by municipal and cooperative distributors of TVA power is also shown.

Power loads on the TVA system have doubled in the past 10 years and are expected to continue to increase in the future. In order to keep pace with the growing demand it has been necessary to add substantial capacity to the generating and transmission system on a regular basis. The major system capacity additions since 1949 are shown in Table 1.

In 1966, as part of its construction program designed to meet increased requirements for generation, TVA decided to construct a nuclear plant on the Browns Ferry site in Limestone County, Alabama. An application to construct and operate Units 1 and 2 was filed with the Atomic Energy Commission (AEC) on July 7, 1966. After extensive review of the suitability of the site and the plant design by the AEC regulatory staff and the independent Advisory Committee on Reactor Safeguards, an Atomic Safety and Licensing Board granted a provisional construction permit on May 10, 1967. Construction was started on May 17, 1967. After a similar review, a permit was issued for Unit 3 on July 31, 1968. Construction for Unit 3 began on August 1, 1968. The Final Safety Analysis Report was submitted to AEC on September 10, 1970, along with a request for authorization to operate all three units of the plant at the designed power level. The AEC is continuing its review of the Browns Ferry Nuclear Plant. Under the current schedule, TVA expects to be permitted to load the nuclear fuel for Unit 1 in January 1972. Full operation of Unit 1 is expected to be authorized in May 1972, Unit 2 in April 1973, and Unit 3 in January 1974.

As a Federal agency, TVA is subject to the requirements of the National Environmental Policy Act of 1969 (NEPA) which became effective on January 1, 1970. In carrying out its responsibilities under the TVA Act, TVA follows a policy designed to develop a quality environment. As a result of this policy, TVA has long considered environmental matters in its decision making. Offices and divisions within TVA employ personnel with a wide diversity of experience and academic training which enables TVA to utilize a systematic, interdisciplinary approach to insure the integrated use of the natural and social sciences and the environmental design arts in planning and decision making as required by NEPA. This detailed statement on the environmental considerations relating to the Browns Ferry Nuclear Plant is being sent to state and Federal agencies for review and comment pursuant to that Act and Office of Management and Budget Circular A-95. It is also being submitted to AEC as the environmental report required of applicants by Appendix D to 10 CFR Part 50.

The Browns Ferry Nuclear Plant was initiated before NEPA became effective and the TVA Board of Directors has determined that it is not practicable to reassess the basic course of action in the design and construction of this plant. TVA has continued to study the plant design, however, so as to minimize adverse environmental consequences. For example, through a continuing study of the release of radioactivity to the environment, TVA has decided to provide extended radioactive waste treatment for gaseous radwaste and additional processing for the liquid radwaste. These systems will reduce the amount of radioactivity released to the environment substantially below the level which would have resulted from the plant design as approved by AEC for construction. In addition, although the plant as designed meets all present applicable water quality standards, studies of the use of cooling towers as an alternative heat dissipation method are underway, in order that the plant can fully meet any future temperature requirements on receiving water.

It should be noted that although the three units at Browns Ferry begin operation at different times, this environmental statement considers the plant as operating with all three units, in order to accurately assess the impact of the plant on the environment, and so that consideration of the cumulative effects of the plant can be assured.

The remainder of this statement is arranged in seven principal sections. The first section provides a baseline inventory of environmental information. The following six sections cover the environmental considerations set out in Section 102(2)(C) of NEPA, as implemented by the CEQ and AEC guidelines.

3.0 GENERAL

The purpose of this section is to provide a basic knowledge of the existing environment and the important characteristics and values of the Browns Ferry site as it presently exists in order to establish a basis for consideration of the environmental impact of the facility.

3.1 Location of the Facility - The Browns Ferry Nuclear Plant is located on an 840-acre tract on the north shore of Wheeler Reservoir in Limestone County, Alabama, at Tennessee River mile (TRM) 294. The site is approximately 10 miles northwest of Decatur, Alabama, and 10 miles southwest of Athens, Alabama. The proximity of the site to local towns, rivers, and state boundaries is indicated on the vicinity map. (Figure 2)

3.2 Physical Characteristics of the Facility - The plant will have the following principal physical structures on the site: reactor containment building, turbine building, radwaste building, service building, transformer yard, 161-kV and 500-kV switchyards, stack, and sewage treatment plant. Figure 3 shows the general arrangement of these facilities. Figure 4 is an artist's concept of how the plant will appear upon completion of construction.

The reactor containment building houses three General Electric boiling water reactors. The plant will have a total electrical generator nameplate rating of 3,456 megawatts. Nuclear fuel is contained inside each reactor pressure vessel. The fuel is in sealed zircaloy tubes and consists of slightly enriched uranium dioxide pellets. The fission process in the fuel produces heat. Water enters the pressure vessel below the fuel and moves through the assembly of fuel tubes called the reactor core. As the water passes through the core, the heat converts it to steam. The steam leaves the reactor through pipes near the top of the reactor, then passes through turbogenerators which generate electricity. The steam is then condensed to water and returned to the reactor, where the cycle is repeated. This closed-cycle process is depicted schematically in Figure 5. The electricity thus produced is distributed to meet the power needs of the TVA system.

The reactor power level will be regulated primarily by control rods. Boron, a chemical element which absorbs neutrons and thereby retards nuclear fission, is sealed within the control rods. The power of the reactor, therefore, can be controlled by positioning the control rods in the core. The power is increased by slowly withdrawing the control rods from the core. The power level may also be controlled, but to a lesser extent, by regulating the flow rate of the water which is circulated through the reactor core.

The principal ways in which the plant will interact with the environment, discussed later in detail, are:

(1) Release of minute quantities of radioactivity to the air and water;

(2) Release of large quantities of heat to Wheeler Reservoir; and

(3) Change in land use from farming to industrial.

3.3 Environment in the Area - In order to assess the impact of the facility on the environment, the following summary description is provided as a baseline inventory of the important characteristics of the region.

1. Topography - The general level of the ground in the area rises gradually from 558 feet above sea level at the north shore of Wheeler Lake to around 800 feet above sea level 10 miles north in the vicinity of Athens, Alabama. The average elevation of the plant site is 575 feet above sea level. The area around the site is generally flat.

2. History* - The Browns Ferry plant site is located in Limestone County, Alabama, which is bounded by Madison, Morgan, Lawrence, and Lauderdale Counties, and the Tennessee state line. Limestone County was first settled by white settlers about 1807, at a place called Simms' Settlement. Settlers were forbidden in sections belonging to the Indians claimed by both Cherokee and Chickasaws, who had, however, made no settlement of their own.

Areas around the site have been explored for Indian mounds, town sites, and artifacts. Nothing of archaeological value has been found on the site.

3. Geology - The regional geologic features in the Browns Ferry site area and the local geologic formations in the immediate plant area have been investigated. TVA studies made of

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* Information excerpted from Alabama Encyclopedia Vol. I, edited by Jesse M. Richardson

extensive drilling, excavation, and testing show that the underlying bedrock will provide more than adequate foundation for Browns Ferry plant structures.

The only formations involved directly in the site area are the unconsolidated materials overlying bedrock and the Tuscumbia and Fort Payne limestones. Only the lower 50 feet of the Tuscumbia formation was encountered at the Browns Ferry site. The Tuscumbia is characterized by medium-to-thick beds of light-gray, medium-to-coarse crystalline, fossiliferous limestone.

The maximum known thickness of the Fort Payne formation in northern Alabama is slightly over 200 feet. At the Browns Ferry site the total thickness, penetrated in one drill hole, is 145 feet. The formation consists of medium-bedded, silty dolomite and siliceous limestone with a few thin horizons of shale. It is predominantly medium to dark gray in color. Near the top, some of the beds are cherty and some of the cores showed zones which were slightly asphaltic. The most distinguishing lithologic feature is the presence of quartz- and calcite-filled vugs up to 1 inch in diameter.

4. Seismology - The Browns Ferry Nuclear Plant is located in an area far removed from any centers of significant seismic activity in historic time. No known earthquake has been centered nearer than 35 miles from the site. The maximum intensity to have been felt at the site in the recorded history of the area from a major earthquake, such as those which occurred in the Mississippi Valley in 1811-1812 (MM XII) or that which occurred in Charleston, South Carolina, in 1886 (MM X), might be felt in the Decatur area with a Modified Mercalli intensity of VII. Acceleration at the site from a recurrence

of any of these major shocks would be far less than the proposed design accelerations for ground motion (0.10g). The nearest faults which are known to exist in the region are shown in Figure 8. These inactive faults are approximately 60 miles away and the occasionally active faults in the New Madrid region of the Mississippi Valley are approximately 200 miles away.

5. Geography - The area surrounding the Browns Ferry site lies near the southern margin of the Highland Rim section of the Interior Low Plateaus. This physiographic subdivision is characterized by a young-to-mature plateau of moderate relief. The general level of the ground rises gradually from 558 feet above sea level at the north shore of Wheeler Reservoir to around 800 feet above sea level 10 miles north in the vicinity of the town of Athens, Alabama. This surface is modified by the drainage patterns of Poplar, Round Island, and Mud Creeks which flow across it from northeast to southwest.

The plant site is located on an old river terrace surface with an average elevation of 575 feet above sea level. The maximum probable flood at the site would reach elevation 561. This level would not create a threat to the plant.

6. Climatology and meteorology - The site is in a temperate latitude about 300 miles north of the Gulf of Mexico. The area is dominated in winter and spring by alternating cool dry continental air from the north and warm moist maritime air from the south.

During this period, migratory cyclonic disturbances with numerous thundershowers and thunderstorms pass through the area. Storms, including tornadoes, reach severest intensity in March and April when maximum air mass contrast generally occurs.

U.S. Weather Bureau statistics show four tornadoes reported in Limestone County in the 49-year period, 1916-1965. In the adjacent and more populated counties, Morgan and Madison, and within 20 to 25 miles of the site, 18 tornadoes were reported in the same 49-year period and 16 of them were within the last 16 years. About half of the tornadoes were classified as funnel sightings and include no documentation on destructive force. Tornadoes in the site area usually move from southwest to northeast and cover an average surface path 10 miles long and 200 yards wide. Winds of 200 mi/h are common in the whirl and occasionally may reach somewhat higher velocities. Months of reported maximum frequency of occurrence are March, April, and June. The probability of a tornado striking a point in Limestone County is about one chance in 5,880 years.

The climate at Browns Ferry site is interchangeably continental and maritime in winter and spring, predominantly maritime in summer, and generally continental in fall. Data collected over a 65-year period (1894-1959) at Decatur, Alabama, indicate the average annual temperature is 62.0° F., with monthly averages from 42.9° F. in January to 80.7° F. in July. The highest daily maximum temperature on record at Decatur is 108° F. and the lowest daily minimum is -12° F. Detailed temperature data are in Tables 2 and 3.

About 50 percent of the annual precipitation at the Browns Ferry site results from migratory storms in December through

April, with January, February, and March usually recording maximum amounts. Most of the remaining precipitation is in June, July, August, and early September when air mass thundershower activity is common. Months with least precipitation are September and October when regional anticyclonic systems often persist over the area. Detailed precipitation information is in Tables 4 and 5. Table 6 contains snowfall data.

Wind speed and direction data collected from February 11, 1967, to December 31, 1968, indicate that the prevailing wind at the site is from the southeast at speeds of 8-12 mi/h. Figure 6 shows the wind speed patterns in a wind rose plot for this time period. This data was collected from a 300-foot TVA meteorological tower at the Browns Ferry site.

There are no physiographical features in the area to cause local entrapment or accumulation of emissions during periods of anticyclonic circulation or atmospheric stagnation.

7. Hydrology -

(1) Ground water - Ground water at Browns Ferry is derived from precipitation. Studies of subsurface waterflow in the area indicate that ground water flows from the structural highs toward the structural lows in the area. Local alterations of rock strata by minor anticlines and synclines prevent long-distance ground water movement from the regional area into the Browns Ferry site area. The principal aquifer in the area is overlain by a thick mantle of residium that retards the movement of shallow ground water. Therefore, the ground water movement in the site is derived from local precipitation that has percolated into the residium. Ground water movement in the area is from the plant site to the Tennessee River.

(2) Surface water - Surface water is derived from precipitation remaining after losses due to evaporation and transpiration. It can be generally classified as local surface runoff or streamflow.

(3) Water use - From its head near Knoxville to Kentucky Dam near its mouth, the Tennessee River is a series of highly controlled multiple-use reservoirs. The primary uses for which this chain of reservoirs was built are flood control, navigation, and the generation of electric power. Secondary uses such as sport and commercial fishing, industrial and public water supply, waste disposal, and recreation have developed.

Water use in the area is not limited to reservoir water since several small public and private water supplies are taken from ground water sources. These withdrawals are small compared with surface uses.

The major industrial water users in the area are located upstream at Decatur, Alabama. These users withdraw a total of about 150 million gallons of process water from the reservoir each day. Most of this water is returned to the reservoir after use with varying degrees of contamination. One large water-using industry, the Champion Paper Division of U.S. Plywood, Inc., is located across the reservoir and some 12 miles downstream from Browns Ferry.

Five public water supplies are taken from Wheeler or Pickwick Reservoirs within the reach from Decatur, Alabama, 12 miles upstream from the site, to Colbert Steam Plant, 49 miles downstream from the site. The Decatur supply is the nearest one to the site. Water supplies for public users are listed in Table 7. The location of each of these water supplies is shown in Figure 7. The nearest downstream public water supply is located at Wheeler Dam.

Florence, Muscle Shoals, and a utility district in Lauderdale County are considering the construction of water supply intakes within the Tennessee River reach specified above. Also, the city of Athens is currently considering a surface water supply to supplement its ground supply, but this supply probably will be taken from the Elk River 23 miles above its confluence with the Tennessee River.

There are 32 public ground water supplies within a 20-mile radius of the site. The nearest supply is at Tennessee Valley High School, approximately 5 miles from the site, and serves approximately 400 people.

8. Land use - The dominant character of the land in the area of the site is small scattered villages and homes in an agricultural area. The statistical data on land use for the counties in the vicinity of the site are shown on Table 8.

(1) Industrial operations - Industrial areas are concentrated along the Tennessee River, primarily at the large population centers. The closest industrial area is adjacent to Decatur, Alabama. Minnesota Mining and Manufacturing Corporation, Monsanto Corporation, and Amoco Chemical Corporation are the three largest industries and are about 7 air miles from the site. The largest industrial complex near Browns Ferry is the Redstone Arsenal, which is located approximately 25 miles east of the site. This is the NASA center for research and development and is the principal single economic force in the area. The remaining industrial area is located in

the Muscle Shoals, Sheffield, Tuscumbia, and Florence area. It is anticipated that the gradual transfer of land from agricultural to industrial use will be continued.

(2) Farming - The dominant character of the land within a 60-mile radius is small, scattered villages and homes in an agricultural area. Between 60 percent and 80 percent of the land in counties nearest the site is used for agriculture. As indicated in Figure 9, the area immediately surrounding the site is still primarily a diversified agricultural region. However, increasingly greater amounts of land are being gradually transferred to industrial use.

(3) Transportation - There are no railroads or principal highways penetrating the site. The Louisville & Nashville Railroad is about 8 miles east of the site, running in a north-south direction, and the Southern Railroad is about 6 miles south of the site, with tracks running in an east-west direction. The nearest principal highways are U.S. 72, about 6 miles north of the site, and State Highway 20, about 4.5 miles south of the site.

(4) Forestry - There are no major commercial forestry operations in the vicinity of the site.

(5) Recreation - Land use for recreation development on Wheeler Reservoir includes Joe Wheeler State Park, Limestone County Park, Lawrence County Park, Mallard Creek public use area, Decatur Municipal Boat Harbor and Park, and Point Mallard Park. Also, there are four commercial boat docks within twelve miles of the site. A limited amount of shoreline has been developed for private residential use.

(6) Wildlife preserves - Approximately 1,240 acres or shoreline and backlands across the river are managed by the State of Alabama for wildlife use under a "use permit" arrangement with TVA which extends for an indefinite time period. Southeast of the site, between Rock Island Creek and the U.S. 31 causeway, the state is using an additional 1,360 acres for wildlife management, also under a "use permit" arrangement. Wheeler National Wildlife Refuge extends upstream from Decatur on both shores of the Tennessee River for approximately 15 miles.

(7) Population distribution - The area in which the Browns Ferry site is located has demonstrated moderate population growth during the last two decades. One of the fifteen counties within a 60-mile radius of the site has shown a decrease in population from 1960 to 1970; of the fourteen counties showing a population increase, seven counties have had significant growth. The general pattern has been a steady decrease in the farm population in all counties and an increase in the rural-nonfarm and urban populations. The counties with the greatest increase in population reflect the growth of the major urban areas - Huntsville, Decatur, and the quad-city area of Florence, Sheffield, Tuscumbia, and Muscle Shoals.

The 1960 population within a 4-mile and 10-mile radius of the site was 1,392 and 22,040, respectively. Figure 10 illustrates the 1960 population distribution within 10 miles of the site.

There are only three centers of population within 60 miles of the site with populations exceeding 25,000. These centers (Decatur, Huntsville, and quad-cities) are at 10, 30, and 30 miles, respectively, and at widely separated directions from the site. There are only three towns within a radius of 20 miles (Athens, Moulton, and Decatur) having a 1970 population greater than 1,800 persons. The population of Athens is expected to increase from 14,360 in 1970 to 22,000 in 1990. For Decatur, the population is expected to increase from 38,044 to 50,000 in the same time period. Within a 60-mile radius, the largest city is Huntsville, located approximately 30 miles due east from the site. The population of Huntsville is expected to increase from its 1970 level of 137,800 to 200,000 by 1990.

(8) Waterways - Figure 1 illustrates the Tennessee River.

(a) Navigation use - Tennessee River traffic, measured at Wheeler Lock 20 miles downstream from the Browns Ferry plant, amounted to 5.5 million tons in 1969, the latest year for which data are currently available. The principal tonnage was in grain and grain products, accounting for 2.5 million tons. Petroleum products, chemicals, and coal traffic each had over

0.5 million ton. The 1970 traffic at Wheeler Lock is estimated to be about 6 percent greater than 1969.

(b) Growth - It is estimated that the Tennessee River traffic will experience an average growth rate of about 4.8 percent annually to 1980, reaching a level of 40.5 million tons in that year.

(9) Government reservations and installations - There are no major government installations within 10 miles of the site. The Redstone Arsenal is located approximately 25 miles east of the site. TVA has the Wheeler Dam 19 miles downstream from the site; the Wilson Dam 35 miles downstream from the site; and the TVA National Fertilizer Development Center at Muscle Shoals, approximately 30 miles west of the site.

9. Ecology - The region around Browns Ferry supports wildlife, waterfowl, fish, and aquatic life. These important species are discussed in the paragraphs below.

(1) Wildlife and waterfowl - Wheeler Reservoir harbors the southernmost wintering population of substantial numbers of Canada geese in the United States. At its 35,000-acre Wheeler National Wildlife Refuge, 40,000 geese regularly spend the winter. Total waterfowl populations on Wheeler include up to 75,000 ducks, primarily mallards, blacks, green-winged teal, widgeon, pintail, gadwall, lesser scaup, and ringnecks. Over 14,000 man-days of waterfowl hunting take place each year on the Wheeler Reservoir. An additional 14,000 man-days are devoted to upland game hunting for rabbits, quail, squirrel, dove, snipe, raccoon, oppossum, and crows. Other public uses--fishing, artifact hunting, camping, picnicking, etc.,--account

for an additional 250,000 man-days of recreational activity on these wildlife management areas.

(2) Fish and other aquatic life - Wheeler Reservoir is classified as a normal, highly productive, warm-water aquatic environment. Benthic habitats in the reservoir range from deposits of finely divided silts to river channel cobble and bedrock. The most extensive benthic habitat is composed of fine-grained brown silt, which is deposited both in the old river channel and on the former overbank areas. The overbank areas are far more extensive than the old river channel and are the most productive.

The silt-laden overbank areas support communities of Asiatic clams, burrowing mayflies, aquatic worms, and midges. Cobble and bedrock areas, found primarily in the old channel, support Asiatic clams, bryozoa, sponges, caddisflies, snails, other clams, and some leeches. All these benthic forms are important sources of food for commercial fish and most are important to game fish.

In the very shallow overbank areas, the major algal species are the suspended diatoms and the green algae.

At times, zooplankton in the surface and deep waters is quite extensive. Common forms include rotifers, cladocerans, and copepods.

Investigations have shown the following fish to be important to sport use: largemouth bass, smallmouth bass, spotted bass, white bass, crappie, bluegill, and sauger. Important commercial fish are bigmouth buffalo, smallmouth buffalo, channel catfish, flathead catfish, blue catfish, carp, drum, and paddlefish. Table 9 lists the species encountered in various samples in Wheeler Reservoir.

A fish population survey for Wheeler Reservoir made in 1970 showed an average of 39,000 fish per acre with an average total weight of 738 pounds. Of the total number of fish counted in the survey, game and panfish accounted for approximately 47 percent; forage fish, 47 percent; and rough fish, 7 percent. The most numerous species were gizzard shad, bluegill, and the long-eared sunfish.

In a 1970 creel census (July through December), white crappie accounted for over 58 percent of the sport catch. Other percentages were: bluegill - 17 percent, smallmouth bass - 7 percent, largemouth bass - 5 percent, white bass - 5 percent, with black crappie, catfish, walleye, sauger, drum, yellow bass, and carp also appearing in the catch.

The 1967 commercial fish harvest for TVA reservoirs in north Alabama, which includes Guntersville, Wheeler, Wilson, and Pickwick Reservoirs, was 2.7 million pounds valued at $397,000. Buffalo dominated the catch, followed by catfish, carp, drum, and paddlefish. Based upon earlier surveys, Wheeler produced about 35 percent of the commercial catch in this area, Guntersville and Pickwick 30 percent each, and Wilson 5 percent.

The Browns Ferry plant is located directly downstream from an extensive area of shallow water, including the mouths of several creeks. Two additional extensive areas of shallow overbank habitat are located on the opposite side of the channel, directly across from the plant and about 2 miles downstream. Limited areas of shallow habitat occur directly downstream from the plant site. Areas of this type usually serve as spawning and nursery sites for most important fish species, as well as being areas of high production of food organisms.

10. Chemical and physical characteristics of air and water -

(1) Air - Other than the data described under Section 2.1.3, Climatology and Meteorology, no additional physical or chemical properties of air have been monitored.

(2) Water - The Browns Ferry site is located 19 miles upstream from the Wheeler Dam. The Tennessee River at Wheeler Dam has a drainage area of 29,590 square miles. The Wheeler Dam, located at river mile 275 in Lauderdale and Lawrence Counties, Alabama, was completed in 1936, forming TVA's third largest reservoir by area at the normal pool elevation of 558 feet. At this elevation the Wheeler Reservoir is 74.1 miles long and covers an area of 67,100 acres, with a volume of 1,131,000 acre-feet and a shoreline length of 1,063 miles. The reservoir has an average width of nearly 1.5 miles and is approximately 7,300 feet wide at the plant site.

(3) Streamflow - Since 1937, the U.S. Geological Survey has maintained a streamflow gaging station at Whitesburg, Alabama, 40 miles above the Browns Ferry site. The average daily streamflow at this station since 1937 has been 42,400 ft^3/s.

Flow duration data for the Whitesburg station have been prepared cooperatively by the U.S. Geological Survey and the Tennessee Valley Authority. For the 1940-1960 period, the following tabulation indicates the percent of time that various daily average streamflows were equaled or exceeded:

Average Daily Flow (ft^3/s)	Percent of Time Equaled or Exceeded
5,000	99.0
17,000	89.5
25,000	75.1
30,000	60.0
35,000	43.7

Considerable seasonal variation in streamflow occurs at the Whitesburg station. Data for the water years 1960 through 1964 indicates an average flow of about 32,000 ft^3/s during the summer months and about 76,000 ft^3/s during the winter months.

Channel velocities at the Whitesburg gage average more than 2 ft/s under normal winter conditions. Due to the lower summer flows, these velocities are reduced to a little more than 1 ft/s under normal summer conditions. These average winter and summer velocities drop to 0.7 ft/s and 0.3 ft/s, respectively, at the Browns Ferry site where the reservoir is wider and the slope of the water surface is less.

(4) Water quality - A comprehensive water quality survey of Wheeler Reservoir was made by TVA during the period May 1962 through April 1965. Results of analyses on samples collected at Tennessee River mile 277.0 are shown in Table 10. Surveys in the downstream reservoirs since 1965 confirm that these data are representative of (1) water quality in Wheeler Reservoir, (2) that there is little year-to-year change, and (3) that there has been no long-term degradation in water quality.

These results are representative of water quality conditions at the Browns Ferry site and indicate that the water quality is very good.

Biological conditions in Wheeler Reservoir were assessed from samples collected at five locations in the main river channel and in one backwater "slough" area. In general, biological populations in the reservoir represented conditions typical of main stream reservoirs. Wide distribution of mayfly larvae indicated good water quality. Plankton populations increased with distance downstream from Guntersville Dam, probably reflecting decreased water turbulence and reduced turbidity in the lower end of the reservoir.

(5) Radiological monitoring - Water samples collected monthly from Wheeler Reservoir (TRM 277.0) during the period from May 1964 through April 1965 showed that the gross beta activity ranged from 0.06 X 10^{-7} μCi/ml to 0.17 X 10^{-7} μCi/ml and averaged 0.10 X 10^{-7} μCi/ml. For the period July 1969 to June 1970 total gross beta activity in the water samples collected monthly from Wheeler Reservoir at the Browns Ferry site ranged from 0.035 X 10^{-7} μCi/ml to 0.093 X 10^{-7} μCi/ml and averaged 0.056 X 10^{-7} μCi/ml.

(6) Temperature - Water temperature observations at selected stations indicate Wheeler Reservoir is only weakly stratified during the summer months and unstratified at all other times. A summary of the observed surface and bottom temperatures is presented in Table 11. Temperature data at Tennessee River mile 305.0, collected by TVA's Hydraulic Data Branch during 1938 through 1943, indicate the temperature pattern observed one year is very similar to that observed in other years. The yearly maximum and minimum temperatures during this period are shown in Table 12.

11. Historical significance of the Browns Ferry site - The nearest historical place listed in the National Register of Historic Places is TVA's Wilson Dam which is 19 miles downstream from Browns Ferry. The possible impact on this historic place is discussed in Sections 5.7.2 and 5.7.3.

3.4 Electric Power Supply and Demand - TVA is the power supplier for an area of approximately 80,000 square miles containing about 6 million people. TVA generates, transmits, and sells power to 160 municipalities and rural electric cooperatives which in turn retail power to their own customers. The approximate areas served by these distributors are shown in Figure 1. These distribution systems, which purchase their power requirements from TVA, serve more than 2 million electric customers, including homes, farms, businesses, and most of the region's industries. TVA also supplies power directly to 46 industries which have large or unusual power requirements and to 11 Federal installations, including the Atomic Energy Commission plants at Oak Ridge, Tennessee, and Paducah, Kentucky.

The importance of an adequate supply of power on the TVA system is by no means limited to electric consumers in the area which TVA supplies directly. This system, which with 19.4 million kilowatts of presently installed generating capacity is the Nation's largest, is interconnected at 26 points with neighboring systems with which TVA exchanges power. The TVA system is, in effect, part of a huge power network. In a time of power emergency, operation of the TVA power system could have a definite impact on power supply conditions from the Great Lakes to the Gulf of Mexico, and from New England to Oklahoma and Texas.

During the past 20 years, loads on the TVA power system have increased approximately 7 percent per year. This rate of growth in power requirements has meant that the capacity of the generating and transmission system has been doubled every 10 years. Until the end of World War II, most of TVA's generating capacity was hydroelectric. By that time, however, most of the suitable hydroelectric sites had been developed, and beginning in 1949 substantially all of the capacity increases were met by the construction of fossil-fueled plants. In the middle 1960's, large-scale nuclear plants had become feasible, and TVA began to take steps to add nuclear capacity to its system. TVA has also begun providing pumped-storage and gas turbine capacity to meet system peak loads. Table 1 shows major TVA system capacity additions since 1949.

The amount of electricity generated in 1965 to meet customer requirements for power exceeded 70.0 billion kilowatt-hours. By 1970, annual electric generation for customer needs had totaled 92.7 billion kilowatt-hours. Generating needs are expected to reach 135 billion kilowatt-hours by 1975. TVA presently must add an average of 1500 megawatts or more of new generating capacity each year to keep up with the rapid increase in electrical power usage in this region.

1. Power needs - The demands on the TVA generating system result in peak demands occurring in winter and summer. The annual peak loads in the TVA service area usually occur between November and March because of electrical heating demands. However, due to seasonal exchange arrangements with other power systems, the expected loads which the TVA generating capacity must actually serve during the next several years will be greater in the summer than in

the preceeding winter. The following tabulation indicates expected loads to be served by TVA during the next several peak seasons:

Period	Estimated Peak Demand TVA System-MW	Net Interchange-MW Received	Net Interchange-MW Delivered	Load Served by TVA-MW
Winter 1971-72	18,300	2,917	--	15,383
Summer 1972	16,240	--	1,800	18,040
Winter 1972-73	20,200	2,060	--	18,140
Summer 1973	18,060	--	2,060	20,120
Winter 1973-74	22,400	2,060	--	20,340

To meet the load increases shown above, additional generating capacity totaling 360 megawatts will be added by TVA to meet the winter peak load to be served in 1971-72, 3,000 megawatts will be added to meet the winter peak load in 1972-73, and 3,405 megawatts will be added to meet the winter peak in 1973-74. Browns Ferry Units 1, 2, and 3 will contribute significantly to meeting these load demands by supplying 3,195 megawatts of the necessary generating capacity.

2. Consequences of any delays - To meet the 1971-72 winter load served by the TVA system (15,383 MW), the dependable capacity will be 18,630 megawatts. This capacity is expected to increase to 21,605 megawatts to meet the 1972-73 winter peak loads and to further increase to 25,005 megawatts to meet the 1973-74 winter peak load. The reserve margins on the TVA system during the winters of 1971-72, 1972-73, and 1973-74 are expected to be 3,247; 3,465; and 4,665 megawatts, respectively. Thus, if TVA is to adequately meet its obligations to its customers during the peak seasons of 1971-73, Browns Ferry Units 1, 2, and 3 are needed as planned.

4.0 ENVIRONMENTAL APPROVALS AND CONSULTATIONS

In addition to its own standards, TVA as a Federal agency is subject to comprehensive and broad-scale environmental procedures and Federal and state consultation and coordination requirements of the National Environmental Policy Act of 1969, 42 U.S.C. § 4321 (1970) (as implemented by Executive Order 11514 (35 Fed. Reg. 4247) and guidelines issued by the Council on Environmental Quality (36 Fed. Reg. 7724)). In addition, TVA is subject to Executive Order 11507 (35 Fed. Reg. 2573), and Office of Management and Budget Circulars A-78 and A-81, relating to the prevention, control, and abatement of air and water pollution in Federal facilities, as well as certain provisions of the Clean Air Act, as amended, 42 U.S.C.A. § 1857 (1970), and the Federal Water Pollution Control Act, as amended, 33 U.S.C.A. § 1151 (1970), which relate to the applicability of various Federal, state, interstate or local air and water quality standards. In addition, TVA is subject to the requirements of Office of Management and Budget Circular A-95 which insure that major generating and transmission projects are coordinated from the point of view of community impact and land use planning with state and local agencies.

TVA has consulted with several Federal, state, and local agencies and officials since 1966 in the planning and construction of the Browns Ferry plant. Federal agencies consulted include the U.S. Fish and Wildlife Service, U.S. Public Health Service, and the Federal Water Pollution Control Administration (now the Water Quality Office of the Environmental Protection Agency). State agencies consulted include the Alabama State Health Department, the Alabama Water Improvement Commission, and the Alabama Department of Conservation.

In addition, officials from Limestone and Morgan Counties and from Athens and Decatur, Alabama, have been consulted.

Regional agencies in the area include Top of Alabama Regional Council on Governments (Limestone, Madison, Marshall, Jackson, and DeKalb Counties), North Central Alabama Regional Planning and Development Commission (Morgan, Lawrence, and Cullman Counties), and Muscle Shoals Council of Local Governments (Lauderdale, Colbert, Franklin, Marion, and Winston Counties). These agencies are concerned with regional planning and development in their multicounty areas. TVA works closely with these agencies on a staff-to-staff basis.

Since a number of the regional concerns are broad in scope and apply to the entire north Alabama region, the regional agencies, the state, and TVA maintain an effective, continuing working relationship for considering these concerns. The resulting overall regional planning effort focuses attention on functional program requirements such as maintaining water quality, improving wildlife management, determining the future roles of agriculture and forestry, and promoting orderly industrialization and urbanization in the north Alabama region. The Browns Ferry project is consonant with positive steps for regional growth in the area.

5.0 ENVIRONMENTAL IMPACT OF THE PROPOSED FACILITY

The primary and secondary social and economic impact of the plant is discussed in this section. "Primary" is interpreted to mean those impacts directly attributable to the plant, while "secondary" is interpreted to be the long-range effects of the plant. Creation of additional employment in the area and purchase of construction materials from local businesses are identified as two primary impacts of the Browns Ferry plant. While the total magnitude of these impacts is large, the distribution of residences and local material supply sources occurs within forty miles of the plant site. A recent survey of the Browns Ferry construction employees showed that over 90 percent lived within a forty-mile radius of the plant site. More than 40 towns were supplying project workers, with nearly 25 percent coming from the Muscle Shoals area. The survey also revealed that, as of April 1971, at least 795 workers had moved into the forty-mile area, locating in at least nine different towns. Over one-half (436) went to Athens, Alabama; 130 located in Decatur; 45 went to Tanner; and the remainder to other nearby towns. Since the bulk of the project's employment needs have been satisfied by local residents, the project has had the secondary impact of tending to stabilize the local economy. At the present employment level (April 1971) of about 3,000 and an average annual wage of about $10,000, the annual income to the region from the project is about $30,000,000. However, Table 13 shows that the peak project employment income in 1970 is only a small percentage of total 1966 personal income for any of the indicated area units.

Purchases and contracts from the local economy over the total construction period will be around $5,000,000. As a primary impact, these purchases represent important contributions to some area businesses. As a secondary impact the additional revenues may offer the opportunity to slightly expand or upgrade facilities in individual instances, although it is unlikely that very many businesses depend on this construction activity as a basis for long-term revenue.

The 436 workers who moved into Athens from outside the area to work on the project represent the largest project-related concentration of population, but account for only 1.3 percent of the 1970 population of Athens and 0.6 percent of the school age population in the city.

Thus, no severe economic dislocation should occur as the project phases out. Employment will scale down gradually from its peak level of 3,000 to approximately 175 permanent operating personnel. These employees will become permanent citizens of the local area.

The following discussion assesses the probable impact of the construction and operation of the facility on the environment.

5.1 Land Use Compatibility - There are no anticipated routine operations of the plant which would prohibit attaining full use of the surrounding land or the Browns Ferry site. The following discussion should be related to the topics under Land use in the baseline inventory. Figure 9 shows the rural character of the area surrounding the site.

1. Industrial operations - The plant should not have an adverse impact on industrial operations in the area.

2. Farming - Except for the land required for the plant, no adverse impact on farming in the area is expected. Baseline hydrological information indicates that ground water movement would prohibit seepage of liquid wastes into surrounding land.

3. Transportation - There are no rearrangements of public roads. The plant should have no adverse impact on the use of land for transportation purposes.

4. Forestry - TVA, through its Division of Forestry, Fisheries, and Wildlife Development, has made investigations of superior hardwood specimens in the Tennessee Valley region. These investigations led to the location of and seed from a superior walnut specimen. Two large tracts of land on the Browns Ferry site will be planted to these superior walnut trees and used to supply seed for future stock.

5. Recreation - The plant should not have any adverse impact on the use of the land for recreation. In fact, the site will provide additional recreational facilities. Provisions are being made for recreation areas, and a visitors' information lobby and overlook will be constructed.

There is little likelihood that the warm water discharges would result in any adverse effect on water-contact recreation in Wheeler Reservoir. The discharged warmed water will mix rapidly in a relatively small zone near the plant and the limited increases in water temperature should not be objectionable to boaters or swimmers in adjacent areas of the reservoir.

Although during some months fish may avoid the immediate area of the plant discharges, in the winter the fish are likely to be attracted to the warm water. This has been the experience at other TVA steam plants.

6. Wildlife preserves - Although the construction of the plant will dislocate some wildlife from the immediate vicinity of the site, this is not expected to be significant. The plant should not have any adverse impact on the use of land for wildlife preserves.

7. Population distribution - The project will result in an approximate increase of 175 permanent jobs at the plant, therefore slightly increasing the pressures for residential development and on public and private facilities to provide the necessary services required. Since no significant social and economic problems have been caused by the large influx of personnel required for the construction of this plant, no adverse impact is expected on the population distribution of the area. The minimum exclusion distance for the site is 4,000 feet. There are no residences within 4,500 feet of the reactor building, and only 208 people within 2 miles. The area within a 10-mile radius is not expected to have significant resident population changes in the future.

The TVA Radiological Emergency Plan provides for orderly evacuation of people from the site and the surrounding area should the need arise.

