Regulatory File Cy.

Received w/Ltr Dated 11-5-71

DAVIS-BESSE
NUCLEAR POWER STATION

SUPPLEMENT
TO
ENVIRONMENTAL REPORT

VOLUME 2

THE
TOLEDO
EDISON
COMPANY

5 TRANSPORTATION OF RADIOACTIVE MATERIAL

5.1 INTRODUCTION

The transportation of radioactive materials in various forms and quantities is necessary for operation and maintenance of all nuclear generating stations. These shipments include:

1. transportation of new fuel assemblies from the fuel fabricator to the reactor.
2. shipment of solid radioactive wastes from the reactor to the waste disposal facility.
3. shipment of irradiated fuel from the reactor to the fuel reporcessing plant.

These radioactive shipments are made in containers which are designed, built and tested according to stringent Federal specifications intended to minimize the release of radioactive materials under other than normal transportation conditions.

All radioactive shipments must also conform with Federal regulations governing the labeling and identification of the shipping containers and the mode of shipment (rail, highway, and water).

All of the categories of radioactive material shipments described above which are made to and from Davis-Besse will be made in accordance with all applicable state and Federal regulations related to radioactive material packaging and shipment. These regulations are intended to prevent significant impact upon life and property which may be related to the transportation of radioactive materials.

The following sections describe, to the extent possible, the general shipping procedures, transport containers, volumes of waste, intransit safety arrangements, routing and frequency of shipments. Also included is a discussion of the potential environmental impact of radioactive shipments associated with Davis-Besse. Future changes in shipping containers or general shipping procedures are likely to occur but are not expected to have a significantly different impact on the environment.

5.2 PACKAGING OF RADIOACTIVE MATERIALS

The packaging of radioactive materials for transport is rigidly regulated by the Federal government through the Department of Transportation (DOT) and the Atomic Energy Commission (AEC). The regulations of these agencies require that radioactive materials must be packaged in containers which have been designed to maintain shielding efficiency and nuclear safety, where required, and leak tightness so that, under normal transportation conditions, there will be no release of radioactive material to the environment.

5.2.1 PACKAGING REGULATIONS

All radioactive materials, not specifically exempted by regulation, which enter or leave the Davis-Besse site will be packaged and transported in accordance with the following regulations, as applicable:

1. Code of Federal Regulations, Title 10, Part 20 (10CFR20) - Standards for Protection Against Radiation (AEC)
2. 10CFR70 - Special Nuclear Material (AEC)
3. 10CFR71 - Packaging of Radioactive Material for Transport (AEC)
4. 49CFR, Parts 1 to 199 - Transportation (DOT)

5.2.2 TYPES OF SHIPPING CONTAINERS

Several types of shipping containers for cold fuel and radioactive waste may be specified at this time, at least in general terms. However, the irradiated fuel shipping container is still in the conceptual design stage and cannot be discussed in detail. This does not preclude an evaluation of the environmental impact of irradiated fuel shipments since all irradiated fuel shipping containers are designed to the same rigid specifications.

5.2.2.1 New Fuel Assembly Containers

New fuel assemblies will be packaged in a Babcock and Wilcox fuel shipping container. The container was designed, built and tested by Container Research Corporation to conform with all applicable AEC and DOT regulations. These shipping containers meet the general standards for all packages, criticality standards for fissile material, standards for normal conditions of transport and standards for hypothetical accident conditions for a single package as specified by the AEC and DOT. Their design, construction and testing has been reviewed by the AEC and DOT and the required AEC license and DOT permit have been authorized.

The fuel assembly containers are designed to accommodate 2 elements and each transport vehicle will carry a maximum of six 2-element containers.

5.2.2.2 Radioactive Waste Shipping Containers

Solid radioactive wastes will consist of spent ion exchange resins, evaporator concentrate, radioactive filters and miscellaneous low activity level wastes. The high level wastes, which include ion exchange resins, evaporator concentrate and radioactive filters, will be mixed with concrete at the drumming station in the waste disposal area and packaged in DOT Specification 17-H, 55 gallon steel drums.

Low activity wastes such as contaminated clothing, rags, paper, gloves and shoe covers will be compressed by a compactor located in the waste disposal area and stored in DOT Specification 17-H, 55 gallon steel drums prior to shipment off-site for land disposal.

5.2.2.3 Irradiated Fuel Shipping Container

Irradiated fuel reprocessing negotiations for the Davis-Besse Station have not yet progressed to the point where the shipping container can be described in detail. In all probability, it will be a container designed for rail shipment.

Spent fuel containers are designed to meet the requirements of the AEC (10 CFR71) and DOT (49CFR173). These regulations require spent fuel containers to withstand the following hypothetical accident conditions to be applied sequentially in the order indicated:

1. FREE DROP -- A free drop through a distance of 30 feet onto a flat essentially unyielding horizontal surface, striking the surface in a position for which maximum damage is expected.
2. PUNCTURE -- A free drop through a distance of 40 inches striking, in a position for which maximum damage is expected, the top end of a vertical cylindrical mild steel bar mounted on an essentially unyielding horizontal surface. The bar shall be 6 inches in diameter, with the top horizontal and its edge rounded to a radius of not more than one-quarter inch, and of such a length as to cause maximum damage to the package, but not less than 8 inches long. The long axis of the bar shall be perpendicular to the unyielding horizontal surface.
3. THERMAL -- Exposure to a thermal test in which the heat input to the package is not less than that which would result from exposure of the whole package to a radiation environment of 1.475° F for 30 minutes with an emissivity coefficient of 0.9, assuming the surfaces of the package have an absorption coefficient of 0.8. The package shall not be cooled artificially until 3 hours after

the test period unless it can be shown that the temperature on the inside of the package has begun to fall in less than 3 hours.

4. WATER IMMERSION (fissile material packages only) -- Immersion in water to the extent that all portions of the package to be tested are under at least 3 feet of water for a period of not less than 8 hours.

The container must be designed and its contents so limited that if it were subjected to the hypothetical accident conditions described above, it will meet the following conditions:

1. The reduction of shielding would not be sufficient to increase the external radiation dose rate to more than 1000 millirem per hour at 3 feet from the surface of the package.
2. No radioactive material would be released from the package except for gases and contaminated coolant containing total radioactivity exceeding neither 1000 curies of noble gases nor 10 curies of radioactive halogens.

5.3 TRANSPORTATION

All radioactive shipments to and from the Davis-Besse site will be made by rail or over the highway by motor carrier. It is tentatively planned to ship irradiated fuel by rail and all other shipments by truck. The regulations governing transportation by rail and motor carriers are contained in the Code of Federal Regulations, Title 49, Part 173. This part of the transportation code defines hazardous materials, which include radioactive materials, and states the precautions that must be observed by the shipper in preparing them for shipment. All shipments will conform with these regulations.

5.3.1 GENERAL SHIPPING PROCEDURES

5.3.1.1 Highway Transportation

Highway transportation of radioactive waste materials will be accomplished by contract or common carriers under contract to Toledo Edison Company. The motor carrier contractors will be responsible for providing the shipping containers and associated handling equipment, transport vehicle, and qualified drivers. In the case of new fuel and irradiated fuel shipments, the new fuel vendor and the irradiated fuel reprocessor will be responsible for all shipping services.

Prior to shipment from or to the Davis-Besse site, all containers will be surveyed to assure that they have been loaded properly and are not damaged. In addition, all packages will be surveyed to assure that external radiation and contamination levels are within limits specified by the appropriate regulations previously discussed. All shipments will conform with all applicable AEC and DOT regulations pertaining to required lables and placards and will be shipped by exclusive use of the vehicle.

Qualified drivers will be equipped with appropriate personnel monitoring devices and the tractor cab will also be monitored for radiation. The drivers will have been trained in the fundamentals of radiological control and will have detailed instructions concerning the actions to be taken in any conceivable emergency situation. Predetermined shipment routes will avoid populated areas whenever practicable and, in general, will employ routes through rural areas. Routine inspection of the shipment at periodic intervals will include radiation measurements as well as visual inspections of the transport vehicle for possible mechanical failures.

Equipment will be provided for determining the condition of the vehicle and cargo, making minor repairs and adjustments and coping with emergency conditions. Inspection equipment will include that which is required by DOT regulations. Portable radiation survey instruments will be provided as required for performing the prescribed surveys.

The drivers will be properly trained will be provided with written instructions covering emergency procedures to be followed in the event of an accident. The transportation contractor will maintain an Accident Recovery Plan in cooperation with the AEC Radiological Emergency Assistance Program. These actions are designed to control release or dispersal of radioactivity and to keep the public away from the scene of an accident. This program coordinates efforts among Federal, State and local emergencies in recovery from accidents involving radioactive materials.

In the event of a vehicular accident of any kind, the drivers will notify local civil authorities as quickly as possible. In the case of a major accident, or one in which damage to the shipment is suspected, or in any case where there is suspicion or evidence of release of radioactive material, the drivers will notify the Manager of the nearest AEC Operations Office immediately. The drivers shall be in attendance and maintain security in the event of any accident. Such notification will also be given in the event of theft or loss of the material.

5.3.1.2 Rail Transportation

The railroad accepting the irradiated fuel shipping container will have the responsibility for assuring that the shipment is made in accordance with applicable regulations. These shipments will be made using the same general procedures previously discussed for highway transportation with regard to in-transit inspection and safety. The same Accident Recovery Plan will be effected by the Carrier in the event of an accident.

5.4 ESTIMATED QUANTITIES AND FREQUENCY OF SHIPMENTS

The number of radioactive shipments discussed below are estimates based upon the best information currently available and are considered conservative. The numbers may change as additional information becomes available, however, they are not expected to increase. In each case the number of shipments refers to the operation of a single unit at Davis-Besse.

5.4.1 NEW FUEL

New fuel assemblies will be shipped from the fuel manufacturing plant to Davis-Besse on a schedule consistent with reactor requirements. The maximum number of truck shipments for the initial core will be fifteen, with five shipments annually thereafter. This assumes each truck will carry six 2-element shipping containers.

5.4.2 RADIOACTIVE WASTES

The quantity of solid radioactive waste has been estimated based upon an evaluation of the performance of the radioactive waste disposal system, anticipated reactor operations and previous recent experience at other operating plants.

The quantity of high level wastes, such as spent resin and filters and evaporator concentrates will be approximately 1800 $ft.^3$ per year which will result in about 3600 $ft.^3$ per year of concreted waste. The 55 gallon steel drums perviously discussed will be used for these shipments. This translates to about 490 drums and about seven (7) truck shipments per year.

The remaining low level waste will be about 900 $ft.^3$ and will be compacted in 55 gallon drums. These drums have a free volume of about 7.35 $ft.^3$. Assuming that the waste can be compacted to about 80% of the free volume of the drum, approximately 150 drums of waste will be generated per year. Each truck shipment till accommodate about 80 drums which results in about two (2) shipments per year.

The transportation contractor and the location of the waste burial facility have not yet been determined.

5.4.3 IRRADIATED FUEL

The irradiated fuel reprocessing contractor and the reprocessing plant site have not yet been designated. Each year about 59 irradiated fuel assemblies will be shipped. It is expected that they will be shipped by rail in containers which will accommodate up to 10 assemblies each. On this basis a total of 6 shipments per year will be made.

5.5 ENVIRONMENTAL IMPACT OF RADIOACTIVE SHIPMENTS

The environmental impact of radioactive material shipments is imperceptable under normal transport conditions. In addition, the use of nuclear power for electrical generation significantly reduces the requirement for shipments of raw materials to, and waste products from, fossil fueled electrical generating stations.

5.5.1 LAND USE COMPATABILITY

The transportation of radioactive materials will be accomplished over existing rights-of-way and will not require additional land use. Also, the frequency of shipments is too low to create traffic problems on U. S. highways or railroads. The size and loaded weights of trucks and rail cars will be well within legal limits. No oversized loads will be employed, therefore, exclusive use of roadways or railways will not be necessary. The transportation of radioactive materials should not affect normal traffic flow in any way.

5.5.2 WATER USE COMPATABILITY

The transportation of radioactive materials will not require the use of nor will it have any interaction with any water source external to the shipping container or transport vehicle.

Water used in conjunction with cleaning, decontaminating and/or flushing shipping containers is considered in another section of this report since these operations are carried out within the plant boundaries.

5.5.3 HEAT DISSIPATION

Spent fuel shipments will dissipate heat to the ambient air at rates that are judged to have an imperceptable effect on air quality.

5.5.4 CHEMICAL DISCHARGES

Transportation of radioactive materials will not result in any discharge of chemicals to the environment. Again, chemical cleaning of cask surfaces will be accomplished within plant boundaries. Discharge of such chemical cleaning agents are considered in another section of this report.

5.5.5 RADIOACTIVE DISCHARGES

Shipping containers are designed such that any radioactive material is sealed within the inner cavity during transportation. No radioactive discharges can occur under normal conditions of transport. Any smearable contamination on the outside surface of the container will be removed prior to shipment such that dispersal of radioactivity will not occur due to weathering or other effects of the container surface in transit.

5.5.6 DIRECT RADIATION EXPOSURE

All shipping containers will be shielded to maintain a maximum dose rate less than 10 mrem/hr at 6 feet from the external surface of the vehicle. The following precautions will be taken to minimize public exposure:

1. A personnel shield will be installed to physically prevent any person from approaching closer than 4 feet from the vehicle centerline.

2. DOT required radioactive materials labelling will be affixed to the vehicle to warn the public that radioactive materials are contained on the vehicle.

3. The loaded vehicle will never be left unattended when not in transit.

4. In the event that the vehicle is disabled in public areas, the operator will maintain an exclusion distance around it such that the maximum dose rate will be less than 2 mrem/hr.

The greatest exposure of the general population to the loaded vehicle occurs when the vehicle is in transit. In general, the routing for both truck and rail shipment will be selected to avoid population centers. Situations, such as rush-hour traffic which would place a person in the vicinity of the loaded vehicle for long periods of time will be avoided.

6. EFFECTS OF CONSTRUCTION

6.1 SCHEDULE AND CONSTRUCTION FORCE

As stated in Section 2.4 of this Supplement, site preparation commenced in May of 1970 and was essentially complete at the end of 1970. Construction of the station structure commenced in September of 1970 after receipt of an exemption from the Commission permitting certain below-grade work prior to issuance of a construction permit. Construction activities increased sharply after issuance of the construction permit on March 24, 1971, and presently most of the major structures are complete below grade with the shield building and turbine-generator foundation at full height and all other structures being constructed above grade.

The turbine building and auxiliary building will be complete in the third quarter of 1972 and the containment building will be complete in the fourth quarter of 1972. Equipment installation will be done as building areas are complete and the [illegible] components of the primary system consisting of the reactor vessel and two steam generators are scheduled for delivery and installation in the fall and early winter of 1972. Installation of piping will commence early in 1972 and continue through 1973. The turbine-generator is scheduled for delivery in spring of 1973 with erection following.

Check-out of systems by the operating force is scheduled to commence in the last half of 1973 as systems and components are completed by construction and will continue into 1974 until all systems are complete and operational. Fuel loading is scheduled for June of 1974 with first turbine operation in September and commercial operation in December 1974.

The average monthly construction force at the site from commencement of site preparation in May of 1970 has gradually increased to the present construction force, as of November 1, 1971, of approximately 650. The peak employment will be reached in early 1973 at which time approximately 1,000 construction workers will be employed.

The building trade craft locals through which construction workers are hired are located in Toledo, Port Clinton, Fremont, and Sandusky, depending on the individual craft. This results in a relatively large area from which the construction workers are drawn from and reduces the impact on the specific locality of the station site. It is not expected, however, that all of the additional construction force can be supplied from the existing force of local building trades and a certain number of out-of-area workers will be temporarily located in the area of the site ranging from Toledo to Sandusky.

The present substantial employment has had no adverse impact on housing or schools and the additional employment is not expected to have any significant impact since the residence location of temporary out-of-area workers would be scattered over a rather large area.

It is estimated that a total direct payroll amount of $75,192,000 will be paid to the construction workers employed at the site which would peak at an estimated monthly figure of $2,250,000. Since the construction labor force residence will be distributed over a relatively large area, the benefits to the general level of prosperity would likewise be spread over the corresponding geographical area.

6.2 SITE PREPARATION AND CONSTRUCTION

The station site contains 954 acres of which over 600 were marsh and beach front ridge areas and about 230 acres were farmland. The remaining 100 acres were wooded areas or low-lying grass areas unsuitable for farming. The marsh areas encompass the entire eastern portion of the site with a narrow marsh area on the northern edge of the western portion.

When acquired, the site contained eight residences and with four residences, there were barns and other farm-type structures. In addition, a large vacant house and farm buildings were on the property acquired from the Bureau of Sports Fisheries and Wildlife. Three of the residences were moved by their previous owners to new locations and all but three of the others were demolished at the start of site preparation. Two of the three remaining will be demolished and the one with farm buildings on the western edge of the site will remain.

Removal of only a few trees was required to accomplish all site preparation work since almost entirely all of the areas involved were farmland or grass areas. Of the original 230 acres of original farmland, all but about 80 had been removed from this category. About 15 acres are now under cultivation in the southern portion of the western half of the site on an arrangement whereby 25% of the crop will be unharvested to provide field forage for waterfowl.

The station structures being located in the center of the site on original upland has not required any use of the marsh areas and the only construction work involved in these areas has been that involved with the intake canal. Work involved in installing the buried discharge pipe to the lake will be along the edge of the intake canal and will not be in the marsh area.

The main station area of about 56 acres has been graded up to a common elevation which ranges from 6 to 12 feet above the original grades. This graded area has installed within it, a storm drain system which collects all storm water and discharges it to a drainage ditch so that there is no storm run-off from the construction area entering the marsh. The ditch receiving the storm water drainage was formed when previous owners of the Navarre Tract dredged material to construct dikes along the property line and runs approximately 7,000 feet along the site boundary prior to entering the Toussaint River. The type of soils used for the grading, the manner in which it was placed, the storm drain system and the length of the on-site ditch assures that there is no possibility of any silt being discharged to the river or lake from the construction area.

The fill material for the grading of the station area has been taken from three other upland locations on the site. These three borrow pits total about 46 acres in surface area. Quarry operations and rock crushing are being conducted in a portion of one borrow pit to provide a stockpile of granular backfill material for construction purposes. These areas are shown on Figures 3-1 and 4-1. All exposed earth surfaces around these borrow pit areas and the cooling tower location drain into the borrow pits which prevents any silt or raw earth from being carried into the marsh areas or other waterways with storm water drainage.

The purpose of the quarry and rock crushing operation is to provide the granular backfill material now being placed in the excavated areas around the lower portions of the station structures. This crushed rock granular material is stockpiled adjacent to the quarry. Most of the amount required has been processed and quarry operations will be discontinued in the near future. The remaining quarry operations will all be performed within the present borrow pits and will involve no further disturbance of the site area. Stockpiled material is now being used and the major portion will be placed in the next few months. This quarry area and the other borrow pit areas will fill with water upon completion of construction de-watering operations. The surrounding land areas will be landscaped which will result in attractive pond areas compatible with and enhancing the wildlife refuge nature of the marsh areas.

The on-site quarry and crushing operation is away from the marsh areas and has had no effect on the wildlife areas. This arrangement has also reduced considerably the truck delivery traffic to the plant site which would have put a burden on area roads and highways.

The site is underlain by glaciolocustrine and till deposits which overlie sedimentary bedrock. These soil deposits have a very low permeability and range in thickness from 15 to 20 feet. These geophysical features have produced an artesian ground water condition in the upper layer of the bedrock which is generally independent of any surface water. Since the main station structures are founded on rock, and, in the case of some structures, 30 feet below the upper rock surface, the excavation required for these structures results in a water flow through the rock aquifer into the excavated area. This presently requires constant pumping from the excavated area to maintain a dry condition for construction.

To prevent excessive water flow into the excavation and excessive lowering of the rock aquifer level off-site, the upper bedrock layer was grouted at the perimeter of the excavation area. This has limited the water flow to a small amount, but the zone of influence on the water table does extend off-site for a short distance, but has not in any manner affected the surface water conditions. This rock aquifer water is generally not suitable for human consumption or household use and the effect on local area wells has been minimal.

With the current construction schedule, all below-grade work in excavated areas will be complete in December 1971 and this pumping will be permanently stopped restoring the rock aquifer to a normal level.

These groundwater elevations have been monitored continuously. In December of 1970, a detailed analysis was made of the groundwater contours resulting 1 from this operation and contours predicted for the maximum expected effect for December 1971. The results of this analysis are shown on Figures 6-4, 5, and 6.

Continuous checks on piezometer BW-1 has shown that the lowest elevation for this location occurred in December 1971 with an elevation of 556.1 or 0.3 feet higher than predicted. In June of 1972, this elevation was 563.0 due to a lesser amount of pumping required in the previous several months since the deepest excavations had been backfilled. 1

With site preparation essentially complete, the remaining work will involve mostly final grading and placing of top soil on the station areas after completion of construction. The construction roadways on-site are wet down during dry periods to reduce any dust problems, both on-site and off-site.

The on-site quarry has eliminated the need for large quantities of off-site fill material with the resulting large amount of truck traffic on area highways. The concrete batch plant for the supply of all concrete required for the station structures is located on-site with the resulting elimination of all traffic on area roads of this type of equipment.

In cooperation with the Ohio Department of Highways, State Route No. 2 which adjoins the western site boundary was widened at the construction road entrance area to provide turning and passing lanes to reduce traffic problems. Parking for all construction workers is provided on-site.

6.3 MARSH AND LAKE AREAS

The only construction activities associated with the station in any of the more than 600 acres of marsh area on the site has been the construction of the intake canal. This work was completed in late 1970 and in the spring of 1971, the dikes were seeded to prevent erosion of the banks and to provide ground cover for wildlife. The buried discharge pipe will be installed alongside the east bank of the intake canal and will not disrupt any marsh areas.

A dike was constructed through the marsh in the northern portion of the site adjacent to the site boundary in the late summer of 1971. This dike was constructed pursuant to the exchange agreement with the U.S. Bureau of Sports Fisheries and Wildlife to separate the site refuge area from the adjacent private marsh and to permit water level control in the site marsh area for improved marsh management. This work was done during this period so as not to interfere with nesting wildlife during spring and summer and to have construction completed prior to arrival of the major migratory flights of waterfowl.

The existing dikes on the Navarre Tract of the site were in poor repair when the site was acquired. These have since been repaired and the water level in the large marsh area lowered in early summer of 1971 with portable pumps to permit added vegetation growth during the summer. This work was done in cooperation with the Bureau and has decidedly enhanced the large marsh area for wildfowl.

Permanent pumping installations will be installed pursuant to the exchange agreement to be operated by the Bureau through the Ottawa National Wildlife Refuge Manager for marsh water level control in accordance with the Bureau's marsh management practices.

The major marsh areas are screened from the construction area by tree growth on the existing dikes and construction activities have in no way adversely affected the use of the marsh areas by wildlife as evidenced by the census count of waterfowl reported in Section 3.4.2 of this Supplement. The local area is a stopping point for the spring migration of whistling swans and these waterfowl were seen in abundance on the north marsh areas of the site in the spring of 1971 in full view of the construction area.

A shall temporary channel with its bottom 3.6 feet below lake datum will be dredged from a point approximately 650 feet offshore into the intake channel to permit delivery of the barge shipment of the reactor vessel. This dredging will be commenced in August of 1972 to permit delivery of the reactor vessel in October. The dredging will be done using a clam bucket method with the excavated material deposited on the northwest side of the channel. Immediately following delivery of the vessel, the excavated material will be replaced. 1

In the summer of 1973, the intake and discharge pipes will be installed using similar excavation methods with the excavated material being replaced following the installation of the pipes.

Both of these anticipated dredging operations have been reviewed by Dr.
Charles E. Herdendorf of the Center for Lake Erie Research, The Ohio State
University, who has concluded that there will be a negligible effect on the 1
shoreline, minimal effect to water quality and benthic habitats, and that
no lasting environmental damage will result from these operations.