TVA's Division of Navigational Development and Regional Studies maintains a continuous study of the population growth of the region. These studies will enable TVA to detect population increases in order to keep the emergency plan current and to ensure that operation of the facility can be properly maintained.

8. Waterways - The location of the diffuser pipes will require special precaution in use of the waterway for navigation purposes.

A barge traveling through water of any depth experiences an increase in draft as opposed to one sitting still. An increase in the speed or a decrease in the depth of water causes an increase in the draft, and the barge will assume a "bow-down" or "stern-down" attitude, depending upon several other factors. Since the water depth over the diffusers is about 10 feet less than in the approach channel, barges will experience some increase in draft as they cross the diffusers. Laboratory tests have shown that for barge speeds in the range of those encountered on Wheeler Reservoir, barges will usually assume a "bow-down" attitude. Navigation channel markers will indicate the location of safe water depths over the diffuser at extreme drawdown elevation. As shown in Figure 11, this section of marked navigation channel will be more than 1000 feet wide and is considerably wider than many sections of marked channel in Wheeler Reservoir and more than three times as wide as the minimum channel width on the Tennessee River waterway.

9. Government reservations - The construction and operation of the Browns Ferry Nuclear Plant should not significantly affect the other Government reservations identified in Section 3.3. Neither should it curtail the future development of Government reservations in the region.

5.2 Water Use Compatibility - Projection of the impact of the facility on the uses of surface and ground water resources of the region has been made in order to assure that adequate consideration is given to alternate and shared uses of the water and to overall plans for development of the area. TVA has discussed the construction and operation of the plant, with regard to the uses of the water, with the Alabama State Health Department, the Alabama Water Improvement Commission, and the Federal Water Pollution Control Administration (Water Quality Office of the Environmental Protection Agency).

Physical, chemical, and hydrologic characteristics of the water and details of water withdrawals were discussed previously in Section 3.3. This section considers the probable impact of the facility on present and projected uses of the water resources.

1. Industrial water uses - Capacity of the river to receive effluent from industrial waste treatment facilities without interfering with other water uses is an important consideration in the industrial use of the water. Potential effects of the facility on the water quality of the river as a result of elevating water temperatures include (1) theoretical lowering of dissolved oxygen concentrations in the water passing through the condenser, and (2) increased rate of biochemical oxygen demand and the increased magnitude of the ultimate biochemical oxygen demand of both municipal and industrial organic wastes in the water affected by elevated temperatures. The discussions of DO and BOD in Section 5.6 indicate that adverse effects on the waste assimilative capacity of the river will not be significant. DO and BOD monitoring will be conducted after the plant begins operation.

2. Public water uses - The major public water uses of the Wheeler Reservoir are for water supplies, recreation, and waste disposal. The closest downstream public surface water supply is Wheeler Dam, which is 19.1 miles downstream and which serves approximately 50 people. An analysis has been made to determine the minimum dilution to be expected between the condenser cooling water discharge and Wheeler Dam. The maximum concentration at Wheeler Dam water intake for a continuous release of r microcuries per second is estimated to be $2.9r \times 10^{-9}$ μCi/ml.

There are 32 ground water supplies within a 20-mile radius of the site. Because the ground water movements are away from these sources as indicated in Section 3.3, there should be no significant effects on ground water uses.

3. Impact on the water resources - The Browns Ferry Nuclear Plant is not expected to have significant impact on the water resources of the area. The plant should not affect the chemical or physical characteristics of Wheeler Reservoir, nor will it alter the present usage of this portion of the Tennessee River.

As will be noted in subsequent portions of this statement, the plant should not cause thermal nor radiological discharges that will adversely affect uses of the reservoir.

Other industrial and public uses, such as water transportation, boating, fishing, etc., should not be significantly affected by the presence of the plant in the area.

5.3 Heat Dissipation - The Browns Ferry plant will release heat to the environment as an inevitable consequence of producing useful electricity. Heat from the fission of nuclear fuel in the reactor is used to produce steam under high temperature and pressure to drive a turbine connected to a generator. After a significant portion of thermal energy in the steam has been converted to mechanical energy in the turbine, the low temperature, low pressure steam is converted to water in a condenser. Condensation is accomplished by passing large amounts of cooling water through the cooling coils in the condenser. This section discusses water quality as affected by thermal discharges.

1. Condenser circulating water - The primary purpose of the condenser circulating water system is to provide water to the condensers of the turbogenerator steam turbine to carry away heat rejected by steam condensation. A secondary purpose is to provide water for auxiliary cooling service and to disperse low-level radioactive wastes from the radwaste treatment building.

The system is designed to provide a flow of 1,890,000 gallons per minute (gal/min) to the condensers and a flow of 90,000 gal/min to auxiliaries for the three units. Three pumps are provided for each unit, each with a capacity of 220,000 gal/min at a design head of 32.5 feet. The pumping station is located at the land end of the intake channel, which has a bottom elevation of 523 feet above sea level. The nine circulating water pumps will carry the water through tunnels to the condensers.

No treatment is provided for the condenser circulating water. An Amertap cleansing system is provided for automatically cleaning condenser tubes when the system is in operation. This mechanical cleansing system uses small sponge rubber balls that are recirculated continuously through the condenser tubes. Therefore, it is not anticipated that the chemicals normally used for algal treatment will be required on this plant.

Operating the condensers requires that filling be accomplished by venting, evacuation by the vacuum system, and operation of at least two circulating water pumps. The three condensers may be operated fully flooded by only one pump by throttling the condenser discharge valves and venting only. The discharge from the condensers passes to the discharge tunnel and on to the diffuser system for mixing with the reservoir water. The diffuser system is described in the next section, Heat removal facilities.

Three pumps will normally operate in parallel for each unit. However, in an emergency if one pump is out of service, the two remaining pumps will deliver approximately 540,000 gal/min at a reduced head of about 20 feet. This is still sufficient flow for unit full load operation.

The cooling water will be drawn from and returned to Wheeler Reservoir. With the units operating fully loaded, the temperature of the cooling water will be raised 25° F. in passing through the condensers. The representative averages of seasonal temperatures of withdrawn and returned water are set forth below.

Average Condenser Water Temperature

	Inlet temperature	Outlet temperature Before Mixing
Fall	67° F.	92° F.
Winter	47° F.	72° F.
Spring	57° F.	82° F.
Summer	79° F.	104° F.

2. Heat removal facilities - It was recognized early in the plant design stages that the condenser water should not be discharged into the surface strata of Wheeler Reservoir. Instead, it was decided that, by means of a diffuser, the condenser water should be mixed as quickly as possible with as much unheated river water as

possible. By this procedure, no excessively warm surface strata will exist, the mixing zone will be restricted to a relatively small area, and the temperature rise after mixing will not exceed 10° F.

Based on extensive TVA studies (discussed in Section 5.6), available data, and the experience of others, at the time Browns Ferry was designed it was concluded that outside the mixing zone: (1) the average temperature over any cross-section should be limited to not more than 93° F. and should not exceed 95° F. at any point at any time, and (2) the rise in temperature of the mixed stream should be limited to not more than 10° F. above natural water temperature at any time. The mixing zone will not be permitted to exceed 75 percent of the total cross-section of the reservoir and will be limited to a reasonable distance from the outfall. These temperature limits have been used in design and are in line with those accepted by the Alabama Water Improvement Commission.

Figure 11 shows the physical relationship of the plant, cooling water conduits, and diffuser pipes, to the main channel and floodplain of Wheeler Reservoir at the plant site.

Thermal diffusion is accomplished by means of three perforated pipes, connected to the discharge conduits of the three units. These perforated, corrugated, galvanized steel pipes are laid side by side across the bottom of the 1,800-foot-wide channel. The channel is approximately 30 feet deep. The pipes are 17 feet, 19 feet, and 20 feet 6 inches in diameter and of different lengths. Each has the last 600 feet perforated on the downstream side with more than 7,000 two-inch diameter holes. Thus, approximately 22,000 holes spaced 6 inches on centers in both directions distribute the 4,400 cubic feet per second (approximate) of cooling water into the river for thermal mixing. The diffuser system design is shown on Figure 12.

The main channel where mixing takes place occupies about one-third of the width of the reservoir but carries about 65 percent of the flow. The reservoir outside the main channel at this location is approximately one mile wide and 3 to 10 feet deep at minimum pool level.

Predictions of surface temperatures upstream and downstream from the plant are shown on Figure 13 and 14 and have been made to illustrate thermal conditions that could exist when:

a. Total riverflow (17,000 ft^3/s) in mid-April would result in a maximum thermal rise of 10° F. above the normal water temperature of 65° F. in the main channel flow immediately below the plant;

b. Total riverflow (21,000 ft^3/s) in mid-August would result in a maximum thermal rise to 93° F. (8° F. above 85° F. normal water temperature) in the main channel flow immediately below the plant.

The dashed lines in Figure 13 and the shaded area in Figure 14 reflect the range of uncertainty in calculated results. Both of these examples illustrate extreme conditions that could occur infrequently when riverflows are relatively low.

To provide an estimate of the number of days in a year when one or both of the control temperatures, i.e., 10° F. rise and/or maximum of 93° F., might be reached, the streamflows and temperatures that actually existed at Wheeler Dam during 1966 and 1967 were analyzed. The mean flow in 1966 was 37,550 ft^3/s and 57,550 ft^3/s in 1967. The long-term mean flow is 49,000 ft^3/s.

It was assumed that all three units were in continuous operation and that all condenser flows were mixed with two-thirds of the streamflow. These calculations demonstrate that, even without allowance for unit outages which might coincide with periods of low flow and high temperature, special flow regulation will be required for only a small percentage of the time to keep water temperatures in the reservoir below the design control temperatures. During those periods when special controls might be applied, the thermal limits will be met by (1) regulating streamflows at the Browns Ferry site, or (2) decreasing power production, or (3) a combination of both.

The decision as to which approach will be used during these periods will be made only after careful consideration of the potential effects of the special operation on all other uses of the TVA reservoir system.

3. Impact of cooling water effluent on temperatures in Wheeler Reservoir - The objective of the diffuser system is to obtain complete mixing of the thermal effluent with that portion of the receiving water available for dilution within the minimum possible distance. Mixing is considered to be complete if the temperature at any point in the cross section is $R(\Delta T) + T$, where T is the temperature of the dilution water, ΔT is the increase in temperature of the condenser flow, and R is the ratio of the condenser flow to the dilution water flow.

As shown on Figure 11, the diffusers do not traverse the entire width of the reservoir. Hence, the entire reservoir flow will not be available for dilution. Field measurements showed that 65 percent of the flow would be available for mixing.

The diffuser design is such that the discharge is essentially constant for the entire length of the diffuser; therefore, the mixing characteristics of the diffuser could be determined from two-dimensional model tests. Such model tests were conducted at the Massachusetts Institute of Technology Hydrodynamics Laboratory for steady flow conditions.

It was found that for the range of flows from 10,000 to 40,000 ft^3/s the diffuser was essentially 100 percent efficient as a mixing device. Comparison of model temperatures with computed fully mixed temperatures showed that complete mixing always occurred in the prototype within 200 feet of the diffusers. These studies also show that completely mixed temperatures will often occur within 75 feet. Figure 15 shows the results (extrapolated from model studies) of a detailed temperature survey in the vicinity of the jet ports. For this case, a 15° F. drop in temperature would occur within 10 feet of the prototype diffuser and the entire flow would be within 1° F. of the fully mixed temperature within about 50 feet.

These tests also showed that an upstream wedge of warm water would develop at flows of less than 40,000 ft^3/s.

To learn more about the effect of unsteady and zero flow on the thermal regime of Wheeler Reservoir, construction of a three-dimensional model of a 5-mile-reach of the reservoir in the vicinity of the plant was begun. The model was designed to simulate all flow conditions including reverse reservoir flow.

This model will be used to obtain as much pre-operational information as possible regarding the effects of many variables on the thermal regime of Wheeler Reservoir. Operation of the model will provide information to guide in the operation of Wheeler and Guntersville hydro projects and Browns Ferry so as to meet standards relative to thermal conditions in the Wheeler Reservoir.

A comprehensive picture of the thermal regime of the reservoir both before and after Browns Ferry goes into operation will be available from temperature monitoring stations at the Tennessee River mile indicated in the following table and shown in Figure 16.

Mile	Date Installed
275.0	Dec. 1968
285.2	Dec. 1970
293.6	Oct. 1968
297.6	Sept. 1969

Each station measures temperatures at ten elevations. The station at mile 293.6 also measures velocity and direction of flow and reservoir stage. Measurements from these stations are telemetered to a central data logger, punched or paper taped, and sent to the computer center for processing and storage. Selected points from the station at mile 293.6 are telemetered to the plant where they are available to the plant operating personnel. If it is found that additional stations are required after the plant goes into operation, they will be added. In addition, water surface temperatures will be monitored several times yearly by means of airborne infrared remote sensing equipment. Special studies consisting of around-the-clock measurements for controlled situations will be set up for the Browns Ferry plant. Essentially simultaneous instantaneous temperature measurements of a large surface area combined with selected vertical temperature measurements will provide additional information concerning the thermal regime of Wheeler Reservoir.

4. Applicable thermal standards - The Alabama proposed standards for water temperature state that "with respect to cooling water discharges only, the ambient temperature of receiving water shall not be increased by more than 10° F. by the discharge of such cooling water, after reasonable mixing; nor shall the discharge of such cooling waters after reasonable mixing cause the temperature of the receiving

waters to exceed 93° F." The Alabama temperature standards have been excepted from approval by the Water Quality Office, Environmental Protection Agency. However, TVA will meet any future applicable temperature standards.

Heat dissipation utilizing the diffuser system designed for Browns Ferry should control thermal discharges so that there is no significant adverse impact on the quality of the water in Wheeler Reservoir. (See Section 7.4, Alternative Heat Handling Methods, for further studies TVA has under way.)

Because of its location inside the state of Alabama, Browns Ferry discharges should not affect the quality of the waters of other states.

5. Applicability of Section 21(b) permit - TVA, as a Federal agency, is not required to obtain a certificate of compliance with applicable state water quality standards, in accordance with Section 21(b) of the Water Quality Improvement Act of 1970 (PL 91-224). TVA is, however, obligated by Section 21(a) of this Act and by Executive Order 11507, "Prevention, Control, and Abatement of Air and Water Pollution at Federal Facilities," to meet all state water quality standards in the operation of its facilities and TVA will meet this obligation. Estimated quantities and concentrations of liquid waste discharges expected from Browns Ferry Nuclear Plant have been reported to the Environmental Protection Agency, as required by Office of Management and Budget Circular A-81.

5.4 Chemical Discharges - Chemicals used at Browns Ferry Nuclear Plant include alum, chlorine, and a polymer used in the water filtration unit; sulfuric acid and sodium hydroxide used for makeup demineralizer regeneration, sodium chromate used as a corrosion inhibitor in closed-cooling water systems and suppression chambers; miscellaneous chemicals used for cleaning and decontamination of equipment; and sodium pentaborate used in the standby liquid control systems. Of these, only the filtration unit chemicals and the demineralizer regenerants are discharged to the river during normal operation. Safeguards against accidental release of other chemicals are provided.

Alum, chlorine, and a polymer are used in the water filtration unit. If the filtration unit were operated at rated capacity, annual consumptions of these chemicals would amount to 8,000 pounds of alum, 250 pounds of chlorine, and 150 pounds of polymer. The actual amounts, however, are expected to be less than 10 percent of these figures. Filtration units are backwashed into the water plant waste sump, and the liquid is pumped to the condenser water discharge conduits. During release, the concentration of alum is about 0.05 ppm, that of chlorine about 0.0003 ppm, and that of the polymer about 0.0002 ppm.

During regeneration of a makeup demineralizer, regenerant solutions containing sulfuric acid and sodium hydroxide are discharged into the water plant waste sump along with backwash and rinse water. The liquids are pumped into the condenser water discharge conduits where they are diluted by the condenser cooling water flow. The concentrations of sulfuric acid and sodium hydroxide in the diluted stream range from about 0.5 to 1.5 ppm each during release, depending upon whether one, two, or three reactor units are in operation. The concentrations are too low to have a measurable effect on the pH of the diluted stream. The U. S. Public Health Service Drinking Water Standards of 1962 specify a maximum sulfate concentration of 250 ppm. TVA's Instruction VIII, "Water Quality Management," specifies 150 ppm. If the makeup demineralizer were operated at its rated capacity, the annual discharge of sulfuric acid and sodium hydroxide would be approximately 66,000 and 36,000 pounds, respectively. The actual discharge is expected to be a fraction of this amount.

Chromate-containing water is drained from components of the closed-cooling water system only when necessary for maintenance purposes. Chromate-containing water from the suppression chamber will not be discharged to the river. In this connection, TVA is continuing to investigate ways to avoid the use of chromate in the suppression chamber and will make the necessary changes if these investigations show that other methods will meet the operation criteria. The water is drained from the closed cooling water system to the radwaste system where it is processed through a non-regenerable mixed bed demineralizer. The treated solution is expected to contain less than 10 ppm of chromate (as CrO_4^{--}), and the total annual release of chromate would rarely, if ever, be as much as 10 pounds. When released and diluted in the discharge conduits, the concentration of chromate is less than 0.013 ppm if one unit is operating and less than 0.0045 if three are operating. The U. S. Public Health Service Drinking Water Standards of 1962 specify a maximum concentration of 0.05 ppm for hexavalent chromium; this value corresponds to 0.11 ppm CrO_4^{--}.

Most equipment cleaning and decontamination operations will be performed with high-pressure water and with detergent solutions. These liquids will be treated in the radwaste system by filtration and will be released to the discharge conduits. Some decontamination operations will involve the use of chemicals such as sodium phosphate, sodium permanganate, ammonium citrate, nitric acid, and hydrofluoric acid. The amounts of such chemicals cannot be determined at this time. They will be drained to the chemical drain tank in the radwaste system where they will be neutralized. Further processing will depend upon the character of the solution. Processing will include filtration and may include demineralization prior to release to the discharge conduits.

Sodium pentaborate used in the standby liquid control system will not be released from the plant. Should it be necessary to drain solution from the system, it will be drained into drums. Storage tanks are designed to resist a design basis earthquake.

It is anticipated that releases of chemical wastes from the Browns Ferry Nuclear Plant will have no significant effect on the biota.

5.5 Sanitary Wastes - All the sewage from the plant will be collected in a yard sewage system which flows by gravity to a treatment plant. Sewage ejectors, which discharge into the yard system, are provided at the pumping station and gatehouse. The sewage treatment plant consists of two 15,000 gallons-per-day units arranged for parallel flow. Biological oxidation and reduction of solids by extended aeration and sedimentation are the methods of treatment. Effluent from the plant flows through a chlorine contact tank and then into the river. The sewage treatment plant is designed and will be operated in accordance with Federal and state standards.

5.6 Biological Impact - One of the most important considerations in carrying out the construction and operation of a nuclear power plant is the formulation of comprehensive ecological studies. This allows documentation of environmental characteristics prior to construction and operation of the plant in order that the effect of construction and operation on the environment can be estimated, and provides a basis for selecting measures to minimize any projected adverse effects. TVA has developed comprehensive ecological monitoring programs. Some of these are currently under way, while others are planned to commence prior to plant startup and continue after the plant is in operation. All of these programs are discussed at various points below.

1. Ecological studies and analyses performed - Subsection (1) lists some of the results of the fish monitoring investigations. Subsection (2) discusses the importance of the locale to the existence of important species, including the possible effects of heated water. While the extent to which all of these effects may be present at Browns Ferry is not yet fully known, it is important from an environmental standpoint to recognize all the possible effects of heated water in order to objectively judge the actual impact of the plant.

Subsection (3) discusses TVA's experience with heated water on aquatic life at its various steam plants. Subsection (4) discusses the passage of planktonic forms and fish larvae through the condensers. Subsection (5) discusses such cooling water phenomena as biochemical oxygen demand.

(1) Identification of species important to sport and commercial use - Fish monitoring investigations have been conducted quarterly since the winter of 1968. These investigations have shown the following fish to be important to sport use: largemouth bass, smallmouth bass, spotted bass, white bass, crappie, bluegill, and sauger. Important commercial fish are: bigmouth buffalo, smallmouth buffalo, channel catfish, flathead catfish, blue catfish, carp, drum, and paddlefish. Table 9 lists the species encountered in various samples in Wheeler Reservoir; as such, it represents neither a complete species list for the reservoir nor a list of the "important" species within each broad category. Important seasonal sport fisheries exist for all game fish noted with the exception of yellow bass, longear, and green sunfish. Important commercial species include the two species of buffalo and the three species of catfish; drum, carp, and paddlefish are of lesser commercial importance. Forage fish are poorly represented here; conventional sampling techniques employed in monitoring and population-inventory studies do not sample small forage fish efficiently. Smith-Vaniz (1968) reports more than 24 species of minnows including 16 species of *Notropis* in the Alabama sections of the Tennessee River system, as well as 18 species of darters. These totals do not include rare or endemic species reported from only one location.

It is difficult and in some cases perhaps invalid to assign given species to tropic levels, since many species will undergo ontogenetic changes in regard to trophic levels will assume a very broad trophic character as adults. Some generalizations are however possible. The basses and gars can be considered as true piscivores as adults; forage fish and some rough fish species can be considered planktivorous; the remainder are essentially omnivorous.

(2) Importance of locale to existence of important species, considering states in life history -

(a) Spawning and larval state -

Important areas - The Browns Ferry plant is located directly downstream from an extensive area of shallow water, including the mouths of several creeks. Two additional extensive areas of shallow overbank habitat are located on the opposite side of the channel, directly across from the plant and about 2 miles downstream. Limited areas of shallow habitat occur directly downstream from the plant site. Areas of this type usually serve as spawning and nursery sites for most important fish species, as well as being areas of high production of fish food organisms.

Possible impact of heated water - Appendix III outlines studies conducted by TVA and others on the effects of heated water on aquatic life. Appendix II describes some preliminary results of the type of monitoring being undertaken in order to fully assess the effects of heated water on aquatic life.

Based upon these studies, it is concluded that the heated water should have no significant adverse effects on aquatic life. The comprehensive monitoring programs which are described in Section 5.6.3 will be used to ascertain the extent to which these effects will apply at the Browns Ferry site after the plant begins operating.

Thermal characteristics of operation - At a riverflow of approximately 43,000 ft^3/s, the thermal discharge from the plant will result in a temperature rise of about 3° F. in the main river channel at a point 200 feet directly downstream from the diffuser pipes. The increase in temperature at the same point for a low flow of 20,000 ft^3/s will be about 8° F. Environmental considerations demand that the worst probable case coincident with plant operation be examined; this has been estimated to represent a flow of 17,000 ft^3/s in April and 21,000 ft^3/s in August. At this velocity, subject to the assumptions of steady flow in the channel, temperatures at a point 2 miles downstream would be elevated 6.5° F. in mid-August and 8.1° F. in mid-April. Similarly, surface temperature increases would be approximately 4.0° F. in mid-August and 6.1° F. in mid-April at a point 2 miles upstream.

Larval fish study - In order to judge the impact of heated water on spawning and larval states in the life history of various species, it is necessary to know to what extent the area to be affected by the plant's heated discharge is used as a spawning site by reservoir fishes. The specific objectives of this study are to:

1. Determine species composition and periodic abundances of larval fishes,

2. Acquire information on occurrence and abundance of young-of-the-year fishes, and

3. Ascertain aspects of the life history of larval, postlarval, and juvenile (young-of-the-year) fishes, such as growth rates, food habits, and movement.

Planned sample types, frequencies, locations, and analyses are discussed below.

Construction activity - Construction activities, notably those involving dredging and landfill, have altered about one-half mile of shoreline habitat. Landfill operations may have altered currents somewhat, contributed silt and excess turbidity, and temporarily affected the distribution of some species of fish directly below the plant. The extent to which these effects may be permanent has not been resolved.

(b) Fish movements - Returns of tagged fish in Wheeler Reservoir indicate that several species show extensive ranges of movement. Data for five species are presented in Table 14. The ranges of movement that are attributable to migratory and nonmigratory behavior are not known.

The heated water may have an effect on the migratory behavior of some fishes. Three-dimensional model studies are being conducted now to determine whether and under what conditions the heated water can extend the width of the reservoir. The linear dimensions, depth, and longevity of the heated area, together with its temperature, will be investigated with regard to its effect on migratory and nonmigratory movements of fishes.

Of the species present in Wheeler Reservoir which are known to make extensive spawning migrations, it appears that sauger are most likely to be affected. Sauger move upstream, usually to the tailwaters of Guntersville Dam, and spawn in late December and early January at temperatures of 41 to 43° F. The effects of a movement through elevated temperatures on reproduction of sauger are not now known. This is also true concerning the effect of the space distribution of the thermal plume on the migration of an important species.

Monitoring programs to consider fish movements are discussed below. One of the sampling stations established to monitor the effects of heated discharges is located directly opposite the plant site. It is anticipated that information gained from this station will include data on the reactions of fish to the thermal discharge and the spatial distribution of the thermal plume.

(3) Time and space changes in temperature distributions - Fish will probably not remain in the area immediately downstream of the diffuser pipes for a distance of 100 feet, due to the thermal gradients and temperatures. The warmer stretches below this area are likely to be more attractive and less detrimental to younger fish. In general, preferred temperature within a species decreases with increasing age. Adult predators may frequent this area during feeding periods. Increased water temperatures in late autumn, winter, and early spring may serve to concentrate fish in the vicinity of the diffuser tubes. Production of food organisms in this area beyond the usual "productive season" may serve as an attractant to young fish; concomitantly, predators will be attracted by the increase in their food resources. This may increase sport and commercial fishing in the vicinity.

(a) TVA experience on effects of heated water - Since 1955, TVA has been observing the distribution in streams and in reservoirs of heated waters discharged from TVA's thermal-electric power plants. The first plants were relatively small compared to the sizes of receiving streams. Over the years the sizes of individual units, power plants, and thermal rises in the condenser cooling water have gradually increased. To ensure that aquatic life in receiving streams is not being adversely affected by thermal discharges, biological surveys have been made at all of TVA's plants. Table 20 illustrates characteristics of these plants.

Typical of these surveys are the detailed temperature and biological studies made in August and September of 1967 at the Widows Creek power plant on Guntersville Reservoir. Heated water there is discharged into the edge of the reservoir, where it "floats" into the main channel and rapidly mixes with streamflow. Temperature and biological data were collected along cross sections of the reservoir above and below the plant. Temperature of the discharge water was between 84° F. and 86° F., about 10° F. higher than temperature in the river above the plant. The warm water plume spread diagonally across the river in less than the upper 10 feet of water, or less than half the river depth. Bottom fauna and periphyton growth were sampled and analyzed.

Results of these studies showed that: (1) the horizontal area of the reservoir covered by the zone of elevated temperatures is small; (2) the maximum temperatures observed in the mixing zone were in the top two feet of water; (3) the maximum increase in temperature in the mixing zone was 10.3° F. on August 30, and 6.1° F. on August 31; (4) the temperature increase in the Tennessee River water after complete mixing was less than 1° F.; (5) the diversity and abundance of bottom fauna above and below the steam plant discharge were similar, and slight differences are attributed to variability of substrate rather than to temperature effects;

(6) the observed periphyton growth was not consistent with the proximity of the observation stations to the discharge; consequently, the differences in growth are not considered to be due to the steam plant discharges; and (7) the discharge from the Widows Creek Steam Plant does not produce significant effects on aquatic life in the Tennessee River.

Although temperature rise in condensers of TVA's fossil-fueled plants typically varies from 10° F. to 18° F., results of similar temperature and biological surveys show that the thermal discharges from the various plants produce no significant adverse effects on aquatic life in the receiving waters. It is interesting to note that fishing in the warm water during the winter months is very popular at most TVA steam plants.

Initial operation of the Paradise Steam Plant on the Green River in Kentucky did produce significant adverse effects on aquatic life. However, these effects were detected by environmental monitoring conducted by TVA and outside consultants. As a result of the findings of the biological studies, lower thermal criteria were established by TVA and cooling towers were installed. Continuing studies are assessing the effectiveness of these measures to correct the effects of initial operation of the plant. Preliminary results indicate that the adverse effects experienced are not permanent. Appendix III provides a detailed analysis of the Green River studies.

TVA's experience demonstrates that warm condenser water can be discharged into surface streams without significant adverse effects on aquatic life. The Paradise experience, although somewhat atypical due to the nature and small size of the Green River, demonstrates the value of comprehensive monitoring programs in detecting adverse effects of thermal discharges at an early stage in plant operation, and indicates that such effects are not permanent.

(4) <u>Effect of passage through condenser on planktonic forms and fish larvae</u> - The volume of water used for condenser cooling raises the possibility that newly-hatched fish and food organisms will pass through the condensers. The temperature rise of approximately 25° F. and pressure changes involved in pumping may kill many of these organisms in the condenser cooling water. However, since only ten percent of the water passing the site at mean annual flow passes through the condensers, any adverse effects are not expected to be significant.

Newly-hatched fish (larval fish) are essentially planktonic, as are many food organisms and the eggs of some species of fish. These may be unable to avoid or withstand the currents in the intake area. The extent to which entrainment of larval fish will be significant is unknown; however, investigations are to be initiated in 1971 to ascertain the distribution and abundance of larval and young fish in several areas of the reservoir, including areas directly above and below the plant site. Further details on this program are contained below.

(5) <u>Implications of withdrawal and return of cooling water</u> - The three units and auxiliaries at Browns Ferry require the withdrawal and return of approximately 1,980,000 gallons of water per minute. The water is withdrawn from and returned to approximately the same level. This constitutes about ten percent of the water passing the site at mean annual flow.

(a) <u>Nutrient circulation</u> - Plankton may be destroyed by passage through the condensers. Destruction of plankton in the condensers will release nutrients that could result in the growth of heterotrophic slimes. This possible effect will be detected by monitoring programs, but no significant adverse effects on important species populations are anticipated.

(b) <u>Reduction of DO concentrations in the condensers</u> - Since warm water can hold less oxygen in solution than can cooler water, the theoretical effects of elevation of water temperatures some 25° F. in passing through the condensers has been considered. For example, the oxygen saturation concentration in water at 85° F. is 7.7 milligrams per liter, whereas at 110° F. the saturation concentration is 6.3 milligrams per liter.

Observations of DO concentrations in Wheeler Reservoir above and below the Browns Ferry site indicate that in the summer months DO concentrations are not at saturation but in the range of 75-80 percent of saturation. Thus, instead of 7.7 mg/l of DO in water at 85° F. the actual concentration is observed to be approximately 6 mg/l. Thus, during the warmer months of the year, even after the temperature is elevated 25° F. in passing through the condenser, saturation concentrations are not apt to be exceeded. Consequently, as regards elevation of water temperatures, no significant reduction in oxygen concentrations should occur.

Another factor tending to lower DO concentrations in water passing through a condenser is the partial vacuum existing at the discharge end of the condenser. This partial vacuum results from the fact that the discharge end of the condenser lies above the hydraulic gradient. This situation is common to all TVA steam plants. While vacuum pumps are installed to remove any accumulated air, experience has shown that very little air accumulates and needs to be removed from the system. Consequently, no significant quantity of oxygen should be lost at Browns Ferry due to this hydraulic situation.

These conclusions are consistent with findings above and below TVA's Paradise power plant where the temperature elevation in water passing through the condensers is approximately the same as at Browns Ferry, and a significant negative pressure exists at the downstream ends of the condenser.

No significant adverse effects on important species populations are anticipated due to the reduction of DO concentrations in the condensers, since no significant quantity of oxygen will be driven off.

(c) Effect of elevated temperatures on biochemical oxygen demand - To provide an estimate of the quantitative effect on oxygen consumption of organic wastes in the waters of Wheeler Reservoir, an organic load of 25,000 pounds per day of 5-day BOD was assumed to be discharged into the reservoir immediately downstream from the plant.

Based on a low total streamflow of 21,000 ft^3/s, an increase in temperature from 85° F. to 93° F., and applicable Streeter-Phelp equations, calculations show that the increase in temperature would result in an increased DO depression of less than 0.1 mg/l.

It is not anticipated that this would have any adverse implications on important species populations.

(6) Measures taken to assure adequate ecological studies - TVA has consulted with the Fish and Wildlife Service, U.S. Department of the Interior, and the Alabama Department of Conservation in developing plans for environmental monitoring for the Browns Ferry plant. A quality control program for radioactive monitoring has been established with the Alabama Department of Public Health Radiological Laboratory and the Eastern Environmental Laboratory - EPA, in Montgomery, Alabama. In addition, TVA has discussed environmental monitoring plans with the Alabama State Health Department, the Alabama Water Improvement Commission, the Bureau of Sport Fisheries and Wildlife, and the Bureau of Commercial Fisheries of the U.S. Fish and Wildlife Service.

2. Studies to be continued - There are no ecological studies to be completed prior to operation of the plant which will affect plant design. The three-dimensional model studies on the diffuser systems will be continued after the plant begins operation.

3. Monitoring programs - The following monitoring programs will be used to determine present and continuing ecological relationships.

(1) Environmental Monitoring Program

(a) General - The preoperational environmental radioactivity monitoring program has the objective of establishing a baseline of data on the distribution of natural and man-made radioactivity in the environment near the plant site. With this background information, it will then be possible to determine, when the plant becomes operational, what contribution, if any, the power plant is making to environmental radioactivity.

Field staffs in TVA's Division of Environmental Research and Development and the Division of Forestry, Fisheries, and Wildlife Development carry out the sampling program outlined in Table 15. Sampling locations are shown in Figures 17 and 18. All the radiochemical and instrumental analyses are conducted in a central laboratory at Muscle Shoals, Alabama. Alpha and beta analyses are performed on a Beckman Low Beta II low background proportional counter. A Nuclear Data Model 2200 multichannel system with 512 channels is used to analyze the samples for specific gamma-emitting isotopes. Data are coded and punched on IBM cards or automatically printed on paper tape for computer processing specific to the analysis conducted. An IBM 360 Model 50 computer is used to solve multimatrix problems associated with identification of gamma-emitting isotopes.

(b) Atomospheric monitoring - Remote air monitoring stations are located at distances out to 35 miles from the plant and the perimeter monitors out to 10 miles; the local stations are inside the plant boundaries. All the monitors are capable of sampling air at a regulated flow of 3 ft^3/min through a Hollingsworth and Voss HV-70 particulate filter; in series with, but downstream of, the particulate filter is a charcoal filter used to collect iodine. Each monitor has a collection tray and storage container to collect rainwater and a horizontal platform that is covered with gummed acetate to catch and hold heavy particle fallout. Thermoluminescent dosimeters are used to record gamma radiation levels at each remote and perimeter station.

Local and perimeter monitors transmit data on airborne beta-gamma levels into the plant by radiotelemetry. These stations will be used to detect any significant airborne release, while the remote monitors will monitor outlying populated areas.

Air filters are collected weekly and analyzed for gross beta activity and specific gamma-emitting isotopes. No analyses are performed until 3 days after sample collection. For the specific radionuclide analysis, the filters for each station for a month are composited and analyzed. The monthly results are combined for each station to obtain a semiannual average. The averages for each station are combined to yield an average for each group of monitors.

Rainwater is composited monthly and analyzed for gross beta activity, specific gamma-emitting isotopes, and radiostrontium. For the gross analysis, a maximum of 500 ml of the sample is boiled to dryness and counted. A gamma scan is performed on a 3.5-liter monthly sample and the results averaged the same as air filters. The strontium isotopes are separated chemically and counted in a low background system.

The gummed acetate that is used to collect heavy particle fallout is changed monthly. The sample is ashed and counted for gross beta activity.

Charcoal filters are collected biweekly and analyzed for radioiodine. The filter is counted in a multichannel system.

(c) Terrestrial monitoring -

Milk - Milk is collected monthly from four farms within a 10-mile radius of the plant and from nearby retail distributors and analyzed for gamma-emitting isotopes and for radiostrontium. So that any relationship between fallout on pastureland and the presence of radionuclides in milk might be seen, pasturage is also sampled at the four farms.

Vegetation - In addition to the pasturage samples mentioned previously, vegetation samples are collected near each monitoring station in the network to determine possible plant uptake of radioactive materials from the soil or from foliar deposition. The data for the specific radionuclide analysis of vegetation are averaged for the four principal locations--local, perimeter, remote, and farm.

Soil - Soil samples are collected near each monitoring station in order that any relationship between the amount of radioactive material found in vegetation and that in soil might be established. The averages for specific analyses are obtained in the same fashion as those for vegetation.

Water - Domestic water supplies, such as surface streams and wells, are sampled and analyzed. Well water is obtained from four private farms within a 10-mile radius of the plant. Public water supplies obtained from the Tennessee River at Decatur, Wheeler Dam, and Sheffield are also analyzed.

Environmental gamma radiation levels - Thermoluminescent dosimeters are placed on a 500-foot grid within the plant boundaries and on the perimeter and remote air monitors to determine the gamma exposure rates at these locations.

Poultry and food crops - Poultry and food crops were collected for the first time during the summer of 1970 and will be obtained again in the summer of 1971. Corn, oats, peaches, tomatoes, potatoes, and chickens were analyzed.

(d) Reservoir monitoring - Samples are collected quarterly along nine cross sections in Wheeler Reservoir--at Tennessee River miles 277.98, 283.94, 288.78, 291.76, 293.70, 295.87, 299.00, 301.06, and 307.52. Samples collected for radiological analysis include water from eight of these cross sections, fish and plankton from three cross sections, and bottom fauna and sediment from four cross sections, as shown in Table 16. In addition, water, plankton, bottom fauna, and sediment are collected at a station located within 500 feet of the diffusers (TRM 293.88). The locations of these cross sections are shown on the accompanying map (Figure 18) and conform to sediment ranges established and surveyed by the Hydraulic Data Branch, TVA. Station 307.52 is located 13.5 miles upstream from the plant diffuser outfall and was selected as a control station.

Samples of water, net plankton, sediment, Asiatic clams, and two species of fish collected quarterly (plankton in only two quarters) are analyzed for radioactivity. Gamma and gross beta activity are determined in water (dissolved and total activity), net plankton, sediment, shells and flesh of clams, flesh of a commercial and a game fish species, and also in the whole body of the commercial species. Tritium is determined in river water and certain public water supplies. The ^{89}Sr and ^{90}Sr contents are determined by appropriate radiochemical techniques for all samples except flesh of clams and white crappie.

Water - From all of the nine cross sections a total of 24 water samples is collected quarterly for determination of suspended and dissolved radioactivity. The locations and depths for sampling are shown in Table 16. Water samples are also collected monthly at the point of plant discharge to the Tennessee River (within 500 feet of the diffuser) and at a point on the Elk River. These samples are a part of the quality control program.

Fish - Radiological monitoring of fish is accomplished by analyzing three composite samples from collections at each of three sampling stations--miles 283.94, 293.70, and 299.00. One sample is composited from the flesh of at least six white crappie, 8 inches or longer; one from the flesh of at least six smallmouth buffalo, 14 inches or longer; and one from at least six whole smallmouth buffalo, 14 inches or longer. These are collected quarterly and analyzed for gamma and gross beta activity. The ^{89}Sr and ^{90}Sr concentrations are determined on the whole fish and flesh of buffalo only, which are as nearly equal in size as possible. The composite samples contain approximately the same quantity of flesh from each of the fish. For each composite, a subsample of at least 50 to 100 grams (wet weight) of material is drawn for counting. After the plant goes into operation, fish will also be sampled at the station located within 500 feet of the diffuser.

Plankton - As indicated in Table 16, net plankton (all phytoplankton and zooplankton caught with a 100 μ mesh net) is collected for radiological analyses at two depths at each of four stations by horizontal tows with a 1/2-meter net. At least

50 grams (wet weight) of material is necessary for analytical accuracy. Collection of this amount will probably be practical only during the period April to September (spring and summer quarters) because of seasonal variability in plankton abundance. Samples are analyzed for gamma and gross beta activity and ^{89}Sr and ^{90}Sr content.

Sediment - Sediment samples are collected from Ekman dredge hauls made for bottom fauna. Gamma and gross beta radioactivity and ^{89}Sr and ^{90}Sr content are determined quarterly in a composite sample collected from each of two points in the cross section at five stations. Locations of these points at each station are shown in Table 16.

Bottom fauna - The flesh of Asiatic clams collected from two points in the cross section at five stations (Figure 18) is analyzed for gamma and gross beta activity at quarterly intervals. The ^{89}Sr and ^{90}Sr contents are determined on the shells only. A 50-gram (wet weight) sample provides sufficient activity for counting.

(e) Quality control - A quality control program has been established with the Alabama Department of Public Health Radiological Laboratory and the Eastern Environmental Laboratory - EPA, Montgomery, Alabama. Samples of air, water, milk, vegetation, and soil collected around the plant are forwarded to these laboratories for analysis. Results are exchanged for comparison.

(2) Fish monitoring - Monitoring areas and stations and sampling locations for fish monitoring are shown in Figure 19. Trap nets (two each in areas A, B, and C) are utilized to provide fish for: (a) radiological analyses, (b) tagging for

investigations of fish movements, and (c) studies on age structure and growth rates of fishes. Gill nets (10 each at stations 1, 2, and 3) provide data used for analyses of: (a) species presence, (b) species abundance, and (c) species diversity. The combination of these three aspects of fish distribution will form the basis for assessment of thermal effects. Information on age structure of species' populations, growth rates, movements of selected species, studies on larval and young fish, results of population inventories and creel censuses will be added in an attempt to provide as complete a picture as possible of thermal effects on fish populations.

It is anticipated that three full years (12 quarters of sampling) of preoperational data will be available; postoperational sampling will be conducted for at least two full years (8 quarters of sampling) and preferably three full years. Assessment of effects will be of a "before-after" nature, utilizing within-station comparisons of characteristics of catch and supportive data. Preliminary results of fish monitoring are given in Appendix II.

(a) Adult fish - The objective of this program is to determine species composition, relative abundance, and movement of fish in Wheeler Reservoir. To judge the effects, both adverse and beneficial, of heated water on fish and their habitat, baseline measurements will be made below, within, and above the proposed heated water discharges.

Fish will be collected quarterly with gill and trap nets set in overbank and channel areas indicated on Figure 19. Data collected from trap nets will be used to determine species composition, movement, and numbers and weights of game and commercial fish per lift at each station before and after plant operation. To determine movement, selected species will be tagged. Fish tagged before the plant operates will serve as the basis for determining normal movement within the reservoir.

Gill nets will be fished one week when trap nets are not in the water. Catches from these nets will supply information on species composition, relative abundance, and fish distribution and movement.

Rotenone samples will be taken below the plant during the summer quarter of each year before and after operation. These samples will serve as a basis for determining standing crop, species composition, and reproductive success.

Quarterly and annual progress reports will be prepared and distributed.

(b) Larval fish - In conjunction with present monitoring of adult fish populations in the vicinity of Browns Ferry Nuclear Plant, there is a need to investigate larval fishes during and after the spawning season and throughout the succeeding summer. It would be of significance to know to what extent the area to be affected by the plant's heated discharge is used as a spawning site by reservoir fishes. The objectives of this phase are:

1. To determine the species composition and periodic abundance of larval fishes.
2. To acquire information on occurrence and abundance of young-of-the-year fishes.
3. To ascertain aspects of the life history of larval, postlarval and juvenile (young-of-the-year) fishes. Such aspects as growth rates, food habits, and movement will be studied as time and facilities permit.

In addition, this study will enable an assessment to be made of the effects of passage through the condensers of fish larvae.

Indirect effects on fish populations will also be investigated. For example, growth rates will be studied. Young fish (this term includes all stages from newly-hatched individuals to and including young-of-the-year fish) provide possibly the best test animals for studies on growth rates because of their rapid absolute and relative rates of growth, their abundance, and because it is relatively easy to process large numbers in a short time.

Sampling will begin just prior to the earliest suspected spawning of species concerned. Larval and postlarval fishes will be collected by towing a net of one-meter diameter constructed of 1/32-inch nylon mesh. Sampling stations and a weekly sampling schedule are described in Table 17.

Stationary nets may be utilized for sampling in the intake basin, depending on accessibility to the basin and on water currents in the basin.

Sampling will be continued until young of all species concerned are large enough to enable them to avoid the meter net. Sampling for young fish will be continued, following the meter-netting phase, by beach seining, electrofishing, and perhaps by surface and midwater trawling. Beach seining will commence before the meter-netting phase ends, in order to maintain continuous sampling throughout the early summer. If conditions of fish concentration and water transparency permit, cast-netting may also be employed.

Sampling will begin in late March or April, pending completion of gear development. Two days sampling per week should be sufficient with two stations being sampled per day. The same schedule will be used for later phases--beach seining, electrofishing, trawling--and will continue into late September.

In terms of analysis of samples, primary importance will be attached during the first season to identification of species and the acquisition of a reference collection.

(3) <u>Additional monitoring for investigation of possible thermal effects</u> - The objective of this monitoring program is to determine if detectable changes occur in selected water

quality and biological parameters in affected areas of Wheeler Reservoir after the Browns Ferry Nuclear Plant begins operation. Appendix IV discusses proposed research.

(a) <u>Frequency of sampling</u> - Surveys were started in January 1969, and are now being made quarterly (Table 18). They will be continued through the first year after all three units are in operation. The frequency and extent of sampling during the second year of full plant operation will depend on results obtained during the first period of study.

(b) <u>Water quality parameters</u> - From eight cross sections (Figure 18) temperature and DO concentrations will be determined at the depths shown in Table 16. Water samples will also be collected in the main channel at each station from a depth of 1 meter for determination of stable trace elements of chromium, copper, iron, zinc, nickel, manganese, iodine, and potassium. At TRM 277.0 the water samples are also being periodically analyzed for coliforms, BOD, color, turbidity, odor, nitrogens, phosphates, pH, alkalinity, total hardness, SO_4, SiO_2, conductance, suspended solids, and total solids (Table 10).

(c) <u>Plankton</u> - For quantitative population estimates, zooplankton are sampled by filtering four or more liters of water, collected with a Van Dorn bottle, through a No. 20 (150 μ) mesh Wisconsin net or bucket. If organisms are too scarce to obtain reliable results by this method, a Clarke-Bumpus net is utilized so that more water can be filtered. Samples are collected from depths and locations in the cross section as shown in Table 15 and Figure 18. Total dry weight, number, and species composition are determined for all samples.

The quantity and photosynthetic activity of phytoplankton present in water samples are estimated by determinations of chlorophyll content, species composition, total number, and primary production rate. Samples of plankton are collected at three points in the cross section at each station (Table 16).

(d) Bottom fauna - Three dredge hauls are made with a Petersen or Ekman dredge at each of three points in six of the eight cross sections of the reservoir. Only two points are being sampled at TRM 307.5 since water is confined mostly to the original channel at minimum pool elevation. Four points are being sampled at TRM 291.8 because of the dissected nature of the channel. Sampling points at the eight stations are located at various distances from the left bank of Wheeler Reservoir in accordance with bottom morphology shown by sediment range profiles. Markers are located on shore and buoys are located in the river to identify sampling stations. The number of samples may be altered depending on the variability observed. Locations are listed in Table 16. Samples are being analyzed for total number and species composition.

(e) Analysis of data - Data collected at three key sampling stations have been selected for routine analysis--TRM 288.8, TRM 293.7, and TRM 307.5. The warm water diffuser is located at approximately TRM 294. A modified control charting procedure will be employed in this study.

Because of possible seasonal trends, means and variances will be calculated for each quarter. The variances will be used to construct a band of values from which the variables would differ only rarely by chance alone.

For unreplicated data, where an estimate of the variance is not available from other sources, trend charts will be used to detect changes in the overall mean. The interpretation of these charts will necessarily be subjective, but where variability is low, the trend charts should be adequate to detect significant changes. Trend charts and modified control charts will be made after the last preoperational survey has been completed.

4. <u>Potential hazards to fish of cooling water intake and discharge</u> - Small meshed traveling screens are provided on the circulating water pump intakes so that larger fish forms will not be entrapped or pass through the condensers. The traveling screen consists of a number of screen sections, fastened top to bottom, to form an endless belt of screens. The screens move continually through the cooling water intake to remove trash and other debris. This debris, along with any entrained fish, is washed off the screen in their upward pass and returned to the reservoir.

TVA has not encountered problems with fish entrapment at any of its large coal-fired steam plants, all of which are equipped with similar screens.

5.7 Radioactive Discharges - In the operation of any nuclear plant, radioactive materials are produced by fission and activation of materials in the reactor. Most of this radioactive material is retained in the fuel elements and removed with the spent fuel, and small amounts are retained in the reactor vessel and associated piping. Normally, small amounts of fission products from inside the fuel rods leak into the coolant. The necessity to continually renew a portion of the primary coolant results in the accumulation of both liquid and gaseous wastes during normal reactor operation. Demineralization and filtration remove all but a small fraction of the dissolved and suspended radioactive matter (but none of the tritium) from the liquid wastes. Liquid wastes containing low concentrations of radioactive impurities are filtered, sampled, analyzed, and diluted as discharged.

1. Waste management - TVA's policy is to keep the discharge of all wastes from its facilities, including nuclear plants, at the lowest practicable level by using the best and highest degree of waste treatment available under existing technology, within reasonable economic limits.

This policy has been implemented at Browns Ferry by improving plant design to include extended treatment for gaseous radwaste and by changing the processing for liquid radwaste. Hydrogen recombiners and 6 charcoal beds will be added to each unit to reduce radioactive gaseous wastes to very low levels. By processing floor drain wastes through a demineralizer, radioactivity in liquid effluents will also be reduced to very low levels. Population doses due to these very low level discharges are considered to be unmeasurable with existing measurement techniques. Calculated doses to the population are given in Section 5.7.2.

The radioactive waste systems are designed to dispose of the radioactive process wastes generated during plant operation. These wastes can be solid, liquid, or gaseous. The liquid and gaseous radioactive wastes are discharged to local water and to the atmosphere, respectively, at concentrations which at a maximum are well below established regulatory limits. Liquid wastes which cannot be reused, discharged to the environs within the regulatory limits, or reprocessed effectively, are packaged for offsite disposal, as are solid wastes.

All gases and liquids are carefully monitored before being released, and complete records are maintained to ensure that concentrations and quantities released are well within applicable limits. Discharge and shipment of solid, gaseous, and liquid radioactive wastes are in accordance with AEC Regulations 10 CFR Parts 20 and 71.

A detailed discussion of the waste processing equipment itself is not undertaken here since it will be evaluted in the context of the 10 CFR Part 50 licensing procedure. Sections (1), (2), and (4) below describe the solid, gaseous, and liquid radwaste systems as originally designed. Sections (3) and (5) describe the extended treatment of gaseous radwaste and additional processing of liquid radwaste respectively.

(1) <u>Solid radwaste system</u> - The solid radwaste system collects, processes, stores, packages, and prepares

for shipment solid radioactive waste materials produced through operation of the three reactor units.

Wet solid wastes are stored in phase separator tanks or the spent resin tank. After appropriate storage periods, the wet solid wastes are packaged in 55-gallon drums, disposable tanks in reu able shields, or disposable tanks with integral shields.

Dry solid wastes, such as contaminated rags, paper, clothing, spent filter elements, laboratory apparatus, small parts and equipment, and tools, are collected in suitable containers placed throughout the plant. Compressible wastes are packed into 55-gallon drums with a baling machine. Large-sized noncompressible items are packed in 55-gallon drums or are mixed with compressible materials and put through the baling machine. Large-sized contaminated items are encapsulated in steel containers or encased in concrete.

Solid radwastes are packaged and shipped from the plant in accordance with the requirements of the AEC, the U.S. Department of Transportation, and the states through which the wastes pass en route to the disposal area.

(2) Gaseous radwaste system - One gaseous radwaste system is provided for each unit. Each system, as originally designed, collects and processes gaseous radioactive wastes from the main condenser air ejectors, the startup vacuum pumps, and the gland seal condensers. The processed gases from each unit are routed to the plant stack for dilution and elevated release to the

atmosphere. Each air ejector offgas line at the stack is continuously monitored by radiation monitors.

Gaseous radwaste consists mostly of the many isotopes of the inert gases krypton and xenon which result only from leaky fuel. In addition, a small amount of volatile iodine may be present, as well as radioactive gaseous products resulting from nuclear reactions with the reactor water and with air dissolved in the water.

The activity leaving the stack is substantially below that leaving the reactor because of decay in transit and the fact that part of the N-13 and N-16 and most of the O-19 remain with the condensate and do not follow the noncondensibles. Other radioactive gases which may also be present are H-3, N-17, Ar-37, and Ar-41. These will be present in amounts so low that they are insignificant when compared with the N-13. About one percent of the activity arriving in the primary steam at the turbine will go to the gland seal condensate.

Gases routed to the plant stack include air ejector and gland seal offgases and gases from the standby gas treatment system. Dilution air is provided by fans within the plant stack. Dilution air input to the stack is required to dilute the hydrogen concentration in the stack gas to less than 4 percent by volume.

The stack is designed to enable prompt mixing of all gas inlet streams in the base and to allow location of sample points as near the base as possible. Stack drainage is routed to the liquid radwaste collection system via a submerged inlet sump. Design values for volume releases from a single unit are given below:

Hydrogen (from Reactor Water Decomposition)	154 ft^3/min
Oxygen (from Reactor Water Decomposition)	77 ft^3/min
Air (Inleakage to Turbine Condenser)	12 - 28 ft^3/min
Water Vapor (to Saturate)	43 - 46 ft^3/min
Activated and Noble Gases	Negligible
Total Gases	286 - 305 ft^3/min

In the absence of fuel rod leaks, N-13 from the air ejector offgases and the N-16 and O-19 from the gland seal system are the principal contributors to environs radiation dose. If fuel rod leaks do occur, the noble radioactive gases, Xe and Kr, become the principal contributors.

(a) Air ejector offgas subsystem - As originally designed, the air ejector subsystem collects gases from the condensers and passes them through holdup piping and filters prior to release to the stack. The 30-minute holdup is provided by means of a long, large-diameter pipe. The pipe is buried underground to provide shielding.

The air ejector offgases are processed through either one of the two particulate filter trains at a time. The other filter train that is not being used provides redundancy to ensure the availability of filters at all times. These filters have a design efficiency of 99.95 percent for particles 0.3 micron and larger.

When the maximum permissible radioactivity concentration in the offgas line is exceeded at the monitoring point, a valve in the line near the stack closes automatically after 15 minutes unless the operator acts to reduce the concentration. This prevents release of excessive radioactivity to the atmosphere.

(b) <u>Gland seal offgas subsystem</u> - The gland seal offgas subsystem collects gases from the gland seal condenser and the mechanical vacuum pumps and passes them through holdup piping prior to release to the stack. This subsystem provides a 1.75-minute holdup time to allow decay of N-16 and O-19. The holdup time if provided by a long, large-diameter pipe between the gland seal exhauster and the stack. Operating and design pressure is atmospheric; no explosive mixture is present during normal operation. No filters or radiation monitors are required.

(3) <u>Extended treatment of gaseous radwaste</u> - The gaseous radwaste system will be changed to further reduce radioactive gaseous wastes to very low levels. Hydrogen recombiners and charcoal beds will be installed in the air ejector offgas system for each unit. The offgases from each unit's air ejector will be passed through hydrogen recombiners. These react radiolytic hydrogen and oxygen to produce water, which can then be condensed and removed. Recombiners reduce the volume of the offgases by about 90 percent and thereby permit greater decay time in the holdup piping downstream of the recombiners. The principal gaseous isotopes and estimated quantities of each are shown in Table 19.

Addition of this equipment substantially increases the holdup time for radioactive noble gases, thus reducing the expected dose at the site boundary to a small fraction of that expected with the 30-minute holdup alone. The following table shows the doses calculated for the 3-unit plant with hydrogen recombiners and 6 charcoal beds installed on each unit.

As Originally Designed With 30-Minute Holdup	Stack Limit 1/	Extrapolated BWR Operating Experience 2/
Fuel Defects %/Unit	0.8	0.5
Offgas Release, Ci/sec	1.11	0.65
Site Boundary Dose, mrem/yr	500	290

Recombiners and Charcoal Beds Installed 3/		Extrapolated BWR Operating Experience 2/
Site Boundary Dose (fence post) mrem/yr	4.6	2.7
Percent 10 CFR Part 20 Limits	0.93	0.54

Releases based on a condenser air inleakage of 18.5 ft^3/min.

1/ For 30-minute holdup.

2/ Based on semiannual operating reports to AEC on BWR's.

3/ For 7.7 day holdup of Xe and 16.5 hour holdup for Kr.

This table is based on actual releases from an operating reactor of similar design to the Browns Ferry plant; it assumes three-unit operation for 365 days per year. The calculations do not take credit for the fact that units are out of service for some periods during the year.

The timing of the completion of the recombiner charcoal bed installation in the air ejector offgas subsystem is not firm, but the work cannot be completed in time to be ready for startup of the first unit. The tentative schedule is for the equipment to be installed and operational before startup at the beginning of the second fuel cycle on Unit 1. Based on BWR operating experience, it is expected that the plant can begin operation while the design and installation of the extended gas treatment system is being completed.

(4) Liquid radwaste system - The liquid radwaste system as originally designed collects, treats, and returns processed radioactive liquid wastes to the plant for reuse. Treated radioactive wastes not suitable for reuse are discharged from the plant or packaged for offsite disposal.

A single system, located in the radwaste building, is designed to handle the radioactive liquid wastes from all three units of the plant. The following are included in the liquid radwaste system:

1. Piping and equipment drains carrying potentially radioactive wastes;
2. Floor drain collector systems in controlled access areas and those areas which may contain potentially radioactive wastes; and
3. Tanks, piping, process equipment, instrumentation, and auxiliaries necessary to collect, process, store, and dispose of potentially radioactive wastes.

The system is divided into several subsystems so that the liquid wastes from various sources can be kept segregated and processed separately. Cross connections between the subsystems provide additional flexibility for processing of the wastes by alternate methods. The liquid radwastes are classified, collected, and treated as either high purity, low purity, chemical, or detergent wastes.

(a) High purity wastes - High purity (low conductivity) liquid wastes are collected in the waste collector tank, and then processed by filtration and ion exchange through the waste filter and waste demineralizer. After processing, the waste is pumped to a waste sample tank where it is sampled and then, if satisfactory for reuse, transferred to the condensate storage tank to be recycled as makeup water. If the analysis of the sample reveals water of high conductivity (>1 μmho/cm) or high radioactivity concentration ($> 10^{-3}$ μCi/ml), it is returned to the system for additional processing.

(b) Low purity wastes - Low purity (high conductivity) liquid wastes are collected in the floor drain collector tank. These wastes generally have low concentrations of radioactive impurities. Processing consists of filtration and subsequent transfer to the floor drain sample tank for sampling and analysis. If the analysis indicates that the concentration of radioactive contaminants is sufficiently low, the sample tank batch is released to the condenser circulating water as necessary to meet plant effluent requirements. Because no radium-226 or radium-228 of plant origin will be present, and because the potential concentration of iodine-129 is very low, a value of $10^{-7} \mu Ci/ml$ above the background is taken as discharge conduit concentration limit for an unidentified mixture of radioisotopes. It is expected that a substantial fraction of the liquid entering the floor drain system will be of low conductivity. This liquid will be transferred to the high purity system for processing by demineralization.

(c) Chemical wastes - Chemical wastes are collected in the chemical waste tank and are of such high conductivity as to preclude treatment by ion exchange. The radioactivity concentrations are variable and substantially affected by the use of decontamination solutions and by the amount of fission product radioactivity present. Normally, the radioactivity concentrations are low enough to meet discharge conduit concentrations limits (after dilution), and these wastes are processed by filtration and dilution in the same manner and with the same equipment as the low purity wastes.

(d) Detergent wastes - Detergent wastes are collected in the laundry drain tanks. These wastes are primarily from radioactive laundry operations and decontamination solutions which contain detergents. Detergent wastes are of low radioactivity concentration ($\leq 10^{-5} \mu Ci/ml$). Because these wastes will foul ion exchange resins and filter media, they are kept separate from the high and low purity wastes. They are sampled, filtered through the laundry drain filter, and discharged into the circulating water discharge conduits.

These liquid wastes are released at a rate to give an unidentified isotope concentration of not more than $10^{-7} \mu Ci/ml$ in the discharge conduits during the period of the discharge. Since the discharge occurs only part of the time, the daily average concentration in the conduits is correspondingly less. The discharge from the conduits to the environs, therefore, is less than MPC for a mixture with unidentified radioisotopes, that is, 10^{-7} μCi/ml. Mixing in Wheeler Reservoir provides additional dilution.

(e) Fuel cask decontamination waste - Water used in decontaminating the spent fuel shipping cask is collected in a tank in the radwaste building. The radioactivity concentration of this water should be less than 10^{-6} μCi/ml. This low activity water is filtered with the laundry drain filter and discharged.

Tritium is present in the plant effluent. However, the concentration expected in the diluted effluent is about 10^{-8} μCi/ml. The MPC for tritium in drinking water is 3×10^{-3} μCi/ml. The proposed Appendix I to 10 CFR Part 50 would require that the estimated annual average concentration of tritium prior to dilution in a natural body of water should not exceed 5×10^{-6} μCi/ml. Thus, it is evident that the tritium in the effluent from the Browns Ferry Nuclear Plant is negligible.

(5) Additional processing of liquid radwaste - The operation of the liquid radwaste treatment system will be modified to further reduce radioactive liquid wastes to very low levels. Because a substantial fraction of the liquids entering the floor drains is expected to be of low conductivity, it will be possible to process tham by demineralization. The demineralized effluent will have a lower radioactivity content and will be recycled or discharged.

This modification of liquid radwaste treatment for Browns Ferry will result in a substantial reduction of radioactivity released in liquid effluents. Excluding the minimal quantities of tritium previously mentioned, only about 5 Ci/yr of radioactive material is expected to be released in liquid effluents from all three units. Table 20 shows the reduction in quantities of principal isotopes resulting from this modification.

2. Important pathways of exposure to man - This section covers the important pathways of exposure to man, estimated increase in environmental radioactivity levels, and potential annual doses to individuals and population groups from principal radionuclides discharged.

(1) Pathways to man - Although the amounts of radioactivity added to the environment from plant operation are small, critical exposure pathways to man have been identified in order to estimate the maximum dose to the individual and to establish the sampling requirements for the environmental radiological monitoring program. These pathways include:

1. Whole body dose from gaseous releases.
2. Drinking water from Wheeler Reservoir and from wells in the immediate vicinity of the plant.
3. Swimming, boating, fishing, or walking along the shore of the lake in the vicinity of the plant.
4. Eating fish from the lake.
5. Consuming milk and other dairy products from locations affected by the gaseous releases.
6. Eating foods grown in areas adjacent to the plant site affected by the gaseous releases.

The environmental monitoring program provides sampling necessary to determine the dose received through these critical pathways. The following items indicate the measurement made and samples collected in order to make the critical pathway-dose correlation.

1. Thermoluminescent dosimeters will be utilized to measure the whole body dose received from the gaseous emissions from the plant. The results from these dosimeters can be compared with the calculations presented in Appendix E, Browns Ferry Nuclear Plant Final Safety Analysis Report, and other doses can be calculated in any sector at any given distance using meteorological data collected at the site. The dosimeters are located on a 500-foot grid onsite, which extends out to a distance of one mile, and at each air monitoring station offsite.

2. River water samples are collected at the point of discharge of the diffuser pipes to the river, 500 feet below this point, and at four other river cross sections, 3 miles to approximately 15 miles downstream of the site. All public water intakes receiving water from the Tennessee River within 50 miles downstream and 15 miles upstream of the plant are also collected. Private well water samples are collected from 10 locations within 4 miles, and 9 public well water supplies are sampled within a 20-mile radius of the plant. The results obtained from the analysis of these samples can be used to calculate the dose received from drinking water from Wheeler Reservoir or wells in the vicinity of the plant.

3. Results obtained from the samples referenced in Item 2 can be used to calculate the dose an individual might receive while swimming, boating, fishing, or walking along the shore of the lake in the vicinity of the plant.

4. Samples of river water, bottom sediment, plankton, and three species of fish are taken from 9 cross sections of Wheeler Reservoir. These samples will be correlated to determine the dose received by an individual eating fish obtained from Wheeler Reservoir.

5. &6. Samples of air particulate matter are collected continuously on fiber glass filters and gum paper trays at 12 locations out to a distance of 35 miles from the plant. In addition, charcoal filters are utilized at each monitor station to sample for iodine. Samples of soil, vegetation, food crops, and milk are also collected to determine dose to the surrounding population through the consumption of food or dairy products.

All samples referenced will be analyzed for the 10 most biologically significant gamma-emitting radioisotopes found in the liquid waste stream of the plant. In addition, an analysis for $^{89,90}Sr$ and ^{3}H will also be performed.

3. <u>Estimated increase in annual environmental radioactivity levels and potential annual radiation dose from principal radionuclides</u> - As previously noted, the releases of radioactivity to unrestricted areas from the Browns Ferry Nuclear Plant will be so low as to be unmeasurable with present measurement techniques. However, TVA has calculated the expected increase in radioactivity levels and potential radiation doses to the population as a result of these low-level releases. These calculations, by necessity, were based on the following very conservative assumptions.

(a) All three reactors operate at full power, 365 days per year, with 0.8 percent failed fuel.

(b) All persons within a four-mile radius of the plant drink water having the same radioactivity concentrations as that in the plant effluent, before dilution (no public water supplies are actually located within this four-mile zone).

(c) For estimation of individual doses, the hypothetical individual is assumed to be located at the highest dose point on the site boundary, 24 hours a day, 365 days per year.

Based on these conservative assumptions, estimated quantities and concentrations of radioactivity released to the environment and calculated radiation doses to the population are summarized as follows:

ESTIMATED QUANTITIES AND CONCENTRATIONS OF RADIOACTIVITY RELEASES AND CALCULATED RADIATION DOSES

BROWNS FERRY NUCLEAR PLANT

	Browns Ferry	Proposed 10 CFR Part 50 Appendix I Limit
A. Liquid Effluents		
1. Annual total quantity (except tritium)	5 Ci	15 Ci
2. Annual average concentration (before dilution in Wheeler Reservoir)	1.3×10^{-9} μCi/ml	2×10^{-8} μCi/ml
3. Annual average concentration of tritium (before dilution in Wheeler Reservoir)	1×10^{-8} μCi/ml	5×10^{-6} μCi/ml
4. Annual whole-body dose to any individual (based on specific isotope identification)	1 mrem	5 mrem
B. Gaseous Effluents		
1. Annual whole-body dose to any individual	4.6 mrem	10 mrem
C. Total Annual Whole-Body Dose to any Individual	5.6 mrem	-----
D. Total Estimated Population Dose (Based on 1,360 people within the 4-mile radius)	3.0* man-rems	-----

*Annual Population doses from naturally occurring background radiation to persons within four miles of the plant is estimated to be 156 man-rems. The Browns Ferry Nuclear Plant will contribute only about 2 percent of this naturally occurring population dose.

4. <u>Conclusion</u> - TVA intends to use data from plant operating records, experience from other operating boiling water reactors of similar design to Browns Ferry and the results of its extensive environmental monitoring program to assure that the plant is operated in accordance with TVA's environmental protection objectives. Based on the very low releases of radioactivity expected from from the Browns Ferry plant, and the calculated low doses to individuals and the general population in the vicinity of the plant, it is concluded that the Browns Ferry Nuclear Plant will operate within all applicable regulations and with a minimum risk to the health and safety of the public.

5.8 <u>Construction Effects</u> - The Browns Ferry plant has been under construction since September 1966, when site preparation began. Construction of units 1 and 2 began in May of 1967, and of unit 3 in August of 1968. All excavation work for structures has been completed, and 53% of the facility has been constructed. All access facilities have been constructed. The roads are still to rough grade. Asphalt surfacing will be completed in 1973.

The condenser water diffuser pipes are currently being placed in the river. The remains of the dike across the intake channel, which was used during the construction of the intake structure, is being dredged. These activities will cause some increased turbidity in the water, but it will be of short duration. Plans call for the riverside to be riprapped. Some of this work has been completed.

The remaining construction activities should not have an adverse impact on the area. Remaining chemical cleaning operations that may be required will be conducted to ensure that any liquids released have been effectively neutralized and diluted to acceptable concentrations prior to release.

A small marina has been constructed to accommodate several boats which will be used in ecological studies.

In addition, a fill has been made for the facilities to be used in the research project on the effects of heated water on aquatic life.

5.9 <u>Aesthetics</u> - The aesthetic design of the Browns Ferry Nuclear Plant is based on the broad principle of total environmental planning, having for its objective the creation of harmony between plant and environment.

The site is a virtually level tract along the shore of Wheeler Lake. The plant structures are grouped in a diminishing progression of scale from the reactor and turbine buildings, with their reinforced concrete bases and high, ribbed metal-sided superstructures, to the lesser service and office buildings. A berm around the base of the reactor building forms a transition between the lake shore and the concrete walls. Earth mounds provide a shield around the area used for removal of radioactive wastes. The concrete service building is a transition between the reactor and turbine building masses and the smaller steel-framed office building. A 600-foot-high hyperbolic curved concrete stack for offgas emissions is designed and positioned as a focal point.

Particular attention is given to site development and landscaping. Natural features of the terrain are preserved as much as possible and utilized to reduce the impact of the installation on man and environment. The plant approach and entry area is fenced to contain and channel circulation through the control points. A specially designed steel fence, of the vertical picket type, departs from the customary industrial fence of mesh and barbed wire. Roads, walks, and planting are planned to create a human scale as a pleasant and inviting setting for both employees and visitors. A visitor overlook makes use of a natural rise in the terrain for a comprehensive view of the project and the lake. The principal access highway closely follows the alignment and grade of an existing county road.

6.0 ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED

The CEQ Guidelines require a discussion of any probable adverse environmental effects which cannot be avoided, such as water or air pollution, damage to life systems, urban congestion, threats to health or other consequences adverse to the environmental goals set out in Section 101(b) of NEPA.

6.1 Water Pollution - Chemical, sanitary, and radioactive wastes will of necessity be discharged into Wheeler Reservoir. Prior to being discharged, however, various treatment is provided to ensure that all applicable standards are met and the quantities and concentrations released will be small enough to ensure that any probable adverse environmental effects are insignificant or undetectable. Additional processing of liquid radwaste will be instituted to keep releases as low as practicable. Water, aquatic life, and life systems will be monitored. Extensive studies on the effects of heated water on aquatic life will be conducted in order to detect any adverse effects.

6.2 Air Pollution - Radioactive releases in the form of gaseous wastes will be discharged into the air. Installation of hydrogen recombiners and charcoal beds will assist in holding these releases to the lowest practicable levels, consistent with current technology and feasibility of available systems. This should hold these releases to levels that will avoid significant adverse environmental effects. Careful monitoring will be conducted to ensure this result.

6.3 Damage to Life Systems - When cooling water passes through the traveling screens enroute to the condensers, fish larvae may be drawn into the intake water. At this time, it is not known the extent, if any, to which fish larvae are present near the condenser cooling water intake. Studies are under way to determine this, and, as operating experience is gained, to develop steps which could prevent or reduce the intake of fish larvae. Plankton present in the condenser cooling water will also be destroyed, in the sense that it is changed as a source of food when seasonally subjected to temperatures in excess of 96.8° F. in passing through the condensers. However, at the time when the most adverse conditions exist for plankton damage, only about 25 percent of the total riverflow passes through the condensers. Based on TVA's experience with other large thermal plants, rapid reseeding of plankton populations downstream of the condenser outfall would be expected. To the extent that this plankton serves as a food source to aquatic life, its destruction is an adverse effect which cannot be avoided.

There may be some loss of existing river bottom fauna and habitat in the immediate vicinity of the diffuser pipes, which is an adverse effect which cannot be avoided.

While these effects cannot be avoided, they are not expected to damage significantly any life system. Extensive studies to be conducted will forewarn possible adverse effects.

6.4 Threats to Health - The facility is being designed and constructed and will be operated in accordance with all applicable Federal and state regulations in order to assure that the health and safety of the public will be safeguarded.

6.5 Socioeconomic Effects - The "primary" and "secondary" social and economic impacts were covered in Section 5.0. As indicated, the total magnitude of these impacts is large; however, the distribution of residences and local material supply sources occurs over a forty-mile radius of the plant site. While this may produce temporary stress on the social infrastructure (schools, roads, housing, and similar services), it will also provide a stimulus to area economical development (jobs, attraction of visitors, etc.). There should be no severe social or economic dislocation as the project construction phases out.

6.6 Conclusion - The operation of Browns Ferry will result in some probable adverse environmental effects which cannot be avoided. However, these effects are not expected to conflict with the environmental goals set out in Section 101(b) of NEPA. If any adverse effects attributable to operation of the plant become evident through the various environmental monitoring programs, then appropriate steps will be taken to correct the situation.

7.0 ALTERNATIVES

Section 102(2)(C) of NEPA requires a discussion of alternatives to the proposed action, and Section 102(2)(D) requires an agency to "study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources."

Decisions leading to plans to construct the Browns Ferry facility were made in 1965-1966, four to five years prior to passage of the National Environmental Policy Act. At that time TVA made economic studies comparing nuclear with conventional fossil-fired units. These studies indicated that nuclear units offered significant economic advantages. The facility is now over 53 percent constructed, with over 90 percent of the design completed. The amount of money expended on the project through May 1971 is $354,740,000. Photographs of various parts of the construction, taken in March and April 1971, are shown in Appendix I. There are no feasible alternatives available at this time to the continued construction and operation of the Browns Ferry facility.

Even though construction on Browns Ferry began prior to passage of NEPA, TVA will, of course, comply with NEPA to the fullest extent possible at Browns Ferry.

7.1 Electric Power Purchases - To supply equivalent amounts of power and energy on a year-round basis to TVA, another large electric utility with extensive transmission interconnections would have to install generating capacity in amounts slightly greater than that of Browns Ferry, build several high capacity transmission lines to the TVA area, and transmit the power to TVA. To construct such facilities on another power system would not avoid an impact on the environmentment, but would only transfer such impact from one area to another. Even if the assumption is made that the plant locational factors and costs would be equal, the cost of transmission lines, the transmission line losses, the use of land for transmission line rights of way, and the exposure to transmission line outages would result in waste of natural resources, materials, and funds, and would provide a more costly and less reliable source of power for the TVA region than will Browns Ferry.