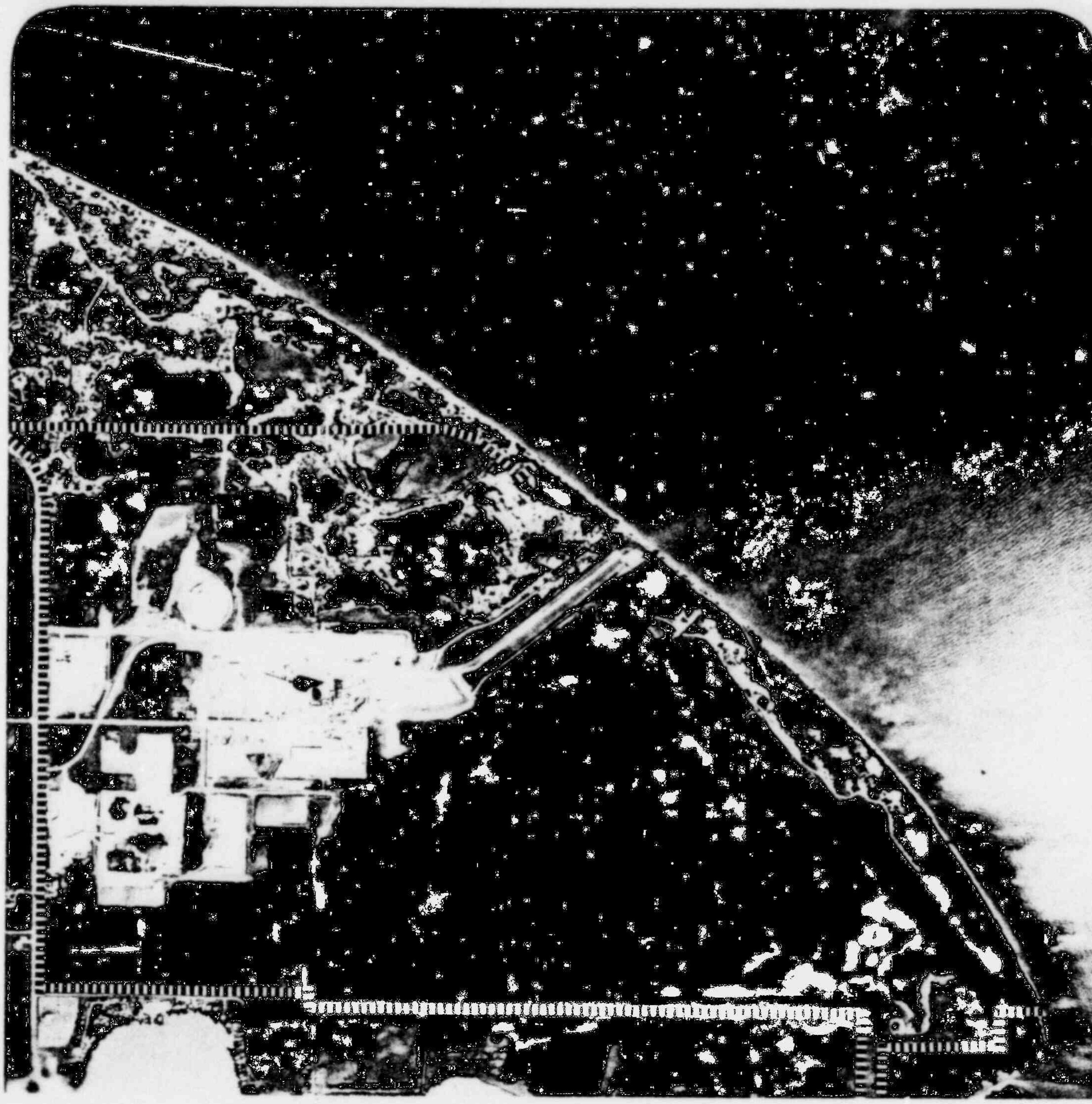
6.4 GENERAL

To illustrate the character of the site in its original condition and the character of the site with the present construction, Figures 6-1, 6-2 and 6-3 are included. Figure 6-1 is an aerial photograph of the site taken on May 17, 1964, prior to acquisition, while Figure 6-2 is an aerial photograph taken on July 31, 1971. Figure 6-3 is a low level aerial photograph taken on August 3, 1971, showing most of the station site. These Figures illustrate dramatically the almost complete absence of any construction effect on the marsh and the very limited construction effect in the area.

IIIIII SITE BOUNDARY

DAVIS-BESSE NUCLEAR POWER STATION
SITE PLAN
AERIAL PHOTOGRAPH
MAY 17, 1964
FIGURE 6-1

AMENDMENT NO. 1



▮▮▮▮▮▮ SITE BOUNDARY

DAVIS-BESSE NUCLEAR POWER STATION
SITE PLAN
AERIAL PHOTOGRAPH
JULY 31, 1971
FIGURE 6-2

AMENDMENT NO. 1

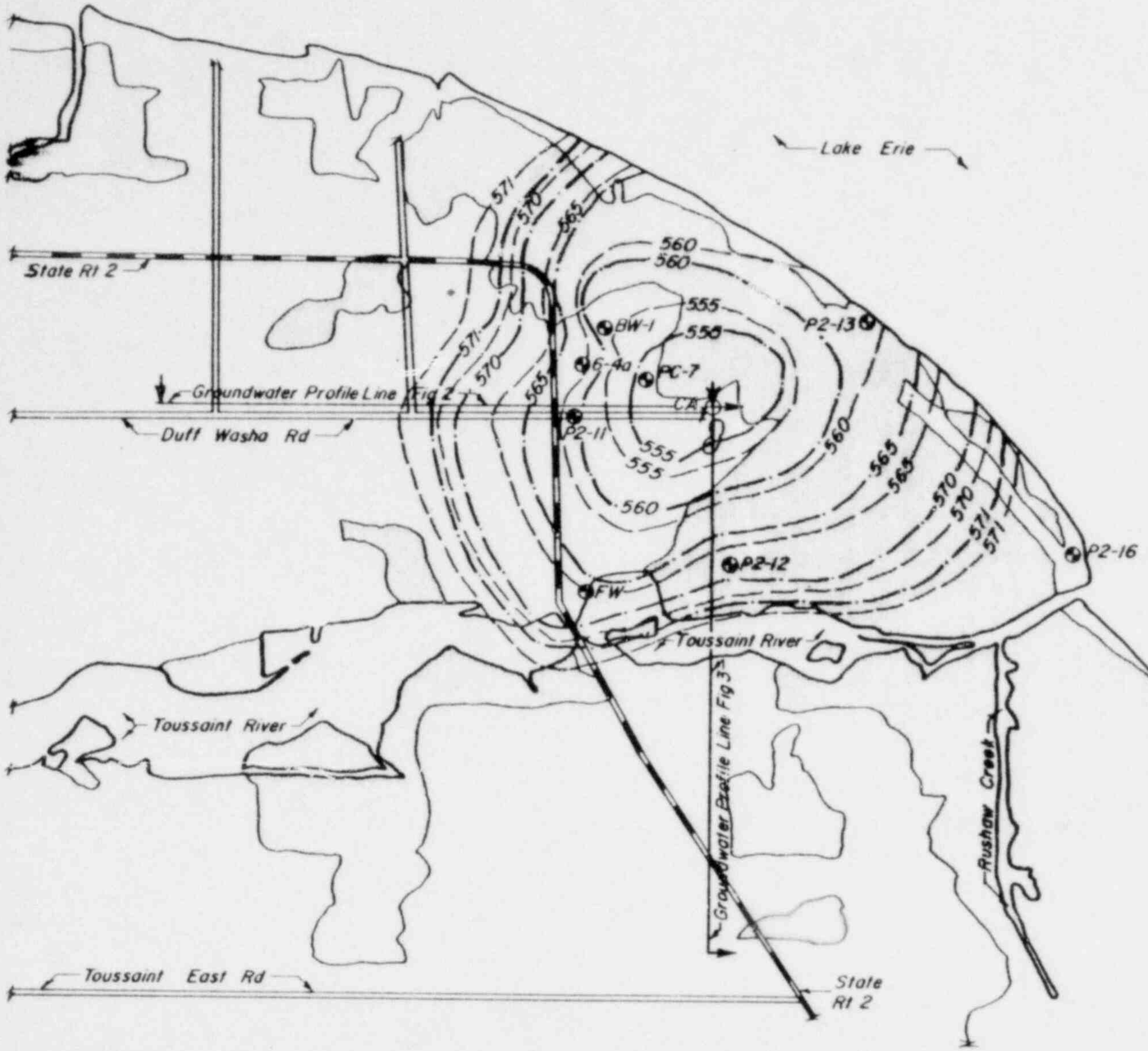
▮▮▮▮▮▮ SITE BOUNDARY

DAVIS-BESSE NUCLEAR POWER STATION

AERIAL PHOTOGRAPH
AUGUST 3, 1971
FIGURE 6-3

POOR ORIGINAL

AMENDMENT NO. 1



LEGEND

- Approx location of marsh deposits
- Major roads
- Shore line of creeks, river and lake
- ⊕ CA Approx location of the center of the containment area excavation
- PC-7 Approx piezometer location and number
- 570 Present (Dec 1970) groundwater contours
- 570 Predicted (Dec 1971) groundwater contours

NOTES:

1. General layout obtained from USGS 7.5 min series quadrangle map, Lacarne, Ohio (1952).
2. Elevations referenced to the International Great Lakes Datum (IGLD).

TABLE OF GROUNDWATER ELEVATIONS

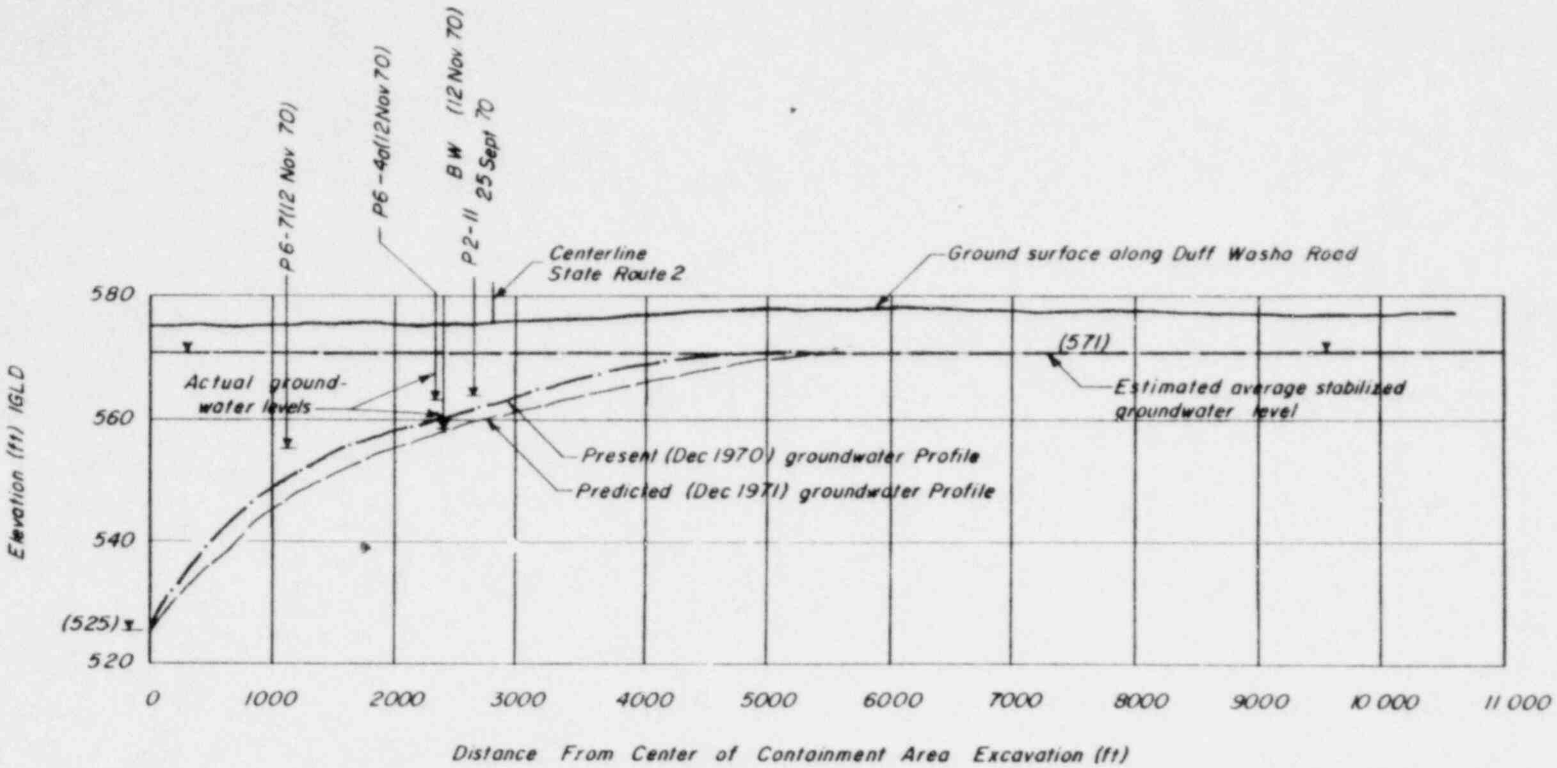
Piezometer Designation	Present Groundwater Elevation (Dec 1970) (Ft)	Predicted Groundwater Elevation (Dec 1971) (Ft)
P2-11	561.2	559.0
P2-12	567.3	566.3
P2-13	562.1	559.9
P2-16	571.7	571.7
BW-1	557.4	555.8
6-4a	563.8	562.5
PC-7	554.0	550.4
FW	566.2	565.4

Scale: 1in = 2000 ft (Approx)

GROUNDWATER CONTOURS — DECEMBER 1970-71

FIGURE 5-4

WCA 68-192A DRS 25 JAN 71 GW.1



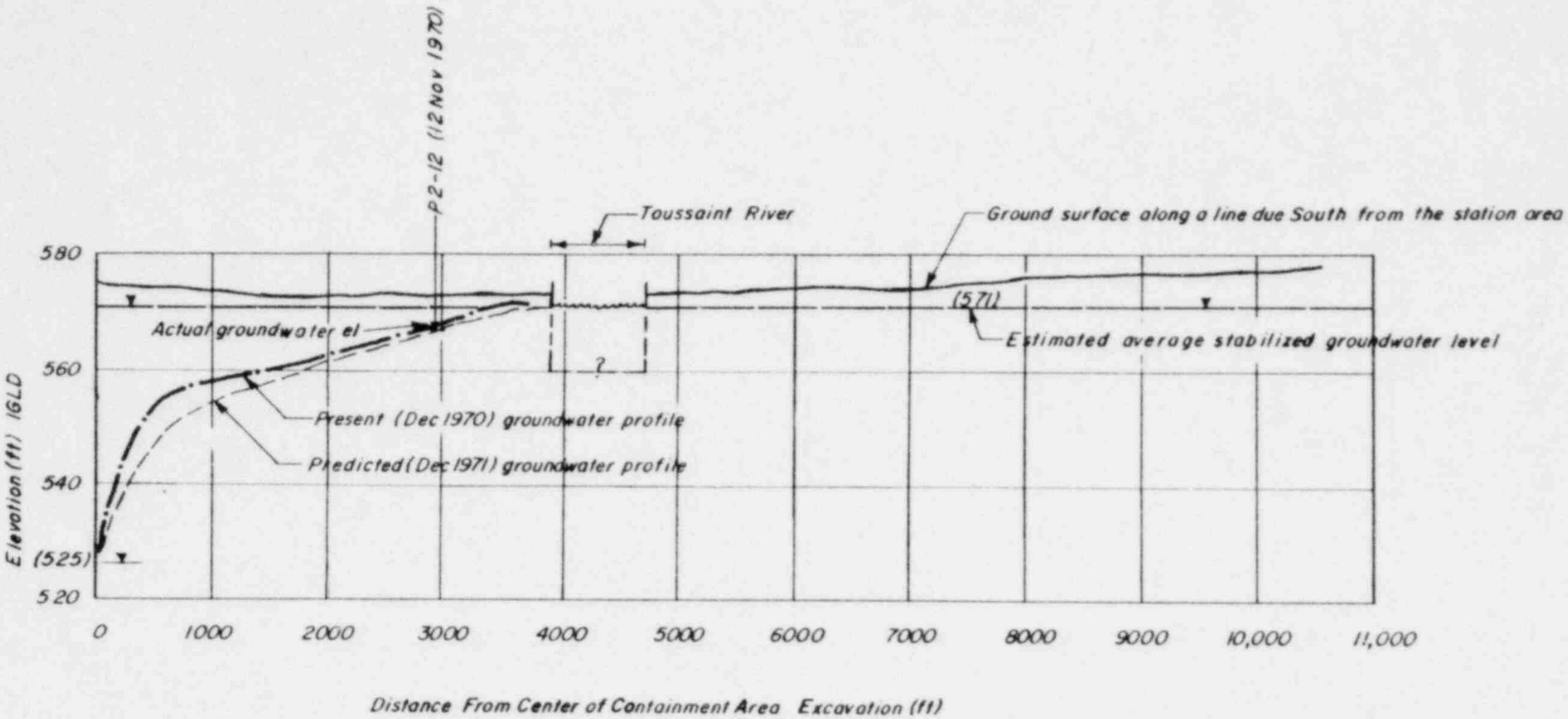
NOTES

1. For plan location of profile line see Fig. 6-4
2. Ground surface determined from U.S.G.S 7.5 min. series quadrangle map Lacarne, Ohio (1952)

FIGURE 6-5

GROUNDWATER PROFILES WEST OF THE STATION AREA

WCA 68-192A PB 29 JAN 70 GW 2



NOTES

1. For plan location of profile line see Fig 6-4
2. Ground surface determined from U.S.G.S 7.5 min. series quadrangle map Locarne, Ohio (1952)

GROUNDWATER PROFILES SOUTH OF THE STATION AREA

FIGURE 6-6

WCA 68-192A PB 29 Jan 1970 GW 3

7 EFFECTS OF OPERATION

7.1 GENERAL

In this section the effects of station operations on the environment are presented together with a discussion of water standards and how the standards will be met by the station discharges. The effects of released radioactivity, while adding a small burden to the environment due to radiation exposure, are insignificant when compared to exposures from naturally occuring background radiation. The effects of water use and discharge are extremely small and will result in no adverse effect to the environment or lake biota. The cooling tower effluent may result in some small inconvenience to the population in limited areas for short periods of time but will not have any significant adverse environment effect.

7.2 RELEASE OF RADIOACTIVE MATERIALS

Subsequent to the submittal of the Preliminary Safety Analysis Report (PSAR) and Environmental Report dated August 3, 1970, the radioactive waste disposal systems to be installed in the Davis-Besse Station have had minor modifications to provide additional processing capability to reduce radioactive releases below those projected in the PSAR stage of design. The present design of these systems are described in section 4.4 of the report.

Based on the expected releases of radioactive material from these systems as described, the expected radiation doses to individuals to the entire population living within 50 miles of the station have been estimated. In establishing the expected radiation doses that might be delivered to the surrounding population, the following significant exposure pathways to man were considered:

a. external whole body exposure to gaseous emissions,

b. inhalation exposure of the thyroid to radioiodines contained in the emissions, and

c. exposure of the whole body resulting from liquid discharges via ingestion of water or fish.

Table 7-1 shows the projected doses that would be delivered from the expected release of radioactive material through the gaseous waste processing system, from containment purging and from minor system discharge. Table 7-2 shows the projected radiation doses that would be delivered from the expected releases through the liquid waste processing systems while Table 7-3 shows the combined effect of considering all possible significant exposure routes.

In addition to estimating the whole body doses that would be delivered as a result of the ingestion of water or fish, calculations were made for certain other organs doses for selected nuclides which could deliver significant doses. The results of this examination show that the whole body dose exceeds any other single organ dose.

Appendix 7A gives the computational models used to calculate doses delivered as a result of station operations along with the assumptions necessary.

To develop doses resulting from station operation a number of assumptions concerning reactor operating conditions, demography, and food consumption must be made. Those assumptions used to develop doses in this section are as follows:

1. The reactor is operating with the expected equilibrium activity in the reactor coolant, i.e., the activity associated with 0.1% defective fuel.
2. The reactor is assumed to be operating with the expected maximum reactor coolant system to steam system leakage of 100 gallons per day.
3. The reactor is operating with the expected maximum reactor coolant leakage to the containment vessel of 100 gallons per day.
4. 200,000 gallons of the water processed in the clean liquid radioactive waste system is released to environment per year.
5. An estimated 48,000 gallons of the reactor coolant per year finds its way, through leakages etc. into the miscellaneous radwaste system.
6. Radwaste system effluents are diluted with 20,000 gpm of dilution water; a mixing factor of 0.8 was assumed.
7. To determine the maximum possible dose to the individual, he was assumed to reside at the station fence 365 days per year, 24 hours per day, and consume 40 lbs of fish per year taken from waters with the maximum radionuclide concentration, and to ingest

2.2 liters of water from the station discharge system prior to any dilution with lake water.

8. To determine population doses it was assumed that all fish were obtained from waters around Camp Perry - Erie Industrial Park and the drinking water was obtained from municipal water intakes of Camp Perry - Erie Industrial Park, Port Clinton, and Toledo - Oregon.
9. The total fish harvest for District 1, about 1,280,000 lbs of edible fish flesh, is consumed by the population within 50 miles of the station.

TABLE 7-1

Radiation Doses from Gaseous Releases

Individual Doses		Rem	
a. WB Noble Gas Site Boundary Exposure			
1. Decay Tank Releases		1.96×10^{-5}	
2. Containment Purging		2.70×10^{-5}	1
b. WB Noble Gas Per Capita Exposure			
1. Decay Tank Releases:	1980	4.91×10^{-8}	
	2000	4.78×10^{-8}	
2. Containment Purging:	1980	7.87×10^{-8}	1
	2000	7.66×10^{-8}	
c. Child Thyroid Site Boundary Milk Ingestion Dose			
1. Decay Tank Releases		5.15×10^{-6}	
2. Containment Purging		7.40×10^{-6}	1

Population Doses		Man-Rem	1
a. Total WB Noble Gas Exposure From Decay Tank Releases:	1980	1.31×10^{-1}	
	2000	2.03×10^{-1}	
b. Total WB Noble Gas Exposure From Containment Purging:	1980	2.10×10^{-1}	1
	2000	3.25×10^{-1}	

TABLE 7-2

Radiation Doses from Liquid Releases

Individual Doses		Rem	
a. 40 lb. fish/year	Undiluted Station Discharge	3.52×10^{-5}	1
	Camp Perry	3.08×10^{-8}	
b. 2200 cc's/day Drinking Water	Undiluted Station Discharge	1.104×10^{-3}	1
	Camp Perry	9.66×10^{-7}	
	Port Clinton	3.31×10^{-7}	
	Toledo & Oregon	1.24×10^{-7}	

Population Doses (1)		Man-Rem
a. Total Man-Rem in 50-Mile Radius:	1980	.0977
b. Annual Average per Capita Dose within 50-Mile Radius:	1980	3.66×10^{-8}

(1) Based on fish ingestion dose from Camp Perry concentration and assuming drinking water from Camp Perry, Port Clinton, and Toledo for population in the appropriate annuli and sectors.

TABLE 7-3

Total Whole Body Radiation Exposures From
Gaseous and Liquid Releases

Individual Doses		Rem	
a. 40 lb. fish/year Ingestion	Undiluted Station Discharge	3.52×10^{-5}	1
b. 2200 cc's/day Drinking Water	Undiluted Station Discharge	1.104×10^{-3}	
c. Site Boundary Noble Gas Dose		4.66×10^{-5}	

Population Doses		Man-Rem	
a. Total Man-Rem in 50-Mile Radius:	1980	.44	1
b. Annual Average per Capita Dose within 50-Mile Radius:	1980	1.64×10^{-7}	

7.3 EFFECTS OF WATER USE AND DISCHARGE

7.3.1 EFFECTS OF HEAT

The limited amount of heat in the station discharge which ranges from a withdrawal of heat from the lake under certain limited conditions to a maximum amount of 138×10^6 BTU per hour will have no adverse effects on the lake.

The excess temperature of water discharge over ambient lake temperature is rapidly degraded by entrainment mixing with lake water by reason of a high velocity discharge through a slot-type orifice designed to produce optimum mixing. The resulting area of the lake that will see temperatures of 1° F or higher than ambient lake temperatures resulting from this discharge is 2.14 acres for the maximum conditions of heat discharged. This area extends for only 658 feet from the discharge orifice which in contrast is 5,000 feet away from the mouth of the Toussaint River and 16,250 feet from Toussaint Reef which is the closest offshore reef of a group of reefs which are of concern as fish spawning areas, particularly pickerel. In contrast with the 2.14-acre size of the area having a 1° F or higher temperature, the 3° or higher area envelops only 0.34 acres and extends only 264 feet from the discharge orifice.
Appendix 4-B contains the computational model used for the determination of plumes and the verification of the adequacy of this model. This Appendix also contains a comparison of the effect on the heat input into Lake Erie with that from the natural sources and shows that it is insignificant and that spatial variations on the order of 2 to 3° F often occur naturally over distances of 5 to 10 miles.

The maximum exposure time of organisms entrained in the thermal plume has been calculated to be less than four minutes for exposure to excess temperatures of

3° F or higher and this exposure time has been shown to not result in measurable biological consequence as cited by Dr. Pritchard in Appendix 4B.

Since the thermal plume commences as a thin 1.5-foot-thick wedge at the lake bottom and increases in thickness along the axis of discharge, the excess temperature in the plume at the point it thickens to the extent of reaching the surface, is only a few degrees. As a result, there will be no large open water areas that would tend to hold late migrating waterfowl in the area.

7.3.1.1 Temperature Standards

There are no emission standards applicable to the Station and we are concerned only with water quality standards, which for certification purposes, are criteria adopted by the proper State agency, here the Ohio Water Pollution Control Board, as authorized by Section 6111.041 Ohio Revised Code, and approved by the Secretary of the Interior (now EPA) pursuant to Section 10 (c) of the Federal Water Pollution Control Act, as to interstate waters.

The main discharge from the Station will be into Lake Erie, an interstate water. Under date of April 11, 1967 the Board adopted criteria as to Lake Erie, by reference to stream-water quality criteria for various uses adopted by the Board June 14, 1966, and made criteria for all uses applicable to this part of the Lake. In other words, the highest criteria for any use would be applicable. Stream water criteria were revised and tightened by a Board resolution of October 10, 1967 and another under date of October 17, 1967. All of these were submitted to the Secretary of the Interior and approved by him under date of March 4, 1968, except that he withheld approval of temperature and dissolved oxygen standards for Aquatic A, which would have applied to Lake Erie and was the highest use prescribing temperature standards. There has been no further Federal approval of Lake Erie criteria and accordingly there are no Federally approved temperature standards for

Lake Erie. This was confirmed by Mr. Harlow, the EPA representative, in his statement to the Ohio Water Pollution Control Board (Appendix 2H of this Supplement).

The latest action of the Ohio Board with respect to Lake Erie is its resolution of April 14, 1970, included as Appendix 7C, which is not Federally approved. Here temperature criteria were prescribed under Aquatic Life A, and were "applicable at any point in the stream except for areas necessary for the admixture of waste effluents with stream water." Subject to this general provision as to mixing zone:

> "C. Maximum temperature rise at any time or place above natural temperatures shall not exceed 5 deg. F. In addition, the water temperature shall not exceed the maximum limits indicated in the following table."

Maximum Temperature in Deg. F. During Month

WATERS	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
All waters except Ohio River	50	50	60	70	80	90	90	90	90	78	70	57

The corresponding maximum ambient lake temperatures by months are as follows:

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Note 1	41	39	46	57	66	77	81	82	81	70	61	50
Note 2	35.7	35.5	40.7	51.6	63.4	71.8	76.5	76.8	73.6	63.6	52.8	33.4

Note 1 - Maximum temperature over past 28 years at Toledo municipal water intake.

Note 2 - Average of the maximum temperatures over past 28 years at Toledo municipal water intake.

It will thus be seen that with allowance for the small mixing zones as shown in Section 4.6.6.3 of this Supplement which is 2.14 acres for 1° F above ambient at the perimeter and 0.11 acres for 5° F, there should be no question as to compliance with Ohio criteria as presently adopted.

As to the Toussaint River, since it is not an interstate water as defined in the Federal Act, no federal approval is required and accordingly the Board's resolution of April 14, 1970 provides the applicable standards.

This resolution provides monthly temperature standards ranging from 50° F to 90°. Since the discharges into the Toussaint will only be storm water runoff, there should be no question of compliance with standards.

7.3.2 CHEMICAL AND SANITARY RELEASES

The character of the chemical and sanitary releases are detailed in Section 4.6.6.2 of this Supplement and the character of existing lake water quality is discussed in Section 4.6.6.1.

Nearly all of the dissolved solids in the discharge were contained in the incoming lake water; very little additional dissolved solids will be added from station processes. The concentration of these dissolved solids, however, will be slightly more than twice that of lake water due to the evaporative loss of water in the cooling tower and resulting concentration of dissolved solids.

Since the constituents of the dissolved solids are essentially that of lake water and the concentration in discharge water will be reduced within a very small area in proportion to the reduction in excess temperature of the discharge, there will be no adverse effects to the lake or lake biota.

7.3.2.1 Water Quality Standards

As stated under 7.3.11, the latest water criteria adopted by the Ohio Water Pollution Control Board and Federally approved (except dissolved oxygen and temperatures for Aquatic A) were covered by resolutions of the Board of October 10 and October 17, 1967, and since all uses were applied to Lake Erie, the highest criteria for any use would be applicable. The October 10 and October 17 resolutions are included as Appendices 7D and 7E.

These may be summarized as follows:

BACTERIA

Coliform not over 1000 per 100 ml as monthly average (not exceed this in more than 20% of samples in month, or over 2400 per 100 ml any day) (Rec-10-10-67)

THRESHOLD-ODOR NUMBER

Not to exceed 24 (at 60° C) as daily average (PWS 10-10-67)

DISSOLVED SOLIDS

Not over 500 mg/l as monthly average value, or over 750 mg/l any time (PWS 10-10-67)

RADIOACTIVITY

Gross beta not over 1000 picocuries per liter (pCi/l) nor activity from dissolved strontium-90 exceed 10 pCi/l, nor from dissolved alpha emitters exceed 3 pCi/l (PWS 10-10-67). Irrelevant since in exclusive jurisdiction of AEC.

CHEMICAL CONSTITUENTS

	mg/l
Arsenic	0.05
Barium	1.0
Cadmium	0.01
Chromium (hexavalent)	0.05
Cyanide	0.025
Fluoride	1.0
Lead	0.05
Selenium	0.01
Silver	0.05
(PWS 10-10-67)	

DISSOLVED OXYGEN

* Not less than 5.0 mg/l during 16 hours of 24, not less than 3.0 mg/l at any time (Aquatic A 10-10-67) (not approved)

pH

* 5.0 to 9, daily average (or medium) preferrred 6.5 - 8.5 (Aquatic A 10-10-67) shall be 6.5 - 8.5 (¶2 10-17-67)

TOXIC SUBSTANCES

* Not over 1/10 of 48 hour median tolerance limit, with exceptions (Aquatic A 10-10-67)

* All Aquatic A applicable at any point in stream except for areas immediately adjacent to outfalls. There cognizance will be given to opportunities for admixture of waste effluent with stream water (Aquatic A 10-10-67) (not approved as to dissolved oxygen or temperature)

The April 14, 1970, resolution of the Board (Appendix 7C), the latest action relating to Lake Erie Criteria, but unapproved Federally, made slight changes in these standards which are immaterial to the discussion here.

The approved state standards contain criteria relating to bacteria, threshold odor, dissolved solids, radioactivity, chemical constituents, dissolved oxygen, pH, and toxic substances. The standards pertaining to dissolved oxygen have not been Federally approved.

In regards to coliform bacteria, the only potential source of coliform input to any water eventually released from the Davis-Besse Station is in the sewage system. The sewage treatment plant will process all sewage wastes and will provide both primary and secondary treatment. In addition, the effluent will be fully chlorinated with a resulting zero release of coliform bacteria to the lake. Since chlorine will be periodically added to the cooling tower system water, any coliform bacteria present in the incoming water from the lake will be removed. The chlorine will be aded to the inlet to the condenser and cooling tower with the blowdown being taken from the cooling tower return. This will ensure that little or no chlorine enters the lake.

Threshold odor is not a consideration since no odor-containing substances will be added to the station effluent.

Since the principal source of discharge is from the cooling tower blowdown, the level of dissolved solids is dependent on that contained in the lake water coming into the station. Based on an average value of 225 mg/l dissolved solids in lake water, which was based on inshore sampling and higher than what would be expected from the more offshore intake location, the average monthly dissolved solids concentration would be about 478 mg/l with a maximum one-hour peak of about 590.

Data from the "Lake Erie Ohio Intake Water Quality Summary 1969," collected by the Ohio Department of Health and Federal Water pollution Control Administration at the Port Clinton water intake showed an average dissolved solids content of about 129 mg/l. Current sampling in the lake offshore from the site at a water depth 7' and 2,700' from shore shows a dissolved solids content of 169 mg/l. This approximates very closely the 1967-1968 data from the "Lake Erie Surveillance Data Summary," conducted by the Cleveland Program Office of the Federal Water Pollution Control Administration, which showed 170 mg/l. Using data from deep water, the average monthly dissolved solids content of the discharge would be 359 mg/l with a one-hour peak of 443. All of these values are within the standards of 500 mg/l on a monthly average and 750 mg/l at any time. It should be noted that of the pounds of dissolved solids contained in the station discharge for one mont's operation, 94% of the dissolved solids are contained in the intake water to the station. The total addition amounts to only a 15 mg/l increase.

The standards contain limits on specific chemical constituents. Specifically; arsenic, barium, cadmium, hexavalent chromium, cyanide, fluoride, lead, selenium, and silver. There will be no releases to plant discharges that contain any of these chemical constituents except possible traces in the form of radionuclides.

The standards pertaining to dissolved oxygen have not been Federally approved. Since the majority of the discharge from the station will be from the cooling tower, the dissolved oxygen content would be controlled by cooling tower conditions. Due to the fact that the cooling tower system water has prolonged and intimate contact with air in the tower, the tower outlet water will always be saturated with oxygen with the content in mg/l corresponding to the saturation temperature limit. At the maximum tower outlet temperature expected which will produce the lowest dissolved oxygen content, the oxygen will be

7.1 mg/l. For many periods of a year, dissolved oxygen content in the discharge will be higher than ambient lake water.

The standards in regard to pH call for a preferred range of from 6.5 to 8.5. The pH of the cooling tower system water will be controlled to set value and since the largest quantity of water discharges will be from the cooling tower system, the pH of the discharge will be a constant 7.3.

In regard to toxic substances, there will be no use of toxic substances that will result in a release to the discharge water.

The approved water quality standards have four minimum conditions which are applicable to all waters at all places and at all times. These are:

1. Free from substances attributable to municipal, industrial, or other discharges, or agricultural practices that will settle to form putrescent or otherwise objectionable sludge deposits.

   There will be no substances in the discharge from Davis-Besse Station that will settle. In fact, the discharge will be freer of suspended solids than the ambient lake water due to settling in th tower basin and settling lagoon.

2. Free from floating debris, oil, scum, and other floating materials attributable to municipal, industrial, or other discharges, or agricultural practices in amounts sufficient to be unsightly or deleterious.

   No debris, oil, scum, or other floating material will be discharged from the station. An oil separator will be installed on the floor drainage system to prevent even an accidental spill.

3. Free from materials attributable to municipal, industrial, or other discharges, or agricultural practices producing color, odor, or other conditions in such degree as to create a nuisance.

There will be no odor or color-producing materials discharged from the station.

4. Free from substances attributable to municipal, industrial or other discharges, or agricultural practices in concentrations or combinations which are toxic or harmful to human, animal, plant, or aquatic life.

   The quantities and concentration of the liquid effluents from the station are set forth in Section 4 of this Supplement. As shown therein, they will be insignificant and accordingly they will not be harmful to human, animal, plant, or aquatic life.

The discharges to the Toussaint River will be from storm drains, equipment drains, and floor drains where the water will be ambient lake quality or better.

7.3.3 OTHER WATER USE AND DISCHARGE EFFECTS

The submerged intake and its entrance design is expected to prevent any significant passage of fish from the lake into the intake canal. The use of traveling water screens in front of the intake wells where all service pumps are located will prevent entry of any fish into the plant systems. The arrangement of the screen backwash system will allow monitoring and recovery of any fish which might gain entry into the canal and be caught on the screens.

The holding basin which receives this backwash water will be routinely checked daily if the traveling screens have been operated. A detail check will be made on a weekly basis of this basin or when operation of the screens indicates fish, in any number, have been washed off. 1

The lake bottom in the area of the slot-type discharge orifice will be rock filled for an adequate distance in front of the discharge so that the relatively high velocity discharge will not cause bottom scour and resulting high turbidity.

7.4 COOLING TOWER EFFLUENT

In 1969, the environmental effects of cooling tower effluent were studied when alternatives for condenser-cooling systems were studied. This study assumed the use of two towers for the Davis-Besse Station and was based on general design information. The results of this study were included in the Report and Plan for Water Use submitted to the Ohio Department of Health in 1969 as discussed in Section 2.3.2.4 of this Supplement.

Following the contract for the single taller cooling tower now being installed at the Davis-Besse Station in spring of 1971, a more comprehensive study of the environmental effects was undertaken by the NUS Corporation based on actual design data for the specific installation and is included in this Supplement as Appendix 7F.

This study analyzed a representative five-year period of meteorological data from the Toledo Express Airport to determine those conditions related to the natural occurrence of fog. The use of Toledo Airport data was necessary since the recording of occurrence of fog conditions was a part of the data required to be analyzed and data from no closer point was available. The analysis of the Toledo data formed the basis for evaluating the potential of producing or intensifying local fog conditions. A comparison of the Toledo data with the two-year on-site meteorological data showed that the Toledo data is quite representative of climatic conditions at the Davis Besse site.

The Toledo data were also processed by the NUS computer codes to determine the environmental effects of the operation of the cooling tower. These codes are based on ananalytical model for calculation, on a hour by hour basis, of plume rise, dispersion and transport utilizing hourly meteorological observations and cooling tower design and operation parameters as input. Results were then examined to determine consistency with on-site meteorological data and the occurrence of such local effects as the lake breeeze and also to assess anomalous situations such as plume downwash. The average visible vapor plume is only 1.5 miles long and is not considered to be a significant environmental effect. The vapor cloud is not expected to be visible over population centers of Toledo or Port Clinton or present any hazards to aircraft operations.

Ground level effects of fog and icing conditions (excluding downwash plume situations) which would be induced by operation of the Davis-Besse cooling tower are considered to be negligible. The probability of the increased occurrence of fog conditions based on analysis of Toledo Airport data has been calculated to be only 0.42% which is not considered to be an environmental problem. It is important to note that the increased occurrence of fog conditions does not represent discrete cases of fog, but rather represents the possibility of fog occuring earlier and lasting longer than normal. The predicted increase in icing conditions attributed to the cooling tower effluent, a maximum of one minute for any 22.5% sector for the winter season, is also considered negligible.

The occurrence of downwash conditions under which the cooling tower effluent is caught in the turbulent wake of the tower structure and brought down to the surface will not be a frequent effect and the persistence of these conditions will not be great for any direction due to expected gustiness and variability of the wind. Approximately 0.79% of the time during the winter season (~17 hours) downwash conditions are calculated to occur that could result in icing on surfaces off-site at a rate of 0.03 - 0.07 inches of ice per hour. However, these calculations are considered to be extremely conservative upper limits since downwash occurrences have not been verified in actual cooling tower operations in the United States.

Due to the low drift carry-over rate of 0.01% only 4×10^2 pounds of water per hour would be expected to leave the tower in the form of water droplets entrained in the cooling tower exhaust. This drift loss is considered an insignificant amount, and less than 1% of this amount would be deposited off-site.

None of these factors associated with the cooling tower effluent are expected to have any significant adverse environmental effects.

APPENDIX 7A

COMPUTATIONAL METHODS FOR DOSES RESULTING FROM GASEOUS EFFLUENTS

Because of decay the gaseous radioactive effluents consist solely of the following: Krypton-85, Xenon-131m,-133m,-133 and Iodine-131, -132, -133, -134 and -135, exposure of a man to an atmosphere contaminated with these radionuclides results only in an external, whole body dose (from submersion in the radioactive cloud of noble gases) and a thyroid dose from the iodine. Since the noble gases are not incorporated in the body, there are no resultant internal doses except from the iodine.

The external, whole body, population dose within annulus "a" resulting from the release of Q_i curies of the i^{th} radionuclide per year from the Davis-Besse Power Station was computed by means of the following equation:

$$D_{a,i} \text{ (man-rem/year)} =$$

$$\frac{1}{2}\left[P_a \times \chi/Q \times Q_i \times 10^{-6} \times 10^{6} \times 3.7 \times 10^{4} \times E_i \times 1.6 \times 10^{-6} \times 1.13 \times \frac{1}{1.293 \times 10^{-3}} \times \frac{1}{10^{2}}\right] \quad (1)$$

where:

1/2 = Geometry factor. The body is assumed to be irradiated from half the solid angle by the radioactive cloud of large volume, that is, it is assumed to be surrounded by an infinite, semi-pherical radioactive cloud.

P_a = Estimated number of persons living within annulus "a".

$(\chi/Q)_a$ = Factor computed from atmospheric dispersion equations for the distance of the midpoint of annulus "a" from the station, and expressed in units of sec/meter^3.

Q_i = Number of curies of the ith radionuclide released from the station per year.

10^{-6} = m^3/cc

10^6 = $\mu Ci/Ci$

3.7×10^4 = dis/sec - μCi

E_i = Effective energy in MeV (of β's and γ's) per disintegration of the ith radionuclide.

1.6×10^{-6} = Ergs/MeV

1.13 = Stopping power of tissue relative to air, for β's and secondary electrons produced by x- and γ- radiation. (1)

1.293×10^{-3} = Density of air, gm/cm^3.

10^2 = Ergs/g-rem

To facilitate the calculations, the terms in the above equation were grouped as follows.

Values for P_a were estimated for the year 1980 population data presented in Figures 2-5 and 2-6 of the Davis-Besse PSAR. In these figures, ten concentric circles of varying radii are drawn about the Davis-Besse site, forming ten annuli, and population data are given for each annulus as well as direction. All values of P_a used in these dose calculations were estimated figures of the year 1980.

The average value of (χ/Q) for a specific annulus was taken to be that for the distance of the midpoint of that annulus from the station. For example, the average χ/Q for the annulus 10-20 miles was taken to be that for a distance of 15 miles from the station. The numerical values for χ/Q used in this evaluation were obtained using computer code WINDIF.[2] These gaseous releases are based on a 30- and 60-day decay (see Section 4.4.2) period before release and assumed 0.1% fuel defects.

The remaining factor in the dose equation is E_i, the effective energy (β's and γ's) per disinegration of the i^{th} radionuclide. The value of E_i for each radionuclide of interest was obtained from ICRP Publication 2 [1]. It is to be noted that for radio-gases Kr-85, Xe-131m, Xe-133 and Xe-133m the Q_f (Quality Factor) and "n" (relative damage factor) are taken to be unity. Hence, the ratio of rems to rads is unity and the dose equations given above may be expressed in units of either rads cf rems.

The population dose (man-rem/year) within the entire area (all ten annuli) resulting from releases of both the radionuclides is given by the equation:

$$D_\Sigma = \sum_{a=1}^{10} D_{a,i} \qquad (2)$$

The following equation was used to compute $\overline{D}$, the average annual dose per person living within the entire area of interest (i.e., all 10 annuli):

$$\overline{D} = D_\Sigma \Big/ \sum_{a=1}^{10} P_a \qquad (3)$$

where $\sum_{a=1}^{10} P_a$ is the total population within that area.

The dose rate in rem/year, at the site boundary (at a distance of 730 meters from the station), due to the radiogases released, was also computed. For a continuous one-year occupancy at the site boundary, a person would receive a dose of .0125 mrem from exposure to the four radiogases released.

The computed dose and dose rate values are based on the estimated expected releases of radiogases.

Small amounts of radioactive iodine-131, -132, -133, and -135 are expected to be released from the Davis-Besse Station during normal operation. Although the external whole body dose from submersion in the cloud of radioactive gases is negligible, iodine taken into the body produces an internal dose (thyroid) because of the large uptake ratio of this organ. The thyroid dose is calculated as follows:

$$D \text{ (rem/year)} = (Q)\ (\chi/Q)\ (BR)\ (DCF)$$

Where:

(BR) = Standard man breathing rate,[1] 2.32×10^{-4} m^3/sec.

(DCF) = Dose conversion factors for iodine are:

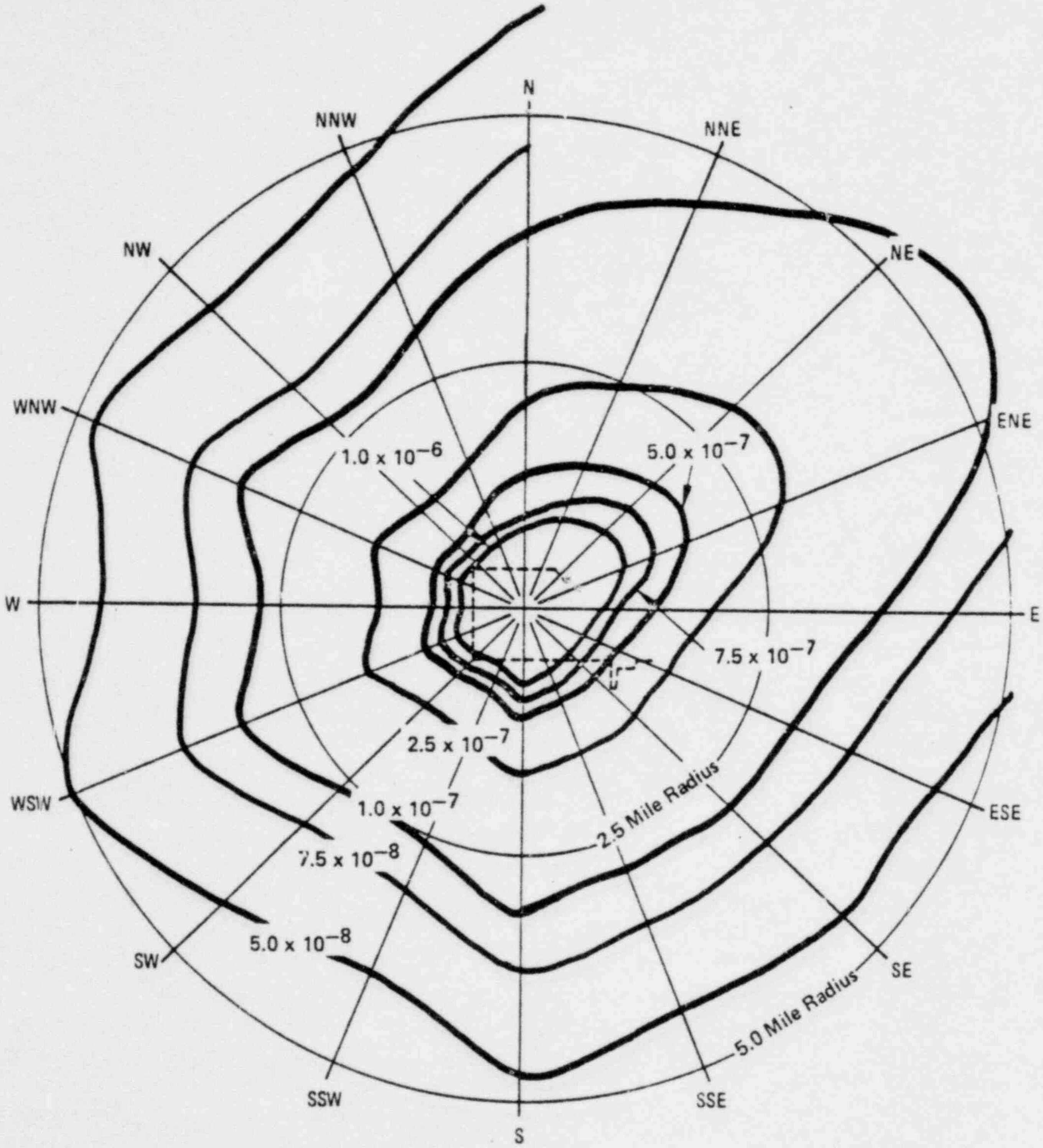
1.48×10^{6} rem/curie for I-131

5.34×10^{4} rem/curie for I-132

4.00×10^{5} rem/curie for I-133

2.5×10^{4} rem/curie for I-134

1.24×10^{5} rem/curie for I-135



POOR ORIGINAL

Units: sec/m^3

Figure 7A-1 - DAVIS – BESSE DISPERSION PARAMETERS X/Q ISOPLETHS FOR 0 – 5 MILES

(Based on Toledo, Ohio Data – Jan. 1959 - Dec. 1963)

Reference (3) from Main Text

APPENDIX 7B

APPENDIX 7B

COMPUTATIONAL METHODS FOR DOSES RESULTING FROM LIQUID EFFLUENTS

The annual whole body dose (rem/year) received by a person who consumes 50 grams daily of fish grown in waters contaminated with radionuclide "i" can be determined from the following equations:

$$D_{a,i} = \frac{\text{Daily intake of "i" via fish}}{\text{Daily intake of "i" resulting in 5 rem/year}} \times 5 \text{ (rem/year)}$$

$$D_{a,i} \text{ (rem/year)} = \frac{50(g_a/\text{day}) \times C_w\ (\mu Ci/cc_w)_i \times C_f \left(\frac{\mu Ci/g_a}{\mu Ci/cc_w}\right)_i}{(MPC)_w\ (\mu Ci/g_w)_i \times 2200\ (g_w/\text{day})} \times 5 \text{ (rem/year)} \quad (1)$$

Where:

C_w = Concentration of radionuclide "i" in the ambient waters of the organisms. For the subject calculations, these values were taken to be the same as those calculated for Camp Perry-Erie Industrial Park.

C_f = Concentration factor for the edible part of the marine organisms concerned. Values by Lawrence Radiation Laboratories were used in these calculations.(4)

$(MPC)_w$ = ICRP - derived value(1) for the maximum permissible concentration of radionuclide "i" in potable water, applicable to chronic intake (168 hr/week) by radiation workers, and for the whole body as the organ of reference.

2200 cc/day = Intake of water by standard man.(1)

5 rem/year = Whole body dose resulting from continuous daily intake (by ingestion) of $(MPC)_w$ (μCi/cc) x 2200 (cc/day) μCi of radionuclide "i".

For the radionuclides of interest, the Q_f (Quality Factor) and the relative damage factor "n" are both taken to be unity. Hence, the ratio of rems to rads is unity and the dose equations in the Appendix may be expressed in units of either rads or rem.