7.2 Alternative Generation - Planning for this capacity required that considerations be given to maintaining a practical mix of hydro, pumped-storage hydro, gas turbine, coal-fired, and nuclear generating units. The system needs, as suggested by TVA planning studies, required that the generating capacity represented by Browns Ferry be either base-loaded coal-fired units or nuclear-fueled units, and detailed consideration was given to these alternatives. Estimates of the total installed cost, assessment of the technical aspects of the offerings, and an economic evaluation were made in comparison with an alternative coal-fired unit similar to our Cumberland Steam Plant.

Because of the unavailability of natural gas and low sulfur residual fuel oil for base-load generating capacity of the magnitude of Browns Ferry, they offer no feasible alternative to the nuclear facility.

There are no sites available in the TVA service area for hydroelectric generation of this capacity.

Thus, there is no feasible alternative to the proposed construction and operation of Browns Ferry for base-load generating capacity of the size required.

7.3 Alternative Sites - The Browns Ferry site was chosen because of the proximity to large load centers and existing transmission lines, the need for added capacity in the area, and the favorable physical characteristics, including hydrology, geology, meteorology, and seismology. It is not practicable to reassess and choose an alternative site at this state in the development and construction of the Browns Ferry plant.

7.4 Alternative Heat Dissipation Methods - TVA's experience with steam plants on the Tennessee River demonstrates that dissipation of heat into the river from existing power plants has not resulted in significant adverse effects on aquatic life. The Paradise studies show the effectiveness of monitoring programs in detecting adverse effects which may develop. TVA's experience at all of its steam plants, and particularly at Paradise, indicates that a maximum temperature of 93° F., and a 10° F. rise, should adequately protect aquatic life in the Tennessee River. Comprehensive monitoring programs already started at Browns Ferry and TVA's extensive knowledge of aquatic life in

Wheeler Reservoir will enable TVA to assess any effects the cooling water discharges may have on aquatic life in Wheeler Reservoir.

Regardless of what temperature standards may finally be adopted by Alabama and approved by the Environmental Protection Agency, TVA will take such steps as are necessary to prevent the development of any significant adverse effects of the Browns Ferry plant on aquatic life.

Results of the comprehensive monitoring programs, in conjunction with the research to be conducted in cooperation with the Environmental Protection Agency outlined in Appendix IV, should provide the data necessary to fully evaluate the current thermal standards and any effects which they may have on aquatic life.

TVA is aware that Alabama may in the future, with EPA approval, tighten present standards for thermal releases. TVA will, of course, take appropriate action on a timely basis to meet any future applicable standard and to protect the aquatic environment.

Among the alternatives being studied to meet possible lower temperature standards are cooling towers for one or more of the Browns Ferry units in various combinations with the utilization of various amounts of cooling water from Wheeler Reservoir. Cooling lakes are not being considered at this time, since the geography of the area is not well suited to development of a large lake. In addition, the physical arrangement of the plant facilities is essentially complete and does not lend itself to the use of such cooling facilities.

Current studies of alternatives will permit the decision on any type of needed auxiliary cooling system to be made on a timely basis. TVA studies indicate that the maximum rise in river temperature will not exceed 5° F. with only the first power unit in service--utilizing the diffuser system with supplementary flow in Wheeler Reservoir and/or by adjustments to the power load carried by the unit. Supplementary flows and load adjustments would only be needed a very small percentage of the time.

8.0 SHORT-TERM USES VERSUS LONG-TERM PRODUCTIVITY

CEQ Guidelines call for a discussion of the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity. This requires an assessment of the construction and operation of the plant for cumulative and long-term effects from the perspective that each generation is trustee of the environment for succeeding generations.

The local short-term uses of the environment are those required to construct and operate the facility. Radioactive effluents will be discharged to the environment, but will be small fractions of the 10 CFR Part 20 limits. A variety of environmental monitoring methods will be utilized to detect and evaluate any radiological impact which might lead to long-term effects in order that timely corrective action can be taken, if required. The effects of chemical and thermal discharges are expected to be negligible.

During the 35-year lifetime of the plant, the site will be used for several environmentally related activities, including recreation, forestry development, and research.

Comprehensive monitoring and studies are scheduled or under way to determine possible effects from plant operation. TVA has a wide variety of experienced personnel in many disciplines to ensure that studies are properly conducted. Experienced consultants will be engaged from time to time to examine TVA findings and to work in areas of special expertise.

These considerations ensure that the local short-term uses of the environment involved in the construction and operation of the plant will not jeopardize the long-term productivity of the environment.

9.0 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

The CEQ Guidelines call for a discussion of any irreversible and irretrievable commitments of resources which would be involved in the construction and operation of Browns Ferry. This requires identifying the extent to which operation of the facility curtails the range of beneficial uses of the environment.

The Browns Ferry plant is located in a rural, relatively isolated and sparsely populated area. The plant will not curtail the beneficial use of land and water resources in the area.

The annual requirement for natural uranium for each reactor is approximately 200 tons of U_3O_8. Some of this uranium can ultimately be recycled for other uses. About 2,000,000 gallons of fuel oil is required for the auxiliary boilers and generators. To the extent that this fuel is consumed and not subject to being recycled to other uses, it is an irreversible and irretrievable commitment of resources. This commitment of resources will be relatively small, however, compared to the benefits obtained from the electricity which will be generated. Moreover, the dependable production of electricity is essential to the health, safety, and welfare of the people.

Since the ultimate disposition of the plant buildings and equipment has not been determined, it must be assumed that both land and construction materials are irreversibly committed. It is unlikely, however, that more than the equipment and land directly in and beneath the reactor building will be ultimately irreversibly and irretrievably committed.

LIST OF TABLES

Table 1

MAJOR TVA SYSTEM CAPACITY ADDITIONS
SINCE CALENDAR YEAR 1949

Plant	Number of Units	Nameplate Capacity-kW Unit	Nameplate Capacity-kW Total	Commercial Operating Date First Unit	Commercial Operating Date Last Unit
Thomas H. Allen 1/	3	330,000	990,000	5-22-59	10-25-59
Bull Run	1	950,000	950,000	6-12-67	6-12-67
Colbert	5	2 @ 200,000	1,396,500	1-18-55	11- 7-65
		2 @ 223,250			
		1 @ 550,000			
Gallatin	4	2 @ 300,000	1,255,200	11- 8-56	8- 9-59
		2 @ 327,600			
John Sevier	4	1 @ 223,250	823,250	7-12-55	10-31-57
		3 @ 200,000			
Johnsonville	10	4 @ 125,000	1,485,200	10-27-51	8-20-59
		2 @ 147,000			
		4 @ 172,800			
Kingston	9	4 @ 175,000	1,700,000	2- 8-54	12- 2-55
		5 @ 200,000			
Paradise	3	2 @ 704,000	2,558,200	5-19-63	2-27-70
		1 @ 1,150,200			
Shawnee	10	175,000	1,750,000	4- 9-53	6-17-57
Widows Creek	8	5 @ 140,625	1,977,985	7- 1-52	2- 7-65
		1 @ 149,850			
		1 @ 575,010			
		1 @ 550,000			

1/ Leased January 1, 1965, from Memphis, Tennessee, Light, Gas, and Water Division

Table 1
(Continued)

MAJOR TVA SYSTEM CAPACITY ADDITIONS
SINCE CALENDAR YEAR 1949

Plant	Number of Units	Nameplate Capacity-kW Unit	Nameplate Capacity-kW Total	Commercial Operating Date First Unit	Commercial Operating Date Last Unit
TVA Hydro					
Boone	3	25,000	75,000	3-16-53	9- 3-53
Chatuge	1	10,000	10,000	12- 9-54	12- 9-54
Cherokee *	2	30,000	60,000	1-29-53	10- 7-53
Chickamauga *	1	27,000	27,000	3- 7-52	3- 7-52
Douglas *	1	26,000	26,000	8- 3-54	8- 3-54
Fontana *	1	67,500	67,500	2- 4-54	2- 4-54
Ft. Patrick Henry	2	18,000	36,000	12- 5-53	2-22-54
Guntersville *	1	24,300	24,300	3-24-52	3-24-52
Hiwassee *	1	59,500	59,500	5-24-56	5-24-56
Melton Hill	2	36,000	72,000	7- 3-64	11-11-64
Nickajack	4	24,300	97,200	2-20-68	4-30-68
Nottely	1	15,000	15,000	1-10-56	1-10-56
Pickwick *	2	36,000	72,000	10-31-52	12-31-52
South Holston	1	35,000	35,000	2-13-51	2-13-51
Wheeler *	5	32,400	162,000	3- 4-50	12-18-63
Wilbur *	1	7,000	7,000	7-19-50	7-19-50
Wilson *	6	3 @ 25,200 3 @ 54,000	237,600	1- 6-50	4-12-62

* Other units in this plant installed in period prior to 1950.

Table 1
(Continued)

MAJOR TVA SYSTEM CAPACITY ADDITIONS
SINCE CALENDAR YEAR 1949

Plant	Number of Units	Nameplate Capacity-kW Unit	Nameplate Capacity-kW Total	Commercial Operating Date First Unit	Commercial Operating Date Last Unit
Alcoa Hydro					
Bear Creek	1	9,000	9,000	4-14-54	4-14-54
Cedar Cliff	1	6,375	6,375	8-22-52	8-22-52
Chilhowee	3	16,667	50,000	8-28-57	10-18-57
Tennessee Creek	1	10,800	10,800	5-19-55	5-19-55
Corps of Engineers Hydro					
Barkley	4	32,500	130,000	1-20-66	3-30-66
Center Hill	3	45,000	135,000	12-11-50	4-11-51
Cheatham	3	12,000	36,000	11-21-59	11- 9-60
Dale Hollow *	1	18,000	18,000	11-17-53	11-17-53
Old Hickory	4	25,000	100,000	4- 9-57	12-23-57
J. Percy Priest	1	28,000	28,000	2- 3-70	2- 3-70
Wolf Creek	6	45,000	270,000	10- 6-51	8-22-52

* Other units in this plant installed in period prior to 1950.

Table 2

AMBIENT AIR

TEMPERATURE DATA
DECATUR, ALABAMA

1879-1958

Month	Avg Temp °F	Avg Max Temp °F	Avg Min Temp °F	Extreme Max Temp, °F	Extreme Min Temp, °F
December	43.7	53.0	34.3	78	- 1
January	42.9	52.3	33.4	79	- 3
February	44.6	54.9	34.4	84	-12
Winter	43.7	53.4	---	---	---
March	53.1	64.1	42.0	93	12
April	61.8	73.2	50.3	92	26
May	70.4	81.8	59.0	100	34
Spring	61.9	73.0	---	---	---
June	78.2	89.3	67.1	108	44
July	80.7	91.2	70.1	107	54
August	79.9	90.6	69.1	107	52
Summer	79.6	90.4	---	---	---
September	74.6	85.9	63.3	104	37
October	63.0	75.2	50.9	100	26
November	51.2	62.3	40.1	86	3
Fall	62.9	74.5	---	---	---
Annual	62.0	72.8	51.2	---	---

Table 3
AMBIENT AIR
TEMPERATURE DATA-BROWNS FERRY NUCLEAR PLANT

March 1967-October 1969

Month	Average Temp °F	Average Max Temp °F	Average Min Temp °F	Extreme Max Temp °F	Extreme Min Temp °F
December	44.4	58.6	25.3	71.0	16.0
January	38.7	57.0	19.5	67.0	10.0
February	38.7	58.3	26.9	67.0	13.0
Winter	40.6	57.9	---	---	---
March	50.7	66.2	31.6	84.0	21.0
April	62.8	74.4	49.6	86.0	33.0
May	67.9	77.9	56.7	89.0	40.0
Spring	60.5	72.8	---	---	---
June	76.5	83.4	62.9	97.0	54.0
July	77.4	82.6	70.2	98.0	55.0
August	75.8	82.8	67.9	99.0	48.0
Summer	76.6	82.9	---	---	---
September	68.5	75.0	57.9	89.0	37.0
October	60.3	72.8	46.6	87.0	30.0
November	48.2	60.5	31.8	78.0	24.0
Fall	59.0	69.4	---	---	---
Annual	59.2	70.7	45.6	---	---

Table 4
PRECIPITATION DATA
Athens, Alabama

1935-1969

Month	Average Number of days with 0-01 inch or more	Monthly Average (inches)	Extreme Monthly Max. (inches)	Extreme Monthly Min. (inches)	Max. in 24 hours (inches)
December	9	5.45	13.70	0.91	4.80
January	11	5.97	14.59	1.53	3.97
February	9	5.62	10.54	1.31	4.85
Winter	29	17.04	---	---	---
March	10	6.17	13.68	1.80	7.35
April	9	4.70	9.34	1.44	2.90
May	8	3.94	9.10	0.33	3.04
Spring	27	14.81	---	---	---
June	7	3.61	9.12	0.50	3.12
July	9	4.47	10.97	0.79	3.27
August	7	3.67	9.36	0.36	3.84
Summer	23	11.75	---	---	---
September	6	3.10	7.45	0.47	3.91
October	5	2.62	6.62	0.15	2.16
November	8	4.17	11.79	1.01	3.02
Fall	19	9.89	---	---	---
Annual	98	53.49	---	---	---

Table 5

PRECIPITATION DATA - BROWNS FERRY NUCLEAR PLANT

March 1967-October 1969

Month	Days with 0.01 inch or more	Monthly Average (inches)	Extreme Monthly Maximum (inches)	Extreme Monthly Minimum (inches)	Maximum in 24 hours (inches)	% of Obs with Precipitation
December	14.5	6.20	8.26	4.14	2.10	11.3
January	12.0	4.99	5.49	4.50	1.63	11.5
February	8.0	2.69	4.11	1.28	1.78	6.4
Winter	34.5	13.88	---	---	---	---
March	6.3	3.13	5.73	1.64	1.56	4.6
April	8.0	3.62	4.75	2.36	4.75	6.2
May	8.0	4.45	6.10	3.03	2.01	6.5
Spring	22.3	11.20	---	---	---	---
June	5.3	1.25	2.14	0.70	1.27	2.0
July	10.0	4.82	7.27	3.23	1.70	4.9
August	11.0	4.96	9.16	1.83	2.76	5.9
Summer	26.3	11.03	---	---	---	---
September	7.0	1.99	2.99	0.70	0.93	5.0
October	6.0	2.38	2.59	2.06	1.23	3.2
November	13.0	4.11	5.34	2.88	1.55	9.1
Fall	26.0	8.48	---	---	---	---

BFNP

Table 6

SNOWFALL DATA
DECATUR, ALABAMA

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Average Snowfall (inches)	0.9	0.8	0.2	T	0	0	0	0	0	T	0.2	0.6	2.7
Average No. Days (trace or more)	1	1	1	*	0	0	0	0	0	*	*	1	6
Average No. Days (0.1 inch or more)	*	*	*	0	0	0	0	0	0	0	*	*	1

T - trace (not measurable)

* - less than one day

Table 7

WATER SUPPLIES WITHIN 20-MILE RADIUS OF BROWNS FERRY AND SUPPLIES TAKEN FROM TENNESSEE RIVER BETWEEN DECATUR AND COLBERT STEAM PLANT

Ref. No.	Public Water Supply	Distance From Site (Miles)[1]	Estimated Population Served[2]	Maximum Demand	Source
1.	Andrell Girl Scout Camp	10.2	220	5,500	Ground
2.	Athens[3]	10.5	16,300	1,900,000	Ground
3.	Chalybeate Jr. High School	13.3	300	7,500	Ground
4.	Clements High School	8.0	650	16,000	Ground
5.	Colbert Steam Plant[3]	49.0	350	65,000	Surface (TRM 245.0)
6.	Courtland[3]	11.6	1,780	40,000	Ground
7.	Decatur[3]	12.0	42,600	17,000,000	Surface (TRM 306.0)
8.	E. Limestone High School	17.2	800	20,000	Ground
9.	Elkmont[3]	17.2	390	15,000	Ground
10.	Fisherman's Resort	17.0	100	2,200	Ground
11.	Hartselle[3]	16.5	11,400	833,000	Surface (Flint Creek Mile 12.3)
12.	Hatton Elementary School	19.6	160	3,100	Ground
13.	Lawson's Trailer Court	9.4	160	10,000	Ground
14.	Lucy Branch Park	8.0	170	700	Ground
15.	Midway Elementary School	13.0	150	3,800	Ground

1. Radial distance to ground supplies (and Flint Creek intake for Hartselle) and river mile distance (from mile 294.0) to surface supplies.

2. For municipal water supplies the population served was estimated by multiplying the number of meters by 3.75.

3. Municipal supply or TVA supply.

Table 7
(Continued)

WATER SUPPLIES WITHIN 20-MILE RADIUS OF BROWNS FERRY AND SUPPLIES TAKEN FROM TENNESSEE RIVER BETWEEN DECATUR AND COLBERT STEAM PLANT

Ref. No.	Public Water Supply	Distance From Site (Miles)[1]	Estimated Population Served[2]	Maximum Demand	Source
16.	Moulton[3]	18.7	2,775	400,000	Ground
17.	Moulton Heights Jr. High School	8.7	200	5,100	Ground
18.	Neel Elementary School	15.8	120	3,100	Ground
19.	New Hope Jr. High School	18.0	260	6,400	Ground
20.	Owens Jr. High School	12.0	450	11,000	Ground
21.	Piney Chapel Jr. High School	15.2	440	11,000	Ground
22.	Pleasant Grove Elementary School	9.7	100	2,600	Ground
23.	Priceville High School	17.7	900	22,000	Ground
24.	Pryor Branch Rest Area	9.5	270	800	Ground
25.	Rogersville[3]	13.0	1,433	150,000	Ground
26.	Sheffield[3]	39.7	16,300	2,407,000	Surface (TRM 254.3)
27.	South Limestone Water and Fire Protection Authority[3]	16.7	610	40,000	Ground
28.	S.W. Center Elementary School	8.5	190	4,700	Ground

1. Radial distance to ground supplies (and Flint Creek intake for Hartselle) and river mile distance (from mile 294.0) to surface supplies.

2. For municipal water supplies the population served was estimated by multiplying the number of meters by 3.75.

3. Municipal supply or TVA supply.

Table 7
(Continued)

WATER SUPPLIES WITHIN 20-MILE RADIUS OF BROWNS FERRY AND SUPPLIES TAKEN FROM TENNESSEE RIVER BETWEEN DECATUR AND COLBERT STEAM PLANT

Ref. No.	Public Water Supply	Distance From Site (Miles)[1]	Estimated Population Served[2]	Maximum Demand	Source
29.	Speake High School	19.5	500	13,000	Ground
30.	Spring Creek Dock	9.8	120	4,400	Ground
31.	Tanner High School	9.8	780	20,000	Ground
32.	Tennessee Valley High School	5.0	400	10,000	Ground
33.	Town and Country Motel	10.0	200	3,100	Ground
34.	Town Creek[3]	17.0	1,594	50,000	Ground
35.	Trinity[3]	7.0	780	80,000	Ground
36.	West Limestone High School	15.5	550	14,000	Ground
37.	Wheeler Dam[3]	19.1	50	72,000	Surface (TRM 274.9)
38.	Wilson Dam (National Fertilizer Development Center[3])	34.6	2,500	4,000,000	Surface (TRM 259.4)

1. Radial distance to ground supplies (and Flint Creek intake for Hartselle) and river mile distance (from mile 294.0) to surface supplies.

2. For municipal water supplies the population served was estimated by multiplying the number of meters by 3.75.

3. Municipal supply or TVA supply.

Table 8.

STATISTICAL DATA FOR NEARBY COUNTIES

Employment - 1960	MORGAN	MADISON	LIMESTONE	LAWRENCE
	COUNTIES			
Agriculture	1,852	3,305	2,765	2,099
Forestry and Fisheries	183	23	44	11
Mining	39	33	8	14
Construction	1,888	2,789	1,116	677
Manufacturing	6,161	13,637	2,304	1,315
Transportation	527	636	264	121
Communication	332	382	118	16
Utilities	163	303	79	156
Wholesale and retail trade	3,219	6,220	1,784	760
Finance, insurance, and real estate	594	859	151	59
Business and personal services	1,893	3,853	1,094	478
Entertainment and recreation services	92	186	35	24
Hospitals	420	390	135	33
Education services	838	1,807	566	282
Welfare and nonprofit organizations	212	335	75	6
Professional and related services	345	866	122	49
Public administration	726	2,117	494	224
Industry not reported	477	741	127	123
Total Employment	19,961	38,482	11,281	6,437

Table 8
(Continued)

STATISTICAL DATA FOR NEARBY COUNTIES

	COUNTIES			
Agricultural Use - 1964	MORGAN	MADISON	LIMESTONE	LAWRENCE
Total farmland (acres)	212,124	335,534	277,443	250,804
Number of farms	2,156	1,949	2,025	1,951
Percent of total land	57.7	65.3	79.5	57.1
Cropland harvested	1,738	1,695	1,741	1,623
Value of Products Sold - 1964 (Dollars)				
(Commercial farms only)				
Crops	4,534,577	13,841,386	10,344,299	8,214,073
Poultry & poultry products	4,411,756	653,119	1,737,650	2,751,190
Dairy products	761,844	954,294	885,537	593,183
Other livestock	3,354,374	1,701,699	1,267,874	1,063,890
Total	13,063,734	17,159,501	14,239,710	12,624,637
Livestock & Poultry on Farms - 1964 (Number)				
Cattle and calves	34,568	43,869	32,512	30,959
(milk cows)	(3,366)	(3,627)	(3,940)	(3,221)
Sheep and lambs	430	211	178	17
Hogs and pigs	13,888	14,599	9,264	11,467
Chickens (4 months old and older)	344,899	121,344	258,883	280,806
Manufacturing Employment - 1966 (by place of work)	9,239	12,421	1,022	1,049

Table 9 Common and scientific names* of fishes of Wheeler Reservoir

Game

Largemouth bass - Micropterus salmoides
Smallmouth bass - Micropterus dolomieui
Spotted bass - Micropterus punctulatus
White bass - Morone chrysops
Yellow bass - Morone mississippiensis
White crappie - Pomoxis annularis
Black crappie - Pomoxis nigromaculatus
Bluegill - Lepomis macrochirus
Warmouth - Lepomis gulosus
Longear sunfish - Lepomis megalotis
Green sunfish - Lepomis cyanellus
Redear sunfish - Lepomis microlophus
Rock bass - Ambloplites rupestris
Sauger - Stizostedion canadense

Rough

Longnose gar - Lepisosteus osseus
Shortnose gar - Lepisosteus platostomus
Spotted gar - Lepisosteus oculatus
Skipjack herring - Alosa chrysochloris
Mooneye - Hiodon tergisus
Bigmouth buffalo - Ictiobus cyprinellus
Smallmouth buffalo - Ictiobus bubalus
Channel catfish - Ictalurus punctatus
Flathead catfish - Pylodictis olivaris
Carp - Cyprinus carpio
Drum - Aplodinotus grunniens
Spotted sucker - Minytrema melanops
Hog sucker - Hypentelium nigricans
Golden redhorse - Moxostoma erythrurum
Black redhorse - Moxostoma duquesnei
River redhorse - Moxostoma carinatum
Blue catfish - Ictalurus furcatus
Paddlefish - Polyodon spathula

Forage

Threadfin shad - Dorosoma petenense
Gizzard shad - Dorosoma cepedianum
Orange spotted sunfish - Lepomis humilis
Logperch - Percina caprodes
Brook silversides - Labidesthes sicculus
Golden shiner - Notemigonus crysoleucas
Emerald shiner - Notropis atherinoides
Bluntnose minnow - Pimephales notatus
Fantail darter - Etheostoma flabellare
Blackstripe topminnow - Fundulus notatus

*According to American Fisheries Society Special Publication No. 6, 1970.

Table 10
WATER QUALITY - TENNESSEE RIVER MILE 277.0

BFNP

Date	Time CS 24-hr. Clock	Location in Stream	Depth	Coliforms Total	Coliforms Fecal	Water Temp.	DO	5-day 20°C. BOD	Color	Turb.	Threshold Odor	Org-N	Nitrogens NH_3-N	Nitrogens NO_2-N	Nitrogens NO_3-N	Phosphates Sol.	Phosphates Tot.	pH	Alkalinity $CaCO_3$ Phen.	Alkalinity $CaCO_3$ Tot.	Total Hardness $CaCO_3$	Ca	Mg	Cl	Na	K	Fe, Total	Mn, Total	SO_4	SiO_2	Specific Conductance at 25°C.	Solids Sus.	Solids Dis.	Solids Tot.
1965			ft.	MPN/100 ml		°C.	mg/l	mg/l	PCU	JCU	No.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/l	µg/l	mg/l	mg/l	Micromho/cm	mg/l	mg/l	mg/l
1-19	1410	Middle	1	2,300	130	8.7	-																											
	1412		10			8.6	11.2																											
	1416		20			8.4	11.2																											
	1418		30			8.4	11.3																											
	1421		40			8.4	11.3																											
	1425		46			8.4	11.2																											
	1426		Comp.*			-	-	2.3	5	43	0.0	0.08	0.06	0.00	0.03	0.06	0.20	7.6	0	48	71	22.4	3.8	19	7.00	0.83	720	80	23	5.3	196	16	127	143
2-11	0644	Middle	1**	380	180	-	-																											
	0645		1			7.6	11.2																											
	0647		10			7.6	11.1																											
	0649		20			7.5	11.0																											
	0651		30			7.3	11.2																											
	0653		40			7.1	11.2																											
	0654		Comp.*			-	-	1.5	5	26	0.0	0.10	0.02	0.00	0.20	0.10	0.12	7.8	0	49	70	20.6	4.6	13	5.40	0.70	480	0	13	5.4	145	15	109	124
3-19	0927	Middle	1			9.3	10.8																											
	0929		10			9.3	10.9																											
	0933		20			9.3	10.9																											
	0938		25			9.3	10.9																											
	0943		30			9.3	10.8																											
	0945		40			9.3	11.0																											
	0950		50			9.3	10.7																											
	0951		Comp.*			-	-	1.6	5	26	0.0	0.00	0.18	0.01	0.02	0.14	0.17	7.7	0	52	74	21.3	5.1	13	5.05	0.40	280	0	12	5.9	167	22	105	127
	0952		1**	110	8	-	-																											
4-22	0640	Middle	1			19.6	10.4											8.1	0	45														
	0642		10			19.5	10.3																											
	0643		20			19.4	10.3											8.0	0	53														
	0644		30			18.6	9.8																											
	0646		40			18.1	8.8											7.7	0	54														
	0649		46			17.7	-																											
	0651		Comp.*			-	-	3.7	15	26	0.0	0.10	0.08	0.00	0.08	0.10	0.22	-	-	-	56	17.8	2.9	6	2.21	0.76	790	0	10	4.8	152	3	88	91
	0710		1**	110	<2.3	-	-																											
Maximum				3,800	840	20.2	11.3	4.6	15	81	2.0	0.56	0.18	0.01	0.24	0.51	0.95	8.1	0	54	74	22.7	5.1	23	8.80	1.33	3,680	600	23	6.5	208	116	137	236
Minimum				<2.3	<2.3	8.4	4.8	0.8	0	7	0.0	0.00	0.00	0.00	0.00	0.00	0.06	6.8	0	28	48	14.1	1.9	4	1.88	0.40	70	0	9	1.2	114	2	67	75

*Surface, mid-depth, bottom composite.
**Surface bacteriological only.

Table 10 (Continued)
WATER QUALITY - TENNESSEE RIVER MILE 277.0

BFNP

Date 1964	Time CS 24-hr. Clock	Location in Stream	Depth ft.	Coliforms Total MPN/100 ml	Coliforms Fecal MPN/100 ml	Water Temp. °C.	DO mg/l	5-day 20°C. BOD mg/l	Color PCU	Turb. JCU	Threshold Odor No.	Org N mg/l	Nitrogen NH_3-N mg/l	Nitrogen NO_2-N mg/l	NO_3-N mg/l	Phosphates Sol. mg/l	Phosphates Tot. mg/l	pH	Alkalinity $CaCO_3$ Phen. mg/l	Alkalinity $CaCO_3$ Tot. mg/l	Total Hardness $CaCO_3$ mg/l	Ca mg/l	Mg mg/l	Cl mg/l	Na mg/l	K mg/l	Fe, Total µg/l	Mn, Total µg/l	SO_4 mg/l	SiO_2 mg/l	Specific Conductance at 25°C. Micromho/cm	Solids Sus. mg/l	Solids Dis. mg/l	Solids Tot. mg/l
5-4	0750	Middle	1	3,600	820	18.6	8.1	1.9	0	29	0.0	0.03	0.00	0.00	0.00	0.25	0.51	7.6	-	40	48	15.9	1.9	5	2.05	1.03	1,020	60	11	5.7	114	24	75	99
	0800		10			18.5	8.0																											
	0805		20			18.4	7.9																											
	0810		25			18.3	8.0	1.2	0	32	0.0	0.58	0.01	0.01	0.11	0.51	0.95	7.5	0	40	48	15.8	2.0	5	1.88	0.99	960	30	11	4.6	116	31	69	100
	0820		30			18.3	7.9																											
	0825		40			18.2	7.8																											
	0835		50			18.1	7.7	1.3	0	91	0.0	0.14	0.00	0.01	0.05	0.18	0.45	7.4	0	44	52	17.6	1.9	4	2.16	0.95	690	50	9	5.6	123	72	76	148
6-2	1520	Middle	1	<2.3	<2.3	25.0	8.0	3.8	10	14	0.0	0.01	0.00	0.00	0.00	0.02	0.06	8.0	0	38	54	14.7	4.1	7	2.48	1.33	230	30	16	3.8	118	17	67	84
	1524		10			24.8	7.9																											
	1528		20			23.9	7.8	2.3	10	13	0.0	0.00	0.00	0.00	0.02	0.00	0.06	7.9	0	37	49	14.4	3.2	7	2.16	0.88	300	0	16	4.3	115	6	69	75
	1536		30			23.7	6.9																											
	1540		40			23.6	6.9																											
	1545		45			23.6	6.8	2.2	10	14	0.0	0.00	0.00	0.00	0.00	0.06	0.08	7.5	0	37	54	14.1	4.6	6	2.16	0.99	480	220	14	4.3	120	48	72	120
7-8	1445	Middle	1	<2.3	<2.3	28.3	7.4	4.6	10	7	0.0	0.56	0.00	0.00	0.01	0.06	0.07	7.7	0	44	58	18.1	3.1	12	4.89	0.70	70	0	17	5.7	164	5	98	103
	1455		10			28.2	7.3																											
	1505		20			28.1	7.1	3.3	5	64	1.0	0.33	0.00	0.00	0.24	0.03	0.08	6.9	0	28	60	18.0	3.6	23	4.89	0.70	80	0	17	5.6	169	118	120	236
	1515		30			27.8	7.1																											
	1525		40			27.2	6.9	3.7	10	8	2.0	0.40	0.03	0.00	0.00	0.08	0.14	7.8	0	44	59	18.5	3.2	12	5.05	0.70	70	0	16	5.4	159	7	96	103
8-13	1300	Middle	1	5	<2.3	29.2	8.5	2.3	5	7	0.0	0.25	0.00	0.00	0.00	0.03	0.08	7.4	0	49	70	22.3	3.5	18	6.62	0.70	240	140	22	1.2	192	10	116	126
	1305		10			29.0	6.2																											
	1310		20			28.9	5.7																											
	1315		30			28.8	5.9	3.2	5	14	0.0	0.12	0.00	0.00	0.01	0.04	0.09	7.4	0	48	70	22.3	3.5	18	6.62	0.83	330	140	22	4.8	192	18	112	130
	1320		40			28.8	6.0																											
	1330		47			28.7	4.9	2.2	5	64	0.0	0.32	0.06	0.00	0.00	0.03	0.13	7.4	0	50	70	22.2	3.7	19	6.62	0.83	3,680	600	16	4.8	189	53	110	163
9-18	1011	Middle	1	110	3	24.4	6.8	1.1	5	13	0.0	0.07	0.00	0.00	0.00	-	0.15	7.4	0	44	68	21.1	3.6	19	8.27	0.70	600	30	22	5.0	189	33	118	151
	1015		10			24.4	6.8																											
	1020		20			24.4	6.8	0.9	5	14	0.0	0.15	0.00	0.00	0.04	-	0.10	7.4	0	45	69	21.5	3.6	19	6.62	0.70	1,060	60	16	4.9	189	19	118	137
	1030		30			24.4	6.9																											
	1045		40			24.4	6.7	1.2	5	19	0.0	0.20	0.01	0.00	0.00	-	0.18	7.3	0	44	68	21.0	3.8	19	6.47	0.70	400	90	20	4.9	185	23	115	138
10-6	0610	Middle	1	81	36	21.4	-	1.9	5	14	0.0	0.01	0.05	0.00	0.00	0.06	0.09	7.6	0	36	71	22.5	3.6	20	8.80	0.70	440	0	13	4.6	208	6	137	143
	0615		10			21.4	7.3																											
	0619		20			21.4	7.3																											
	0624		25			21.5	7.4	1.7	5	14	0.0	0.02	0.00	0.01	0.01	0.05	0.11	7.6	0	44	72	22.3	3.9	20	8.80	0.70	480	0	13	4.0	204	19	128	147
	0627		30			21.5	7.4																											
	0630		40			21.5	7.3																											
	0635		48			21.5	7.2	1.8	5	14	0.0	0.04	0.02	0.01	0.01	0.05	0.10	7.7	0	46	71	22.7	3.5	20	8.80	0.70	580	0	13	4.6	204	9	134	143
11-23	1504	Middle	1	940	940	14.0	8.8																											
	1509		10			14.0	8.9																											
	1514		20			14.0	8.8																											
	1518		30			14.0	8.7																											
	1521		40			14.0	8.9																											
	1525		45			14.0	8.8																											
	1526	Comp.*				-	-	2.0	5	20	0.0	0.17	0.02	0.00	0.00	0.10	0.37	7.3	0	40	57	17.5	3.2	13	8.44	0.83	880	140	16	6.5	161	28	112	140
12-15	0625	Middle	1	1,100	230	9.7	9.9																											
	0630		10			9.7	10.0																											
	0633		20			9.7	10.1																											
	0637		30			9.7	10.1																											
	0640		40			9.7	10.0																											
	0641	Comp.*				-	-	1.7	5	14	0.0	0.12	0.00	0.00	0.00	0.10	0.15	7.4	0	43	64	20.0	3.5	16	7.00	0.83	780	30	12	6.2	172	2	129	131

*Surface, mid-depth, bottom composite.

Table 11

OBSERVED WATER TEMPERATURES - WHEELER RESERVOIR TENNESSEE RIVER MILE 300.3

May 1964 to May 1965

Date	Distance From Right Bank % of Width	Surface--1 ft Depth Temperature ° F	Bottom Temperature ° F	Bottom Depth, ft
May 6, 1964	33.3	66.0	65.7	(30)
	66.6	65.8	65.7	(30)
June 2, 1964	33.3	74.5	73.9	(25)
	66.6	74.5	73.9	(30)
July 8, 1964	33.3	83.1	81.9	(25)
	66.6	82.8	81.5	(30)
August 13, 1964	33.3	82.6	80.6	(27)
	66.6	82.6	80.6	(30)
September 18, 1964	33.3	75.6	75.4	(27)
	66.6	75.7	75.7	(28)
October 6, 1964	33.3	69.3	69.1	(24)
	66.6	69.4	69.1	(35)
November 23, 1964	33.3	56.8	56.8	(25)
	66.6	57.2	57.2	(30)
December 15, 1964	33.3	49.5	49.5	(25)
	66.6	49.5	49.5	(25)

Table 11
(Continued)

OBSERVED WATER TEMPERATURES - WHEELER RESERVOIR TENNESSEE RIVER MILE 300.3

May 1964 to May 1965

Date	Distance From Right Bank % of Width	Surface--1 ft Depth Temperature ° F	Bottom Temperature ° F	Bottom Depth, ft
January 19, 1965	33.3	43.5	43.5	(22)
	66.6	43.9	43.9	(27)
February 11, 1965	33.3	46.8	46.8	(20)
	66.6	46.9	46.9	(30)
March 18, 1965	33.3	49.6	49.6	(20)
	66.6	49.6	49.6	(30)
April 22, 1965	33.3	64.7	64.8	(25)
	66.6	65.7	64.8	(34)

Table 12

OBSERVED MAXIMUM AND MINIMUM
TEMPERATURES-WHEELER RESERVOIR
TENNESSEE RIVER MILE 305.0

1938 - 1943

Calendar Year	Surface Temperature °F. *	
	Maximum	Minimum
1938	82.9	37.2
1939	87.4	43.5
1940	83.1	34.9 **
1941	83.7	44.1
1942	82.9	42.1
1943	86.0	42.1

* Data from records, Hydraulic Data Branch, TVA.

** Temperature recorded as ice was clearing

Table 13

SELECTED ECONOMIC DATA FOR THREE TRADE AREAS IN NORTHERN ALABAMA AND SOUTH CENTRAL TENNESSEE

Trade Area	Number of Counties	1970 Population			1966 Personal Income		1967 Retail Sales		
		Trade Area	Largest County	Largest City	Trade Area	Principal County	Trade Area	Principal County	Principal City
Huntsville, Ala-Tn	6	341,141	186,540	137,802	$770,253	$595,983*	$418,374	$299,526*	$245,922
Quad-Cities, Ala-Tn	6	201,350	117,743#	47,146#	388,080	255,582#	230,704	143,016#	103,135#
Decatur, Ala	3	157,032	77,306	38,044	296,825	193,340	179,467	102,572	77,873
Totals	15	699,523	381,589	222,992	1,455,158	1,044,905	828,545	545,114	426,930

All dollar amounts are in thousands of dollars ($000's).

* Disclosure regulations of the Office of Business Economics require that income data for SMSA's be reported as a single unit. Hence, Madison and Limestone Counties are reported as the Huntsville SMSA. For the sake of comparability of data, retail sales are shown above on the same basis.

Due to commuting patterns between Colbert and Lauderdale Counties, principal county data include both counties while city data are for Florence and Sheffield combined.

Table 14

TAGGING AND RECAPTURE DATA FOR FIVE SPECIES OF FISH
WHEELER RESERVOIR

February 1969-January 1971

Species	Total Tagged	Returns	Percent Returns	Net Movement Returns (km)	Range (km) +	Range (km) -
Channel catfish	1,776	32	1.8	-1.3	23.3	29.0
Blue catfish	395	14	3.5	-0.9	19.3	15.3
Flathead catfish	460	46	10.0	-0.5	27.4	13.7
White crappie	823	37	4.5	+6.2	128.7	24.1
White bass	230	9	3.9	-15.5	37.0	33.8

\+ Upstream from point of release.

\- Downstream from point of release.

TABLE 15

TVA-BUILT THERMAL-ELECTRIC POWER PLANTS

Plant	Unit Number	Normal Full Load, per Unit	First Year of Commercial Operation		Total Plant			Mean Flow of Receiving Stream
			First Unit	Last Unit	Thermal Rise in Condensers	Condenser Flow	Heat to Stream (Btu)	
		megawatts			°F	gal/min	billions per hr	ft^3/s
Browns Ferry	1-3	1,150	'72	'74	25	1,800,000	22.2	49,000
Bull Run	1	900	'67		18	397,900	3.6	4,310
Colbert	1-4	200	'55	'55	13	865,500	5.8	50,500
	5	500	'65					
Cumberland	1,2	1,300	'72	'73	12	1,616,000	9.3	24,000
Gallatin	1,2	250	'56	'57	16	592,400	4.7	18,000
	3,4	275	'59	'59				
John Sevier	1-4	200	'55	'57	15	454,000	3.5	3,540
Johnsonville	1-6	125	'51	'53	13	1,029,000	6.5	61,000
	7-10	150	'58	'59				
Kingston	1-4	150	'54		14	967,000	6.9	6,300
	5-9	200		'55				
Paradise	1,2	690	'63	'63	26	452,400	5.8	8,370
Shawnee	1-10	150	'53	'56	12	1,076,000	6.5	255,400
Watts Bar	1-4	60	'42	'45	10	280,800	1.5	26,400
Widows Creek	1-4	135	'52		15	1,092,400	8.2	35,200
	5,6	130		'54				
	7	525	'61					
	8	525	'65					

Table 16

TYPES AND LOCATIONS OF SAMPLES COLLECTED
TO MONITOR PREOPERATIONAL AND OPERATIONAL CONDITIONS IN WHEELER RESERVOIR
IN RELATION TO THE BROWNS FERRY NUCLEAR PLANT

TRM Station	Distance From Left Bank feet	Distance From Left Bank percent	Depths for Water meters	Depths for Zooplankton, Chlorophyll, and Phytoplankton Cell Counts meters	Depths for Productivity[1/] meters	Benthic Fauna n[3/]	Sediment n	Fish[2/]
274.90								R
277.98	1,000	13	1,5	1,5		3		
	4,000	51	(1),5	1,5		(3)	(3)	
	6,500	83	(1),3,5,(10),15	(1),3,5,(10),15	0,1,3,5	(3)	(3)	
283.94	1,500	16	1,5	1,5		3		(T)
	3,600	40	(1),5	1,5		3		
	7,100	78	(1),3,5,(10)	1,3,5,10	0,1,3,5	3		
288.78	2,000	20	1,5	1,5		3		
	4,000	41	(1),3,(5)	1,3,5	0,1,3,5	(3)	(3)	
	8,000	82	(1)	1		(3)	(3)	
291.76	1,000	12	1	1		3		
	3,000	36	1,5	1,5		3		
	5,000	60	(1)	1		3		
	7,000	84	(1),(5)	(1),3,(5)	0,1,3,5	3		
293.70	4,450	43	1	1		3		
	6,800	65	(1)	1	0,1,3,5	(3)	(3)	(T),G,R
	9,200	88	(1),3,(5),7	1,3,5,7		(3)	(3)	
293.88	6,300	80	(1),(5)	(1),(5)		(3)	(3)	

Table 16 (contd.)

TYPES AND LOCATIONS OF SAMPLES COLLECTED
TO MONITOR PREOPERATIONAL AND OPERATIONAL CONDITIONS IN WHEELER RESERVOIR
IN RELATION TO THE BROWNS FERRY NUCLEAR PLAN

TRM Station	Distance From Left Bank feet	Distance From Left Bank percent	Depths for Water meters	Depths for Zooplankton, Chlorophyll, and Phytoplankton Cell Counts meters	Depths for Productivity[1] meters	Benthic Fauna n[3]	Sediment n	Fish[2]
	2,000	22	1	1		3		
295.87	4,000	44	(1),3,(5)	1,3,5	0,1,3,5	3		
	7,500	82	(1)	1		3		
299.00								(T),G
	700	6	1	1		3		
301.06	3,200	26	(1),3,(5)	1,3,5	0,1,3,5	3		
	7,200	58	(1)	1		3		
307.52	1,800	24	(1),3,(5)	(1),3,(5)	0,1,3,5	(3)	(3)	R
	2,800	37	(1),5	1,5		(3)	(3)	

1. Location of lower depths depends on depth of photic zone.
2. G = gill net; T = trap net; R = rotenone.
3. Number of dredge hauls.
( ) Indicates samples for radiological analyses. Water, sediment, plankton, and benthic fauna will also be collected within 500 feet below the diffuser (TRM 293.88) and analyzed for gamma activity. Fish will be sampled at this station after the plant goes into operation.

Table 17

LARVAL FISH SAMPLING STATIONS IN WHEELER RESERVOIR AND WEEKLY SAMPLING SCHEDULE

Station		Number of Hauls Day	Night
First Day's Sample			
Upstream - TRM 297-299			
A. Mid-channel			
1. Surface		2	2
2. 5-meter		2	2
B. Shoreline - surface		2	2
	Total	6	6
Plant Site - TRM 294			
A. Mid-channel			
1. Surface		2	2
2. 5-meter		2	2
B. Shoreline - surface		2	2
	Total	6	6
C. Intake basin (stationary net)*			
Second Day's Sample			
Downstream - TRM 284-285			
A. Mid-channel			
1. Surface		2	2
2. 5-meter		2	2
B. Shoreline - surface		2	2
	Total	6	6
Elk River - ERM 4			
A. Mid-channel			
1. Surface		2	2
2. 5-meter		2	2
B. Shoreline - surface		2	2
	Total	6	6

* Sampling with stationary net in intake basin will be scheduled according to construction progress.

Table 18

SAMPLING AND ANALYSIS SCHEDULE
ENVIRONMENTAL RADIOACTIVITY MONITORING

Station Location	Air Filter	Charcoal Filter	Rain-water	Heavy Particle Fallout	Soil	Vegetation	Milk	River Water	Well Water	Public Water	Aquatic Life and Sediment
Muscle Shoals	W	BW	M	M	SA	SA	M			M	
Lawrenceburg	W	BW	M	M	SA	SA					
Fayetteville	W	BW	M	M	SA	SA					
Huntsville	W	BW	M	M	SA	SA					
Cullman	W	BW	M	M	SA	SA					
Rogersville	W	BW	M	M	SA	SA					
Athens	W	BW	M	M	SA	SA	M				
Decatur	W	BW	M	M	SA	SA	M			M	
Courtland	W	BW	M	M	SA	SA					
Site NW	W	BW	M	M	SA	SA					
Site N	W	BW	M	M	SA	SA					
Site NE	W	BW	M	M	SA	SA					

W - Weekly BW - Biweekly M - Monthly Q - Quarterly SA - Semiannually

Table 18

(Continued)

SAMPLING AND ANALYSIS SCHEDULE
ENVIRONMENTAL RADIOACTIVITY MONITORING

Station Location	Air Filter	Charcoal Filter	Rain-water	Heavy Particle Fallout	Soil	Vegetation	Milk	River Water	Well Water	Public Water	Aquatic Life and Sediment
Farm B						M	M		M		
Farm H						M	M		M		
Farm T						M	M		M		
Farm D						M	M		M		
Wheeler Dam										M	
Elk River								M			
Wheeler Reservoir								M-Q			Q

W - Weekly BW - Biweekly M - Monthly Q - Quarterly SA - Semiannually

Table 19

PRINCIPAL GASEOUS RADIONUCLIDES
AND EXPECTED DISCHARGE RATES FROM THREE-UNIT PLANT[1]

Isotope	Half Life	Probable Maximum Discharge Rate, Ci/s 6 Bed
^{83m}Kr	1.86 hr	7.1×10^{-5}
^{85m}Kr	4.4 hr	5.1×10^{-3}
^{85}Kr	10.4 yr	8.0×10^{-5}
^{87}Kr	1.3 hr	2.7×10^{-5}
^{88}Kr	2.8 hr	3.6×10^{-3}
^{89}Kr	3.2 min	---
^{131m}Xe	12.0 day	1.0×10^{-4}
^{133m}Xe	2.3 day	1.9×10^{-4}
^{133}Xe	5.27 day	2.1×10^{-2}
^{135m}Xe	15.6 min	---
^{135}Xe	9.2 hr	1.9×10^{-7}
^{137}Xe	3.8 min	---
^{138}Xe	17.0 min	---
Total		3.0×10^{-2}

[1]Extended system with hydrogen recombiners, holdup piping, and six charcoal beds and with 0.8 percent fuel defects.

Table 20

EXPECTED ANNUAL RADIOACTIVITY RELEASE IN LIQUID EFFLUENTS EXCLUDING TRITIUM[1]

Discharge Rates for Three-Unit Plant

Isotope[2]	Half-Life	Release Rate (Ci/yr)[4] System as Designed	With Add'l Processing
Sr-89[3]	50.6d	2.9×10^{-1}	3.6×10^{-2}
Sr-90[3]	28y	7.8×10^{-2}	9.8×10^{-3}
Sr-91[3]	9.7h	3.6	4.5×10^{-1}
Mo-99[3]	66h	7.7	9.6×10^{-1}
I-131	8.05d	3.6	4.5×10^{-1}
I-133	20.8h	6.0	7.5×10^{-1}
I-135	6.7h	2.7	3.4×10^{-1}
Cs-134	2.1y	3.9×10^{-2}	4.9×10^{-3}
Cs-137	30y	7.8×10^{-2}	9.8×10^{-3}
Ba-140[3]	12.8d	7.7	9.6×10^{-1}
Ce-144[3]	284d	1.0×10^{-2}	1.2×10^{-3}
Np-239	2.35d	7.8	9.8×10^{-1}
Co-58	70d	4.2×10^{-1}	5.2×10^{-2}
Co-60	5y	4.2×10^{-2}	5.2×10^{-3}
	TOTAL	40 Ci/yr	5 Ci/yr

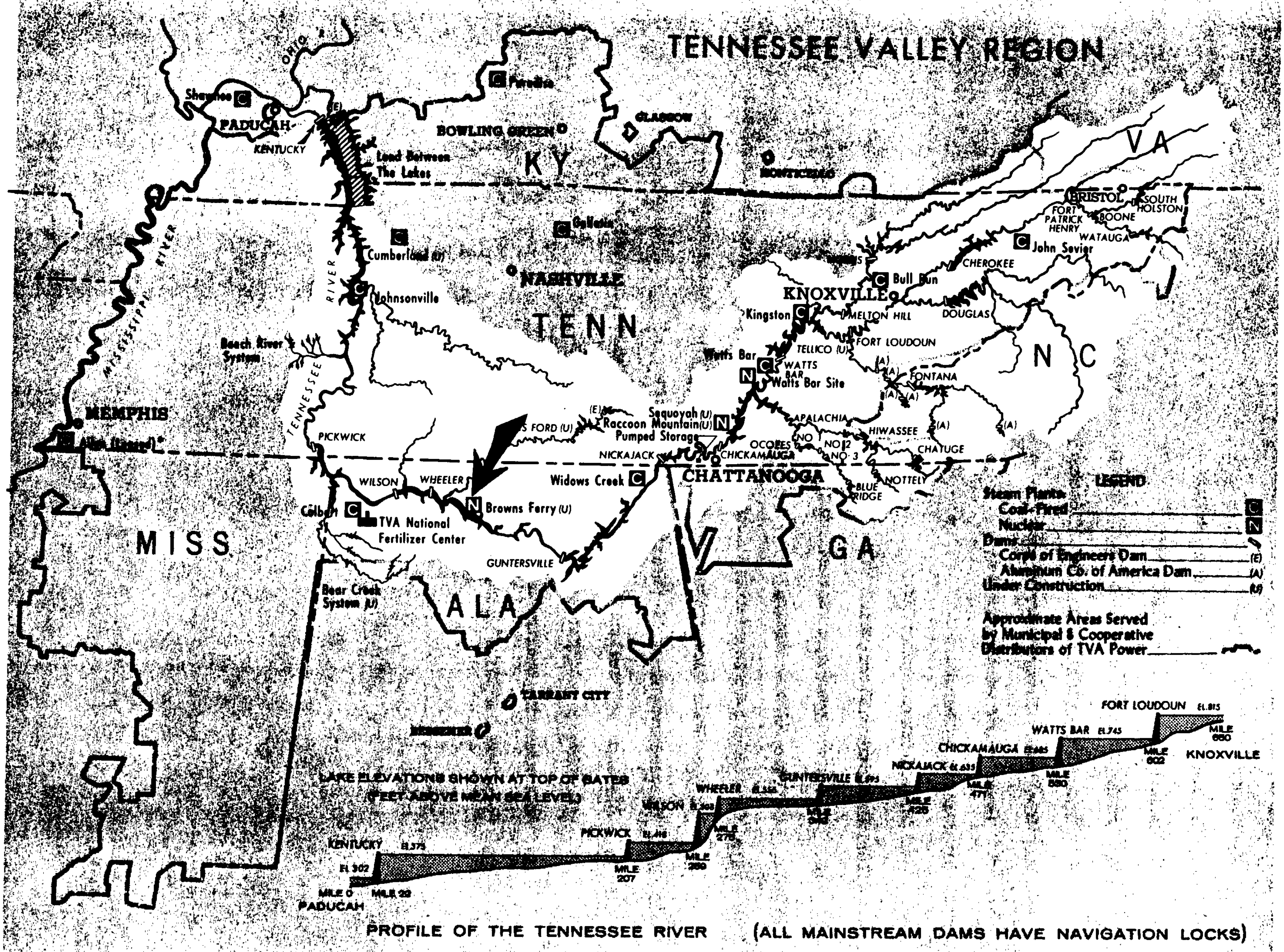
1. Tritium releases are expected to approach about 20 Ci/yr from the plant. The distribution between gaseous and liquid wastes will depend upon the actual amount of water leaving by each route.

2. Isotopes having a half-life less than 2.3 hours were excluded because the holdup in the plant would generally be sufficient to result in negligible concentrations in released wastes. Other isotopes of the elements listed were considered. The radionuclides Zr-95, Nb-95, Ru-103, Ru-100, Te-129m, Te-132, Nd-147, Na-24, S-35, P-32, Cr-51, Mn-54, Mn-56, Fe-55, Fe-59, Cu-64, Ni-65, Zn-65, Zn-69m, Ag-110m, Ta-182, and W-187 were also considered. These radionuclides may be present, but if present will be negligible or in trace concentrations relative to those isotopes listed and were omitted from the table.

3. Daughter isotopes of Yttrium, Technetium, Lanthanum, and Praseodynium may be observed in waste samples in equilibrium with or approaching equilibrium with their parent depending upon sample and analysis timing and procedure.

4. Although two significant numbers are used in expressing the release rates as a convenience for making further calculations, only one significant figure is warranted by the source data.

LIST OF FIGURES



PROFILE OF THE TENNESSEE RIVER (ALL MAINSTREAM DAMS HAVE NAVIGATION LOCKS)