The fish ingestion dose was calculated as follows:

$$D_{a,i} \text{ (rem/year)} = \frac{(C) \times (50.0) \times (5)}{2200}$$

Where:

$C = (C_w) \times (C_f) \text{ (MPC)}_w$

When the fish is contaminated with n radionuclides, the total, annual whole body dose is:

$$D_a \text{ (rem/year)} = \sum_{i=1}^{n} D_{a,i} \qquad (2)$$

For these calculations, all radionuclides (excluding the radiogases) listed in Table 8A-2 of Appendix 8A.

The population doses resulting from the liquid effluents discharged to Lake Erie were calculated as follows:

If it is assumed that one person consumes 50.0 grams of fish flesh daily, the number of persons, P_a, who in one year consume the annual amount, A_a (gross pounds), harvested is:

$$P_a \text{ (Persons)} = \frac{A_a \text{ (gross pounds/year)} \times f_a \frac{\text{edible pounds}}{\text{gross pounds}} \times 453.6 \text{ (gm/lb)}}{50.0 \text{ (gm/day-person)} \times 365 \text{ (days/year)}} \qquad (3)$$

Where:

$A_a = 3.8 \times 10^{-6}$ lbs/year* (landings from District 1)[5]

f_a = Approximately one-third for fish[6]

The total population dose D_Σ (man-rem/year) = $(P_a) \times (\Sigma D_a)$

Where P_a is as determined by equation (3) and ΣD_a, by equation (2).

Type of Seafood	P_a (Persons)	$D_{a,i}$ (rem/yr/person)	Population Dose D_Σ (man-rem/yr)
(a) Fish	3.15×10^4	2.61×10^{-7}	.082

The annual whole body dose (rem/year) received by a person who consumes his total daily water intake (2200 cc) contaminated with radionuclides "i" can be calculated from the following equations:

$$D_i = \frac{\text{Concentration of i in drinking water}}{\text{Concentration of i resulting in 5 rem/yr}} \times 5 \text{ rem/year} \quad (6)$$

$$D_i = \frac{C_w}{(MPC)_w} \times 5$$

When the water is contaminated with n radionuclides, the total annual whole body dose is:

$$\Sigma D_i \text{ (rem/year)} = \sum_{i=1}^{n} D_i \quad (7)$$

The calculation of the concentration of radioactive materials as a function of distance from the point of discharge was based on the computation made for tritium (H-3). More tritium is discharged into the lake from the station than any other radioactive material.

The modified Fickian equation used for calculation of tritium dispersion is as follows:

$$\overline{C}(x,0,0) = \frac{Q}{2\pi x (Ky\ Kz)^{1/2}} \quad (8)$$

Where:

$\overline{C}$ (x,0,0) = Average centerline (maximum) concentration Ci/cm^3

Q = Continuous release source term (Ci/sec)

x = Downstream distance (cm)

Ky = Diffusivity in lateral direction (cm^2/sec)

Kz = Diffusivity in vertical direction (cm^2/sec)

From Okubo and Farlow[7] for Lake Erie drogue studies, K_y >3 x 10^4 cm^2/sec. in all cases. The same was observed in the Lake Michigan studies. For conservatism, a value of 1 x $10^4 cm^2$/sec has been used in this study. The conservative estimate of K_z (1 cm^2/sec) used in the PSAR (Appendix 2D page 2D-82) is also used here. Thus, the centerline concentration is expressed as:

$$C(x,0,0) = \frac{Q}{2\pi x} = \frac{1.59 \times 10^{-3}}{x} \qquad (9)$$

The calculations of average annual concentration isopleths were made using the following assumptions.

1. The warm discharge rises to the surface and follows the surface current.
2. The surface current is in the direction of the surface winds (approximately).
3. All winds from ENE to NNW result in a southerly directed surface current at the shore line. Similarly all winds ranging from E to SSE result in a northly directed surface current at the shore line.

Using the above equations and assumptions the isopleths may be calculated by weighting the annual average source term by the frequency of flow in that direction based on the available meteorological summary from the PSAR. Calms are accounted for by distributing the occurrence over all directions proportionately.

In order to compute the population dose from ingestion of radioactive material from drinking water, the following assumptions regarding population were made:

1. The total 1980 population from the 0-5 mile annuli (2380) received potable water at the Camp Perry and Erie Industrial Park concentration.
2. The total 1980 projected population from the 5-10 mile anulus, SE sector (3098); S sector (4678); and SW sector (3369) received potable water at the Port Clinton concentration.
3. The total 1980 projected population from the 5-10 mile anulus, W sector (2429); 10-20 mile annulus, W sector (28,488); 20-30 mile annulus, W sector [479,888 - - includes Toledo (429,000)]; the 10-20 mile annulus, NW sector (970); and the 20-30 mile anulus, NW sector (150,928) received potable water at the Toledo and Oregon concentration.

REFERENCES

(APPENDICES 7A & B)

1. ICRP Publication 2: Report of Committee II on Permissible Dose for Internal Radiation, (1959). International Commission on Radiological Protection. Pergamon Press, New York, 1959.

2. Kim, Y. S., WINDIF - A Wind Diffusion Program for the CDC - 3600 Computer, NUS-207, December 2, 1964.

3. Goldman, M.I., "United States Experience in Management of Gaseous Wastes from Nuclear Power Stations", Treatment of Airborne Radioactive Wastes, IAEA Symposium, New York, 26-30 August 1968, pp. 763-783.

4. Chapman, W.H., H. L. Fisher, and M. W. Pratt, "Concentration Factor of Chemical Elements in Edible Aquatic Organisms." UCRL 50564, December 30, 1968.

5. Michigan, Ohio and Wisconsin Landings, Annual Summary C. F. S. No. 5236. United States Department of the Interior, 1969.

6. Personal Communication, Harry W. Calley, Jr., NUS, and Mr. Lyles, Director of Statistics, Bureau of Commercial Fisheries, July 23, 1969.

7. Okubo, A. and J. S. Farlow, "Analysis of Some Great Lakes Drogue Studies", Proceedings of the 10th Conference on Great Lakes Research 1967.

APPENDIX 7C

APPENDIX 7C

WATER POLLUTION CONTROL BOARD
OHIO DEPARTMENT OF HEALTH
COLUMBUS, OHIO

RESOLUTION ESTABLISHING AMENDED CRITERIA OF STREAM-WATER QUAL.TY FOR VARIOUS USES ADOPTED BY THE BOARD ON APRIL 14, 1970

WHEREAS, Section 6111.03, of the Ohio Revised Code, provides, in part, as follows:

"The water pollution control board shall have power:

(A) To develop programs for the prevention, control and abatement of new or existing pollution of the waters of the state; ...." and

WHEREAS, Primary indicators of stream-water quality are needed as guides for appraising the suitability of surface waters in Ohio for various uses; and

WHEREAS, The stream-water quality criteria for various uses and minimum conditions applicable to all waters adopted by the Board of June 14, 1966, have been amended by the Ohio River Valley Water Sanitation Commission; and

WHEREAS, The criteria adopted by the Board on October 10, 1967, have been further amended by the Ohio River Valley Water Sanitation Commission;

THEREFORE BE IT RESOLVED, That the following amended stream-water quality criteria for various uses, and minimum conditions applicable to all waters, and policies for protection of high quality waters and for water quality design flow, are hereby adopted in accordance with amendments of the Ohio River Valley Water Sanitation Commission, and the recommendations of the Federal Water Pollution Control Administration.

AND BE IT FURTHER RESOLVED, That the amended stream-water quality criteria for various uses, for minimum conditions, for protection of high quality waters, and, for water quality design flow, be made applicable to the following waters of the state:

1. Maumee, Tiffin, St. Joseph, and St. Marys River Basins;
2. Lake Erie & Interstate Waters thereof;
3. Great Miami, Whitewater, and Wabash River Basins;
4. Ashtabula River, Conneaut and Turkey Creeks;
5. Ohio River of Ohio-West Virginia and Ohio-Kentucky;
6. North Central Ohio Tributaries of Lake Erie;
7. Scioto River Basin;
8. Little Miami River Basin;
9. Rocky, Cuyahoga, Chagrin, and Grand River Basins;
10. uskingum River Basin;
11. Hocking River Basin.

MINIMUM CONDITIONS APPLICABLE TO ALL WATERS AT ALL PLACES AND AT ALL TIMES

1. Free from substances attributable to municipal, industrial or other discharges, or agricultural practices that will settle to form putrescent or otherwise objectionable sludge deposits.

2. Free from floating debris, oil, scum and other floating materials attributable to municipal, industrial or other discharges, or agricultural practices in amounts sufficient to be unsightly or deleterious.

3. Free from materials attributable to municipal, industrial or other discharges, or agricultural practices producing color, odor or other conditions in such degree as to create a nuisance.

4. Free from substances attributable to municipal, industrial or other discharges, or agricultural practices in concentrations or combinations which are toxic or harmful to human, animal, plant or aquatic life.

PROTECTION OF HIGH QUALITY WATERS

Waters whose existing quality is better than the established standards as of the date on which such standards become effective will be maintained at their existing high quality, pursuant to the Ohio water pollution control statutes, so as not to interfere with or become injurious to any assigned uses made of, or presently possible, in such waters. This will require that any industrial, public or private project or development which would constitute a new source of pollution or an increased source of pollution to high quality waters will be required, as part of the initial project design, to provide the most effective waste treatment available under existing technology. The Ohio Water Pollution Control Board will cooperate with other agencies of the state, agencies of other states, interstate agencies and the Federal Government in the enforcement of this policy.

WATER QUALITY DESIGN FLOW

Where applicable for the determination of treatment requirements the water quality design flow shall be the minimum seven consecutive day average that is exceeded in 90 percent of the years.

STREAM-QUALITY CRITERIA

FOR PUBLIC WATER SUPPLY

The following criteria are for evaluation of stream quality at the point at which water is withdrawn for treatment and distribution as a potable supply:

1. Bacteria: Coliform group not to exceed 5,000 per 100 ml as a monthly average value (either MPN or MF count); nor exceed this number in more than 20 percent of the samples examined during any month; nor exceed 20,000 per 100 ml in more than five percent of such samples.

2. Threshold-odor Number: Not to exceed 24 (at 60 deg. C.) as a daily average.

3. Dissolved solids: Not to exceed 500 mg/l as a monthly average value, nor exceed 750 mg/l at any time.

4. Radioactivity: Gross beta activity not to exceed 1,000 picocuries per liter (pCi/l), nor shall activity from dissolved strontium-90 exceed 10 pCi/l, nor shall activity from dissolved alpha emitters exceed 3 pCi/l.

5. Chemical constituents: Not to exceed the following specified concentrations at any time.

Constituent	Concentration (mg/l)
Arsenic	0.05
Barium	1.0
Cadmium	0.01
Chromium (hexavalent)	0.05
Cyanide	0.025
Fluoride	1.0
Lead	0.05
Selenium	0.01
Silver	0.05

FOR INDUSTRIAL WATER SUPPLY

The following criteria are applicable to stream water at the point at which the water is withdrawn for use (either with or without treatment) for industrial cooling and processing:

1. Dissolved oxygen: Not less than 2.0 mg/l as a daily-average value, nor less than 1.0 mg/l at any time.

2. pH: Not less than 5.0 nor greater than 9.0 at any time.

3. Temperature: Not to exceed 95 deg. F. at any time.

4. Dissolved solids: Not to exceed 750 mg/l as a monthly average value, nor exceed 1,000 mg/l at any time.

FOR AQUATIC LIFE A

The following criteria are for evaluation of conditions for the maintenance of a well-balanced, warm-water fish population. They are applicable at any point in the stream except for areas necessary for the admixture of waste effluents with stream water:

1. Dissolved oxygen: Not less than an average of 5.0 mg/l per calendar day and not less than 4.0 mg/l at any time.

2. pH:

   A. No values below 6.0 nor above 8.5.

   B. Daily fluctuations which exceed the range of pH 6.0 to pH 8.5 and are correlated with photosynthetic activity may be tolerated.

3. Temperature:

   A. No abnormal temperature changes that may affect aquatic life unless caused by natural conditions.

   B. The normal daily and seasonal temperature fluctuations that existed before the addition of heat due to other than natural causes shall be maintained.

   C. Maximum temperature rise at any time or place above natural temperatures shall not exceed 5 deg. F. In addition, the water temperature shall not exceed the maximum limits indicated in the following table.

	Maximum Temperature in Deg. F. During Month											
WATERS	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
All waters except Ohio River	50	50	60	70	80	90	90	90	90	78	70	57
Main Stem-Ohio River	50	50	60	70	80	87	89	89	87	78	70	57

4. Toxic substances: Not to exceed one-tenth of the 48-hour median tolerance limit, except that other limiting concentrations may be used in specific cases when justified on the basis of available evidence and approved by the appropriate regulatory agency.

FOR AQUATIC LIFE B

The following criteria are for evaluation of conditions for the maintenar of desirable biological growths and, in limited stretches of a stream, for permitting the passage of fish through the water, except for areas necessary for admixture of effluents with stream water:

1. Dissolved oxygen: Not less than 3.0 mg/l as a daily-average value, nor less than 2.0 mg/l at any time.

2. pH: Not less than 6.0 nor greater than 8.5 at any time.

3. Temperature: Not to exceed 95 deg. F. at any time.

4. Toxic substances: Not to exceed one-tenth of the 48-hour median tolerance limit, except that other limiting concentrations may be used in specific cases when justified on the basis of available evidence and approved by the appropriate regulatory agency.

FOR RECREATION

The following criterion is for evaluation of conditions at any point in waters designated to be used for recreational purposes, including such water-contact activities as swimming and water skiing:

Bacteria: The fecal coliform content (either MPN or MF count) not to exceed 200 per 100 ML as a monthly geometric mean based on not less than five samples per month; nor exceed 400 per 100 ML in more than ten percent of all samples taken during a month.

FOR AGRICULTURAL USE AND STOCK WATERING

The following criteria are applicable for the evaluation of stream quality at places where water is withdrawn for agricultural use or stock-watering purposes:

1. Free from substances attributable to municipal, industrial or other discharges, or agricultural practices that will settle to form putrescent or otherwise objectionable sludge deposits.

2. Free from floating debris, oil, scum and other floating materials attributable to municipal, industrial or other discharges, or agricultural practices in amounts sufficient to be unsightly or deleterious.

3. Free from materials attributable to municipal, industrial or other discharges, or agricultural practices producing color, odor or other conditions in such degree as to create a nuisance.

4. Free from substances attributable to municipal, industrial or other discharges or agricultural practices in concentrations or combinations which · toxic or harmful to human, animal, plant or aquatic life.

APPENDIX 7D

APPENDIX 7D

WATER POLLUTION CONTROL BOARD
OHIO DEPARTMENT OF HEALTH
COLUMBUS, OHIO

RESOLUTION REGARDING AMENDED CRITERIA OF STREAM-WATER QUALITY FOR VARIOUS USES ADOPTED BY THE BOARD ON OCTOBER 10, 1967

WHEREAS, Section 6111.03, of the Ohio Revised Code, provides, in part, as follows:

"The water pollution control board shall have power:

(A) To develop programs for the prevention, control and abatement of new or existing pollution of the waters of the state; . . . " and

WHEREAS, Primary indicators of stream-water quality are needed as guides for appraising the suitability of surface waters in Ohio for various uses; and

WHEREAS, The stream-water quality criteria for various uses and minimum conditions applicable to all waters adopted by the Board on June 14, 1966, have been amended by the Ohio River Valley Water Sanitation Commission;

THEREFORE BE IT RESOLVED, That the following amended stream-water quality criteria for various uses, and minimum conditions applicable to all waters, are hereby adopted in accordance with amendments of the Ohio River Valley Water Sanitation Commission.

MINIMUM CONDITIONS APPLICABLE TO
ALL WATERS AT ALL PLACES AND AT ALL TIMES

1. Free from substances attributable to municipal, industrial or other discharges, or agricultural practices that will settle to form putrescent or otherwise objectionable sludge deposits.

2. Free from floating debris, oil, scum and other floating materials attributable to municipal, industrial or other discharges, or agricultural practices in amounts sufficient to be unsightly or deleterious.

3. Free from materials attributable to municipal, industrial or other discharges, or agricultural practices producing color, odor or other conditions in such degree as to create a nuisance.

4. Free from substances attributable to municipal, industrial or other discharges, or agricultural practices in concentrations or combinations which are toxic or harmful to human, animal, plant or aquatic life.

POOR ORIGINAL

IMAGE EVALUATION
TEST TARGET (MT-3)

6″

MICROCOPY RESOLUTION TEST CHART

IMAGE EVALUATION
TEST TARGET (MT-3)

6″

MICROCOPY RESOLUTION TEST CHART

STREAM-QUALITY CRITERIA

FOR PUBLIC WATER SUPPLY

The following criteria are for evaluation of stream quality at the point at which water is withdrawn for treatment and distribution as a potable supply:

1. Bacteria: Coliform group not to exceed 5,000 per 100 ml as a monthly average value (either MPN or MF count); nor exceed this number in more than 20 percent of the samples examined during any month; nor exceed 20,000 per 100 ml in more than five percent of such samples.

2. Threshold-odor Number: Not to exceed 24 (at 60 deg. C.) as a daily average.

3. Dissolved solids: Not to exceed 500 mg/l as a monthly average value, nor exceed 750 mg/l at any time.

4. Radioactivity: Gross beta activity not to exceed 1,000 picocuries per liter (pCi/l), nor shall activity from dissolved strontium-90 exceed 10 pCi/l, nor shall activity from dissolved alpha emitters exceed 3 pCi/l.

5. Chemical constituents: Not to exceed the following specified concentrations at any time:

Constituent	Concentration (mg/l)
Arsenic	0.05
Barium	1.0
Cadmium	0.01
Chromium (hexavalent)	0.05
Cyanide	[.02] 0.025
Fluoride	[2] 1.0
Lead	0.05
Selenium	0.01
Silver	0.05

FOR INDUSTRIAL WATER SUPPLY

The following criteria are applicable to stream water at the point at which the water is withdrawn for use (either with or without treatment) for industrial cooling and processing:

1. Dissolved oxygen: Not less than 2.0 mg/l as a daily-average value, nor less than 1.0 mg/l at any time.

2. pH: Not less than 5.0 nor greater than 9.0 at any time.

3. Temperature: Not to exceed 95 deg. F. at any time.

4. Dissolved solids: Not to exceed 750 mg/l as a monthly average value, nor exceed 1,000 mg/l at any time.

FOR AQUATIC LIFE A

The following criteria are for evaluation of conditions for the maintenance of a well-balanced, warm-water fish population. They are applicable at any point in the stream except for areas immediately adjacent to outfalls. In such areas cognizance will be given to opportunities for the admixture of waste effluents with stream water:

1. Dissolved oxygen: Not less than 5.0 mg/l during at least 16 hours of any 24-hour period, nor less than 3.0 mg/l at any time.

2. pH: No values below 5.0 nor above 9.0, and daily average (or median) values preferably between 6.5 and 8.5.

3. Temperature: Not to exceed 93 deg. F. at any time during the months of May through November, and not to exceed 73 deg. F. at any time during the months of December through April.

4. Toxic substances: Not to exceed one-tenth of the 48-hour median tolerance limit, except that other limiting concentrations may be used in specific cases when justified on the basis of available evidence and approved by the appropriate regulatory agency.

FOR AQUATIC LIFE B

The following criteria are for evaluation of conditions for the maintenance of desirable biological growths and, in limited stretches of a stream, for permitting the passage of fish through the water, except for areas immediately adjacent to outfalls. In such areas cognizance will be given to opportunities for admixture of effluents with stream water:

1. Dissolved oxygen: Not less than 2.0 mg/l as a daily-average value, nor less than 1.0 mg/l at any time.

2. pH: Not less than 5.0 nor greater than 9.0 at any time.

3. Temperature: Not to exceed 95 deg. F. at any time.

4. Toxic substances: Not to exceed one-tenth of the 48-hour median tolerance limit, except that other limiting concentrations may be used in specific cases when justified on the basis of available evidence and approved by the appropriate regulatory agency.

FOR RECREATION

The following criterion is for evaluation of conditions at any point in waters designated to be used for recreational purposes, including such water-contact activities as swimming and water skiing:

Bacteria: Coliform group not to exceed 1,000 per 100 ml as a monthly average value (either MPN or MF count); nor exceed this number in more than 20 percent of the samples examined during any month; nor exceed 2,400 per 100 ml (MPN or MF count) on any day.

FOR AGRICULTURAL USE AND STOCK WATERING

The following criteria are applicable for the evaluation of stream quality at places where water is withdrawn for agricultural use or stock-watering purposes:

1. Free from substances attributable to municipal, industrial or other discharges, or agricultural practices that will settle to form putrescent or otherwise objectionable sludge deposits.

2. Free from floating debris, oil, scum and other floating materials attributable to municipal, industrial or other discharges, or agricultural practices in amounts sufficient to be unsightly or deleterious.

3. Free from materials attributable to municipal, industrial or other discharges, or agricultural practices producing color, odor or other conditions in such degree as to create a nuisance.

4. Free from substances attributable to municipal, industrial or other discharges or agricultural practices in concentrations or combinations which are toxic or harmful to human, animal, plant or aquatic life.

APPENDIX 7E

APPENDIX 7E

WATER POLLUTION CONTROL BOARD
OHIO DEPARTMENT OF HEALTH
COLUMBUS, OHIO

AMENDED RESOLUTION REGARDING ENHANCEMENT OF WATERS OF THE STATE APPROVED BY THE BOARD ON OCTOBER 17, 1967

To emphasize its continuing program of pollution abatement and to insure further enhancement of the quality of the waters of the state, the Ohio Water Pollution Control Board hereby adopts the following policies and requirements to supplement the Water Quality Standards for interstate waters which were adopted on January 10, April 11, and June 13, 1967:

1. Where applicable for the determination of treatment requirements the water quality design flow shall be the minimum seven consecutive day average that is exceeded in 90 percent of the years.

2. Where applicable, the treatment requirements shall be such as to maintain the pH of the receiving waters in the preferred range of 6.5 to 8.5.

3. Where applicable, the treatment requirements shall be based on maintaining a preferred average of 3.0 mg/l and a minimum of 2.0 mg/l of dissolved oxygen for waters designated as Aquatic Life B.

4. In addition to the criteria for waters designated for Aquatic Life A, specific requirements shall be set for each area where thermal discharges are of importance in order to limit the rate of change of temperature, and to limit the increase to 5 deg. F. in the stream section under consideration. This requirement shall not be applicable to those areas where the water temperature is affected by the hydrodynamics of the receiving waters.

5. The staff of the Ohio Department of Health shall cooperate with the Ohio River Valley Water Sanitation Commission, the Commonwealth of Pennsylvania, the Federal Water Pollution Control Administration, and other interested agencies in studies for the determination of desirability of possible amendments to the threshold odor criterion for the Mahoning River at the Ohio-

Pennsylvania state line, and shall report and make recommendations to the Board by not later than October 1, 1969.

6. The June 1, 1967 report of the Lake Erie Technical Committee recommending phosphate level objectives for Lake Erie shall be used as a guide in determining treatment requirements.

7. Furthermore, with respect to all water quality standards for interstate and intrastate waters, the Board and the Ohio Department of Health will encourage and assist other agencies such as the Ohio Water Commission and the Soil Conservation Service, U. S. Department of Agriculture, in the implementation of effective soil erosion control programs, and programs for the reduction of the run-off of phosphorus, nitrogen compounds, and pesticides.

APPENDIX 7F

NUS - 799

EVALUATION OF ENVIRONMENTAL EFFECTS

OF A

NATURAL DRAFT COOLING TOWER

AT THE

DAVIS-BESSE NUCLEAR POWER STATION

Prepared For

THE TOLEDO EDISON COMPANY

July , 1971

by

Environmental Safeguards Division
NUS Corporation
4 Research Place
Rockville, Maryland 20850

Approved: ______________________
Morton I. Goldman
Vice President &
General Manager

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

I. SUMMARY AND CONCLUSION

NUS has undertaken an evaluation of environmental effects of the 493' high natural draft cooling tower being installed for the Davis-Besse Station as part of Toledo-Edison's over-all program of environmental quality assurance. The NUS computer codes that have been developed for this type of evaluation work, are based on accepting meteorological data that has been processed by the National Oceanographic and Atmospheric Administration. This extensive data for a number of years of record, is available for all major weather stations such as the Toledo Express Airport. On-site meteorological data, available for the Davis-Besse site for a 2-year period, can be correlated with National Oceanographic and Atmospheric Administration data from any location.

The approach chosen was to analyze a representative 5-year period of meteorological data from the Toledo Express Airport (which records the occurrence of fog conditions) to determine those conditions related to the natural occurrence of fog. The relative humidity was determined to be an adequate indication of the probability of the occurrence of fog for the Toledo area. This information formed the basis for evaluating the potential of producing or intensifying local fog conditions. Comparison of on-site meteorological data with the Toledo data indicates that the Toledo data are quite representative of climatic conditions at Davis-Besse.

The Toledo data were also processed by the NUS computer codes to determine the environmental effects of the operation of the cooling tower. These codes are based on an analytical model for calculation, on a hour by hour basis, of plume rise, dispersion and transport utilizing hourly meteorological observations and cooling tower design and operation parameters as input. Results were then examined to determine consistency with on-site meteorological data and the occurrence of such local effects as the lake breeze and also to assess anomalous situations such as plume do... sh. The average visible vapor plume is only 1.5 miles long and is not considered to be a significant environmental effect. The vapor cloud is not expected to be visible over population centers of Toledo or Port Clinton or present any hazards to aircraft operations.