Figure 1

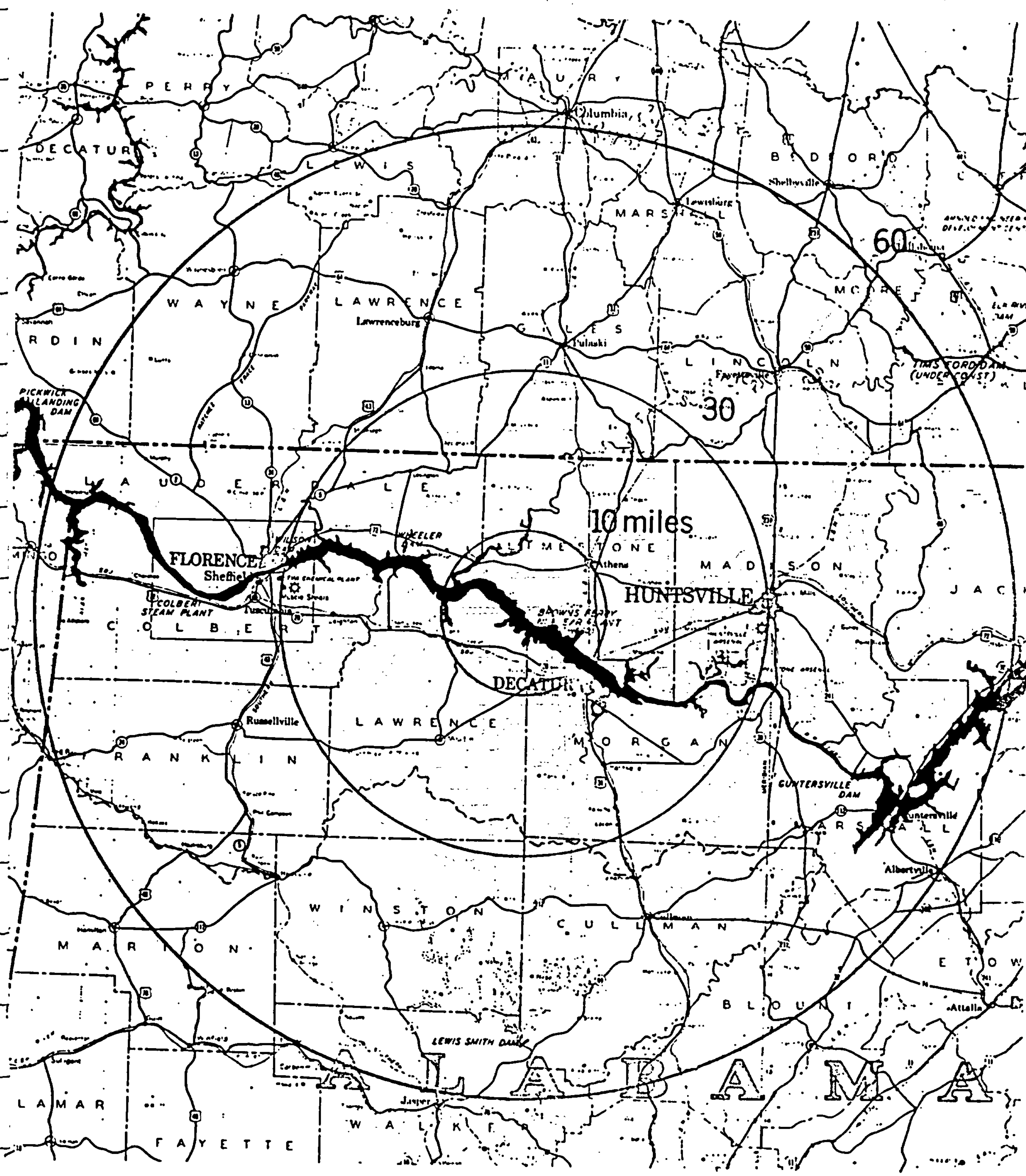


Figure 2
VICINITY MAP - 0 TO 60 MILE RADIUS

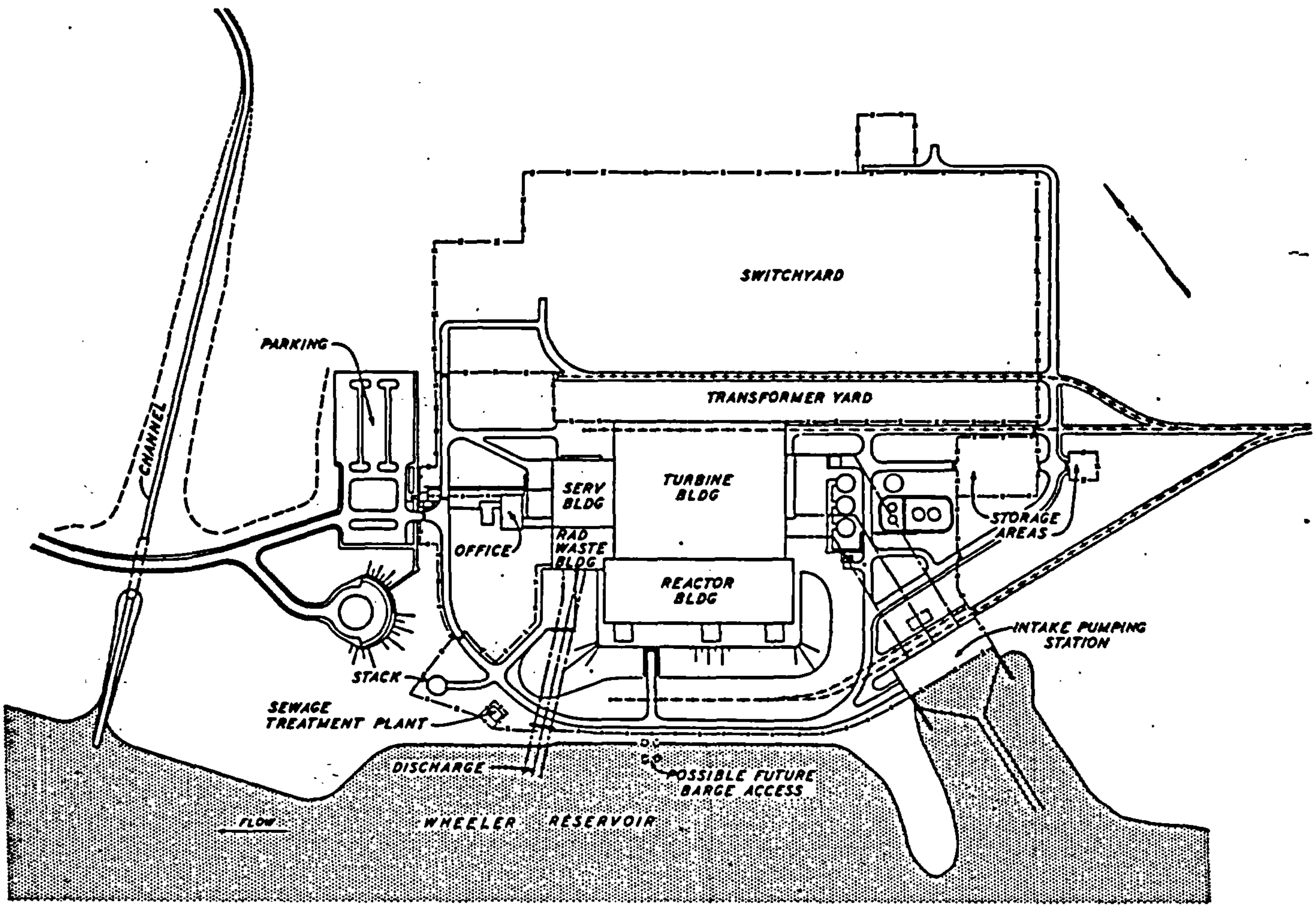


Figure 3

Arrangement of the Plant Site

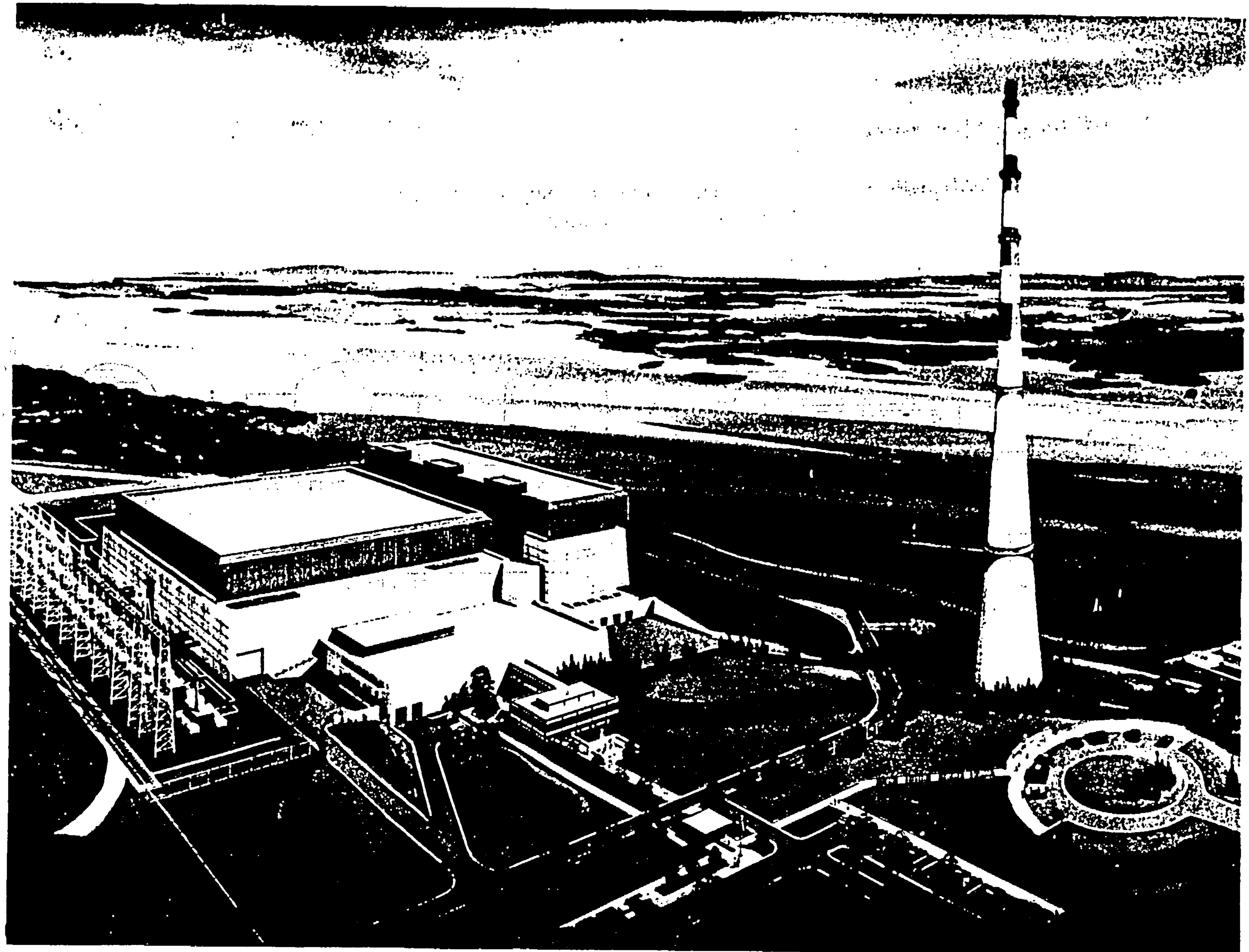


Figure 4

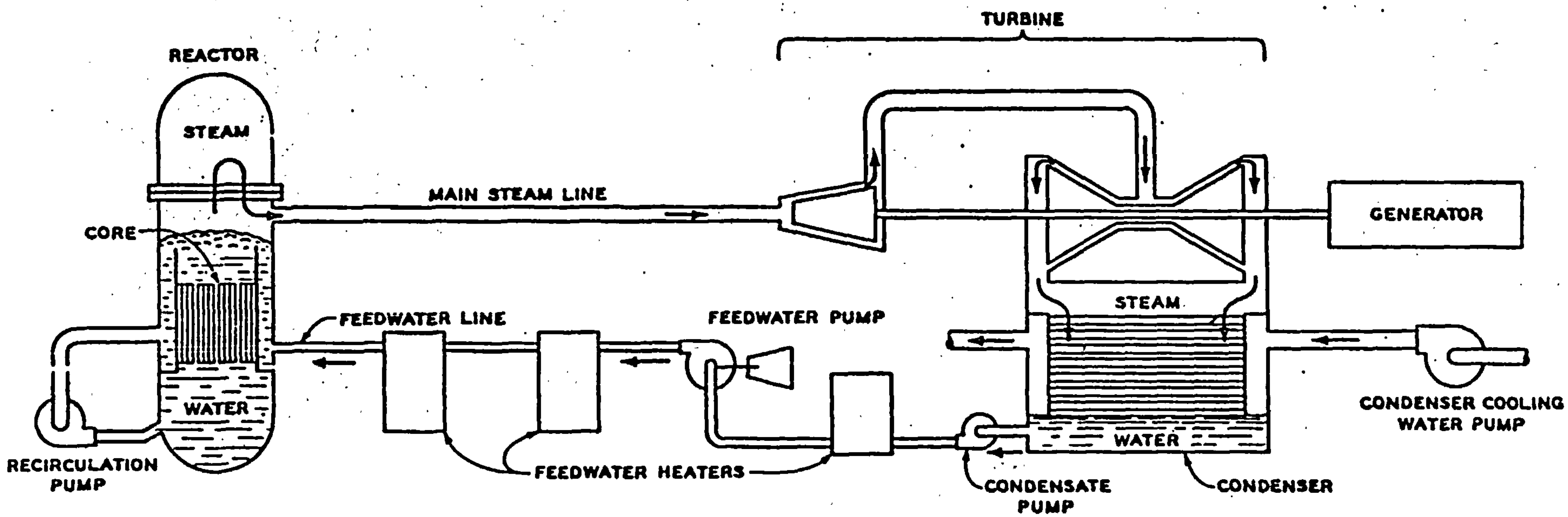


Figure 5
Browns Ferry Plant Simplified Steam Cycle

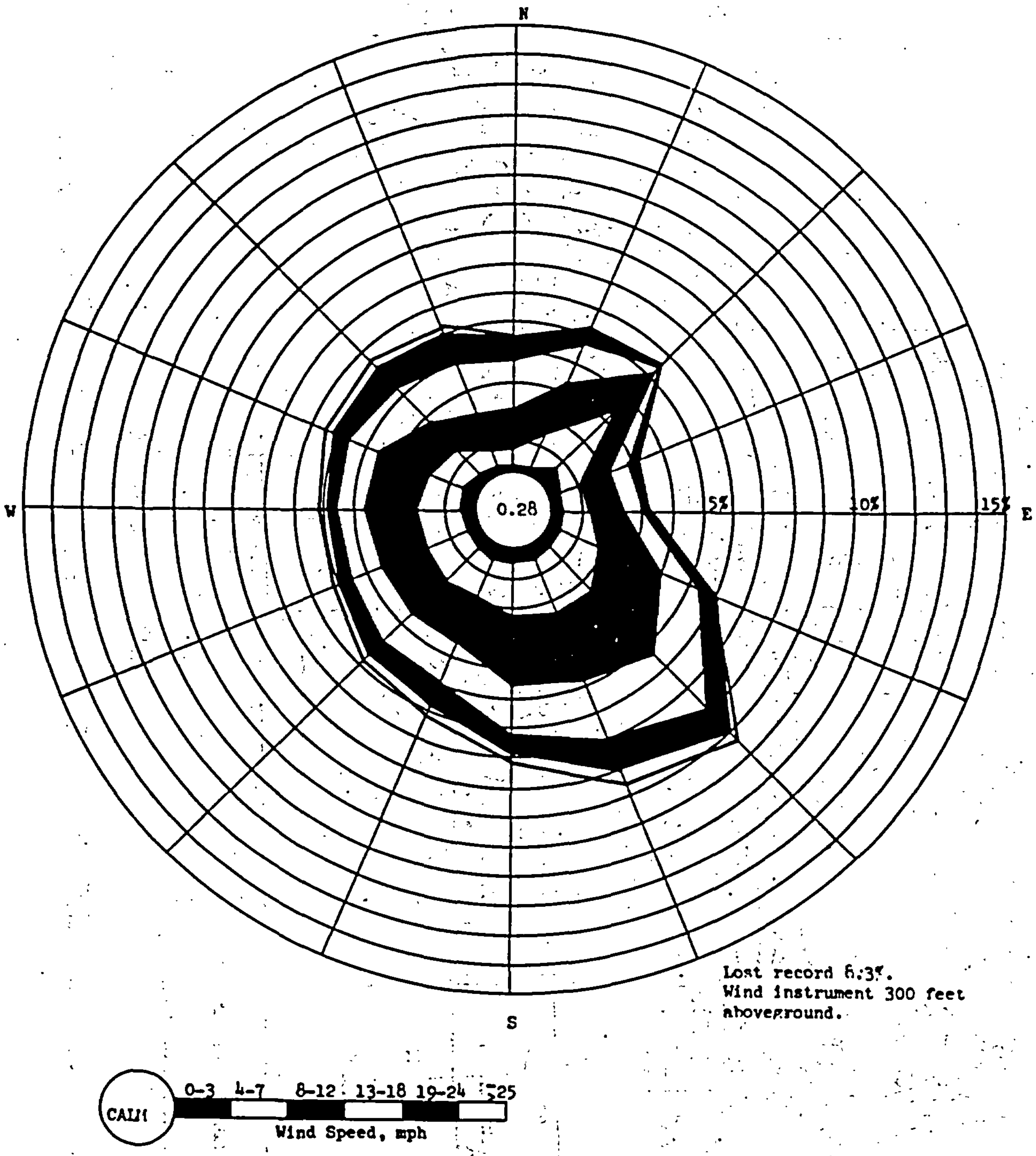


Figure 6

WIND ROSE - BROWNS FERRY SITE

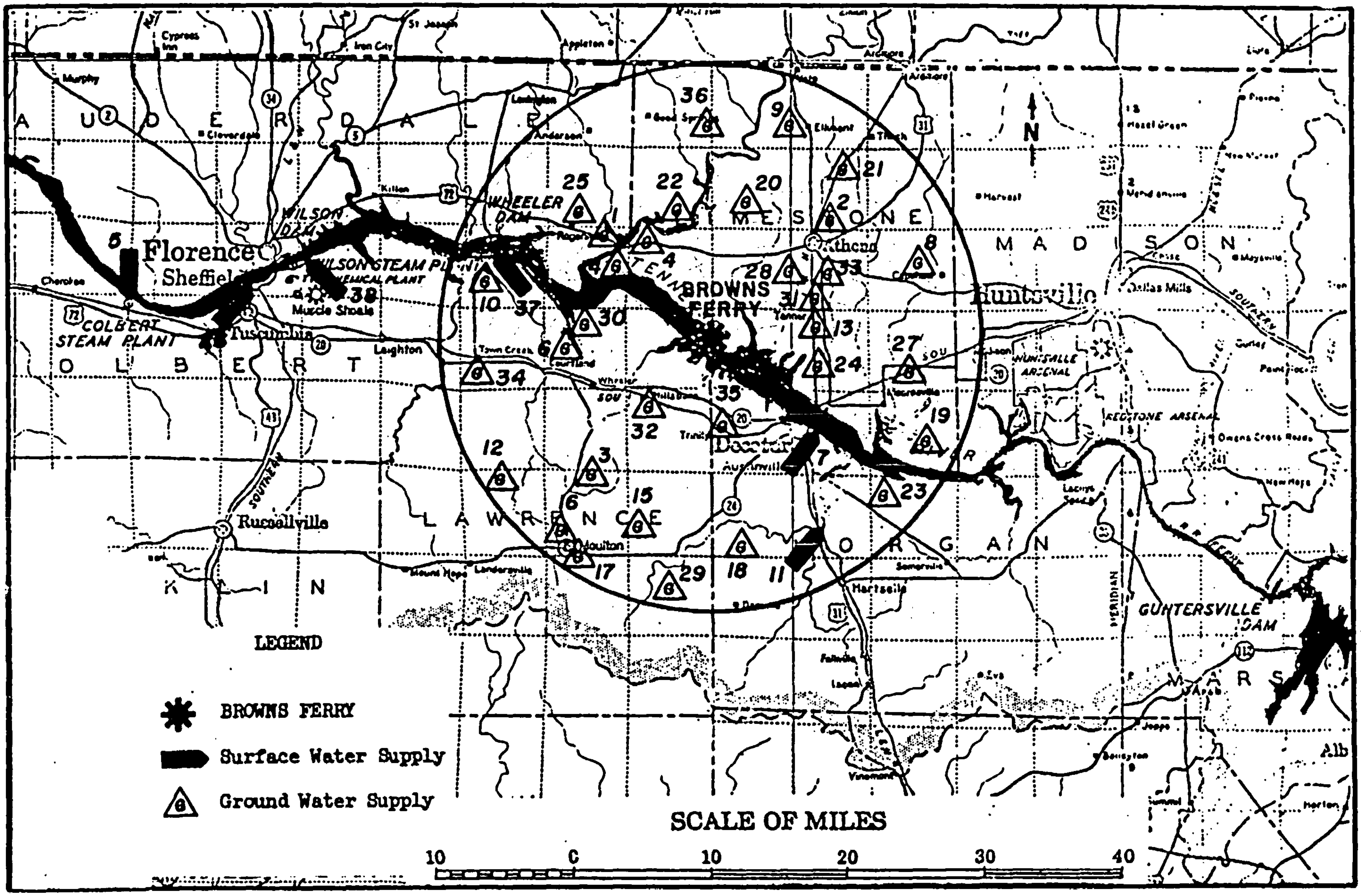


Figure 7

LOCATION OF WATER SUPPLIES

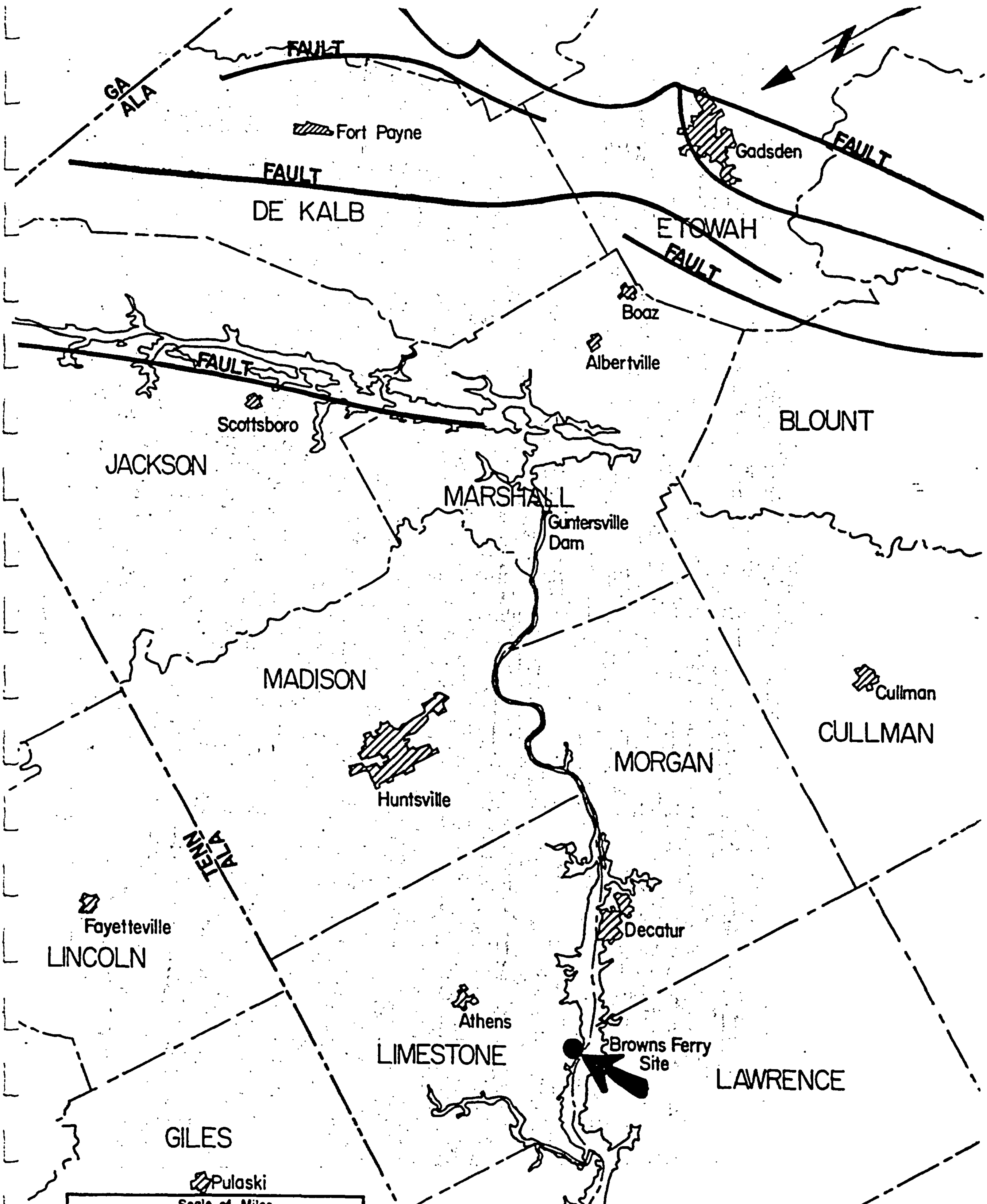


Figure 8 FAULTS IN REGION

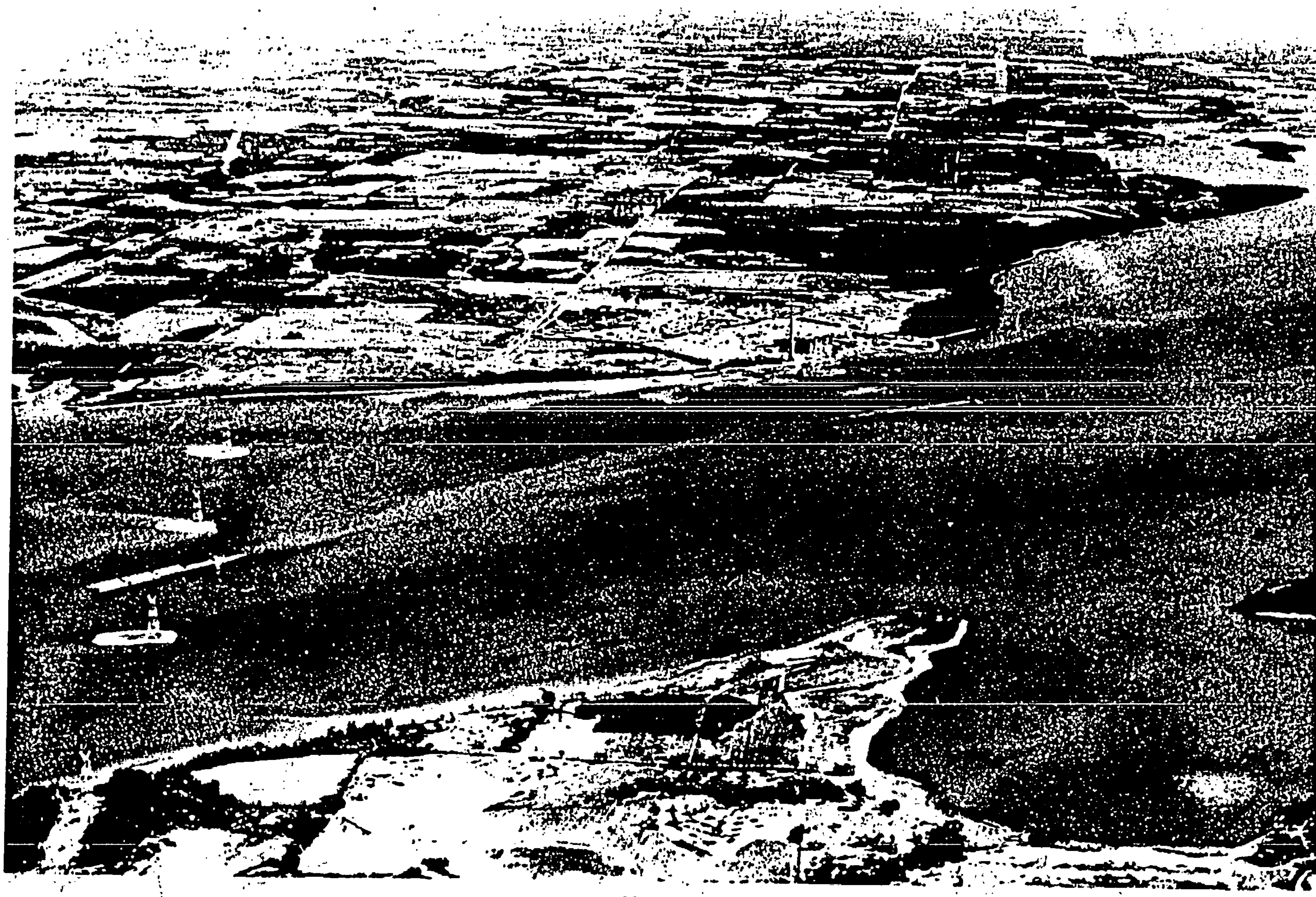


Figure 9

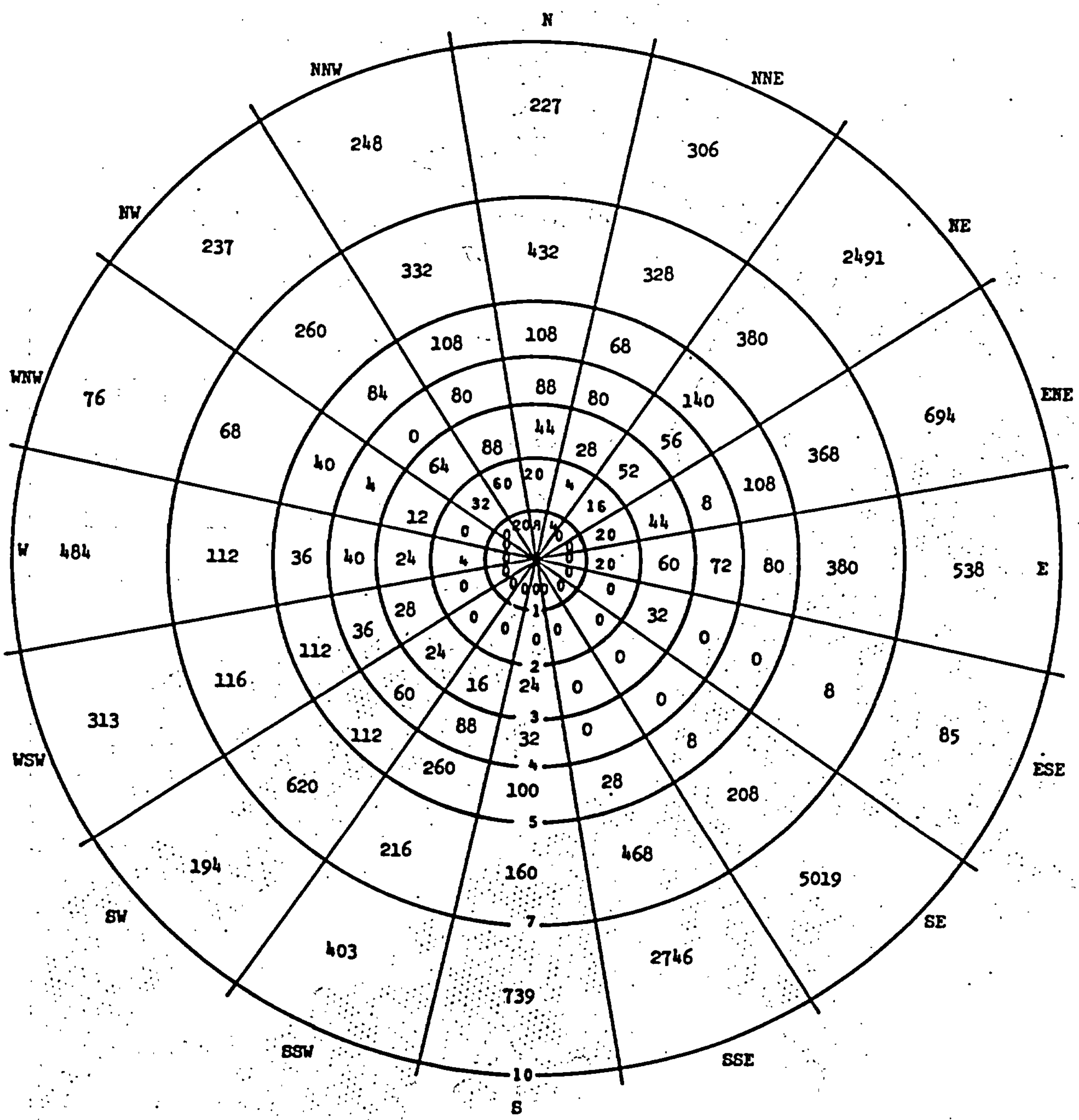


Figure 10

POPULATION DISTRIBUTION WITHIN
10-MILE RADIUS OF BROWNS FERRY SITE

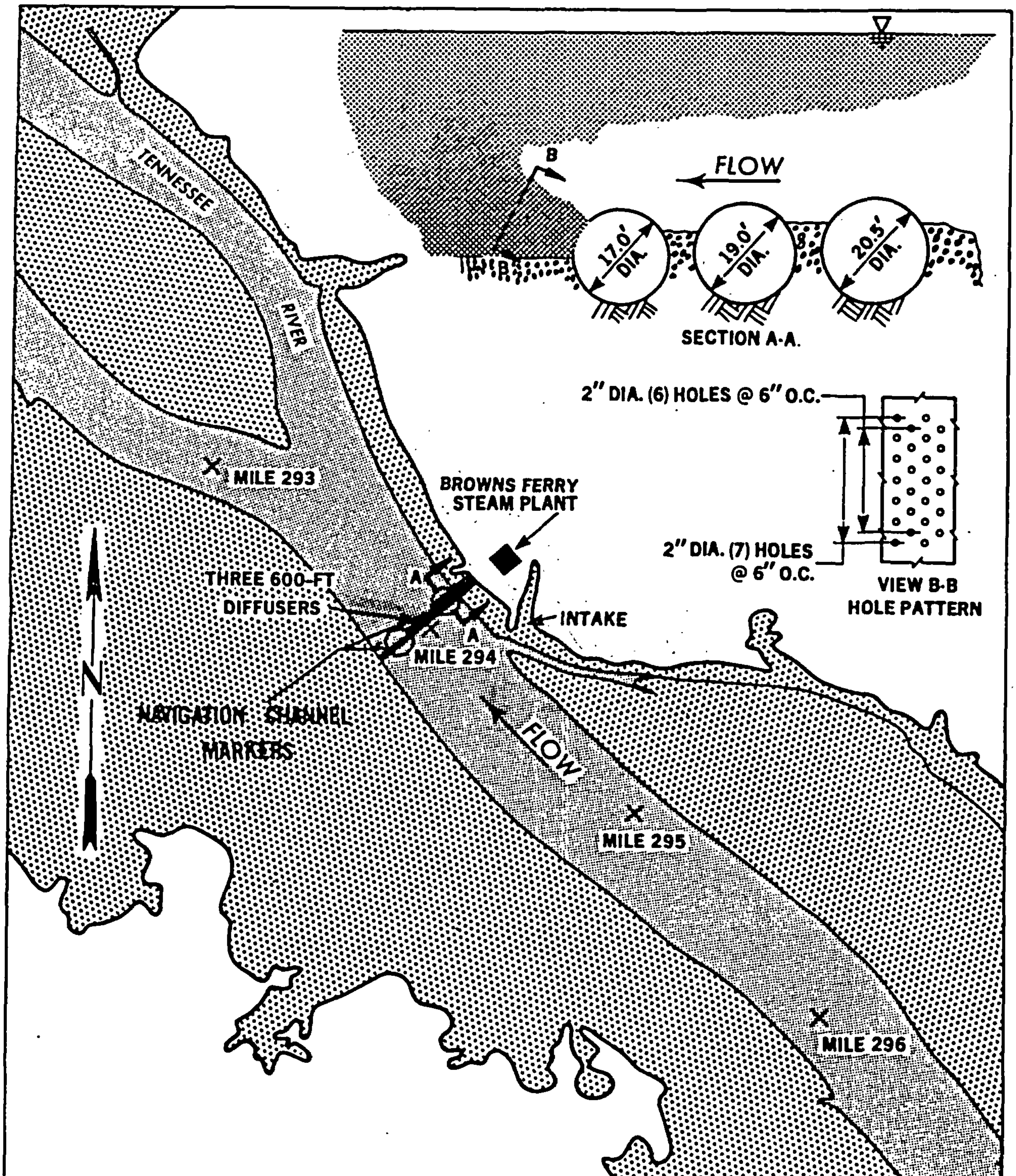
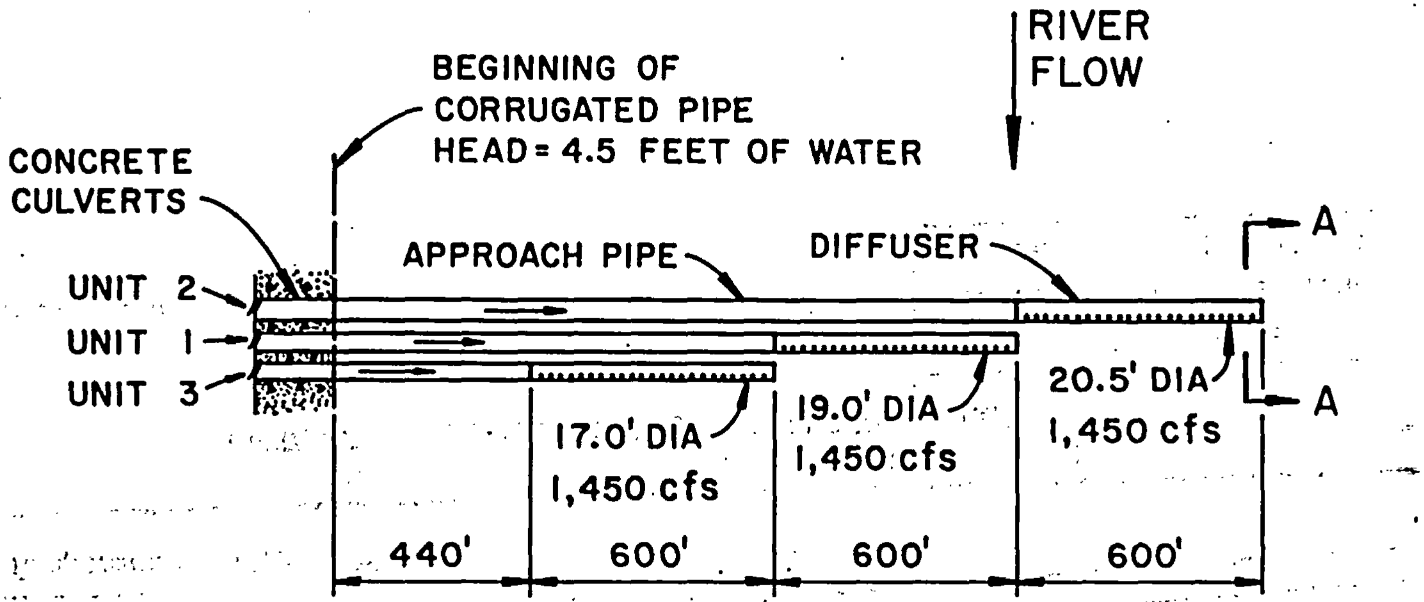
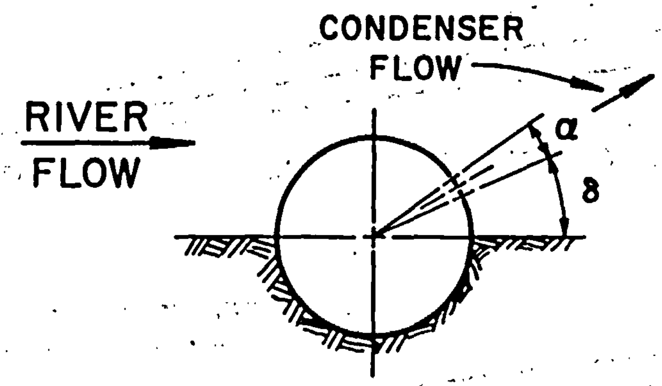


Figure 11
Diffuser System and Channel Markings



PLAN



SECTION A-A

ALTERNATIVE HOLE PATTERNS	
1" HOLES	2" HOLES
ALTERNATELY 25 AND 26 HOLES PER CORRUGATION	ALTERNATELY 6 AND 7 HOLES PER CORRUGATION

GALVANIZED STEEL PIPE
STRUCTURAL PLATE
#3 GAGE, 2"x6" CORRUGATION

2" HOLE SCHEME
ACCEPTED FOR CONSTRUCTION
$\alpha \approx 21°$ AND $\delta \approx 24°$