Ground level effects of fog and icing conditions (excluding downwash plume s. uations) which would be induced by operation of the Davis-Besse cooling tower are considered to be negligible. The probability of the increased occurrence of fog conditions based on analysis of Toledo Airport data has been calculated to be only 0.42% which is not considered to be an environmental problem. It is important to note that the increased occurrence of fog conditions does not represent discrete cases of fog, but rather represents the possibility of fog occurring earlier and lasting longer than normal. The predicted increase in icing conditions attributed to the cooling tower effluent, a maximum of one minute for any 22.5% sector for the winter season, is also considered negligible.

The occurrence of downwash conditions under which the cooling tower effluent is caught in the turbulent wake of the tower structure and brought down to the surface will not be a frequent effect and the persistence of these conditions will not be great for any direction due to expected gustiness and variability of the wind. Approximately 0.79% of the time during the winter season (~17 hours) downwash conditions are calculated to occur that could result in icing on surfaces off-site at a rate of 0.03 - 0.07 inches of ice per hour. However, these calculations are considered to be extremely conservative upper limits since downwash occurrences have not been verified in actual cooling tower operations in the United States. Due to the low drift carry-over rate of 0.01% only 4×10^2 pounds of water per hour would be expected to leave the tower in the form of water droplets entrained in the cooling tower exhaust. This drift loss is considered an insignificant amount, and less than 1% of this amount would be deposited off-site.

II. DAVIS-BESSE STATION LOCATION

The Davis-Besse Nuclear Power Station is located 20 miles east-southeast of Toledo and 17 miles west-northwest of Sandusky, Ohio, with 1960 populations of 379,133 and 31,989 respectively, on the southwestern shoreline of Lake Erie. The closest population center (17 miles to the south) is Fremont with a 1960 population of 17,573. However, there are two populated areas (the first about two-thirds of a mile northwest of the site, and another to the southwest at the same distance) consisting mainly of summer cottages near the site. The Davis-Besse site location and geographic features for a 50-mile and 20-mile radius are presented in Figures 1 and 2, respectively.

The topography of the site and the region in general is relatively flat with elevations varying only approximately six feet above lake level with very little slope. The major topographical feature is Lake Erie which borders the site on the northern and eastern boundaries. The site plan is presented in Figure 3.

The nearest highway is Ohio State Route 2, which runs along the west site boundary and turns west at the northwest corner of the site. This highway, which connnects Cleveland and Toledo, crosses the Toussaint River on a two-lane bridge at the southwest corner of the site. Ohio State Route 19 runs south from State Route 2 to Oak Harbor and Fremont, Ohio. This highway crosses the Toussaint River about three miles west of the station site. A country road runs directly west of the site, one-half mile south of State Route 2 to State Route 19.

The closest commercial airport is Toledo Express Airport, 38 miles west of the station, and the nearest airport with a paved runway is located 13 miles to the east-southeast at Port Clinton. The nearest VHF Omni-Directional Radio Range Airway (designated V232) runs west-northwest and east-southeast, approximately seven miles south of the site.

III. APPLICABILITY OF SITE METEOROLOGICAL DATA

The purpose of this section is to demonstrate the applicability of the Toledo Express Airport meteorological data to the Davis-Besse site and to identify the local meteorological conditions pertinent to evaluation of the effects of cooling tower operation. In order to determine the environmental impact of the natural draft cooling tower, Toledo Airport data (rather than site data) were utilized for computer reduction. The Toledo data are available on magnetic tape compatible with available NUS computer codes. More importantly, the occurrence of fog conditions at the airport are noted along with other pertinent meteorological parameters. Site meteorological data were also analyzed in detail in order to properly apply the results of the Toledo analysis specifically to the Davis-Besse site.

The Toledo data which were used for the analysis of environmental effects from operation of the Davis-Besse cooling tower consisted of five years of observations for the period of January, 1959 through December, 1963. Selection of the five-year period is arbitrary, since any anomalous meteorological occurrences would tend to average out in a climatological record of a five-year duration. Data for a similar time period during which site measurements were recorded were not available in computer compatible form for utilization in this study.

The Toledo Express Airport is located on a wide (five to seven miles), level, sandy region in a rural area about 25 miles southwest of Maumee Bay which is on the western end of Lake Erie. This location (38 miles west of the Davis-Besse site) would generally be expected to be influenced by the same climate and meteorological conditions as the site, with the possible exception of the lake effect which will be discussed later in this section.

On-site meteorological data from the Davis-Besse Station are available for the period October, 1968 through November, 1970, including wind data and temperature lapse measurements (ΔT) at 20-foot, 100-foot, and 300-foot tower levels as well as surface (5') temperature and wet bulb readings at the site. These data provide a basis for comparison with meteorological observations available from the Toledo Express Airport for the period 1959 through 1963 (representative of average climatic conditions at Toledo) in order to determine the applicability of Toledo Airport data to the Davis-Besse site. To accomplish this task it is necessary to compare wind direction, wind speed, atmospheric stability, and temperature and humidity distributions for the two locations. The 300-foot wind level of the measured levels at Davis-Besse is considered most representative of wind conditions at and above the cooling tower exit elevation, which will be 493' above grade elevation.

A. Wind Direction

Wind direction determines the actual trajectory of the cooling tower plume effluent and thus the areas of possible environmental effects. Comparison of average wind direction roses for the low tower level (20') at Davis-Besse for the period October, 1968 through November, 1970 with data from the Toledo Airport (also at a 20' elevation) for the period January, 1959 through December, 1963 indicates that the directional frequencies of occurrence are very similar. However, the wind data measured on-site at the 300' tower level are considered more representative of plume transport conditions at or above the cooling tower exit elevation. Comparison of the annual 300' wind rose from Davis-Besse for the period October, 1968 through November, 1970 with the low-level (20') Toledo data for the 5-year period also indicates a close similarity. Therefore, it can be reasonably stated that wind directions reported at Toledo will generally (on an annual average basis) be representative of effluent transport (directional) conditions for the natural draft cooling tower.

The wind roses for the period January, 1959 through December, 1963 from Toledo (20') and for the 20-foot and 300-foot levels of the Davis-Besse tower for the period October, 1968 through November, 1970 are presented in Figure 4 for comparative purposes. The three wind roses show quite similar distribution with a predominant flow from the southwest.

Seasonal wind roses for the Toledo data and for the 300' Davis-Besse data are presented in Figures 5 and 6, respectively. The lake breeze effect (the local onshore flow of air from the lake to the shore due to the surface temperature differences) results in an increase of northerly and easterly component winds during the spring and summer at Davis-Besse as indicated by the site 300' wind data. The lake effect is not as noticeable at the inland location of the Toledo Express Airport. The lake effect will be discussed in greater detail in Section III-E.

B. Wind Speed

Wind speed is an important parameter as a measure of the relative dilution of the cooling tower effluent and also of possible conditions of downwash of the plume to the ground. Comparison of low-level wind speed data from Davis-Besse and Toledo reveals the similarity between the two sites. The annual average wind speed for Davis-Besse and for Toledo for the same data period are presented in Table I. The applicability of Toledo wind data to Davis-Besse is indicated by the similarity of the low-level average wind speeds for the period October, 1968 through November, 1970. (Differences in average speeds can generally be attributed to the higher sensor exposure elevation of 30' at Toledo for this data period since the wind sensor at Toledo was changed from 20' on November 1, 1968.) In assessing the environmental impact of the Davis-Besse cooling tower, low-level wind speeds were extrapolated to appropriate plume heights. (The basis for these extrapolations are discussed in Section III-F.)

C. Atmospheric Stability

Atmospheric stability is a measure of the dispersion capacity of the atmosphere. Dispersion is generally enhanced during unstable conditions and somewhat suppressed during stable conditions. There are several methods to categorize stability conditions which are described below.

Stability classifications at Davis-Besse were based on temperature lapse measurements (ΔT). The vertical temperature profiles of the uppermost layer for which on-site measurements were available ($\Delta T_{300' - 145'}$) are most representative of actual dispersion conditions at and above

TABLE I

COMPARISON OF TOLEDO AND DAVIS-BESSE WIND SPEED DATA

		Average Wind Speed, m.p.h.
300' (10/68 - 11/70)	Davis-Besse	16.0
100' (10/68 - 11/70)	Davis-Besse	11.8
20' (10/68 - 11/70)	Davis-Besse	8.8
30' (10/68 - 11/70)	Toledo	9.5
20' *(1/59 - 12/63)	Toledo	8.8

* Wind sensor elevation changed to 30' at Toledo Express Airport on November 1, 1968.

the level of the cooling tower effluent. A listing of the distribution of stability based on Davis-Besse ΔT measurements is presented in Table II. Stability classifications for the five years of Toledo data are incluaed in Table III for comparative purposes. These data were classified by the Pasquill-Turner[1,2] method based on time of day, solar insolation, wind speed, etc. which is an accepted method for classifying standard Weather Bureau Station observations. The stability classes proposed by Pasquill-Turner range from "A", the most unstable and best dispersion, to "F", stable and relatively poor dispersion. An additional classification category, "G", has been added to facilitate a more complete classification system. Comparison of the two data sets indicate a fairly similar distribution. The Toledo data have higher frequencies of unstable and neutral occurrence. However, use of the Toledo stability data to assess environmental effects of the proposed cooling tower is conservative since higher ground level concentrations result during unstable conditions for elevated releases.

D. Temperature and Relative Humidity

The dimensions of the visible plume and the possibility of icing during certain winter conditions are dependent on the ambient temperature and relative humidity. A comparison of Davis-Besse and Toledo average monthly data presented in Table IV illustrates the similarity of the two locations. In general, Toledo temperature and humidity data are representative of Davis-Besse with the possible exception of lake breeze (flowing from the lake to the shore) effects. During the late spring and summer lower temperatures and higher humidities can be expected during lake breeze situations. However, plume dissipation conditions are at a maximum during these seasons. During the winter the frozen lake essentially acts as a land surface and is not a major local influence.

TABLE II

DAVIS-BESSE (Δ T $_{300' - 145'}$)

ATMOSPHERIC STABILITY DISTRIBUTIONS (% OF TOTAL OBSERVATIONS)

(Lapse Rates ^{O}C/100m)

	UNSTABLE ($\Delta T < -1.5^{O}$)	NEUTRAL ($-1.5 \leq \Delta T < -0.5^{O}$)	SLIGHTLY STABLE ($-0.5 \leq \Delta T < 1.5^{O}$)	STABLE ($\Delta T > 1.5^{O}$)
Spring ('69,'70)	15.2	49.5	20.6	14.7
Summer ('69,'70)	12.6	43.9	27.6	15.9
Autumn ('69,'70)	3.5	38.2	29.1	29.2
Winter ('68-'69 '69-'70)	4.3	64.0	25.0	6.7
ANNUAL (10/68-11/70)	8.3	49.6	25.5	16.6

TABLE III

TOLEDO EXPRESS AIRPORT (PASQUILL-TURNER CLASSIFICATIONS) ATMOSPHERIC STABILITY DISTRIBUTION (% OF TOTAL OBSERVATIONS)

	UNSTABLE	NEUTRAL	SLIGHTLY STABLE	STABLE
(1/59 - 12/63)	(A-C)	(D)	(E)	(F-G)
Spring	13.3	62.8	9.6	14.4
Summer	32.9	33.6	8.2	25.3
Autumn	13.8	53.5	11.3	21.4
Winter	4.5	75.6	9.7	10.2
ANNUAL	16.2	56.3	9.7	17.8

TABLE IV

TOLEDO EDISON - DAVIS-BESSE

Average Temperature and Relative Humidity

Toledo			Davis-Besse			
1970	T(°F)	R.H.(%)	1970	T(°F)	T_w(°F)	R.H.(%)
Jan.	16.2	74	Jan.	16.3	14.8	74
Feb.	24.3	72	Feb.	25.5	23.4	73
Mar.	31.8	71	Mar.	30.0	27.2	70
Apr.	48.9	70	Apr.	48.0	42.0	60
May	61.1	64	May	61.4	54.0	62
Jun.	67.2	69	Jun.	68.4	62.2	71
Jul.	71.1	72	Jul.	72.3	66.3	73
Aug.	69.6	74	Aug.	72.8	67.5	76
Sep.	64.4	75	Sep.**	65.8	60.6	74
Oct.	54.0	72	Oct.	54.0	49.5	73
Nov.	39.8	77	Nov.	40.4	37.7	78
Dec.*	26.6	80	Dec.*	30.1	27.9	77

* 1968

** Based on Limited Data

T_w - Average wet bulb temperature

E. Lake Breeze

Although the Toledo Airport is located 25 miles from Lake Erie, the annual distributions of wind direction and atmospheric stability are quite similar to site data. This implies that the Toledo Airport data are applicable to Davis-Besse on an annual basis, although the lake breeze effect may be a significant factor, especially during late spring and early summer. During periods of light geostrophic winds in spring and summer, surface winds may develop which blow onshore (lake to land) during the day, and offshore (land to lake) at night. The formation of the lake breeze is the result of the temperature variation between water and land. Although water has a higher thermal capacity than soil, turbulent mixing by wind and waves effects a continuous downward transport of surface heat through large masses of water. In contrast with the strong heating of the air over the shoreline region, the air over the strip of water off shore is only mildly warmed and, as a result, a temperature difference between land and water develops. This difference diminishes toward sunset and may reverse during the night. As the warmed air over the land begins to rise, a horizontal density gradient is formed which causes the heavier colder air over the water to flow underneath the warmer air. To insure the continuity of the circulation cell, there is a return motion of the warmer air from land to lake at higher levels.

Studies of lake breeze phenomena at the Great Lakes have been made, including several investigations on the eastern shore of Lake Michigan.[3,4,5] Moroz[3] has examined the physical features of a lake breeze wind system occurring on the eastern shore of Lake Michigan, about midway between Muskegon and Holland, Michigan. Observations made during the summer of 1964[3] and 1965[4] show that over the land the depth of the layer of onshore flow varied from approximately 400 meters to 750 meters, with maximum velocity of 5 to 7 m sec^{-1} (11 - 15.5 mph) observed within 250 meters of the surface directly over the lake shore. Above the lake breeze circulation, a well-defined return flow was noted which is two to four times as thick as the onshore flow, with velocities being somewhat less. The region of onshore flow extended 20 to 30 km inland (12.5 to 18.5 mi). In early afternoon, the onshore flow is directed approximately perpendicularly to the shoreline, gradually veering in a clockwise direction to a course parallel to the shoreline, under the influence of the Coriolis Force of the earth's rotation.

The occurrence of the lake breeze is dependent upon the magnitude of the gradient wind and the temperature differential across the shore. Lake breezes occur when the land surface is cooler than the lake surface. The stronger this differential, the more intense the circulation, and the greater its horizontal and vertical extent becomes. Olsson[4] reports that studies conducted on the western shore of Lake Erie and on the eastern shore of Lake Michigan found lake and land breezes to occur on more than one-third of the days in the summer half of the year.

Intense lake breeze surface inversions have been observed near the shore under onshore flow conditions. Lyons[7] has indicated that these inversions rarely extend much beyond the 100-meter level. Vapor plumes from the Davis-Besse cooling tower would easily penetrate these lake breeze inversions, and for most situations the tower height would be above the inversion layer; also, the surface layer will immediately be heated by the land, destroying the surface inversion as verified by analysis of site data. In fact, the cooling tower plume would tend to penetrate and/or loft above low-level inversions reducing possible ground level effects. Moroz and Koczkur[8] have investigated plume behavior from a large thermal generating station on the Lake Ontario shoreline. The authors observed that in order to penetrate the onshore flow to reach the off shore flow aloft, final plume heights on the order of 500 to 750 meters above the surface must be attained, which are commensurate with calculated plume heights for the cooling tower. Therefore, it is concluded that the lake breeze will pose no significant restriction to dilution conditions.

Another potential effect of the lake breeze is the decrease in ambient air temperature and increase in relative humidity with the onshore flow of warm moist air during the late spring and summer. However, these conditions are concurrent with conditions of maximum plume dissipation and would only influence the lowest 100 m air layer. The cooling tower effluent would not normally encounter this moist surface air layer which will be rapidly transformed with overland travel. During the winter the frozen lake will essentially act as a land surface with no local effects.[4]

F. Upper-Air Meteorology

Hourly data records obtained from the Toledo Airport Weather Station are representative of the surface meteorology. However, the magnitude of the heat dissipation from the Davis-Besse plant is sufficient to carry vapor plumes to substantial heights. It is necessary, then to obtain some representations of the upper atmosphere. This is of particular interest with regard to the depth of surface inversions and the variations of relative humidity with height.

Five years of upper-air data from the weather station at Flint, Michigan (1958 - 1962) were processed with the NUS computer program, LAPSE, to determine the height and depth of inversions. Although the thickness of ground-based inversions varies from less than 50 meters to over 500 meters during the year, the mean depth was about 250 meters (820 feet), which would be easily penetrated by the Davis-Besse cooling tower effluent, resulting in a lofting plume.

Inversions above the surface are also quite variable in height and depth, but do affect the extent of vapor plume rise. As a limit to the maximum height of vertical plume rise, the data of Holzworth [9] for mean maximum mixing depth (MMMD) for the southwestern shore of Lake Erie were applied. The MMMD by month is given in Table V. Since the mixing depth is a function of the maximum surface temperature, in most areas of the United States it is lowest in the coldest months. During summer in the Great Lakes region, mean maximum mixing depths are also relatively shallow (in comparison to other regions) because maximum temperatures over the water are less than over the adjacent land.

The extent to which the atmosphere can absorb water from an evaporative heat dissipation system without forming a visible cloud is dependent on the temperature and relative humidity at the height at which the vapor plume stabilizes. The Flint, Michigan upper-air data was, therefore, investigated to obtain a representation of the variation of relative humidity with height. The mean value of relative humidity versus height is presented in Table VI for the months of January, April, July, and October.

TABLE V

ESTIMATED MEAN MAXIMUM MIXING DEPTHS
FOR THE DAVIS-BESSE SITE

	MMMD (Meters)
January	480
February	500
March	820
April	850
May	1100
June	1190
July	1400
August	1320
September	1100
October	600
November	650
December	500

TABLE VI

VARIATION OF RELATIVE HUMIDITY WITH HEIGHT

Height Range (Feet)	RH, %			
	January	April	July	October
1000 - 1500	75	65	67	75
1500 - 2000	77	55	67	75
2000 - 3000	80	60	67	70
3000 - 4000	77	75	72	70

As is observed, the values do not change significantly with height. In addition, an examination of vertical relative humidity profiles recorded at the lake shore under lake breeze conditions showed that the relative humidity was almost constant with height [3]. Accordingly, the assumption of constant relative humidity with height was considered a satisfactory relationship for application in this study.

Since the wind speed normally increases with height in the atmospheric layer of interest in dispersion studies, an adjustment of the surface wind speed is made. The variation in wind speed with height is related to the stability. A power law profile may be expressed as:

$$u = u_1 \left(\frac{z}{z_1} \right)^{P_z}$$

The value of the exponent used in the study was $P_z = 0.24$ based on average wind speed data recorded at Davis-Besse at 20' and 300'.

IV. METEOROLOGY AND NATURAL FOG OCCURRENCE

The purpose of this section of the report is to examine the meteorological conditions representative of the Davis-Besse Station area and to determine those conditions related to natural fog occurrence. This information forms the basis for evaluating the potential of producing or intensifying local fog conditions. It is not the purpose of this phase of the investigation to develop an actual fog prediction model (in the sense of predicting related to time) but only to determine when and under what conditions fog occurs.

A. Meteorological Data

The occurrence of fog in the vicinity of the Davis-Besse Station site was investigated using the 24-hour meteorological data available from the Toledo, Ohio Airport. The Toledo Airport Weather Station is located in a well-exposed location, approximately 25 miles southwest of Maunee Bay on Lake Erie. The weather conditions observed at the airport are considered representative of the power station site.

The data used for the Toledo Airport consisted of a five-year period (January, 1959 through December, 1963). The Toledo Airport data were reported in accordance with the Weather Bureau standard WBAN form and were obtained on magnetic tape. An extensive computer reduction of data was, therefore, possible.

B. Natural Fogs

Fog is essentially a cloud that has developed on the ground. Therefore, the processes leading to fog formation are similar to those for cloud formation with some modifications for the presence of the earth's surface. In general, the conditions that promote water vapor condensation in ground-level air may lead to fog conditions. Aside from the inter-related thermodynamics of the surface air and ground layer, a number of other factors may indirectly influence the formation of fog. These factors include: the size, character and number of condensation nuclei, the extent of cloud cover, the wind speed and direction, the time of day, and the atmospheric turbulence.

The surface air may generally be treated as a mixture of dry air and water vapor, and the most frequent and effective cause of fog is the cooling of humid surface air to a point where vapor condensation occurs. The condensation generally takes place on a larger and more active condensation nucleus and may occur well before the dew point temperature (saturation) is reached. However, as long as the moisture content is sufficiently different from the saturation value, condensation does not occur and fog conditions cannot exist. The occurrence of fog is not solely a function of temperature and cooling rates alone. As mentioned above, other factors are of concern, particularly the vertical transfer of heat and moisture (atmospheric turbulence), wind speed and presence of condensation nuclei.

C. The Influence of Atmospheric Stability

The dependence of fog formation on atmospheric stability is indicated in Table VII and VIII, which present Pasquill-Turner stability distributions for all observations and for fog only observations, respectively, for the five-year period of Toledo data. Although the occurrence of fog can be

TABLE VII

PERCENT OCCURRENCE OF ATMOSPHERIC STABILITY (PASQUILL-TURNER) CONDITIONS FOR THE TOLEDO AIRPORT

ALL OBSERVATIONS

ANNUAL AVERAGE ('59 - '63)

	Unstable			Neutral	Slightly Stable	Stable	
Stability Index	A	B	C	D	E	F	G
Day	.58	4.53	11.09	34.04			
Night				22.23	9.73	11.17	6.65

TABLE VIII

PERCENT OCCURRENCE OF ATMOSPHERIC STABILITY (PASQUILL-TURNER) CONDITIONS FOR THE TOLEDO AIRPORT

FOG ONLY

ANNUAL AVERAGE ('59 - '63)

	Unstable			Neutral	Slightly Stable	Stable	
Stability Index	A	B	C	D	E	F	G
Day	.12	3.13	7.27	40.28			
Night				36.65	2.77	5.46	4.33

generally associated with neutral stability ("D" occurs 76.9 percent of the time during fog conditions); the reverse statement is not valid, since fog occurs in only 9.5 percent of the total observations.

D. The Influence of Wind Speed

The dependence of the occurrence of fog on wind speed is illustrated in Figure 7 for the five-year period of Toledo data. It is evident that wind speed is a factor in the occurrence of fog. However, this relationship is indirect as opposed to the direct influence on the occurrence of fog of the relative water vapor content of the air (discussed in the following section).

E. The Influence of Relative Humidity

Relative humidity defect (RHD) is here defined as the difference between saturated relative humidity (100 percent) and ambient relative humidity. When air is saturated with moisture, the relative humidity defect is zero. It is readily apparent that fog will be highly dependent on the value of the RHD, but it is not necessary that the RHD be zero for fog to occur. The relationship of the RHD to the occurrence of fog is illustrated in Figures 8 and 9 (plots of the RHD versus the probability of fog occurrence).

As expected, there is a strong relationship between the occurrence of fog and the RHD. There is some variation in the probability of fog occurrence for a given RHD with hours of observation and with season of the year. However, these effects are averaged out on an annual basis although fog conditions may be overestimated during the spring and summer and underestimated during the autumn and winter. The probability of fog is approximately 65 percent for RHD values of zero and drops to 3 percent for RHD values of about 20 percent. It is, however, important to note that fog conditions do exist with probabilities significantly different from zero for the higher RHD values. To a great extent, the higher RHD values may represent the remnants of a dispersing fog under changing conditions of relative humidity. This should be particularly true during the late morning hours. However, an examination of detailed observations has supported the conclusion that fogs do exist and can, in fact, form under conditions where the relative humidity is different from zero, i.e., unsaturated conditions.

F. Summary Discussion and the Quantitative Probability of Fog

The foregoing paragraphs have examined the conditions related to natural fog occurrence, which are considered representative of the Davis-Besse Power Station site. From the airport data, it is concluded that the single parameter of greatest importance in fog formation is humidity which has been characterized in this report as the RHD. For RHD values approaching zero, there is better than a 65 percent probability that fog conditions will be observed. To obtain an analytical representation of the probability of fog formation, the correlated effects of the meteorological parameters of cloud cover, wind speed, and RHD on fog occurrence were examined. It has been found that, for the area of the Davis-Besse Station, the probability of fog is adequately represented by a single relationship with RHD.