Figure 12
Diffuser System Design

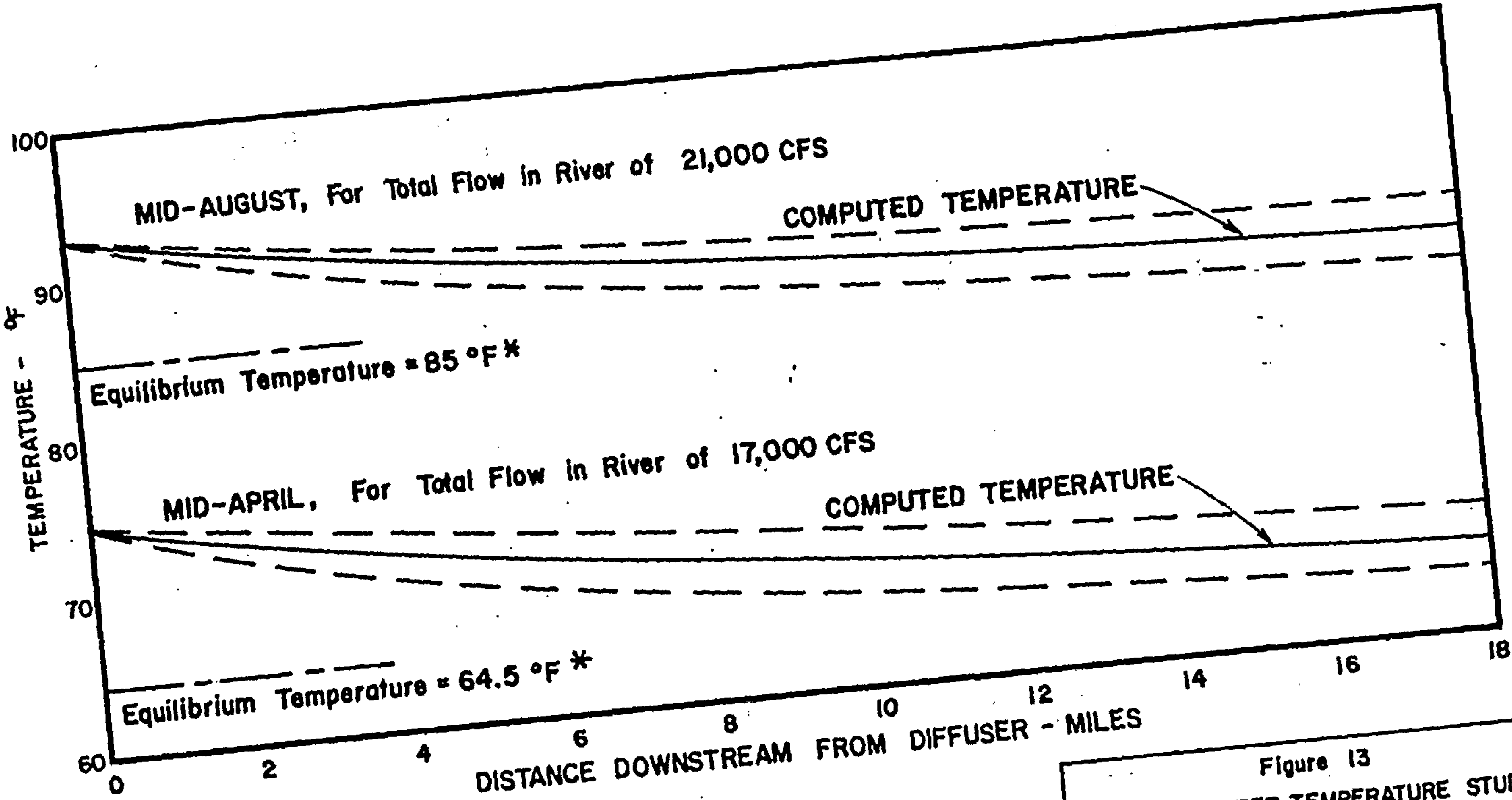


Figure 13
SURFACE WATER TEMPERATURE STUDIES
TEMPERATURE VS DISTANCE DOWNSTREAM

* Assumed upstream water temperature

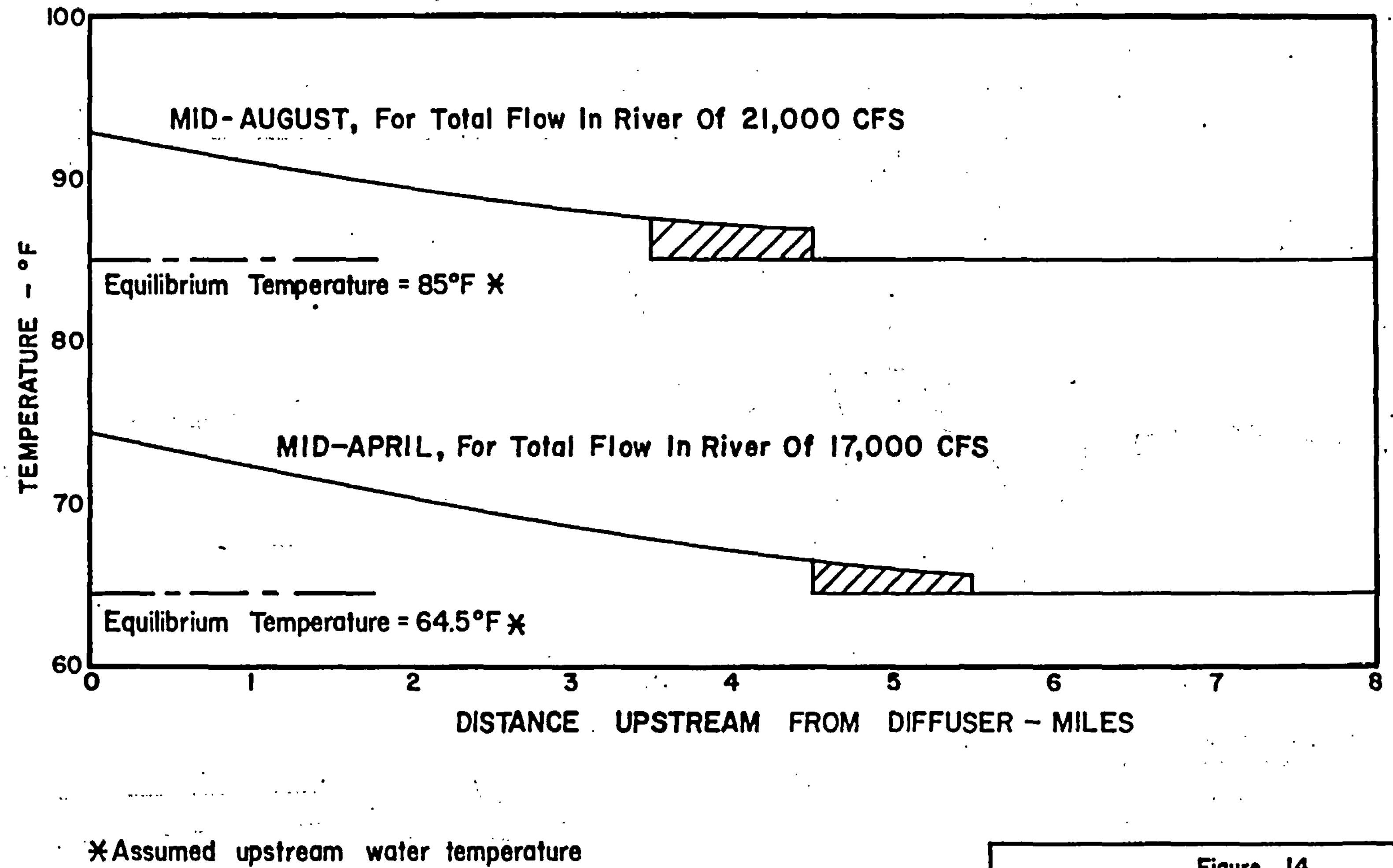


Figure 14
SURFACE WATER TEMPERATURE STUDIES
TEMPERATURE VS DISTANCE UPSTREAM

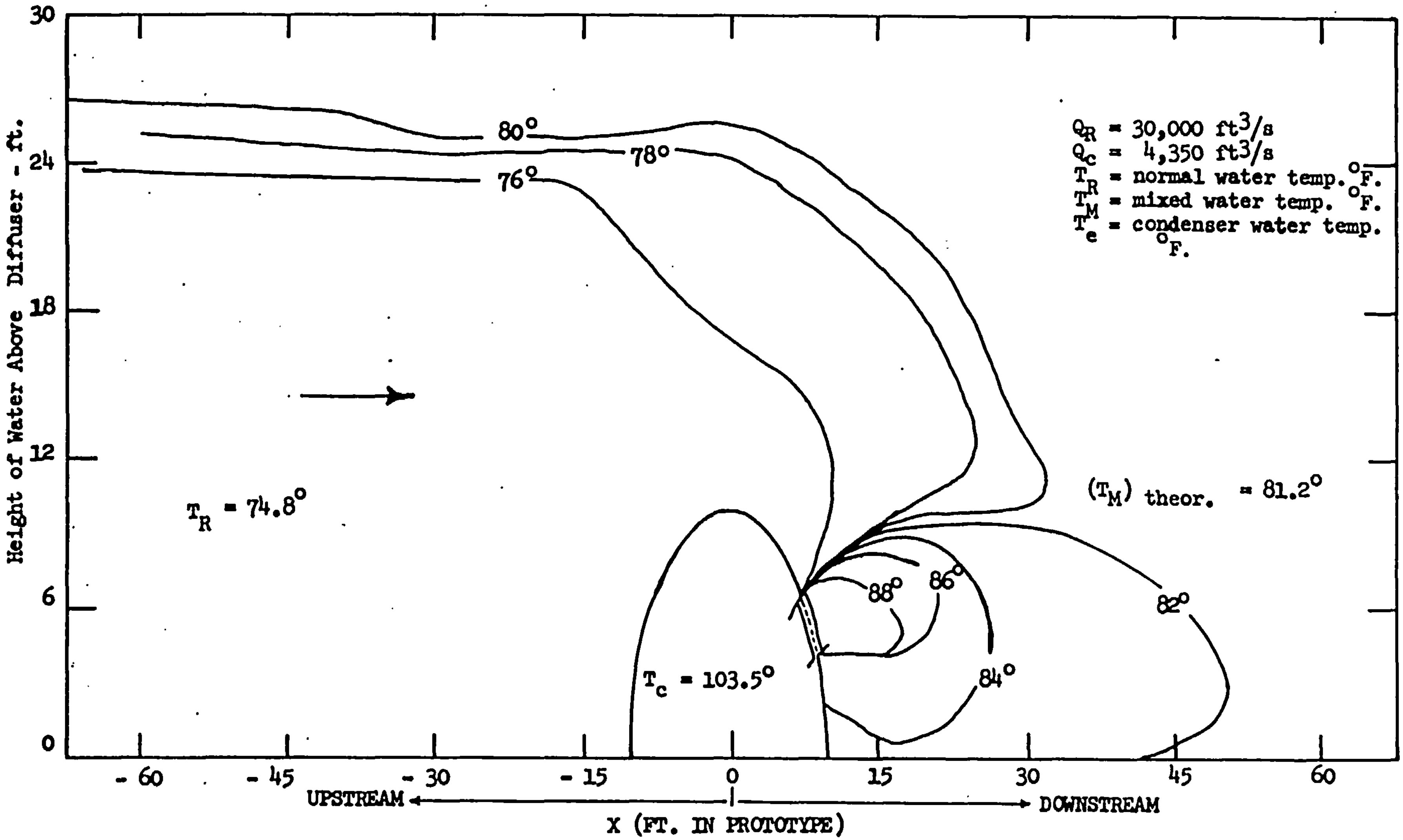


Figure 15 Temperature Survey in Vicinity of Jet Ports

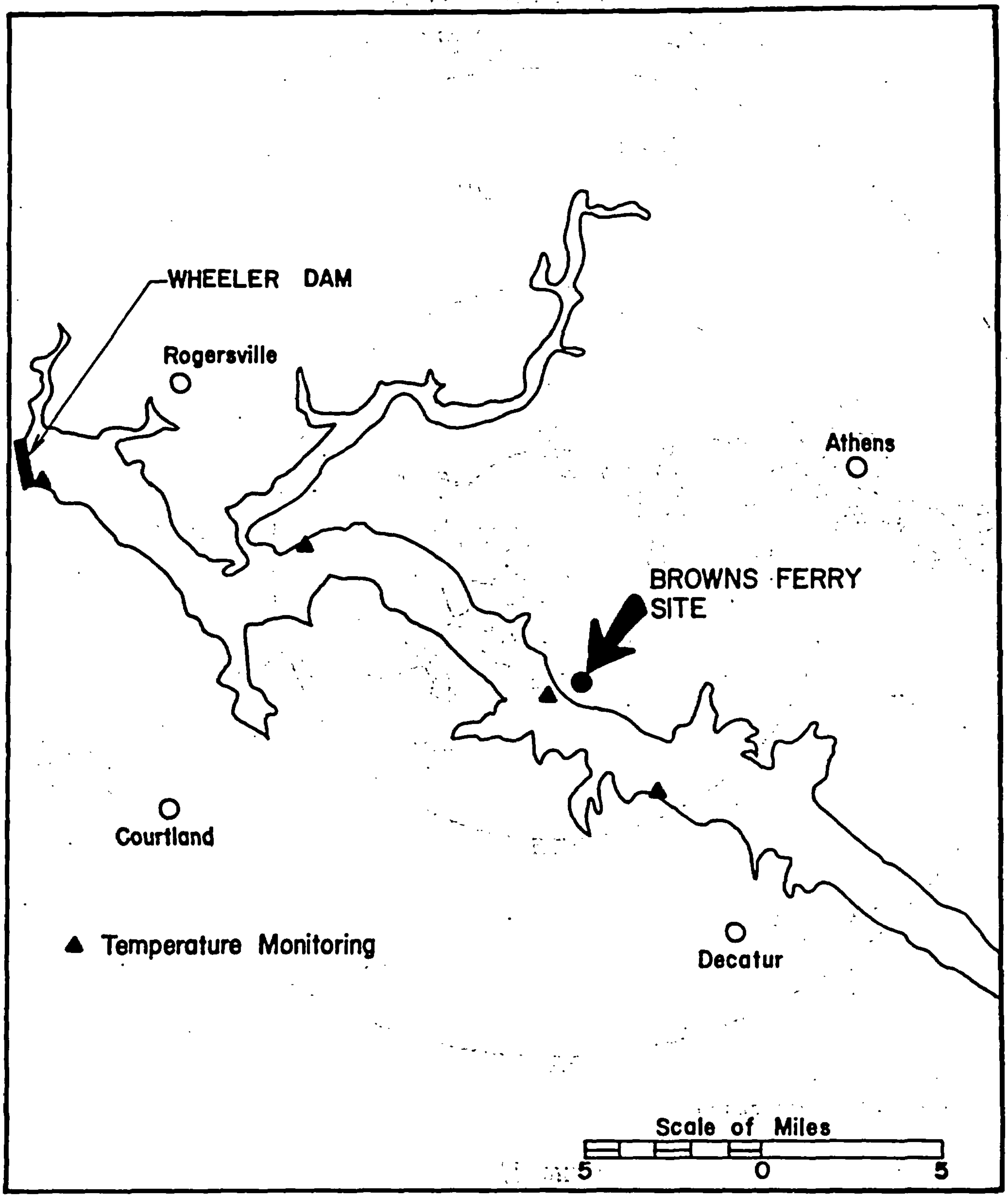


Figure 16

LOCATION OF WHEELER RESERVOIR TEMPERATURE MONITORING STATIONS

ATMOSPHERIC AND TERRESTRIAL MONITORING NETWORK

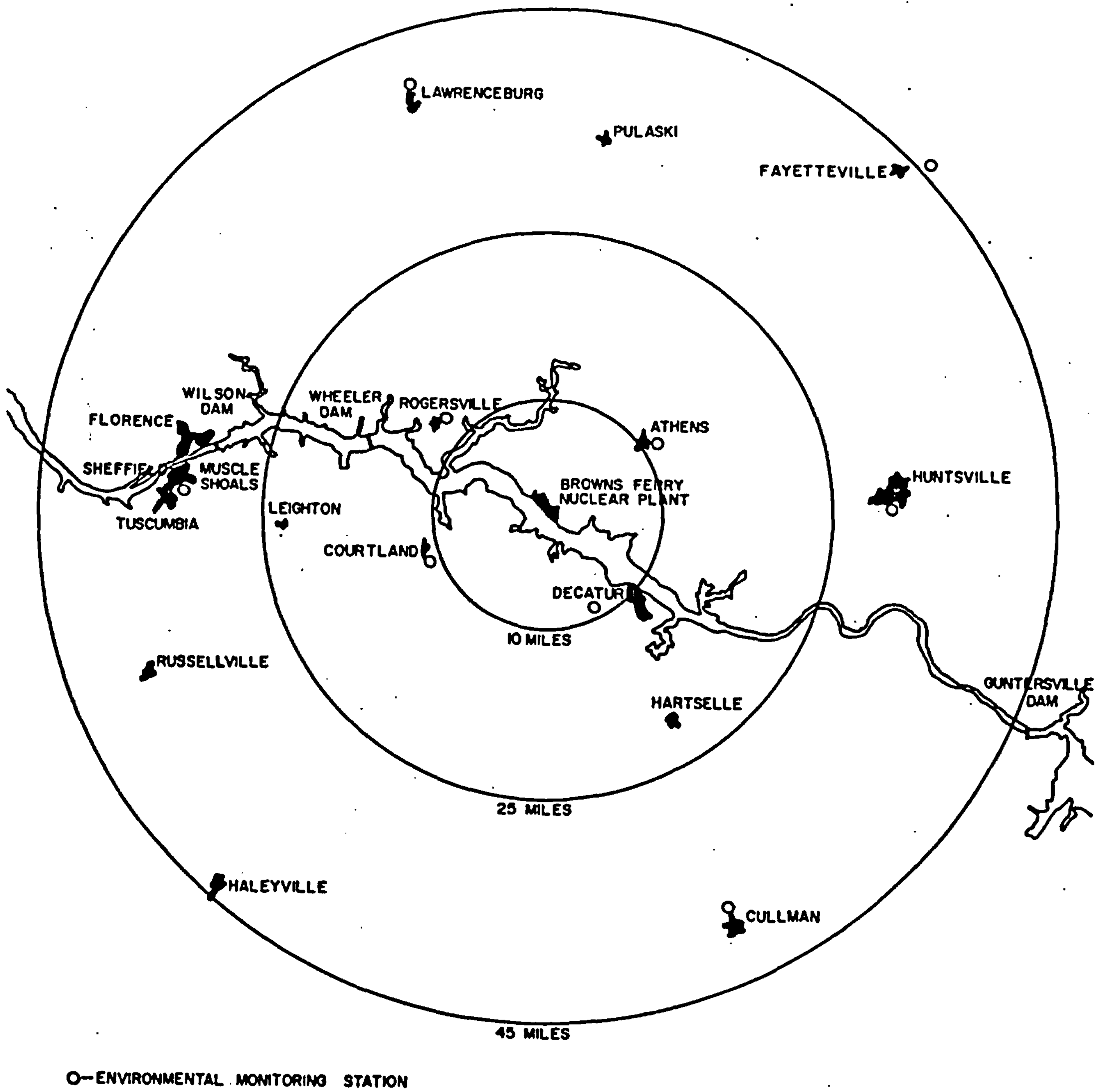
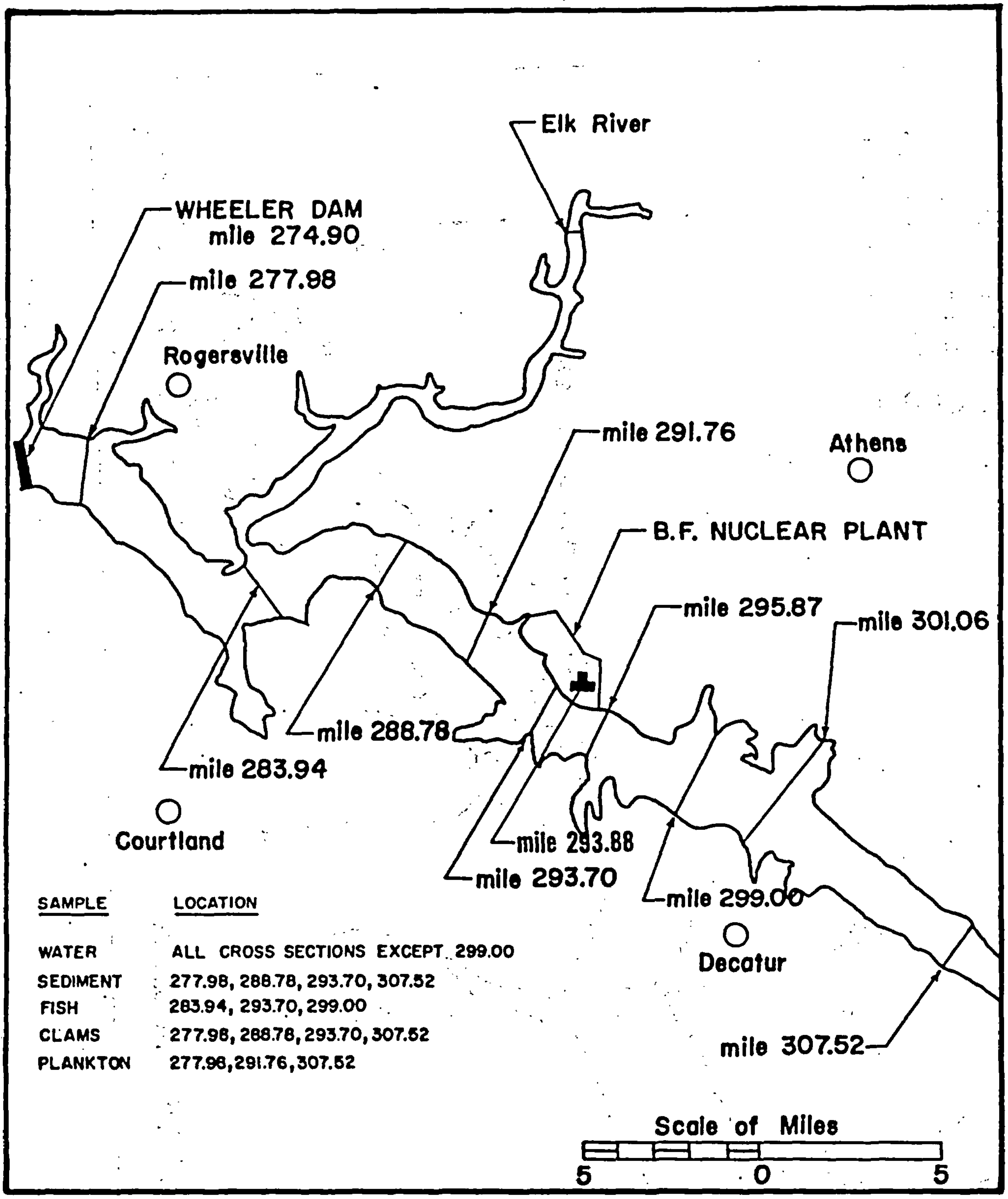


Figure 17

RESERVOIR MONITORING NETWORK



SAMPLE	LOCATION
WATER	ALL CROSS SECTIONS EXCEPT 299.00
SEDIMENT	277.98, 288.78, 293.70, 307.52
FISH	283.94, 293.70, 299.00
CLAMS	277.98, 288.78, 293.70, 307.52
PLANKTON	277.98, 291.76, 307.52

Figure 18

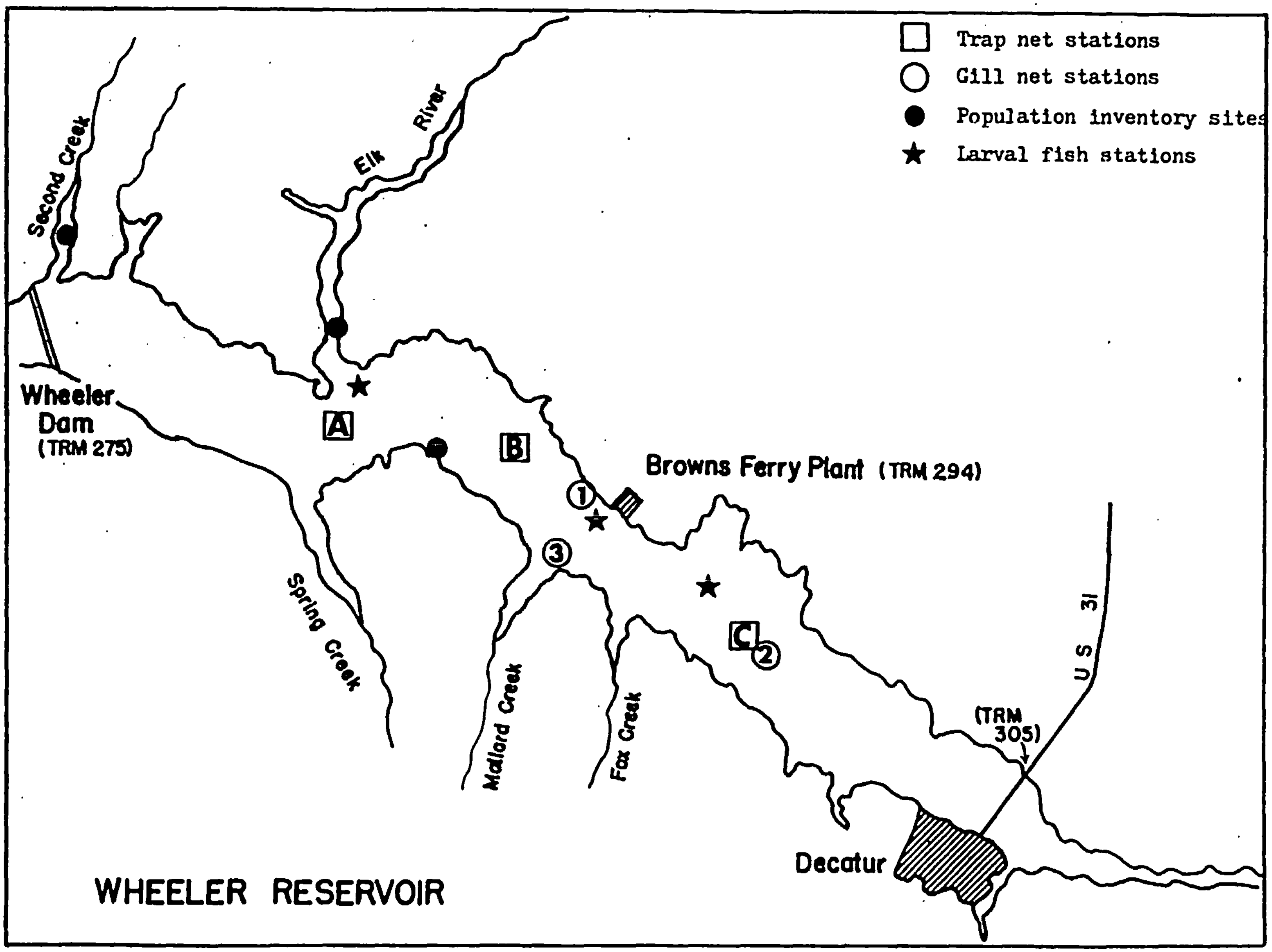


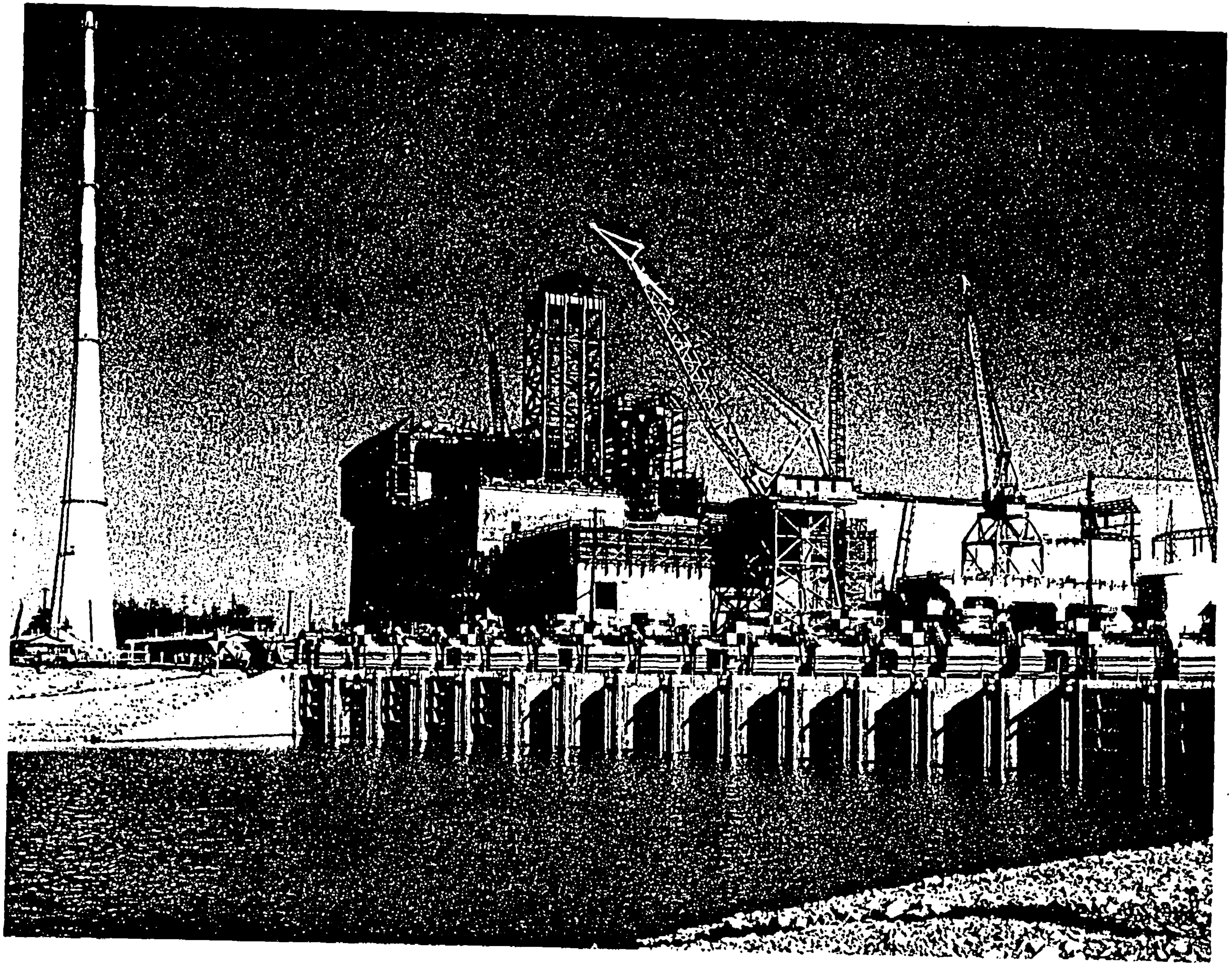
FIGURE 19

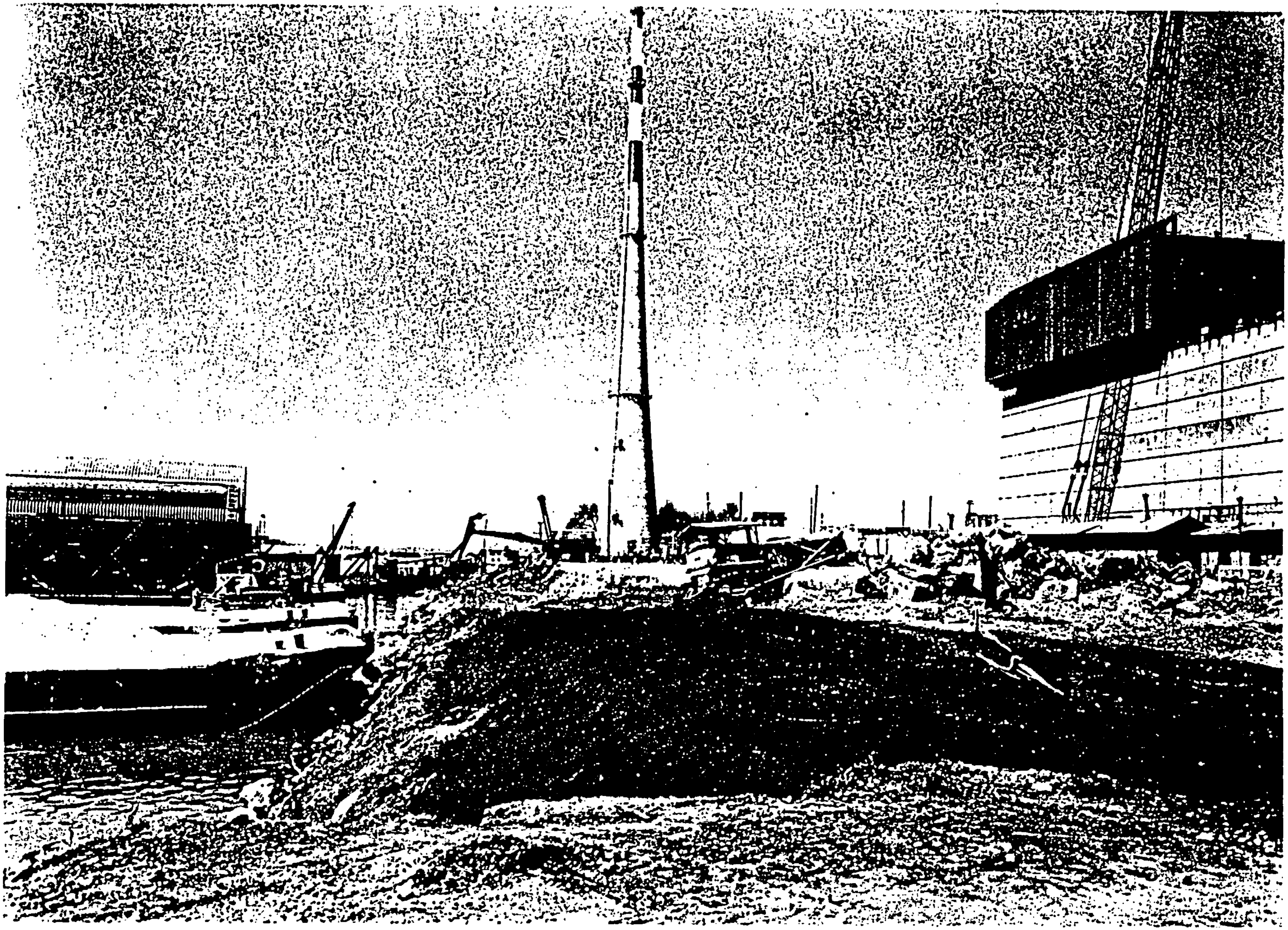
TRAP NET AND GILL NET STATIONS

APPENDIX I

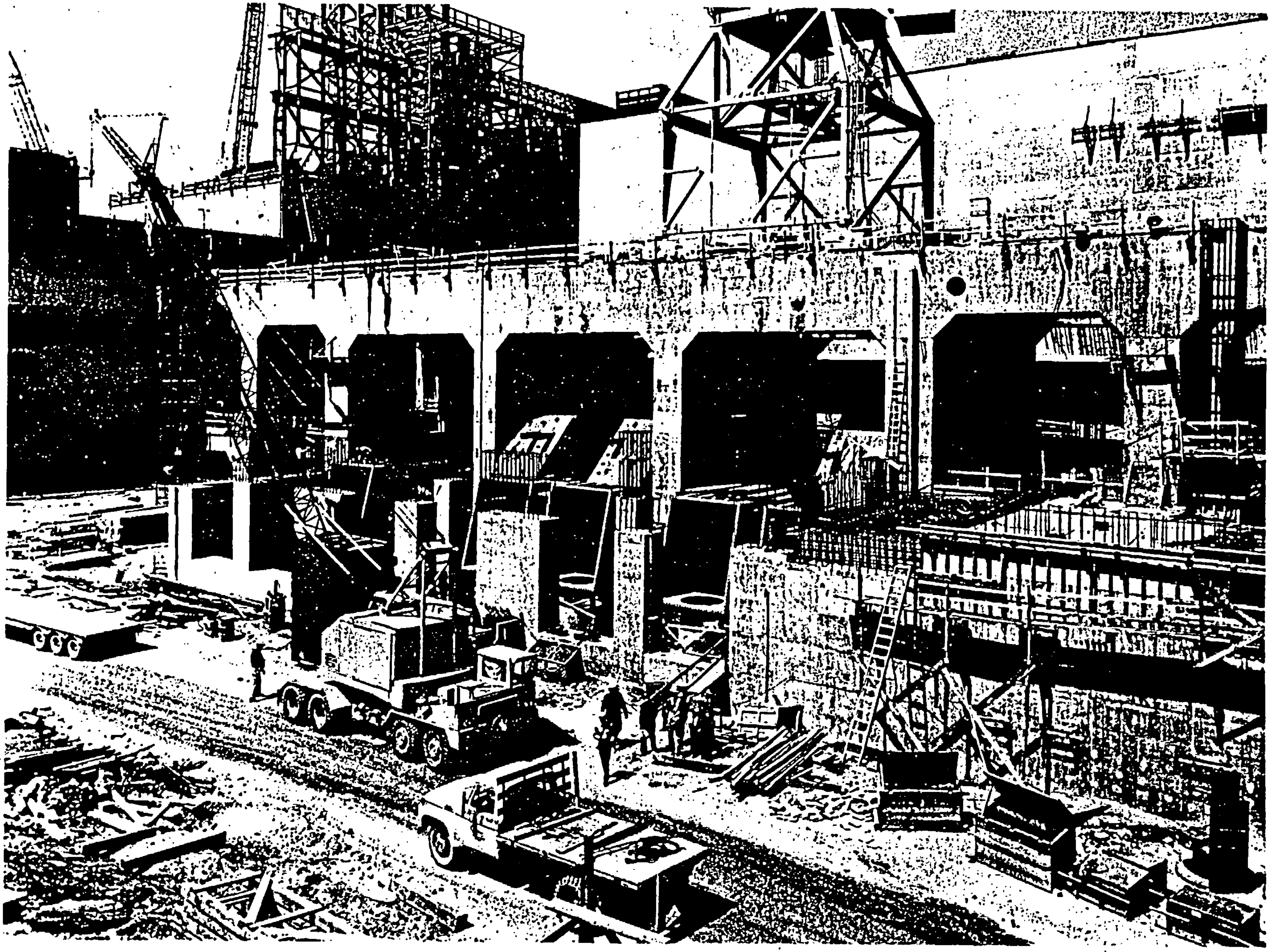
CONSTRUCTION PHOTOGRAPHS

Attached are photographs of the construction site at Browns Ferry Nuclear Plant. These photographs were taken in March and April of 1971.

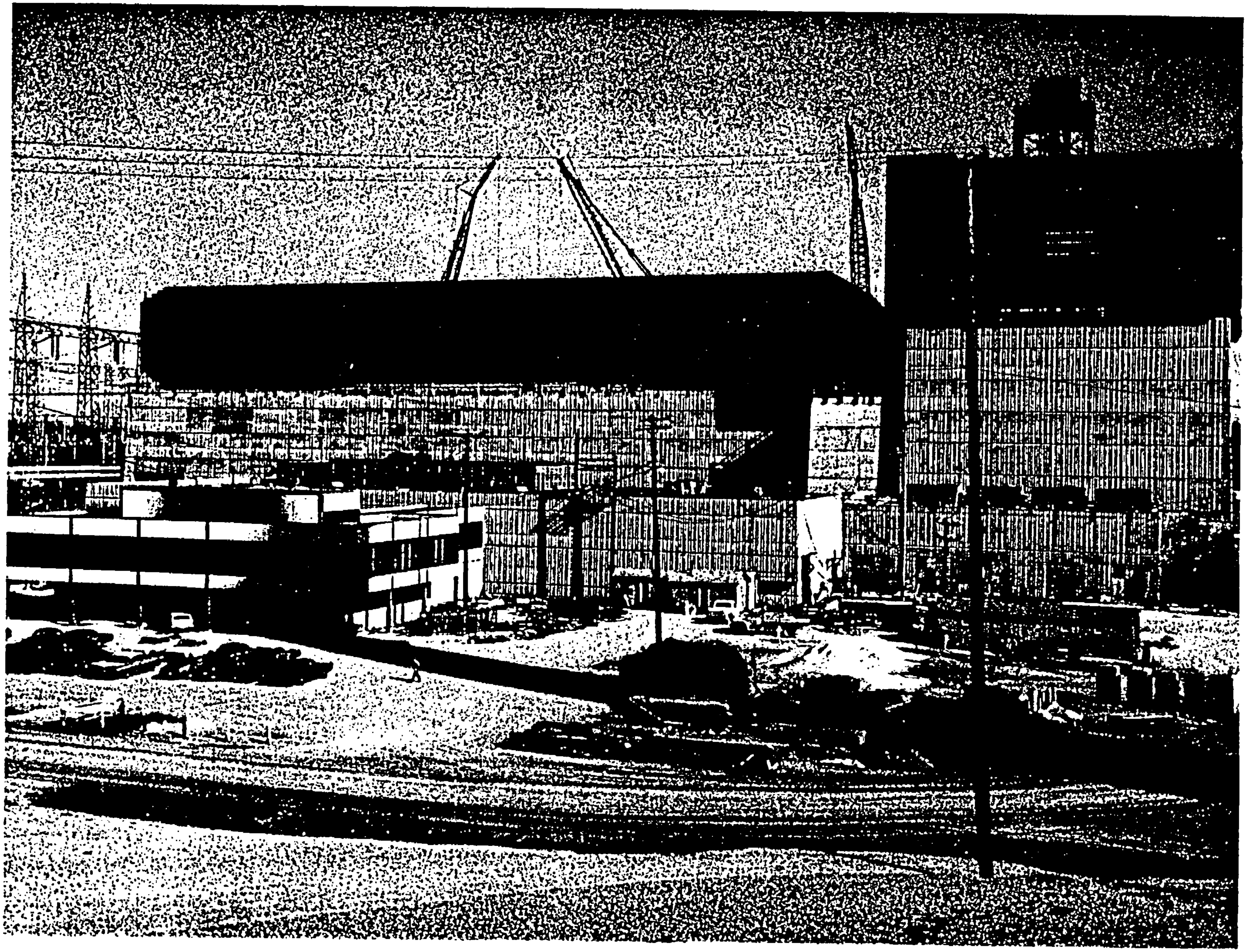


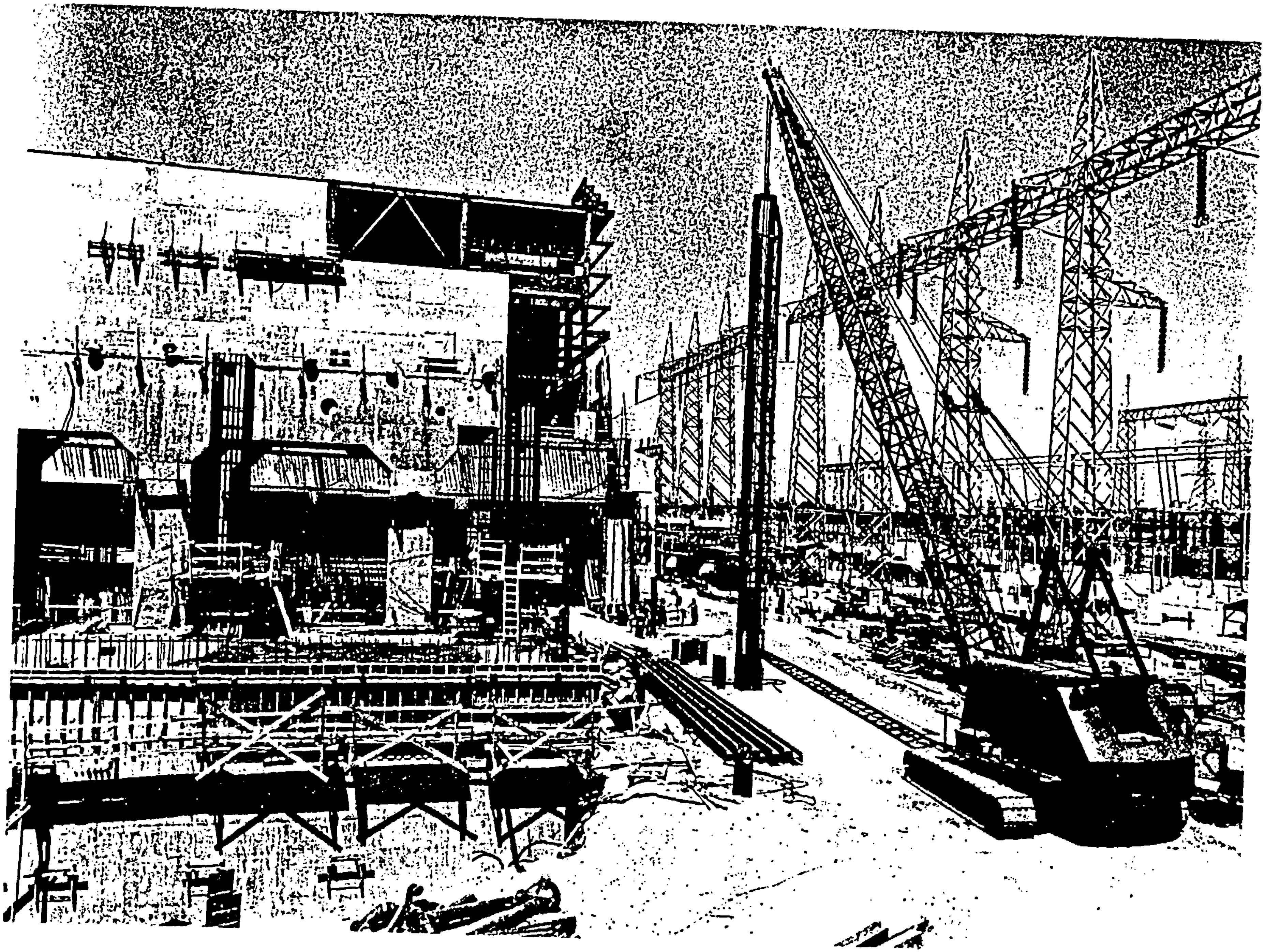


General yard grading along river bank south of the reactor building in the area of the 36-inch water line from the biothermal pumping station to the biothermal area - view west

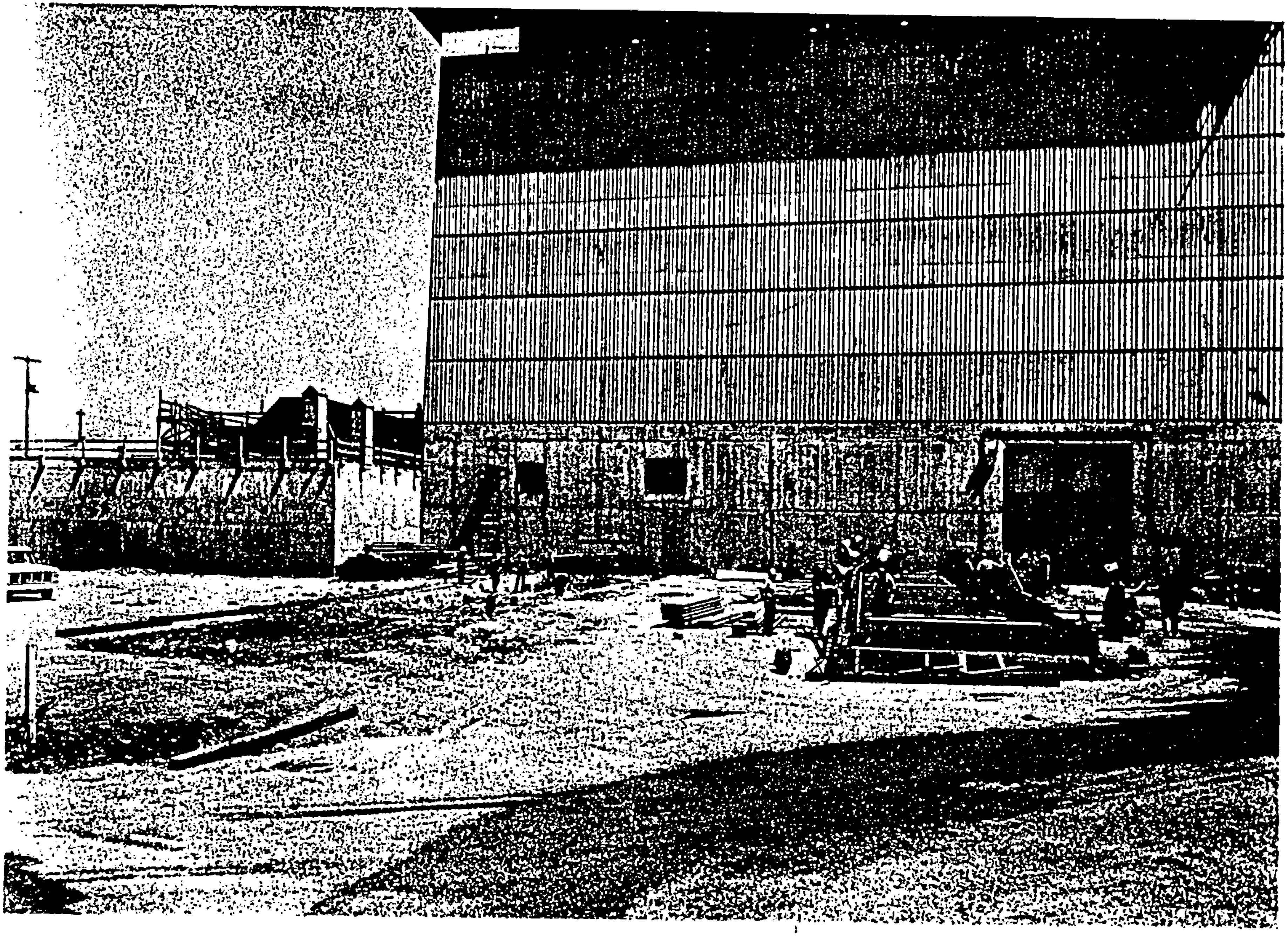


Unit 3 condenser erection - view looking west

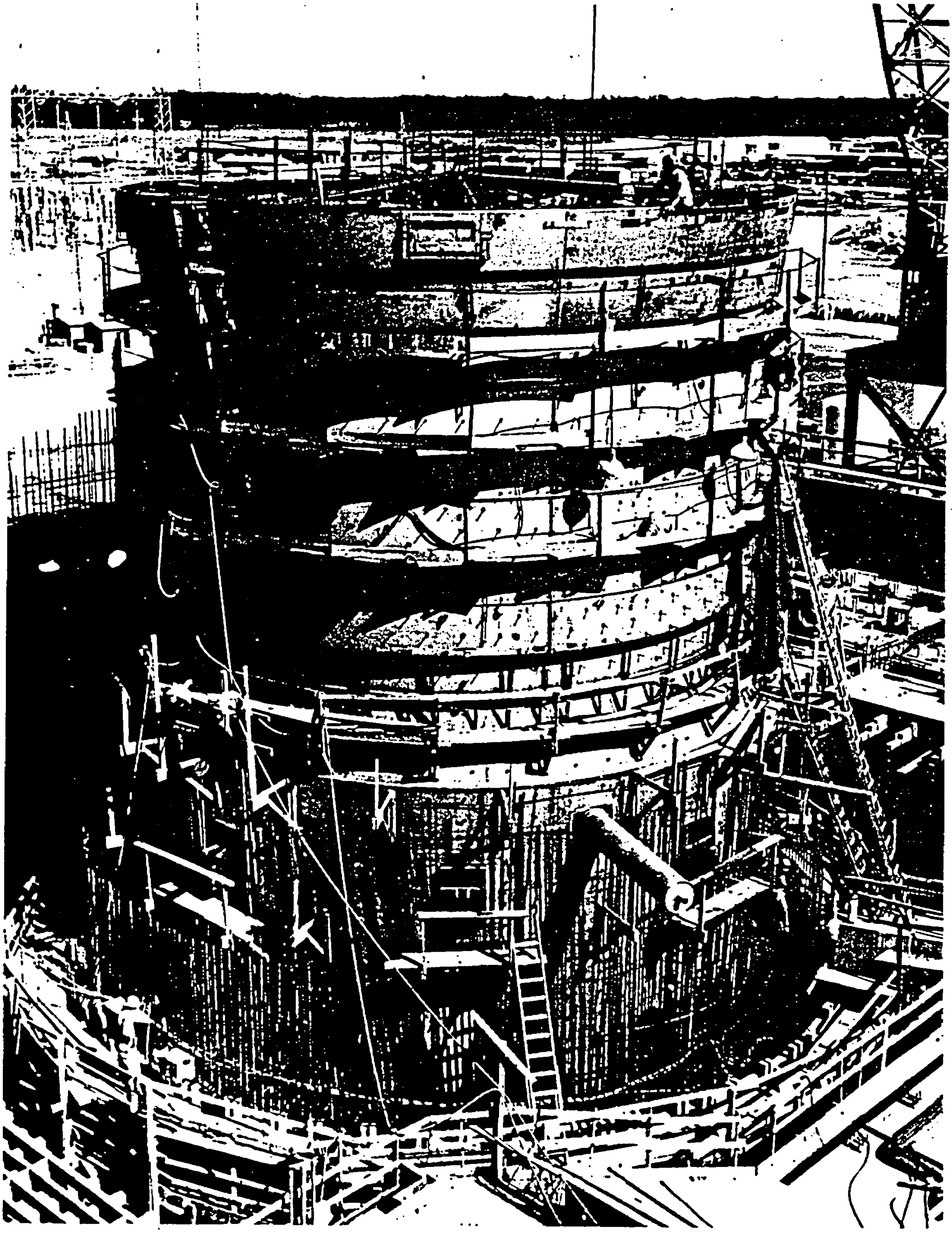


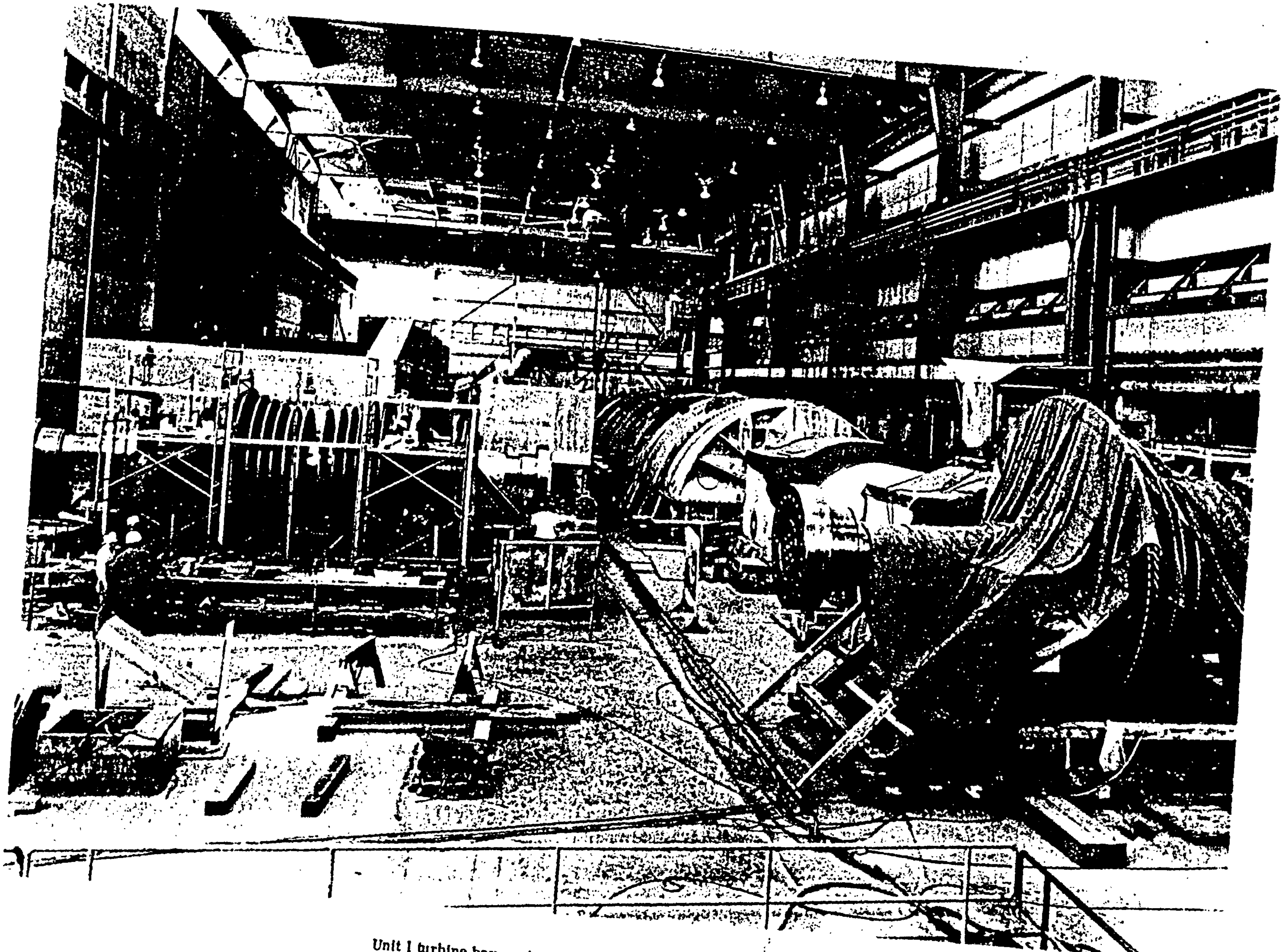


Driving H-beam piling along the unit 3 turbine a-line wall - view looking northwest