After inspections of the various aspects of the meteorological data, a mathematical expression was developed to represent the quantitative probability of fog for the area of the Davis-Besse Station. The form of the analytical representation is as follows:

$$\text{Probability of fog} = 50\left[1 - \text{erf}\left(\frac{RHD - \lambda}{C}\right)\right]$$

where:

λ = 0.046

C = 0.124

The production, or enhancement, of fog by operation of a high-volume evaporative heat dissipation system can be expected to occur under similar conditions as those for natural fog occurrence.

V. DISPERSION OF VAPOR FROM AN EVAPORATIVE HEAT DISSIPATION SYSTEM

The effect of an evaporative heat dissipation system on the formation of fog and icing conditions is determined by the quantity and location of added moisture and the existing ambient air condition. The probability of fog formation or fog persistence will be increased by the addition of moisture from the cooling system effluent. The major factors of significance in determining the enhancement of fog occurrence are the quantity and quality of the effluent air, the height of cooling tower effluent rise, and the downwind dispersion of the effluent plume.

A. Heat Dissipation System Parameters

The preliminary design characteristics of the subject evaporative heat dissipation system, a natural draft tower, are presented below.

A natural draft (or hyperbolic) tower is a large cylindrical structure of hyperbolic cross section. The necessary cooling air flow is obtained by the natural draft action of the air after it is heated and moistened by contact with the turbine condenser cooling water. The reference design characteristics and dimensions necessary to dissipate 6.2×10^9 BTU/hour for the Davis-Besse natural draft tower are as follows:

Heat Load, BTU/hr	6.2×10^9
Height of Tower, Ft.	493
Throat Diameter, Ft.	247
Base Diameter, Ft.	411

Inlet Water Temp., °F	116
Outlet Water Temp., °F	90
Water Flow, gpm	480,000
App.oach, °F	18
Design Wet Bulb, °F	72
Evaporation Loss (Winter), gpm	7500-8000
Evaporation Loss (Summer), gpm	10,500

B. Plume Rise

The effective height of rise of a vapor plume is the sur f two factors: the actual height of release above the plant grade, and the rise of the plume above the release point due to buoyancy effects. There are a number of relationships which have been developed to relate emission parameters and the ambient conditions of stability and wind speed to the resulting plume rise. However, the Briggs formulae were selected for application to the present study[10,11]. The formulations presented by Briggs are a recent development, and have considered the data from a large number of field research programs.

The equations for plume rise developed by Briggs have been derived from conventional power station chimneys and their applicability to cooling tower emissions requires additional consideration. In a power plant stack the heat energy added to the intake air is seen as an increase in exhaust air temperature with little change in the absolute humidity (pounds of water per pound of dry air). The increased specific volume is, therefore, due to the increased temperature. In an evaporative cooling system, both water and heat are added to the ambient air, and the water vapor has a significant effect in increasing the specific volume. Accordingly, to properly apply the Briggs equations for cloud rise, an effective heat emission rate, corresponding to the difference in specific volume of the tower effluent and the ambient air, is used. This effective heat is simply the equivalent energy which would be required to obtain the effluent specific volume by raising only the temperature of inlet air. A different cloud rise will, of course, be obtained for each set of atmospheric conditions of ambient air and wind speed. In the study performed, the conditions at each hour were considered for plume rise and downwind concentration by use of the computer program, FOG-3. The FOG 3 program is basically a linking of NUS programs used for data processing, plume rise, and plume dispersion calculations.

Two relationships are used for maximum plume rise. The first is applicable to neutral, unstable and slightly stable conditions, and the second to stable conditions (positive temperature lapse rate).

Plume rise as a function of downwind distance is given by:

$$\Delta H = 1.6\, F^{1/3}\, u^{-1}\, x^{2/3}$$

where:

$$F = 3.7 \times 10^{-5}\, Q$$

and:

ΔH = plume rise above discharge height (meters)

u = mean wind speed (m/sec)

x = downwind distance, meters

Q = effective heat emission rate, calories/sec

The maximum plume rise ΔH_m, in unstable, neutral, and slightly stable conditions is taken as :

$$\Delta H_m = 1.6 F^{1/3} u^{-1} (3.5 x^*)^{2/3}$$

where:

$$x^* = 14 F^{5/8} \qquad F < 55 \ m^4/sec^3$$

or

$$x^* = 34 F^{2/5} \qquad F > 55 \ m^4/sec^3$$

The maximum plume rise under stable atmospheric conditions is given as:

$$\Delta H_m = 2.9 \left(\frac{F}{u s} \right)^{1/3}$$

where:

$$s = \frac{g}{T} \quad \frac{\delta \theta}{\delta z}$$

and:

g = gravitational acceleration, m/sec^2

T = average absolute temperature of ambient air, $^{\circ}K$

$\frac{\delta \theta}{\delta z}$ = vertical potential temperature gradient of atmosphere, $^{\circ}K$/meter

C. Plume Dispersion

The dispersion of the plume of warm, saturated air from the cooling tower is treated in a manner analogous to the dispersion of any material emitted into the air. Relationships for computing the airborne concentration parameters are presented in the literature. The formulation used in this analysis is that presented by Gifford[12,13] derived from the work of Cramer[14], Pasquill[15], and Meade[16], generally referred to as the Gaussian plume model. Since the dispersion of the vapor cloud is the result of turbulent transfer, the redistribution of the heat and water vapor in the plume may be treated in this manner using the Gaussian plume model.

The basic relationship for maximum ground concentration from an elevated point source can be written as:

$$\chi = \frac{Q}{\pi \bar{u} \sigma_y \sigma_z} \exp - \left\{ \frac{\left(H_s + \Delta H \right)^2}{2 \sigma_z{}^2} \right\}$$

where:

χ = ground level concentration at downwind distance, x, units/cubic meter

Q = emission rate, units/second

$\bar{u}$ = mean wind speed, meters/second

σ_y, σ_z = plume dimensions in the crosswind and vertical dimensions, respectively, meters

ΔH = height of plume rise, meters

H_s = height of emission, meters

For this calculation, the material being dispersed (Q) is considered to be the difference between the absolute humidity (pounds of water per pound of dry air) of the cooling tower exit air and that of the ambient air. This excess moisture is dispersed as the effluent cloud grows and increases the relative humidity (or decreases the RHD) of the surrounding ambient air.

During the initial period of plume rise, up to the height of maximum rise, the vapor plume can be considered to have a characteristic radius $\gamma z+r$; where the value z is the height of rise above the cooling tower exit, r is the exit radius of the cooling tower and γ is empirically given as 0.5 . It is standard practice to select the cloud dispersion parameters such that 95 percent of the cloud is encompassed in a 2σ radius. Accordingly, up to the height of maximum cloud rise, the plume dispersion parameters can be estimated as:

$$\sigma_y = \sigma_z = 0.5 \left[\gamma z + r\right]$$

Beyond the point of maximum cloud rise, the vapor plume is dispersed by the natural turbulent action of the atmosphere, rather than by entrainment processes related to plume rise. At distances beyond the point of maximum rise, the plume dispersion parameters are represented as suggested by Hillsmeier - Gifford[17].

D. Length of the Visible Plume

A vapor plume is visible when the entrained ambient air produces a mixture above the saturation level. Cold weather and high humidity are the atmospheric conditions conducive to long visible plume lengths. A natural draft tower is especially capable of producing long visible plumes, as the vapor cloud is capable of rising to great heights where the upper-air temperature is low and cannot absorb the added moisture.

To estimate the probable length of the visible vapor plume, the temperature at the point of maximum rise is determined from the atmospheric stability category which can be related to lapse rate. Using the maximum water content for saturated air at these temperatures, the travel distance required to dissipate the excess moisture by plume growth and entrainment of ambient air was calculated. To perform these calculations, it is assumed that the relative humidity of the upper air does not exceed a value of 90 percent for purposes of plume length calculation. Relative humidity values above 90 percent may occur at higher elevations but these are likely to be associated with natural cloud cover. Thus, a long plume would be expected to blend into the existing cloud cover.

VI. ENVIRONMENTAL EFFECTS OF EVAPORATIVE HEAT DISSIPATION SYSTEMS

The environmental effects of evaporative heat dissipation systems can be separated into direct effects related to the visible plume, and indirect effects associated with the addition of moisture to the atmosphere, which may induce fog conditions or icing from fog formation.

A. Effect of Visible Plume

The visible vapor plume aloft usually presents only an esthetic problem. However, under conditions of high humidity, cold weather, and high wind speed, the plume may be brought down to the ground relatively close to the source. Under these conditions visibility could be impaired, and, at freezing temperatures, icing of roads and structures could result. This phenomenon is examined further in Part C of this section.

A natural draft tower has a relatively concentrated moisture emission and a large plume rise, which may produce long visible plumes at times. However, visible plumes longer than 5 miles are estimated to occur only 3 percent of the total hours of the year. The average visible plume is 1.5 miles in length, and does not represent an environmental problem. The vapor cloud will not be visible over population centers as the frequency of occurrence of plume lengths longer than 9.3 miles is estimated to be only 0.01 percent. A probability plot of these estimates of the visible plume lengths for Davis-Besse are presented in Figure 10 for reference.

B. Induced Fog and Icing Conditions

Beyond the visible portion of the vapor plume the evaporated moisture will continue to be dispersed by the turbulent action of the atmosphere. It can be anticipated that some of this moisture will be carried to the ground, and increase the relative humidity to an extent which may increase the likelihood of fog or icing conditions. To examine this, the meteorological data were processed with the analytical formulations of fog probability and plume rise and dispersion calculations to estimate the probable increase in fog or icing conditions.

Table IX lists the increased probability of fog for a 22.5^{o} sector (based on the average of all directions) at distance up to 40 km (25 miles) for operation of the proposed natural draft tower. These increased probabilities for fog formation are actually negligible and are put into proper perspective by Table X which lists the increased number of hours fog may be induced by cooling tower operations on an annual basis. A similar listing for the maximum seasonal increases (which occurs during winter) in fog formation is presented in Table XI for onshore (winds blowing onshore from the lake) and offshore (winds blowing offshore out over the lake) wind flows. Even during these worse case situations the ground level effect of the cooling tower operation would be neglible.

Although the maximum effects increase with distance from the plant site, as indicated in Tables IX - XI, up to the 25 miles value for which the computer codes presently calculate, it is expected that this value adequately represents the maximum probable effect which would be attributed to the cooling tower effluent. It should also be noted that the increase in fog is

TABLE IX

PREDICTED CHANGE IN PROBABILITY OF FOG FOR A 22.5° SECTOR
(BASED ON THE AVERAGE OF ALL DIRECTIONS)
DUE TO OPERATION OF THE PROPOSED DAVIS-BESSE COOLING TOWER

(in percent of total observations)*

Distance (Miles)	Spring Mar, Apr, May	Summer Jun, Jul, Aug	Autumn Sep, Oct, Nov	Winter Dec, Jan, Feb	Annual
0.3	3.2×10^{-6}	1.5×10^{-6}	7.5×10^{-6}	3.3×10^{-5}	1.0×10^{-5}
0.6	5.5×10^{-6}	2.3×10^{-6}	1.4×10^{-5}	4.4×10^{-5}	1.5×10^{-5}
0.9	5.9×10^{-6}	2.3×10^{-6}	1.4×10^{-5}	4.4×10^{-5}	2.0×10^{-5}
1.2	6.2×10^{-6}	2.3×10^{-6}	1.4×10^{-5}	4.4×10^{-5}	1.5×10^{-5}
2.5	6.4×10^{-6}	1.3×10^{-6}	1.3×10^{-5}	4.4×10^{-5}	1.5×10^{-5}
3.7	1.6×10^{-5}	8.8×10^{-6}	7.9×10^{-5}	7.8×10^{-5}	5.6×10^{-5}
5.0	8.3×10^{-5}	4.7×10^{-5}	3.0×10^{-4}	5.1×10^{-4}	2.2×10^{-4}
6.2	1.8×10^{-4}	9.7×10^{-5}	5.3×10^{-4}	1.0×10^{-3}	4.3×10^{-4}
9.3	4.1×10^{-4}	2.1×10^{-4}	8.7×10^{-4}	2.2×10^{-3}	8.7×10^{-4}
24.8	1.7×10^{-3}	4.3×10^{-4}	2.0×10^{-3}	7.0×10^{-3}	2.5×10^{-3}

* Based on Toledo Express Airport data 1959-1963

TABLE X

PREDICTED INCREASE IN OCCURRENCE OF FOG (IN HOURS)
FOR A 22.5° SECTOR (BASED ON THE AVERAGE OF ALL DIRECTIONS)*
DUE TO OPERATION OF THE PROPOSED DAVIS-BESSE COOLING TOWER

Distance (Miles)	Annual Increase in Fog (Hours)
0.3	8.7×10^{-4}
0.6	1.3×10^{-3}
0.9	1.7×10^{-3}
1.2	1.3×10^{-3}
2.5	1.3×10^{-3}
3.7	4.9×10^{-3}
5.0	1.9×10^{-2}
6.2	3.8×10^{-2}
9.3	7.6×10^{-2}
24.8	2.2×10^{-1}

*Based on Toledo Express Airport data 1959-1963

TABLE XI

MAXIMUM PREDICTED CHANGE IN PROBABILITY OF FOG FOR A 22.5° SECTOR DUE TO OPERATION OF THE PROPOSED DAVIS-BESSE COOLING TOWER

(In Percent of Total Observations)*

	Winter (Dec, Jan, Feb)	
Distance (Miles)	ENE (Onshore Flow)	SW (Offshore Flow)
0.3	1.8×10^{-7}	3.9×10^{-7}
0.6	2.1×10^{-7}	7.3×10^{-7}
0.9	2.1×10^{-7}	7.4×10^{-7}
1.2	2.1×10^{-7}	7.4×10^{-7}
2.5	2.1×10^{-7}	7.4×10^{-7}
3.7	9.3×10^{-7}	1.9×10^{-6}
5.0	2.9×10^{-6}	6.5×10^{-6}
6.2	6.4×10^{-6}	1.4×10^{-5}
9.3	1.7×10^{-5}	3.8×10^{-5}
24.8	6.1×10^{-5}	1.4×10^{-4}

* Based on Toledo Express Airport data 1959-1963

calculated for the centerline of the plume and treated as if representative of an entire 22.5° sector. This is quite conservative at large distances since at 25 miles an arc span of 10 miles for a 22.5° sector would occur and probabilities of increased fog conditions would be less when averaged over the entire area.

It is possible that the lake effect may increase the probability of fog over the values presented in Tables IX - XI. However, this is not considered to be a significant factor. The wind direction frequencies for fog occurrences are presented in Figure 11 and indicates that even at Toledo Express Airport, 25 miles inland, that winds flowing off the lake have higher frequencies of fog conditions.

A natural draft cooling tower essentially does not directly induce ground level fog. It is important to note that the increased hours of induced fog (as differentiated from direct plume effects) do not represent discrete cases of fog occurrence which would not otherwise occur, but rather represent the possibility of fog occurring earlier than normal and lasting longer. During the year there are an average of 831 hours of fog occurring naturally. An annual increase of 3.5 hours in the occurrence of fog conditions, the highest increase observed, based on the summation of the individual sector contributions at 40 km, represents only a 0.42 percent increase which is not a significant change and therefore should not be a major environmental problem.

The predicted increases in induced fog under icing conditions (temperatures less than 32°F) which might be attributed to operation of the Davis-Besse cooling tower are presented in Table XII and represent almost negligible environmental effects. The associated increase in hours of icing conditions

TABLE XII

PREDICTED CHANGE IN PROBABILITY OF ICING FOR A 22.5° SECTOR (BASED ON THE AVERAGE OF ALL DIRECTIONS) DUE TO OPERATION OF THE PROPOSED DAVIS-BESSE COOLING TOWER*

(in percent of total observations)

Distance (Km)	Spring (Mar, Apr, May)	Autumn (Sep, Oct, Nov)	Winter (Dec, Jan, Feb)
0.3	-	3.4×10^{-6}	7.0×10^{-5}
0.6	-	4.6×10^{-6}	8.0×10^{-5}
0.9	-	4.6×10^{-6}	8.0×10^{-5}
1.2	-	4.6×10^{-6}	8.0×10^{-5}
2.5	-	4.6×10^{-6}	7.9×10^{-5}
3.7	3.2×10^{-5}	1.3×10^{-4}	3.8×10^{-4}
5.0	7.5×10^{-4}	2.1×10^{-3}	1.8×10^{-3}
6.2	1.7×10^{-3}	4.2×10^{-3}	3.7×10^{-3}
9.3	2.8×10^{-3}	5.5×10^{-3}	7.5×10^{-3}
24.8	3.6×10^{-3}	6.4×10^{-4}	2.2×10^{-2}

* Based on Toledo Express Airport data 1959-1963

TABLE XIII

PREDICTED INCREASE IN OCCURRENCE OF ICING CONDITIONS (IN HOURS) FOR A 22.5° SECTOR DUE TO OPERATION OF THE PROPOSED DAVIS-BESSE COOLING TOWER

(In Percent of Total Winter Observations)

Winter (Dec, Jan, Feb)*

WIND DIRECTION**

Distance (Km)	NNE	NE	ENE	E	ESE	SE	SSE	S
0.3	--	--	2.0×10^{-6}	--	7.9×10^{-6}	2.0×10^{-6}	1.7×10^{-6}	2.8×10^{-7}
0.6	--	--	2.0×10^{-6}	--	9.4×10^{-6}	3.7×10^{-6}	2.0×10^{-6}	2.6×10^{-6}
0.9	--	--	2.0×10^{-6}	--	9.4×10^{-6}	3.7×10^{-6}	2.0×10^{-6}	2.6×10^{-6}
1.2	--	--	2.0×10^{-6}	--	9.4×10^{-6}	3.7×10^{-6}	2.0×10^{-6}	2.6×10^{-6}
2.5	--	--	2.0×10^{-6}	--	9.4×10^{-6}	3.7×10^{-6}	2.0×10^{-6}	2.6×10^{-6}
3.7	5.7×10^{-7}	5.9×10^{-6}	7.1×10^{-6}	6.5×10^{-6}	1.6×10^{-5}	8.5×10^{-6}	4.6×10^{-5}	6.1×10^{-5}
5.0	2.1×10^{-5}	4.4×10^{-5}	4.1×10^{-5}	2.7×10^{-5}	4.4×10^{-5}	2.4×10^{-5}	2.6×10^{-5}	4.2×10^{-4}
6.2	5.4×10^{-5}	1.1×10^{-4}	1.0×10^{-4}	6.1×10^{-5}	9.2×10^{-5}	5.0×10^{-5}	6.1×10^{-4}	7.2×10^{-4}
9.3	1.6×10^{-4}	3.1×10^{-4}	2.9×10^{-4}	1.7×10^{-4}	2.4×10^{-4}	1.3×10^{-4}	1.8×10^{-4}	9.2×10^{-4}
24.8	5.9×10^{-4}	1.1×10^{-3}	1.1×10^{-3}	6.4×10^{-4}	8.8×10^{-4}	4.6×10^{-4}	6.5×10^{-4}	1.3×10^{-3}

Distance (Km)	SSW	SW	WSW	W	WNW	NW	NNW	N
0.3	1.1×10^{-6}	--	3.7×10^{-6}	2.8×10^{-6}	5.7×10^{-7}	2.8×10^{-5}	2.8×10^{-7}	2.8×10^{-7}
0.6	1.1×10^{-6}	2.8×10^{-7}	5.1×10^{-6}	3.5×10^{-6}	1.1×10^{-6}	3.7×10^{-5}	5.7×10^{-7}	2.8×10^{-7}
0.9	1.1×10^{-6}	2.8×10^{-7}	5.1×10^{-6}	3.5×10^{-6}	1.4×10^{-6}	3.7×10^{-5}	8.5×10^{-7}	2.8×10^{-7}
1.2	1.1×10^{-6}	2.8×10^{-7}	5.1×10^{-6}	3.5×10^{-6}	1.4×10^{-6}	3.7×10^{-5}	8.5×10^{-7}	2.8×10^{-7}
2.5	1.1×10^{-6}	2.8×10^{-7}	5.1×10^{-6}	3.5×10^{-6}	1.4×10^{-6}	3.5×10^{-5}	8.5×10^{-7}	2.8×10^{-7}
3.7	3.3×10^{-5}	5.0×10^{-6}	1.8×10^{-5}	1.2×10^{-5}	6.3×10^{-5}	2.6×10^{-4}	7.9×10^{-6}	6.4×10^{-6}
5.0	2.0×10^{-4}	5.7×10^{-5}	9.0×10^{-5}	5.5×10^{-5}	3.8×10^{-4}	1.4×10^{-5}	4.2×10^{-5}	3.3×10^{-5}
6.2	3.7×10^{-4}	1.7×10^{-4}	2.7×10^{-4}	1.6×10^{-4}	1.1×10^{-4}	3.1×10^{-4}	9.6×10^{-5}	7.7×10^{-5}
9.3	6.8×10^{-4}	5.5×10^{-4}	8.1×10^{-4}	4.6×10^{-4}	3.3×10^{-4}	5.3×10^{-4}	2.7×10^{-4}	2.1×10^{-4}
24.8	1.8×10^{-3}	2.2×10^{-3}	3.1×10^{-3}	1.8×10^{-3}	1.2×10^{-3}	1.3×10^{-3}	9.8×10^{-4}	7.9×10^{-4}

* Based on Toledo Express Airport data 1959-1963

** Affected area would be 180° from the indicated wind direction since wind direction is defined as the direction from which the wind is blowing are listed in Table XIII for each individual wind direction for the winter season based on Toledo data. Less than 1 minute of icing conditions at the maximum would be expected from the cooling tower effluent according to data in Table XIII. Significant variations from the indicated Toledo data would not be expected at the Davis-Besse site since the lake effect is not a major effect during the winter when the lake surface is generally frozen and/or warmer than the land surface.

C. Downwash

1. Technical basis and frequency of occurrence

Under particular conditions of wind speed and wind direction, the effluent discharged from an elevated source can become entrained in the turbulent flow fields which may develop leeward of the source and adjacent buildings. Additionally, unfavorable flow patterns may form in the lee of sharp topographical features close to the source. The exhaust entrained in this turbulent wake can be brought down to the ground without appreciable plume rise. This phenomena of plume behavior is called "downwash". Downwash conditions would be the only basis for occurrence of a ground-level plume at Davis-Besse and were therefore examined in this study.

The occurrence of downwash from the natural draft tower has been examined using the criteria developed by Overcamp and Hoult [18]. Based on observations of a model cooling tower towed in a water-filled tank, they concluded that downwash will occur if the wake boundary grows faster than the plume rises. This will occur at the critical wind speed, which is given by the following equation:

$$R_e = 0.53\,(\beta Fr)^{2/3}$$

where:

R_e = ratio of exit velocity to wind speed at the top of the tower at which the plume will mix in the wake of the cooling tower structure

β = entrainment parameter = 0.78

Fr^* = densimetric Froude number = $\dfrac{w_o}{\sqrt{\dfrac{g\,D\,(\rho_1 - \rho_2)}{2\rho_1}}}$

w_o = exit velocity

g = gravitational acceleration (m/s^2)

D = cooling tower exit diameter

ρ_1 = density of ambient air

ρ_2 = density of exit air

* Calculated for each season

Insofar as the exit velocity and buoyancy vary with the ambient conditions and the heat rejection requirements established by the station loading, the Froude number (and hence the critical wind speed) will vary throughout the year. Typical summertime and wintertime conditions indicate ground-level critical wind speeds of 15 and 19 mph, respectively, as representative. Wake mixing of the visible plume is, therefore, expected when surface winds greater than 17 mph occur on an average annual basis which corresponds to 28 mph at the 500-foot tower exit height.