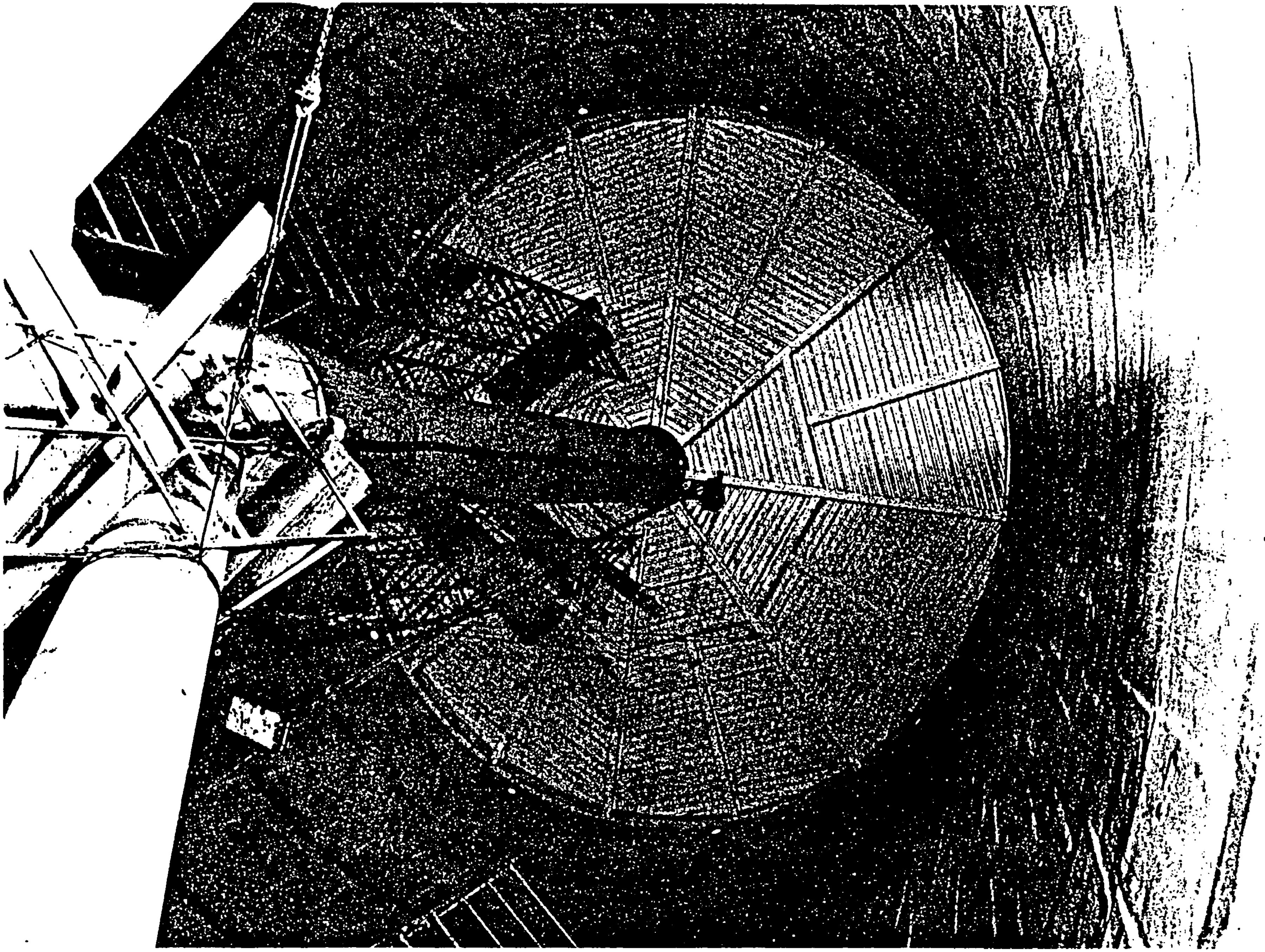


RHR & EECW pipe tunnel south of unit 1 reactor building - view looking north

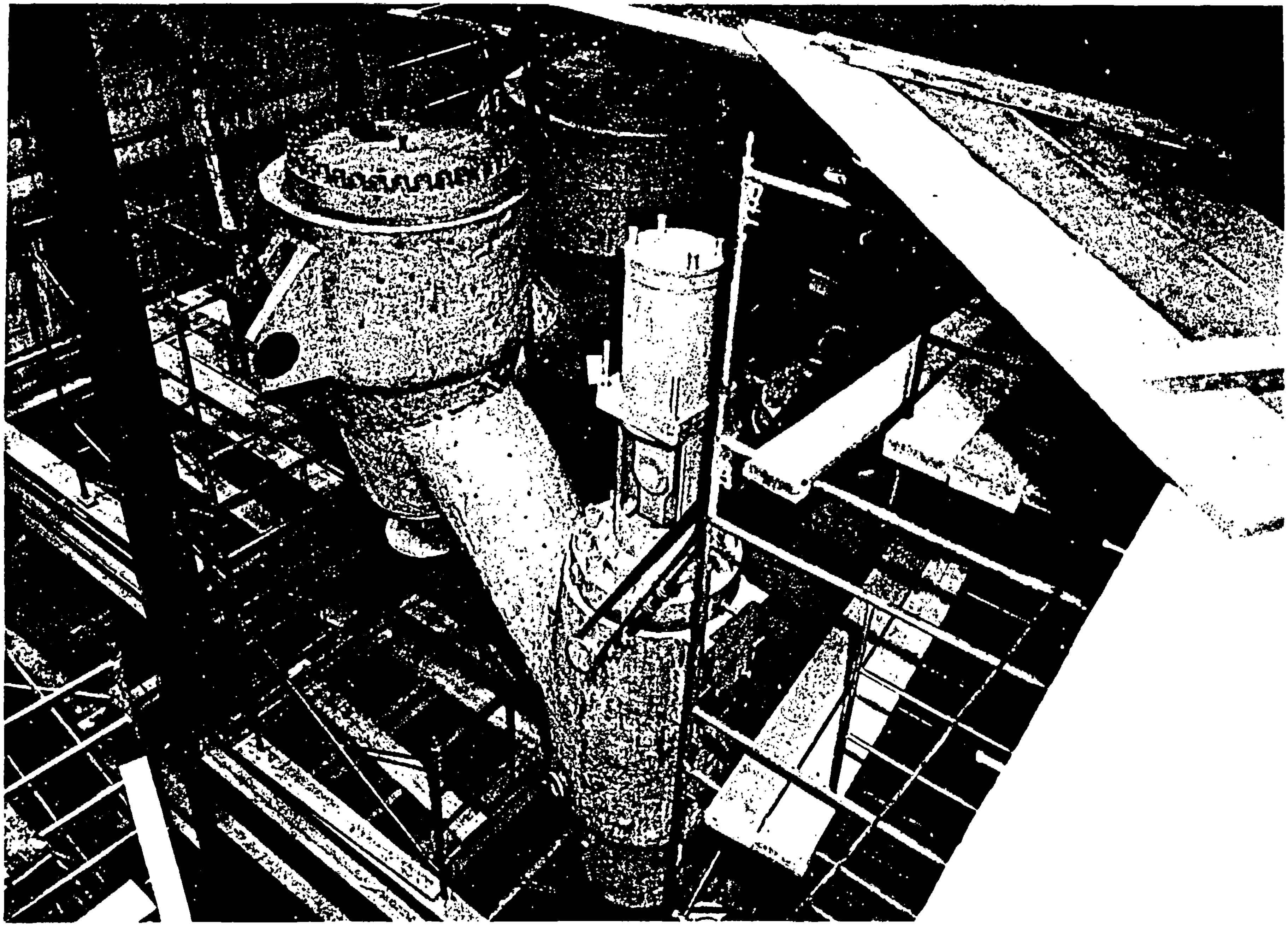




Unit 1 turbine bay - view looking south on the elevation 617.0 floor



Off-gas exhaust stack and roof deck at elevation 667.0



Installing unit 1 turbine stop valves and control valves

CRD housing clean room and handling device for moving housings into the drywell for installation

APPENDIX II

PRELIMINARY RESULTS OF MONITORING

Analyses of characteristics of gill-net catches have been made on the basis of two full years (8 quarters) of sampling.

Diversity and Abundance--Species diversity* appears to follow a characteristic repetitive pattern at Stations 1 and 2 (Figure 1). Importance values** of channel catfish and white bass also follow characteristic repetitive patterns (Figure 2 and 3); these species may be useful as indicator species. Additional species will be considered as indicators if characteristic patterns of abundance emerge at the termination of the preoperational phase of monitoring.

Tagging--As of the winter quarter (January) 1971, a total of 4,480 fish representing 16 species has been tagged and released. Of these, 158, or approximately 3.5 percent, have been recaptured.

Future efforts in this aspect of the monitoring program may include intensive tagging and displacement of selected species in order to more clearly elucidate patterns of movement of important species. In addition, we are considering the possibility of using sonic fish tags to track individual fish in order to investigate avoidance reactions to thermal discharges.

Population Inventories--Sampling of selected coves with rotenone provides data on reproductive success and early growth of

* Diversity = (no. species - 1) / $\log_e$ total catch.
**Importance value (I.V.) = (catch/trap night) x 100 (frequency of occurrence).

Figure 1. Diversity of gill-net catch, Wheeler Reservoir.

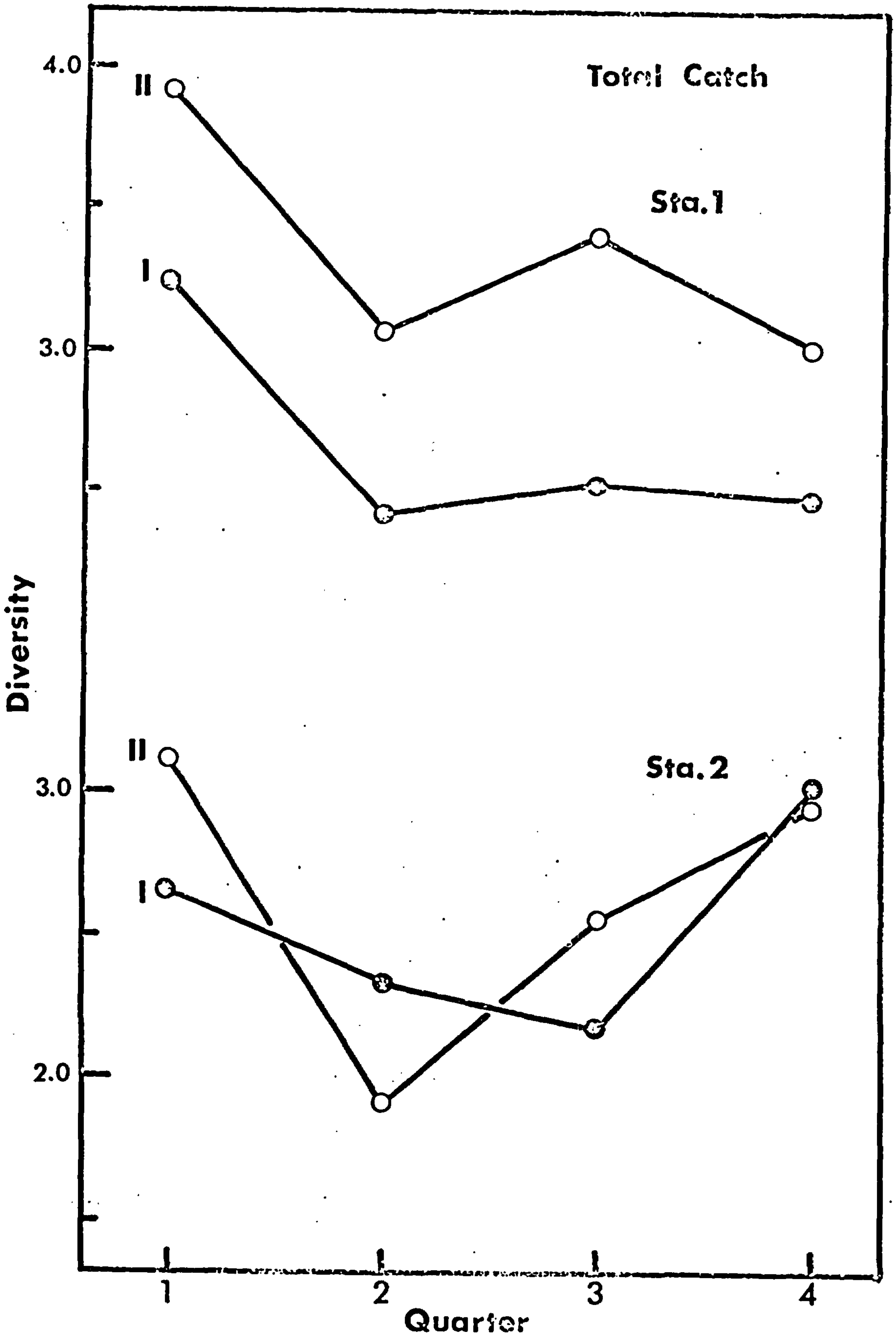


Figure 2. Log importance values, Channel catfish, Wheeler Reservoir.

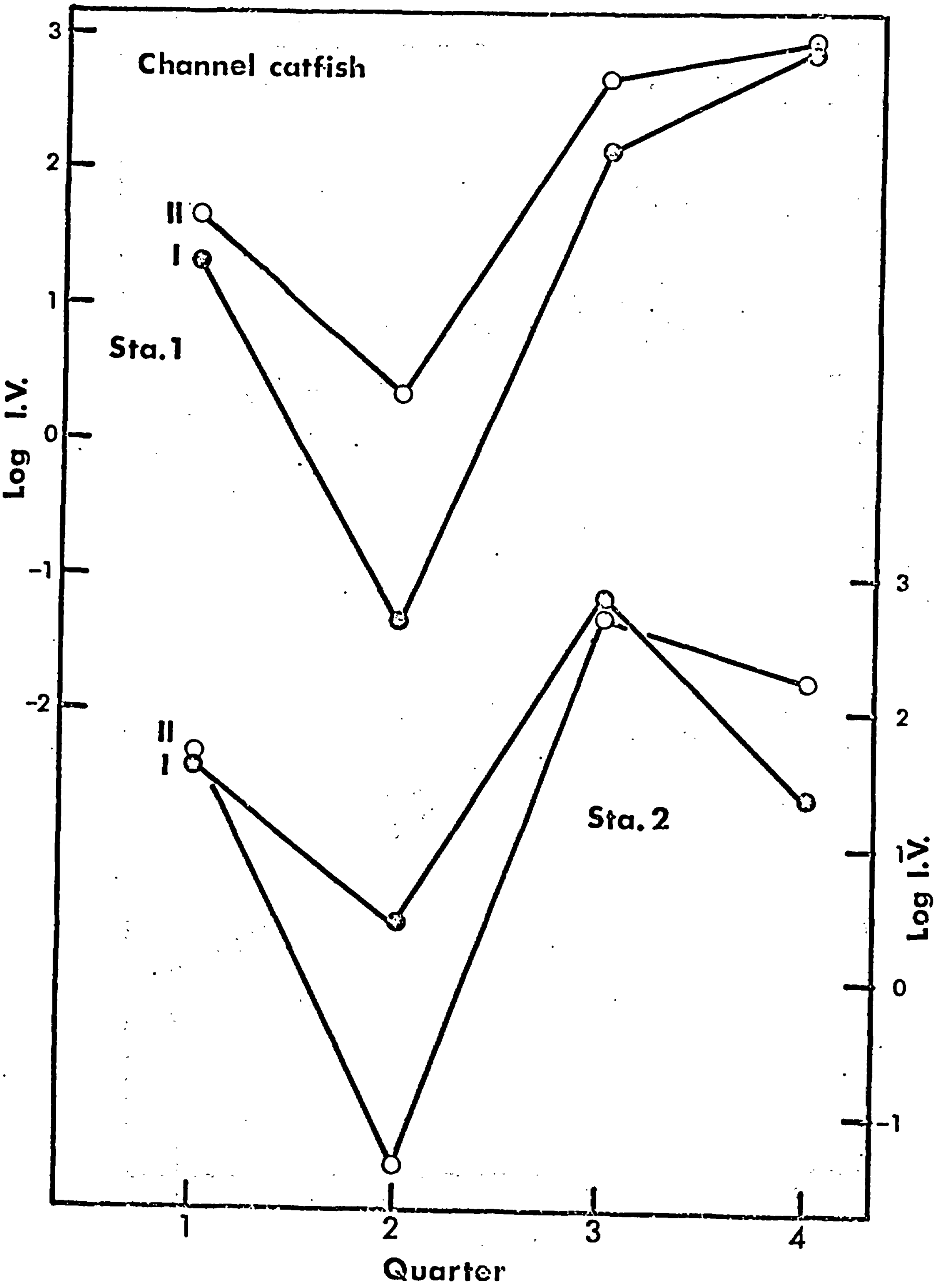
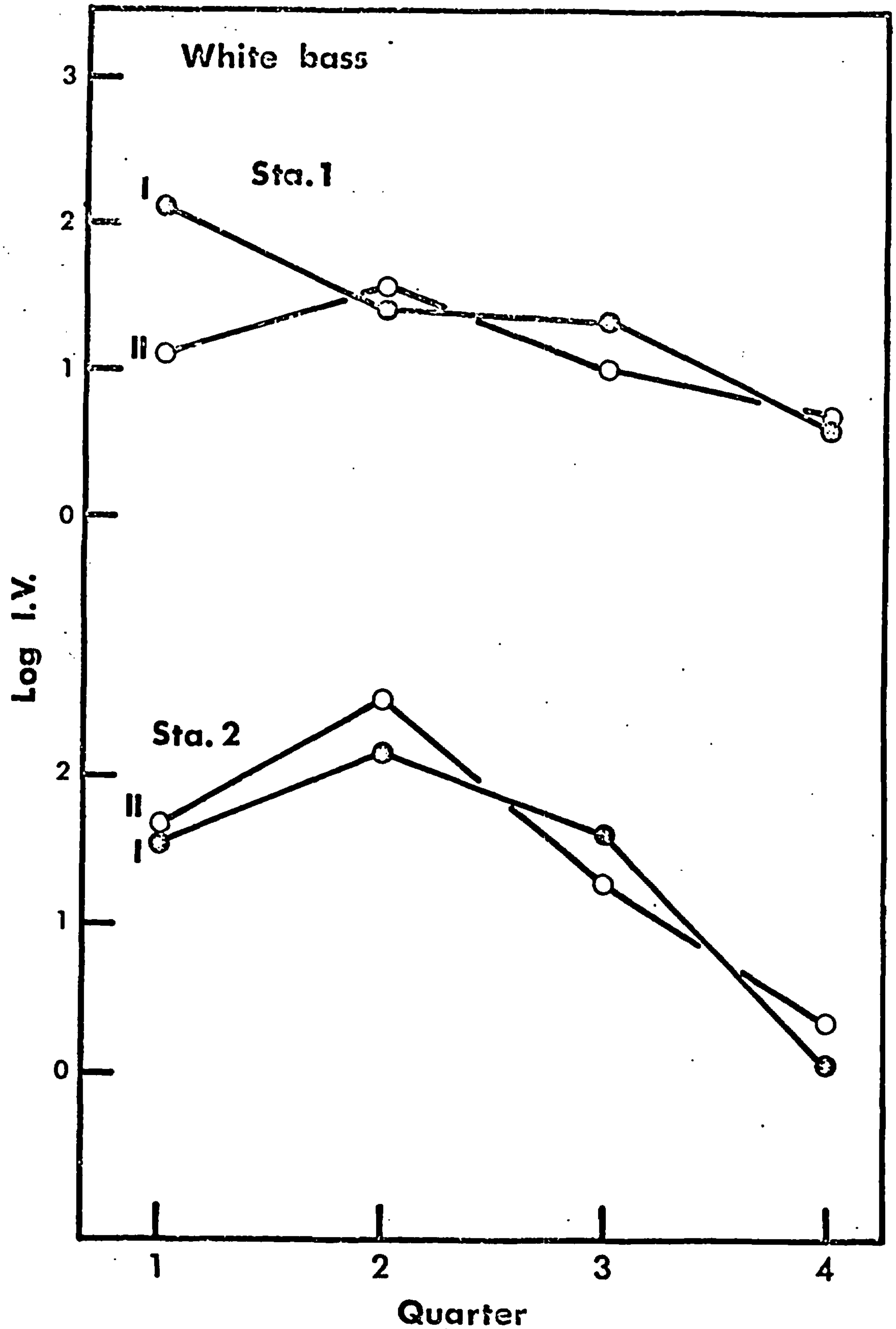


Figure 3. Log importance values, White bass, Wheeler Reservoir.



certain species, provided such samples are repeated for several years for the same coves at the same time of year. Estimates of production, based on three coves sampled in both 1969 and 1970 range from 414 to 1,157 kg/ha (370 to 1,033 pounds per acre). Inspection of the data indicates that gizzard shad may be subject to large fluctuations in year-class strength. The same may be true for other species (bluegill, spotted sucker), while some species (largemouth and smallmouth bass, freshwater drum) appear to have only minor fluctuations in reproductive success. These data will serve as baseline data with which to compare results in the postoperational phase of sampling.

APPENDIX III

STUDIES BY TVA AND OTHERS ON THE EFFECTS OF HEATED WATER AT PARADISE STEAM PLANT

Introduction

The Paradise Steam Plant consists of three units--two of 650 megawatts each, and one of 1,150 megawatts. Prior to operation, baseline monitoring of fish and fish-food organisms were made. The maximum river temperature (average over any cross section) permitted by TVA was 95° F. Two years after operation of units one and two commenced, studies made of aquatic life in the Green River below the plant noted reductions in levels of aquatic life below those indicated in the baseline studies. As a result of these studies, units one and two operate on cooling towers when high water temperatures exist. Unit three operates on cooling towers at all times. Temperature criteria of 90° F. for the maximum river temperature averaged over any cross section and limiting surface temperature to 93° F. were put into effect in 1968. Further monitoring is being conducted to assess effects of the tighter thermal controls.

The following discussion provides a synopsis of the effects of heated water on aquatic life at Paradise Steam Plant.

1. Studies by the Academy of Natural Sciences of Philadelphia

The Green River does not possess the normal complement of biotic characteristics of flowing streams. The departure toward a stillwater situation is largely attributable to long-existing alterations of the stream for navigation. The pool on which the Paradise plant is located is maintained by navigation locks, thus creating a "canal-type" situation. Summer stream velocities are low because of the deep channel and low flows. Benthic insect fauna are scarce in this pool situation because channel margins are steep and the overbank area development of a littoral fauna is sharply limited. In addition, heavy barge traffic within the pool churns bottom sediments thus creating unstable substrate conditions.

Stream invertebrates are largely restricted to zooplankton, predominantly species typical of lakes. Since benthic insects are scarce, the transitory zooplankton community assumes the major role in converting plant material to animal protein and thus constitutes a major energy channel connecting the fish population to the detrital-algal base in the food chain.

The staff of the Philadelphia Academy of Sciences directed by Dr. Ruth Patrick investigated the attached and planktonic flora, protozoa, invertebrate fauna, and insect fauna. Samples were collected over a 20-mile stretch of river extending downstream from a station 1 mile above the plant. The preoperational study was conducted in 1961--about two years prior to plant startup. A second study was conducted in 1965--two years after startup of the plant.

The 1965 study showed a reduction in species diversity and abundance, compared to that established in the 1961 study. The invertebrates showed the greatest decline over the four-year interval. The major changes were nearest the plant and were less severe at greater distances. The presence of coal dust and heavy barge traffic apparently contributed to the degeneration in quality.

2. Fish Population Studies

Dr. Hunter Hancock of Murray State University, Kentucky, made an extensive survey of the effects of heated water on fish population. With fish as with the food chain organisms, diversity of species and abundance are taken as a general indication of quality. Dr. Hancock made fish counts in the summers of 1961, 1963 (after startup), 1964, 1965, 1966, and 1967. Catches were poor in 1961 and became poorer afterwards. Catches were on the order of one fish per net day of effort. A general decline in catch was experienced at all stations after startup. The catch improved in 1965 and 1966, but was low again in 1967. Thus, the relative abundance of fish in all operational years up to the use of cooling towers in 1968 was lower than the 1961 preoperation level. The composition of the catch showed a smaller fraction of game fish and a larger fraction of edible rough fish. However, some game species (white bass and spotted bass) were more numerous in 1966 than in 1961 collections. The forage, nonedible rough, and pan fish were not present in great enough numbers to show a trend. Since the trend in catch was the same at stations above and well below the plant, as in the immediate vicinity of the plant, it is difficult to conclude how much of the effect was due to the addition of waste heat. A more recent study was made in 1970; preliminary results of this study are similar to those found in 1965-66.

3. Studies of Zooplankton by TVA Biologists

TVA biologists made a special study of the effects of temperature on zooplankton. Laboratory studies indicated a lethal threshold of about 97° F. for the dominant species of the Green River. Laboratory results were substantiated by a series of field studies in May of 1964. Field studies revealed a large mixed plankton population isolated in the floating pool of warm water which develops upstream of the plant. Zooplankton were extremely abundant here at temperatures up to, but not exceeding 96.8° F. The organisms were being seeded in this area by the approaching colder water and were flourishing at temperatures below the lethal limit. Sampling in the discharge canal where temperatures exceeded 101° F. indicated the organisms were not surviving passage through the condensers. To prevent plankton depletion of downstream reaches over extended periods or distances, either the temperatures within the condensers must be reduced below the thermal threshold for zooplankton or a portion of the streamflow permitted to bypass the plant and seed that flow diverted through the plant.

During the period May 15 to May 27, 1964, sufficient zooplankton bypassed the steam plant to reseed effluent water. Approximately 3 miles below the plant the zooplankton population equalled or exceeded population levels measured in unmodified upstream reaches. Rapid recovery was attributed to an accelerated reproductive rate in the thermally favorable downstream areas.

4. Periphyton Studies

Periphyton is an association of aquatic plants, both pigmented and nonpigmented, growing attached or clinging to the various types of substrate surfaces (river bottom, logs, stems, and leaves, etc.) in a river or lake. Periphyton in rivers is the principal food source for many benthic, herbivorous organisms and grazing fish, provides shelter, contributes oxygen to water, and constitutes a major source of river phytoplankton. Studies were undertaken to characterize the rate of periphyton production in the Green River.

General methods employed in the surveys included the collection of temperature data throughout cross sections of the receiving waters both above and below the discharge point, collection of bottom fauna with a Petersen dredge above and below the discharge point, and the use of racks of artificial substrates (plexiglass slides) for collection of periphyton growth below the surface. The slides were analyzed for total organic matter, phytopigment absorbency, and autotrophic index.

The periphyton data provide a good indication of the effects of cooling water passing through the condensers. If water passing through the condensers is heated too much, aquatic organisms (such as phytoplankton and zooplankton) suspended in it are killed. After being killed, these organisms can form a "luxury level" of food for heterotrophic or "slime" organisms downstream. These heterotrophic organisms are dependent upon organic matter for food. In contrast to this, autotrophic organisms (e.g., phytoplankton) rely on inorganic carbon and other minerals in the water for their food supply. Consequently, any marked reduction in the ratio of autotrophic to heterotrophic organisms in the total mass of periphyton could indicate that elevated temperature is killing at least some of the plankton passing through the condensers and increasing "slime" growth.

The following conclusions were drawn: (1) During the summer months periphyton growth rates in the Green River are substantially reduced in the vicinity of the steam plant. In the late fall and early winter, downstream growth rates may be moderately enhanced. (2) Recovery generally occurred about 15 miles downstream. (3) The station in the immediate vicinity of the Paradise Steam Plant showed the largest proportion of heterotrophic slimes. Below the plant the proportion of algae in the periphyton increased progressively with distance and was greater at the downstream recovery stations than at the upstream control stations. (4) Downstream from the plant, the relative periphyton production rates progressively increased. The warm water discharges clearly favored the production of the heterotrophic slimes during the warm summer months. (5) As regards the total supply of fish food in the periphyton, little net change due to the plant was observed. However, the findings indicate that the potential for problems due to slime growth would be increased in any industrial water-using operations located close downstream from the power plant.

The first unit at Paradise went into commercial operation in May 1963. While the second unit did not go into commercial operation until November 1963, it was initially fired up on August 21, 1963. During the initial firing, flow in the Green River was less than condenser flow. During two periods in the fall of 1963 (September 12 to September 13, and September 23 to October 1), the maximum mean temperature determined at Green River mile 99.5 exceeded 95° F.

Five winter fish inventories were made by TVA and Kentucky biologists in the years 1962-1966. A much larger winter fish population is consistently found in the vicinity of the discharge canal than in the river above and below the plant. Distribution of fish by type paralleled summer findings, except game fish were much more numerous than in preoperational samples. Fishermen know that steam plant discharge canals are excellent spots for fishing in winter months.

The 95° F. temperature maximum recommended in 1962 remained in effect during 1963, 1964, and 1965. Because of the reduction in species diversity and abundance indicated by Dr. Patrick's 1965 study, it was concluded that the temperature criteria should be changed. About this time the construction of a third unit at Paradise was planned. Cooling towers were to be provided for the new unit. Since the existing two units were required to operate under reduced load for a long period each year to meet the 95° F. criterion, and since operation would be further curtailed by new temperature limits, it appeared desirable to provide cooling towers for all three units. A maximum mean river temperature of 93° F. was allowed until the first cooling tower was put into operation during the summer of 1968. The new criteria established by TVA limit maximum mean river temperature to 90° F. and surface temperature to 93° F.

APPENDIX IV

PROPOSED RESEARCH PROJECT ON EFFECTS OF HEATED WATER ON AQUATIC LIFE

Proposed Research Project on Effects of Heated Water on Aquatic Life

TVA is planning a large-scale biological research project to explore the effects of heated water on aquatic life. This is a long-term project to be conducted in cooperation with the Environmental Protection Agency.

The objectives of the proposed experiments are:

1. To determine the relationship between annual temperature regime and growth, reproduction, mortality, and yield of warmwater commercial and sport fish populations living under nearly natural conditions. Each of the above processes will be modeled mathematically using methods similar to those described by Ricker (1958) and Beverton and Holt (1957). Parameters in these models will be related to the annual temperature regime using several equations reviewed by Andrewartha and Birch (1954) and Watt (1968). These results will be used to predict the effect of different annual temperature regimes on growth, mortality, reproduction, production, and yield from a fishery.

   Measures of condition and size distribution will also be made on the fish. Emphasis in these studies will be placed on sport and commercially valuable fish populations because these populations are of immediate and measurable importance. The significance of changes in fish populations is more easily evaluated, from the viewpoint of human economics, than is the significance of changes in other aquatic populations, and increased water temperature will probably have a greater effect on fish than on other aquatic life.

2. The accuracy of "safe" water temperature regimes estimated using laboratory experiments will be evaluated by comparing results from the channel studies with "safe" levels determined by using both LD_{50} values and experiments similar to those done by Mount and Stephan (1967).

3. The relationship between annual temperature regime and the production of warmwater, commercially valuable mussel populations living under nearly natural conditions will be determined using the same methods as will be used for fish.

4. The relationship between annual temperature regime and the production of warmwater bottom fauna and other fish food organisms will be modeled using methods similar to those to be used for the fish studies.

5. The effect of different annual temperature regimes on the ecological relationships between fishes and their food organisms will be studied using conceptual models similar to those developed by Beverton and Holt (1957). The models will be fitted to the data by the method of

least squares, and then the effect of temperature on the parameters in the model will be studied.

6. The effect of different annual temperature regimes on algal community composition will be determined by estimating the relative frequencies of occurrence of different groups. Mathematical models for algal productivity will be constructed.

7. The effect of temperature on the relationships among streambottom microbial populations will be studied.

8. The effect of different annual temperature regimes on the competitive interaction between two species of fish will be investigated.

9. The effect of annual temperature regime on the predation of one species of fish on another fish species may be investigated.

10. The feasibility of using systems models for determining the effect of different annual temperature regimes on the structural and functional relationships of stream communities will be investigated.

In completing the above objectives, the Browns Ferry project will provide data for establishing temperature criteria for warmwater streams, data for determining the accuracy of laboratory estimates of safe water quality criteria, and data for investigating the potential of applying systems analysis in ecology.

A total of eight naturalistic stream channels will be used. Two of these channels will serve as biological controls water of natural temperature. The other six channels will contain water with temperatures elevated to some degree above that in the control channels.

Water will be supplied to the channels from Wheeler Reservoir. Water of natural temperature will come through a special intake located near the upstream end of the intake canal for the power plant. Warm water for the three pairs of experimental channels will be heated in heat exchangers. The source of heat for the heat exchangers will be warm water discharged through a manifold from the power plant condensers.

The captive fish and associated biota will be exposed to the experimental conditions 100 percent of the time. In streams or reservoirs receiving heated discharges, effects of heat would be less since upper limit temperatures in the heat-receiving stream or reservoir will occur only intermittently due to variables such as variations in streamflows, powerloads, etc. Consequently, the controlled experiments should yield the most detrimental (or beneficial) effects possible of the particular heat regimes.

The findings from the research should have wide application. Given proper interpretation, they should be of great value in setting or adjusting water quality standards for temperature. The data obtained should help define the degree of protection needed for aquatic life, together with the degree to which warmwater streams can be used, in the public interest, to absorb heated discharges from industry.

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