TABLE XIV

ANNUAL FREQUENCY AND LENGTH OF PLUME DOWNWASH CONDITIONS
FOR INDIVIDUAL WIND DIRECTIONS

(In percent of total observations)

Based on 1 Year of Toledo Airport Data

Plume Length (Feet)	NNE	NE	ENE	E	ESE	SE	SSE	S
0-100	--	--	--	--	--	--	--	--
100-200	--	--	--	--	--	--	--	--
200-400	--	--	--	--	--	--	--	--
400-600	--	--	--	--	--	--	--	--
600-1000	--	--	--	--	--	--	--	--
1000-3000	--	.05	--	.02	--	--	--	--
3000-7000	--	.05	--	--	--	--	--	--
7000-10000	--	--	--	--	--	--	--	--
10000-15000	--	--	--	--	--	--	--	--
Above-15000	--	.02	--	--	--	--	--	--

Plume Length (Feet)	SSW	SW	WSW	W	WNW	NW	NNW	N
0-100	--	--	.02	--	.05	--	--	--
100-200	.02	--	.02	--	.02	--	--	--
200-400	.02	--	.02	--	.10	--	--	--
400-600	--	.02	--	--	.02	--	--	--
600-1000	--	--	.24	--	--	.02	.07	--
1000-3000	.02	.17	.02	.22	.29	.22	.05	--
3000-7000	--	--	--	--	--	--	--	--
7000-10000	--	--	--	--	--	--	--	--
10000-15000	--	--	--	--	--	--	--	--
Above-15000	--	--	--	--	--	--	--	--

TABLE XV

WINTER FREQUENCY AND LENGTH OF PLUME FOR DOWNWASH CONDITIONS CONCURRENT WITH TEMPERATURES ≤32°F FOR INDIVIDUAL WIND DIRECTIONS

(In percent of total winter observations)

(Based on 5 Winter Seasons of Toledo Airport Data for Temperatures ≤ 32°F)

Plume Length	NNE	NE	ENE	E	ESE	SE	SSE	S
0-100	--	--	--	--	--	--	--	--
100-200	--	--	--	--	--	--	--	--
200-400	--	--	--	--	--	--	--	--
400-600	--	--	--	--	--	--	--	--
600-1000	--	--	--	--	--	--	--	--
1000-3000	.01	.10	.16	--	--	--	--	--
3000-7000	--	.03	--	--	--	--	--	--
7000-10000	--	--	--	--	--	--	--	--
10000-15000	--	--	--	--	--	--	--	--
Above 15000	--	--	--	--	--	--	--	--

Plume Length	SSW	SW	WSW	W	WNW	NW	NNW	N
0-100	--	--	.03	--	--	.01	--	--
100-200	--	--	--	--	--	--	--	--
200-400	--	--	--	--	--	--	--	--
400-600	--	--	--	--	--	--	.01	--
600-1000	--	.01	.04	.01	.09	.05	.04	--
1000-3000	.04	.42	1.09	.44	.30	.21	.14	.03
3000-7000	--	--	--	--	.03	--	--	--
7000-10000	--	--	--	--	--	--	--	--
10000-15000	--	--	--	--	--	--	--	--
Above 15000	--	--	.10	--	--	--	--	--

.01% ≅ 2 Hours

Table XIV lists the annual frequency of occurrence of downwash conditions and the length of the visible plume for each wind direction based on Toledo Airport data. A similar listing is presented in Table XV for winter occurrences which generally represent potential icing conditions. For purposes of evaluating ground-level effects, according to Overcamp and Hoult[18], the downwashed plume will touch the ground two-to-four tower lengths (1000-2000 feet) downwind.

The distribution of downwash conditions listed in Tables XIV and XV indicate that the frequency of the plume reaching the ground is rather small for any individual wind direction. It should be emphasized in interpreting these tables that the affected area will be opposite to the associated wind direction. (Wind direction is defined as the direction from which the wind is flowing.) However, only 1 year of Toledo data were utilized for the particular detailed analysis of downwash plume lengths distributions presented in Table XIV. The total frequency of downwash conditions for this randomly chosen sample year was only 1.7% compared to 10.2% expected,based on the 5-year period of Toledo data. However, the distribution of plume lengths during downwash situations should be indicative of expected average annual conditions. The distribution of downwash conditions based on analysis of 2 years of 300' level Davis-Besse site data indicate that downwash conditions may occur as often as 12.8% of the time, not greatly different than the 10.2% based on Toledo data.

The frequency distribution by direction of downwash conditions based on site data are presented in Figures 12 and 13 on a seasonal and annual basis, respectively. It is significant to note that downwash conditions are predominantly associated with southwesterly winds (or winds blowing offshore out over the lake) and thus the possible offsite effects are minimized.

Table XV is based on analysis of 5 winter seasons of Toledo data to more accurately define potential icing conditions due to downwash. Frequencies of downwash conditions presented in Table XV represent potential icing conditions since concurrent ambient surface temperatures are $\leq 32^{\circ}F$. Based on this data, the frequency of downwash conditions potentially resulting in icing is generally less than 0.25% (~5 hours) for any onshore wind direction sector. The total frequency of icing conditions for winds from the NW clockwise through SE which would be the most significant directions for offsite areas is 0.79% of the winter observations. The extent of such effects based on plume lengths tabulated in Table XV would be largely expected to be confined to the immediately contiguous areas (i.e., within 3000').

It should be stressed, however, that these values of downwash are an upper limit of occurrence, and that observations at operating natural draft cooling tower installations in this country have not confirmed this behavior.

2. Ice formation from moist, non-visible plume effects

The cooling tower effluent is usually at substantially higher temperatures than the ambient air and for all practical purposes is saturated with moisture. As the effluent combines with the cooler ambient air the resultant mixture may or may not be above the saturation limit, depending on the effluent temperature and the ambient conditions of temperature and relative humidity. If the resultant mixture is below the saturation level, condensation will not occur and the moist plume will not be visible. However, even if the plume is initially visible due to condensation at some point downwind the condensed water droplets will re-evaporate and the plume will no longer be discernable. Even though the moist plume is not visible, contact with colder surfaces will result in heat transfer to the surface and, potentially, condensation of moisture onto the surface. Under freezing conditions, ice formation is then to be expected. However, this will only be a significant ground level effect during conditions of plume downwash, discussed in Section VI, C-1.

To determine whether the rates of ice build-up from a non-visible plume could represent an area of concern, several cases were examined. The assumptions made in this analysis are given below:

(1) The surface of concern (below the ice film) remained at constant temperature of 10°F

(2) The moist plume was at 100% relative humidity

(3) The rate of ice formation is limited by the water vapor mass transfer rate or the heat energy balance

(4) Heat balance is determined by heat conduction through ice, air, to ice heat tranfer, heat of fusion, latent heat and heat radiation from plume and ice surface

In the case of a 50°F plume (which is treated as representative of the reduced plume temperature expected by the time the visible plume dissipates at the ground during winter downwash conditions) the rate of ice formation is limited by a water vapor mass transfer rate of 0.03 inches per hour. In this case, potential ice thicknesses are not great, requiring 10 hours to produce 0.3 inches of ice.

However, these icing effects are only expected at ground level during the occurrence of a downwashed plume. The frequency of these occurrences affecting land areas (discussed in Section VI-C-1) are expected approximately 0.79% of the time during the winter. This frequency and the rates of icing are considered to be quite conservative upper-limit estimates since downwashing of plumes has not been operationally verified in the United States from natural draft towers.

3. Ice formation from condensed water droplets

The potential of ice formation from a non-visible moist plume has been discussed. However, under ambient conditions of low temperature and high relative humidity, the mixing of the ambient air and hot, saturated plume can result in condensation of moisture. Very fine water droplets are formed from this condensation of moisture which produce the visible nature of the plume. Due to the small size and, therefore negligible settling velocity of these droplets, they are suspended and carried along with the vapor plume. Therefore, this effect would only be of significance during downwash conditions discussed in Section VI-C.

In the event that the visible plume intersects a structure, or surface, at sub-freezing temperatures, the fine droplets impinging on the surface can result in ice formation. The rate of ice build-up is controlled by the incident rate of droplets on the surface and the heat balance necessary to sustain freezing conditions.

To examine the potential of ice formation from suspended fine water droplets, an analysis was performed for a one-inch diameter wire and a flat surface exposed to the visible plume. Basic assumptions in these analyses were as follows:

(1) Condensation droplets in a visible vapor plume are typical of droplets in clouds; median diameter of 10 micron and concentration of 96 droplets per cubic centimeter

(2) The incident rate of suspended droplets is determined by the wind speed

(3) The surface temperature of the wire and flat surface (below the ice layer) remain constant

(4) Heat balance is determined by heat conduction through ice, air to ice heat transfer, heat of fusion, latent heat and heat radiation from plume and ice surfaces.

The rate of ice build-up on a one-inch diameter wire and maximum thicknesses of ice as limited by heat transfer considerations is approximately 0.023 feet/hour for a reference 10 m/s (22 mph) wind during typical winter icing conditions 10°-20° ambient temperatures and $50^{\circ}F$ plume temperatures after mixing to the surface during a downwash situation. The rate of ice build-up for a flat surface is approximately 0.07"/hour for the same conditions.

As is evident from icing rates, ice does not form rapidly from fine water droplets impinging on a wire and the maximum ice thickness which can be sustained while continuously exposed to the vapor plume is not great (approximately 0.08 inches). Significant thicknesses of ice can, however, result on flat surfaces where the geometry is more favorable for interaction with the plume and for heat removal. It is interesting that the initial rate of ice build-up on a flat surface due to fine water droplets suspended in the plume can be less than observed for the non-visible plume under high plume temperatures. At high plume temperatures and low surface temperatures, the partial pressure difference for water vapor is such that rapid condensation of a surface from a non-visible plume is possible. At low vapor plume temperatures, the suspended droplets form ice at a faster rate than can be affected by vapor diffusion.

The calculated ice formation rate is 0.07 inches/hour for a 10-meter/sec (22 mph) wind, which is not insignificant, and under long periods of sub-freezing conditions and persistent wind direction, substantial ice thicknesses are possible. Also, the rate of ice formation does not decrease with decreasing plume temperatures.

Again, these icing effects are expected at the surface only during the occurrence of a downwash plume. The frequency of these occurrences affecting land areas (discussed in Section VI-C-1) are expected only approximately 0.79% of the time during the winter season based on available site wind data. This frequency and the rates of icing presented are considered to be quite conservative upper limit estimates since downwashing of plumes has not been verified in the United States from hyperbolic tower installations.

D. Drift

High-volume wet cooling towers of the type being installed at Davis-Besse, remove waste heat by evaporation of large quantities of water. Evaporation of 4×10^6 pounds of water per hour can be expected during winter time conditions. However, the expected drift carry-over rate of 0.01% would result in only 4×10^2 pounds of water per hour which would leave the tower in the form of water droplets entrained in the cooling tower exhaust. This drift loss is considered an insignificant amount, and only less than 1% of this amount would be deposited off site.

REFERENCES

1. Pasquill, F., "The Estimation of the Dispersion of Windborne Material", Meteorology Magazine 90 (February, 1961), 33-49.

2. Turner, D. Bruce, "Relationships Between 24-Hour Air Quality Measurements and Meteorological Factors in Nashville, Tennessee." Journal of the Air Pollution Control Association, XI (October, 1961), 483-489.

3. Moroz, William J., The Lake Breeze Circulation Along the Shoreline of a Large Lake. The University of Michigan, College of Engineering, Department of Meteorology and Oceanography, 1965.

4. Olsson, Lars E., Lake Effects on Air Pollution Dispersion. The University of Michigan, Ph.D. Thesis, 1969.

5. Walke, Gerald J., "Topographic Influences on Diffusion Coefficients at a Shoreline Site". Paper presented at the International Symposium on Fission Product Release and Transport Under Accident Conditions, Oak Ridge, Tennessee, 1965.

6. Hewson, E. Wendell, Gill, Gerald C., Walke, Gerald J., Smoke Plume Photography Study, Big Rock Point Nuclear Plant, Charlevoix, Michigan. The University of Michigan, Department of Meteorology and Oceanography, 1963.

7. Lyons, Walter A., "Mesoscale Transport of Pollutants in the Chicago Area as Affected by Land and Lake Breezes." Paper presented at the Second International Clean Air Congress, Washington, D.C., 1970.

8. Moroz, W.J., and Koczkur, E., "Plume Rise and Dispersion Near the Shoreline of a Large Lake When Flow Patterns are Dominated by the Lakebreeze." Proceedings of the U.S.A.E.C. Meteorological Information Meeting, Chalk River, Ontario, 1967.

9. Holzworth, George C., "Estimates of Mean Maximum Mixing Depths in the Contiguous United States." Monthly Weather Review, 92 (May, 1964), 235-242.

10. Briggs, Gary A., Plume Rise, Oak Ridge: U.S. Atomic Energy Commission, 1969.

REFERENCES (Continued)

11. Briggs, G.A., "Some Recent Analyses of Plume Rise Observations." Paper presented at the Second International Clean Air Congress, Washington, D.C., December, 1970.

12. Gifford, F.A., Nuclear Safety, I, 56-62, March, 1960.

13. Gifford, F.A., Nuclear Safety, II, 56-59, December, 1960.

14. Cramer, H.E., "A Brief Survey of the Meteorological Aspects of Atmospheric Pollution." Bulletin of the American Meteorological Society, XL (April, 1959).

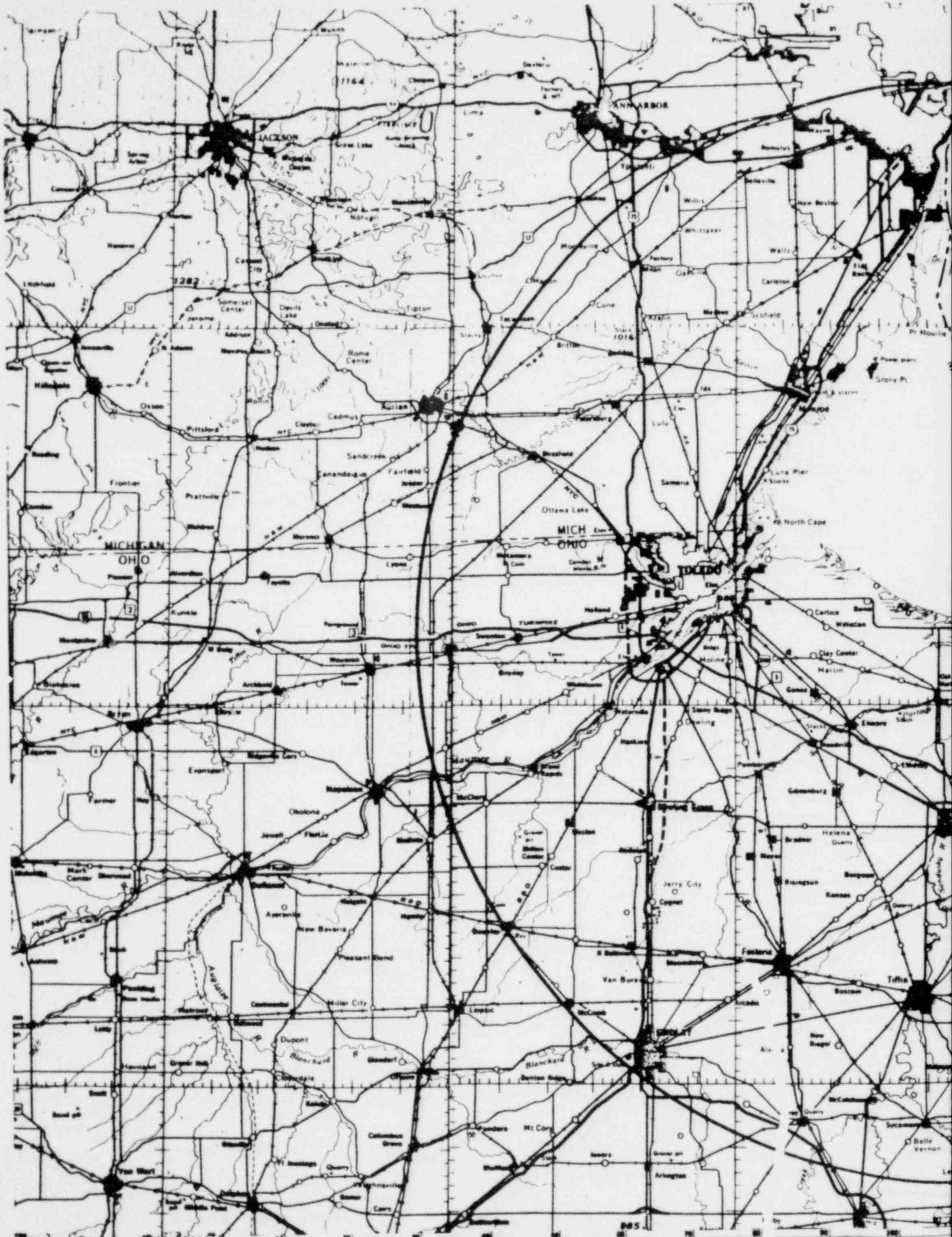
15. Pasquill, F., Atmospheric Diffusion. New York: D. Van Nostrand, 1962.

16. Meade, P.J., Technical Note No. 33, Part I, World Meteorological Organization, 1960.

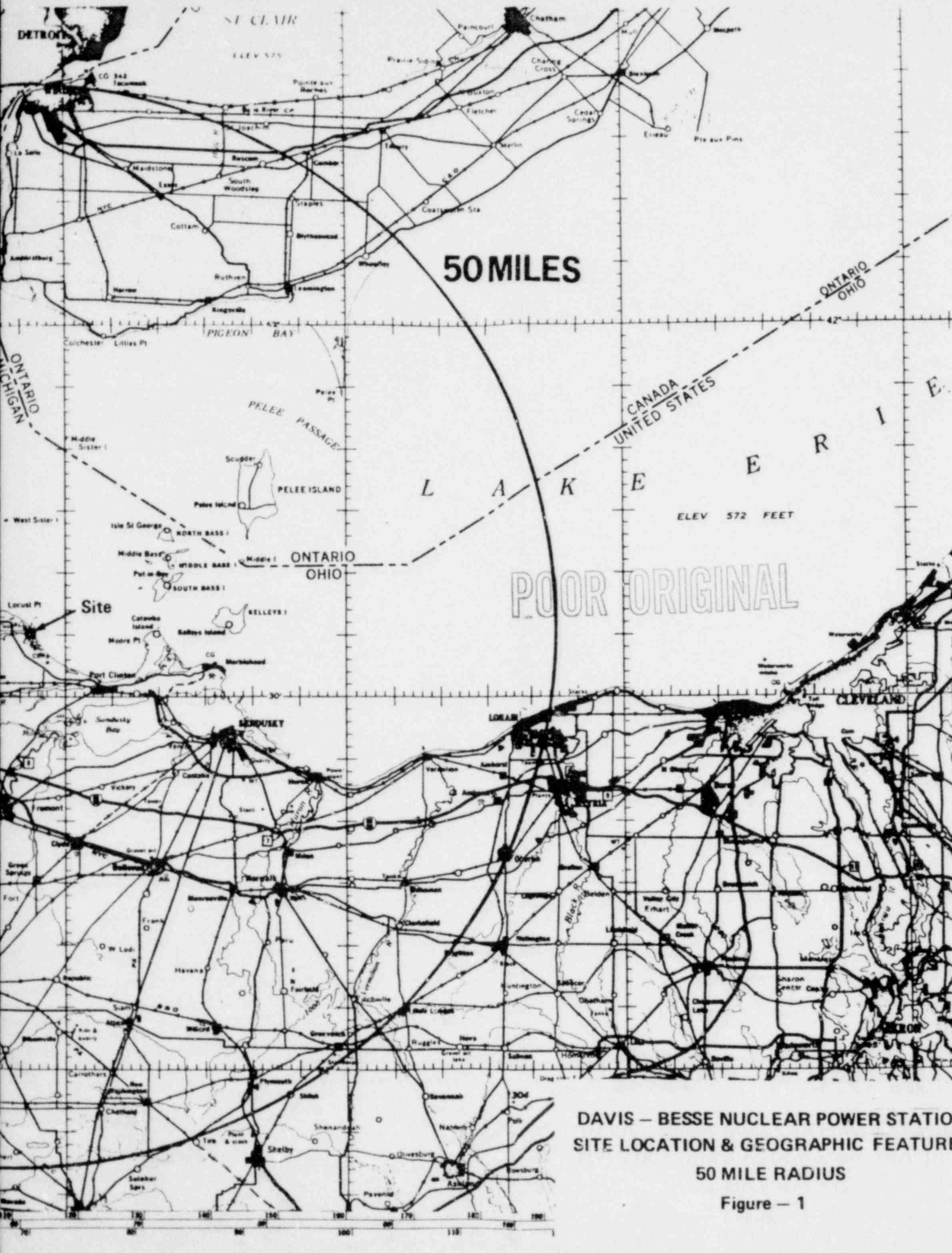
17. Hilsmeier, W.F., and Gifford, F.A., "Graphs for Estimating Atmospheric Dispersion", U.S.A.E.C. ORO 545, July, 1962.

18. Overcamp, J.J., and Hoult, D.D., "Precipitation from Cooling Towers in Cold Climates." Fluid Mechanics Laboratory, Department of Mechanical Engineering, Massachusetts Institute of Technology, Publication No. 70-7, May 1970.

FIGURES

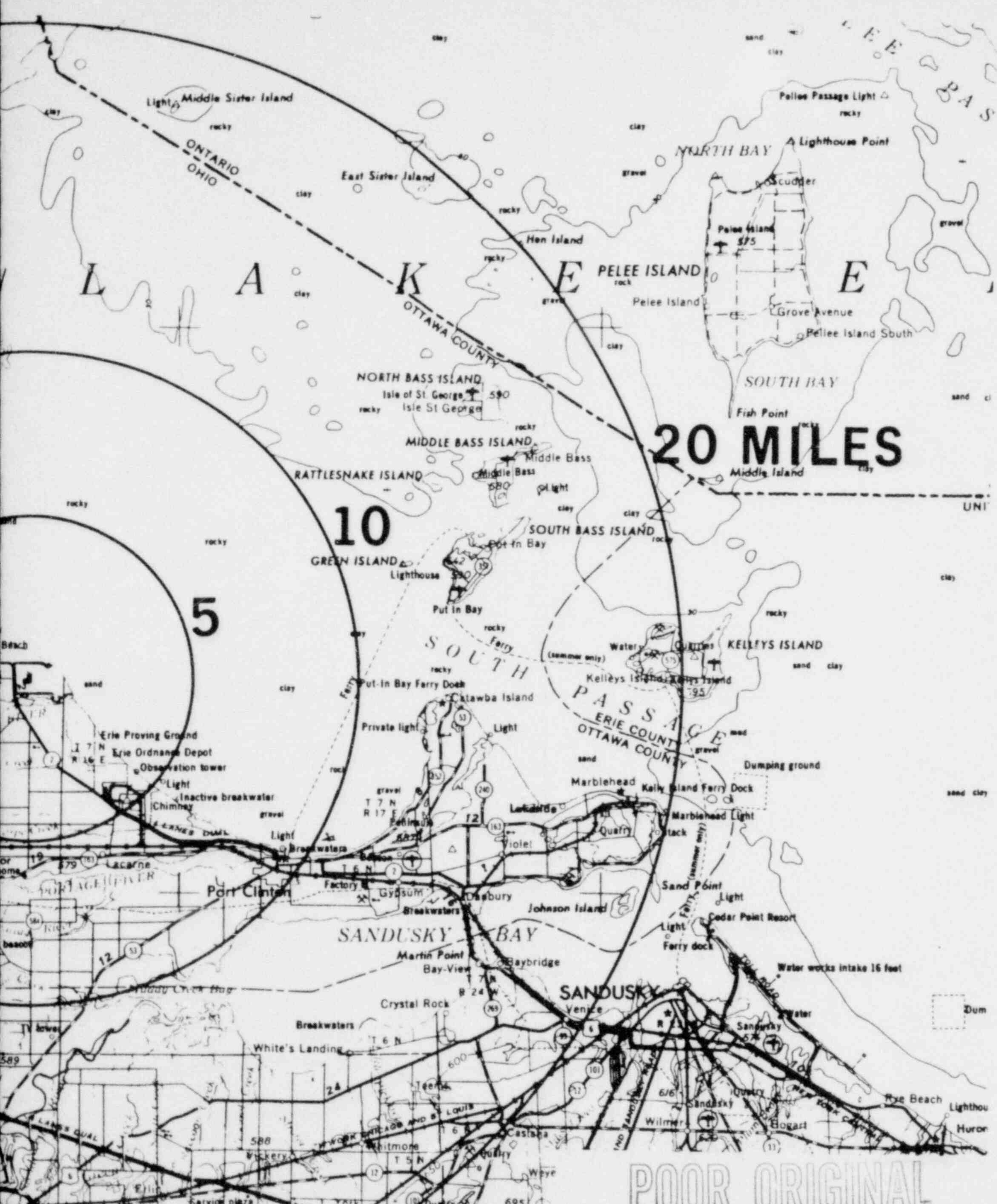


JACKSON
ANN ARBOR
TOLEDO
MICHIGAN
OHIO
MICH
OHIO
Somerset Center
Devils Lake
Tipton
Rome Center
Cadmus
Sandcreek
Canandaigua
Fairfield
Frontier
Pittsford
Ottawa Lake
Cone
Willis
Whittaker
Carleton
Scofield
Pt Mouille
Story Pt
Luna Pier
North Cape
Lulu
Samaria
Evansport
Farmer
Oholona
Jewell
New Bavaria
Pleasant Bend
Van Buren
Miller City
Dupont
Blanchard
Columbus Grove
Mt Cory
Arlington
Jerry City
Helena
Fostoria
Tiffin
Bascom
Kansas
Clay Center
Martin



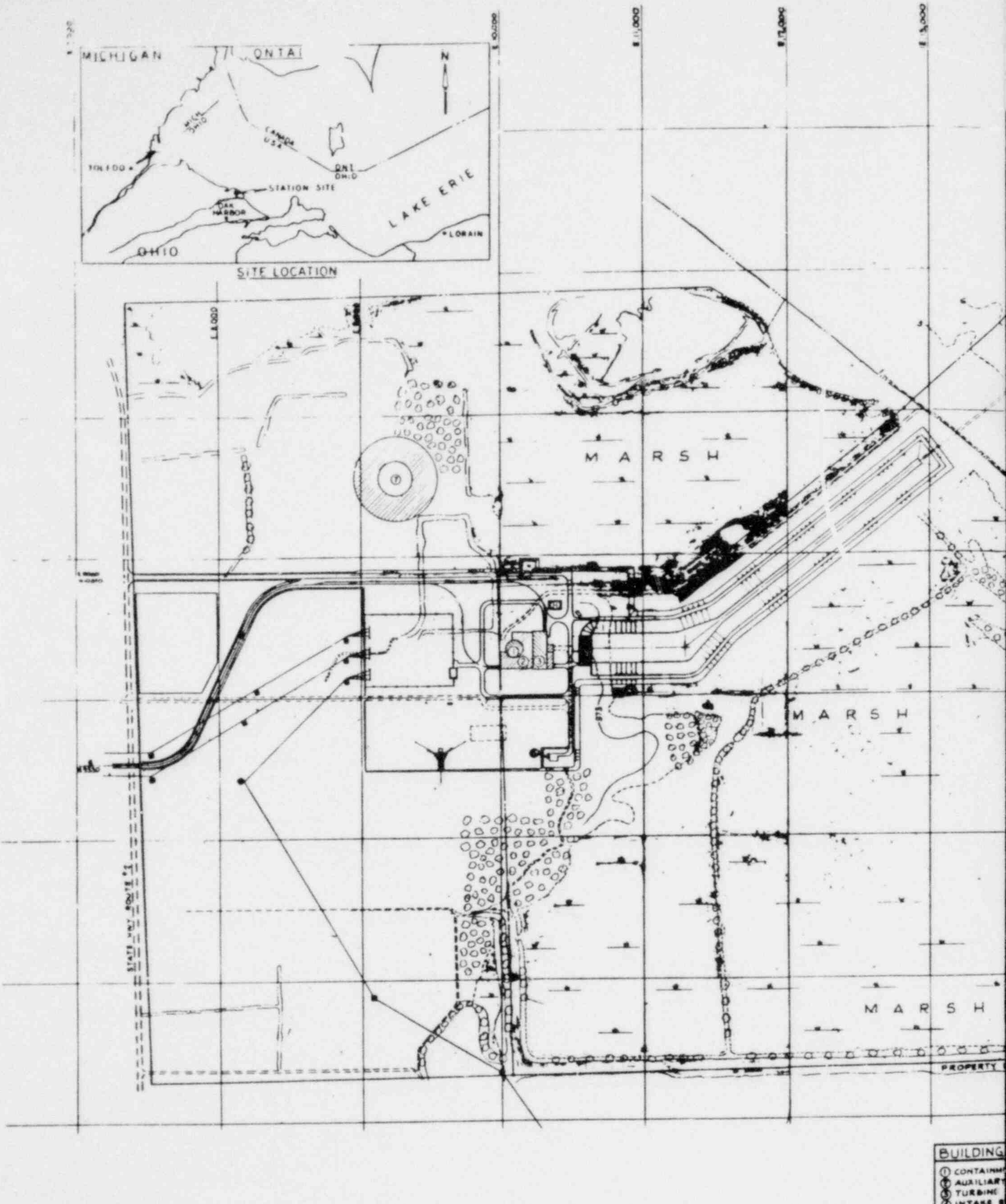
DAVIS – BESSE NUCLEAR POWER STATION
SITE LOCATION & GEOGRAPHIC FEATURES
50 MILE RADIUS
Figure – 1

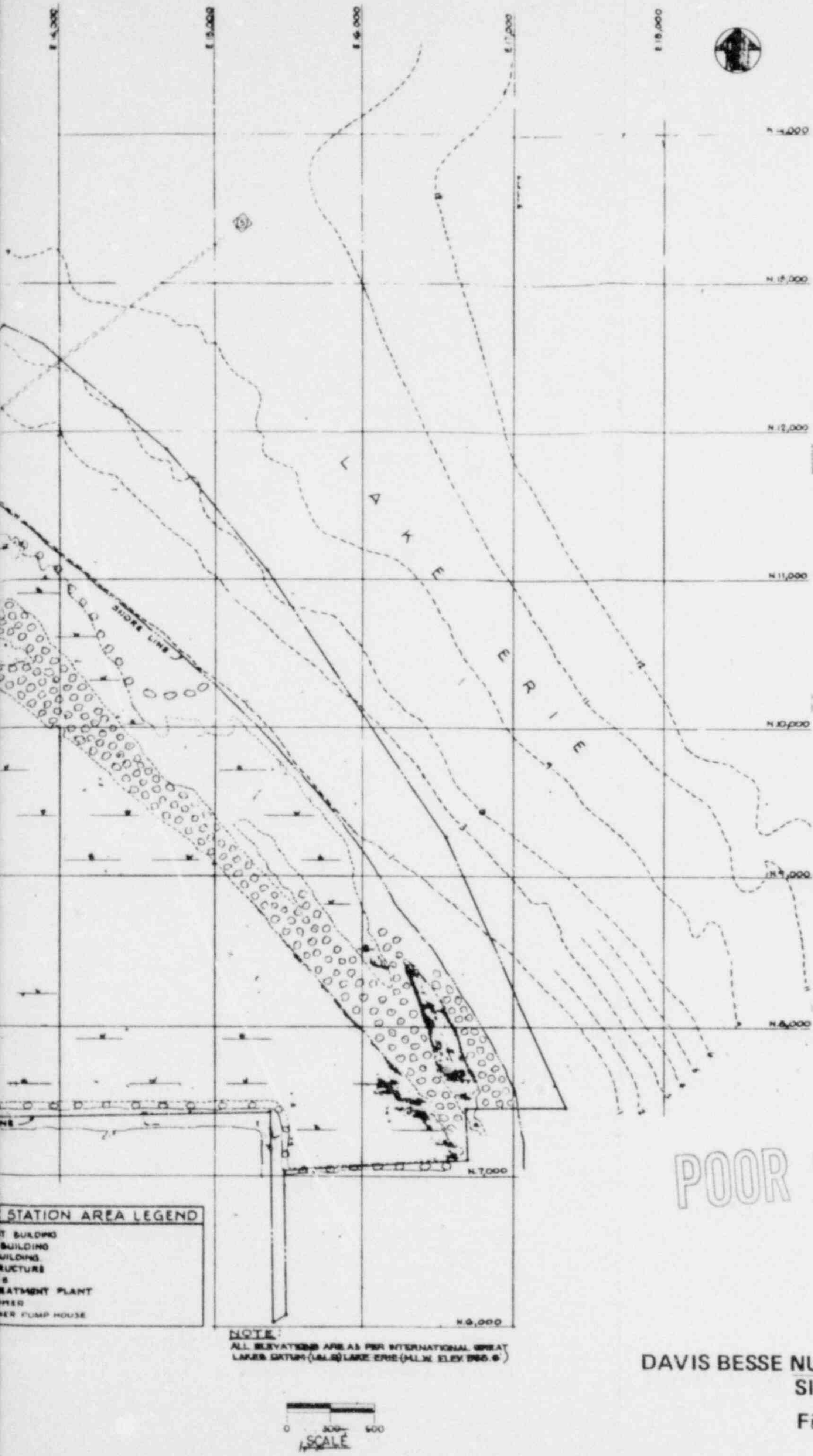
Bolles Harbor
Dumping ground
Private light
North Shores
Yargerville
Lakewood
Super power plant
St Anthony
Temperance
Breakwaters
MICHIGAN
OHIO
Toledo Harbor Light
North Cape
Turtle Island
MONROE COUNTY
LUCAS COUNTY
MAUMEE BAY
West Sister Island
Wildlife Refuge
Point Place
Cedar Point
Harbor View
South Shore Park
Niles Beach
Pipeline
Light
Reno Beach
Lakeland
TOLEDO
Fire station
Magee Marsh Wildlife Area
Williston
LUCAS COUNTY
OTTAWA COUNTY
Trowbridge
Clay Center
Millbury
Latchie
Perrysburg
Genoa
Rocky Ridge
Limestone
Stony Ridge
Lemoyne
Dowling
Dunbridge
Luckey
Woodville
OTTAWA COUNTY
SANDUSKY COUNTY
WOOD COUNTY
SANDUSKY COUNTY
Sugar Ridge
Pemberville
Scotch Ridge
Hessville
Bowling Green
Silo
Gibsonburg
Tower
New Rochester
Woodside
County home
Cloverdale
Rollersville
Helena
Quarry
Tinney
Millersville



DAVIS BESSE NUCLEAR POWER STATION
SITE LOCATION & GEOGRAPHIC FEATURES
20 MILE RADIUS

Figure – 2

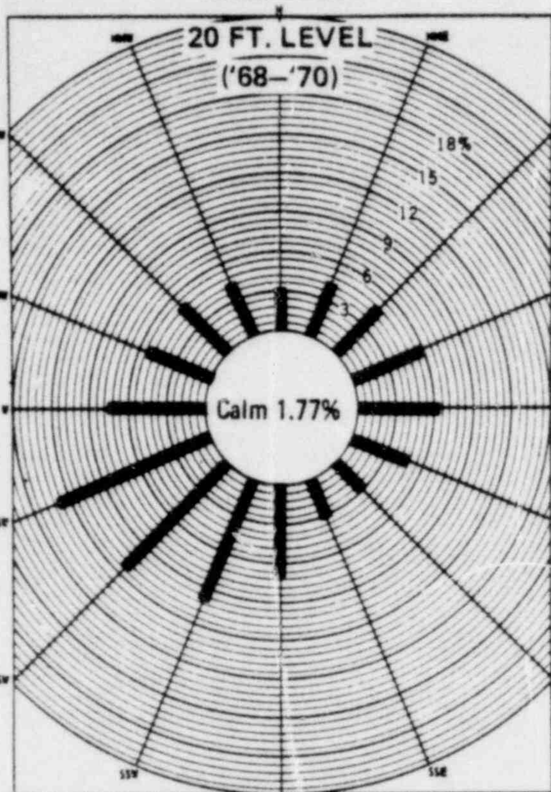

MICHIGAN
ONTAI
N
TOLEDO
STATION SITE
OAK HARBOR
LAKE ERIE
LORAIN
OHIO
SITE LOCATION
MARSH
MARSH
MARSH
PROPERTY
BUILDING
CONTAINM
AUXILIARY
TURBINE
INTAKE S
INTAKE C
SEWAGE
COOLING
COOLING



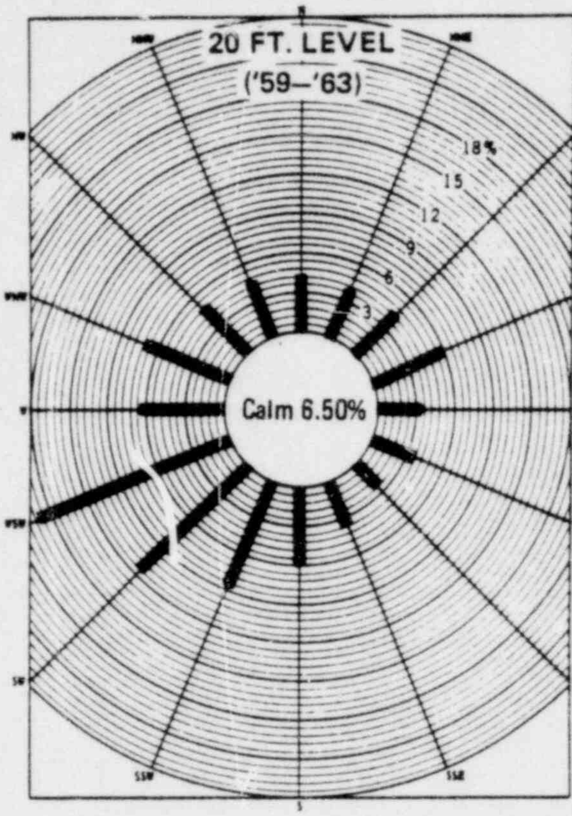
DAVIS BESSE NUCLEAR POWER STATION
SITE PLAN

Figure – 3

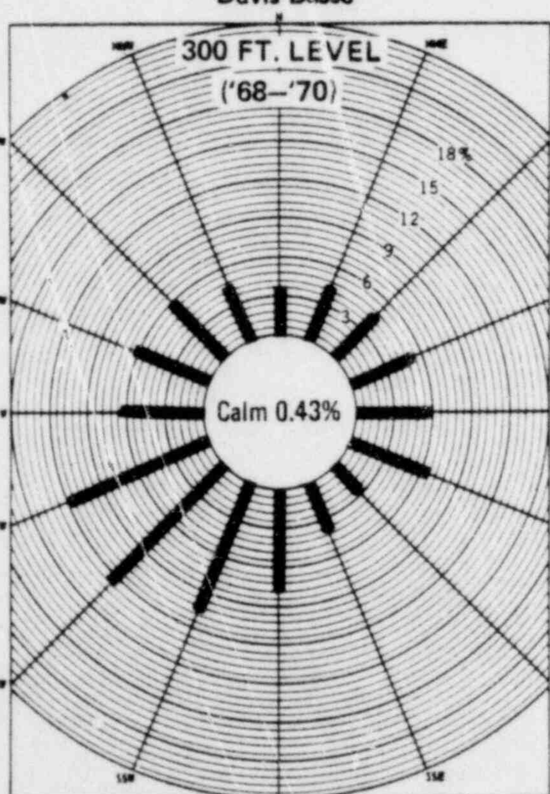
Davis Besse



Toledo Airport

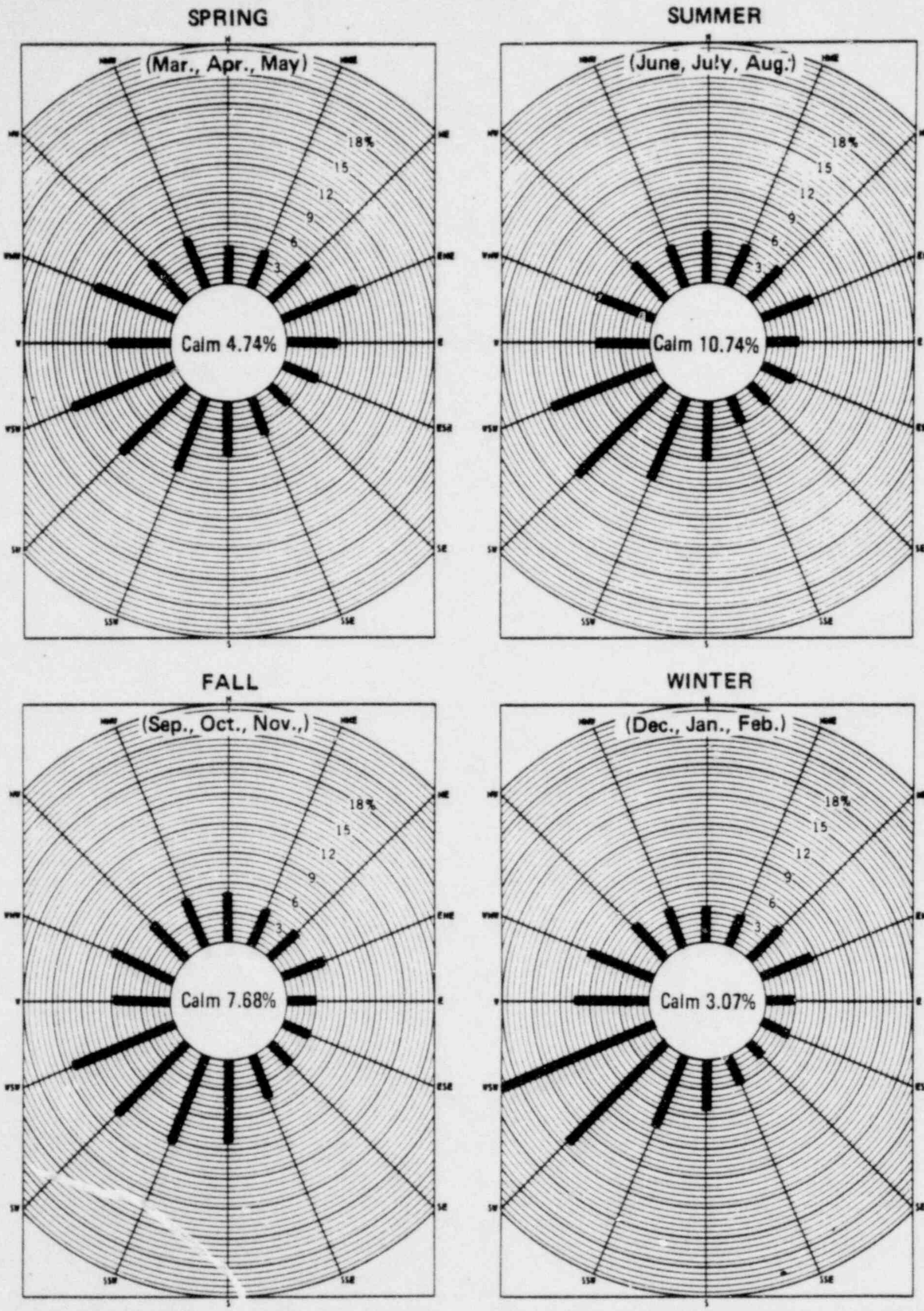


Davis Besse



ANNUAL WIND ROSES

Figure – 4



SEASONAL WIND ROSES
TOLEDO AIRPORT – 20 FOOT LEVEL
('59–'63)
Figure 5

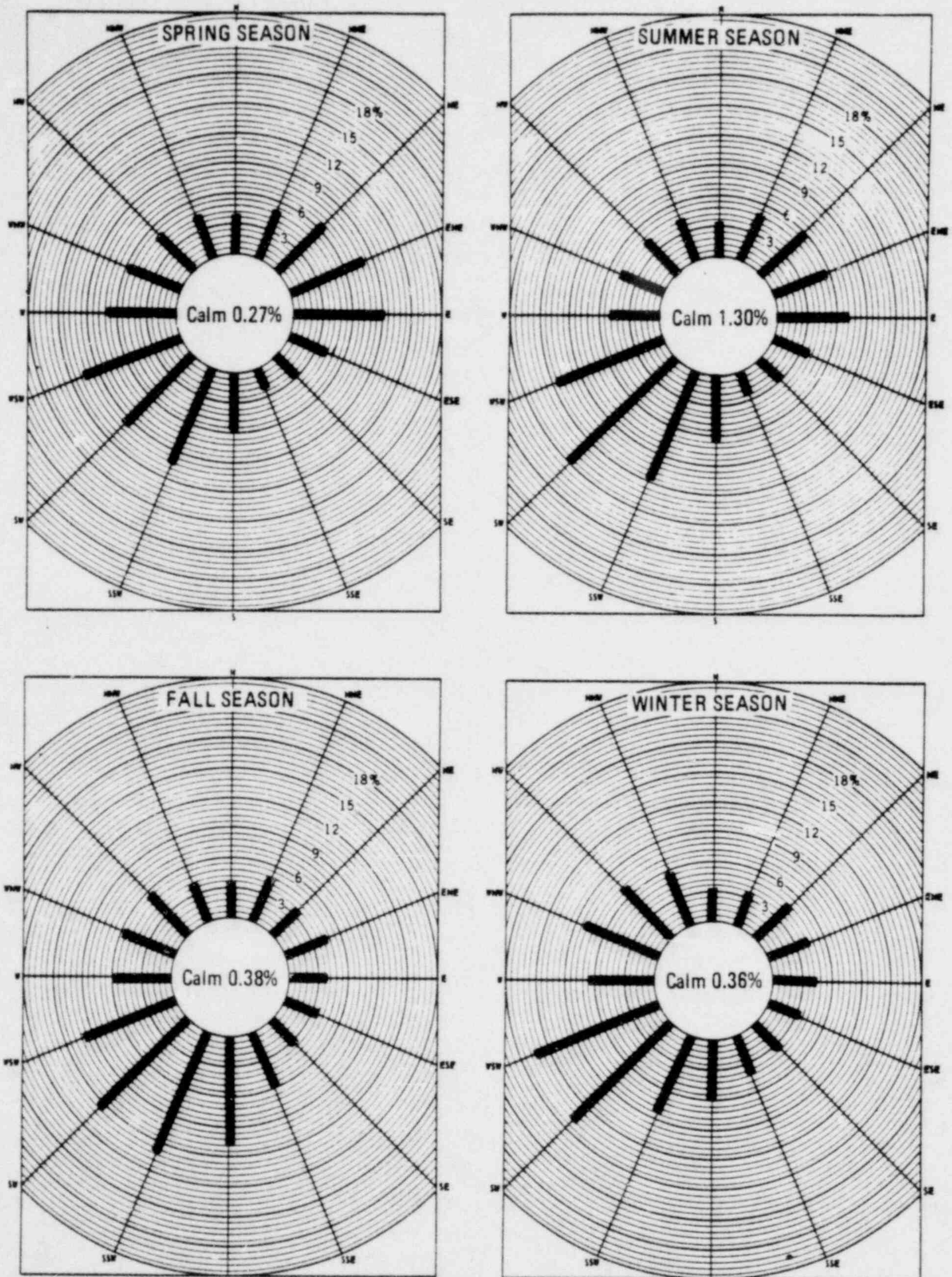


Figure 6

SEASONAL WIND ROSES

DAVIS–BESSE – 300 FT. LEVEL

('68 – '70)

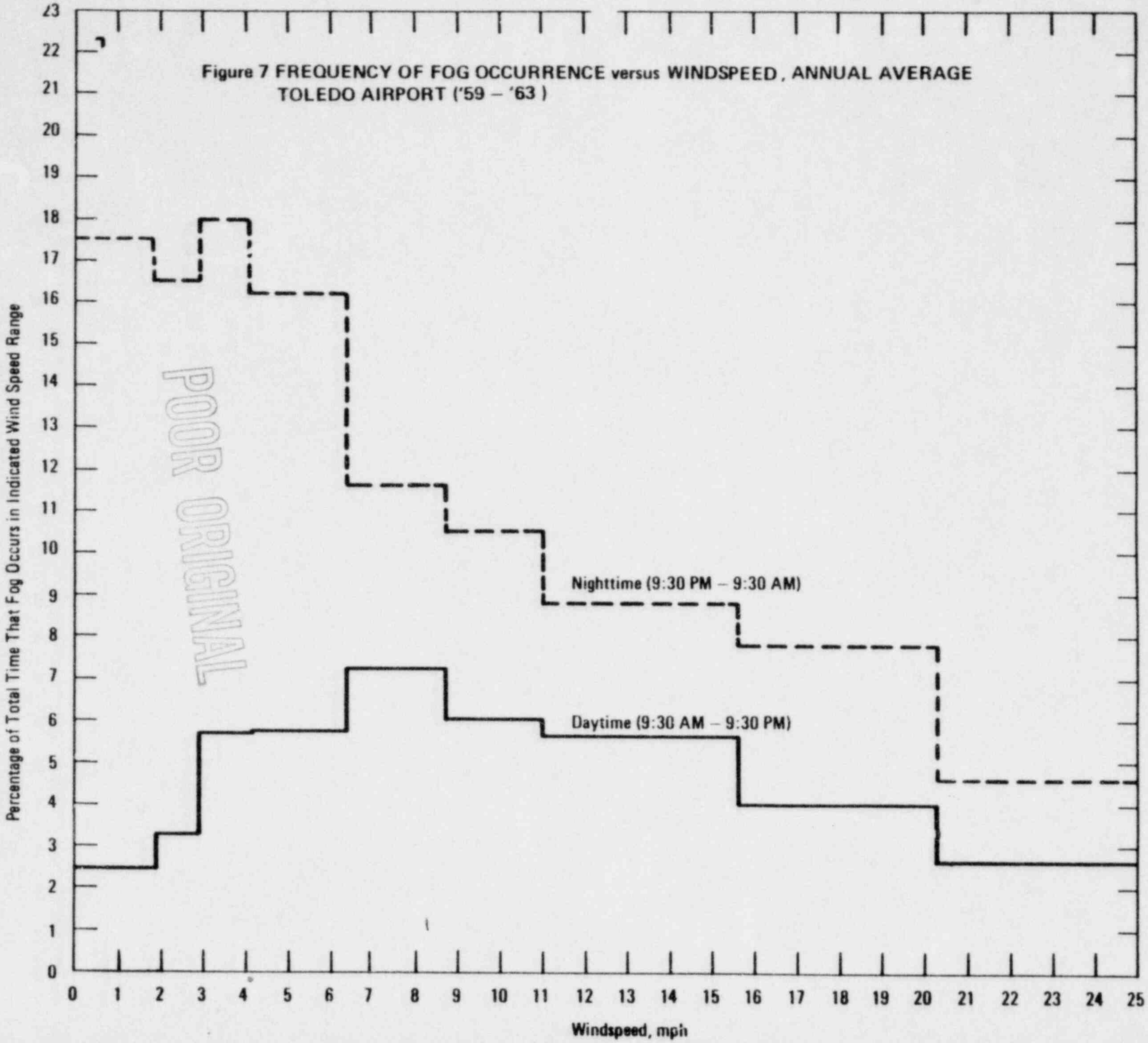


Figure 7 FREQUENCY OF FOG OCCURRENCE versus WINDSPEED, ANNUAL AVERAGE
TOLEDO AIRPORT ('59 – '63)
Nighttime (9:30 PM – 9:30 AM)
Daytime (9:30 AM – 9:30 PM)
POOR ORIGINAL
Percentage of Total Time That Fog Occurs in Indicated Wind Speed Range
Windspeed, mph

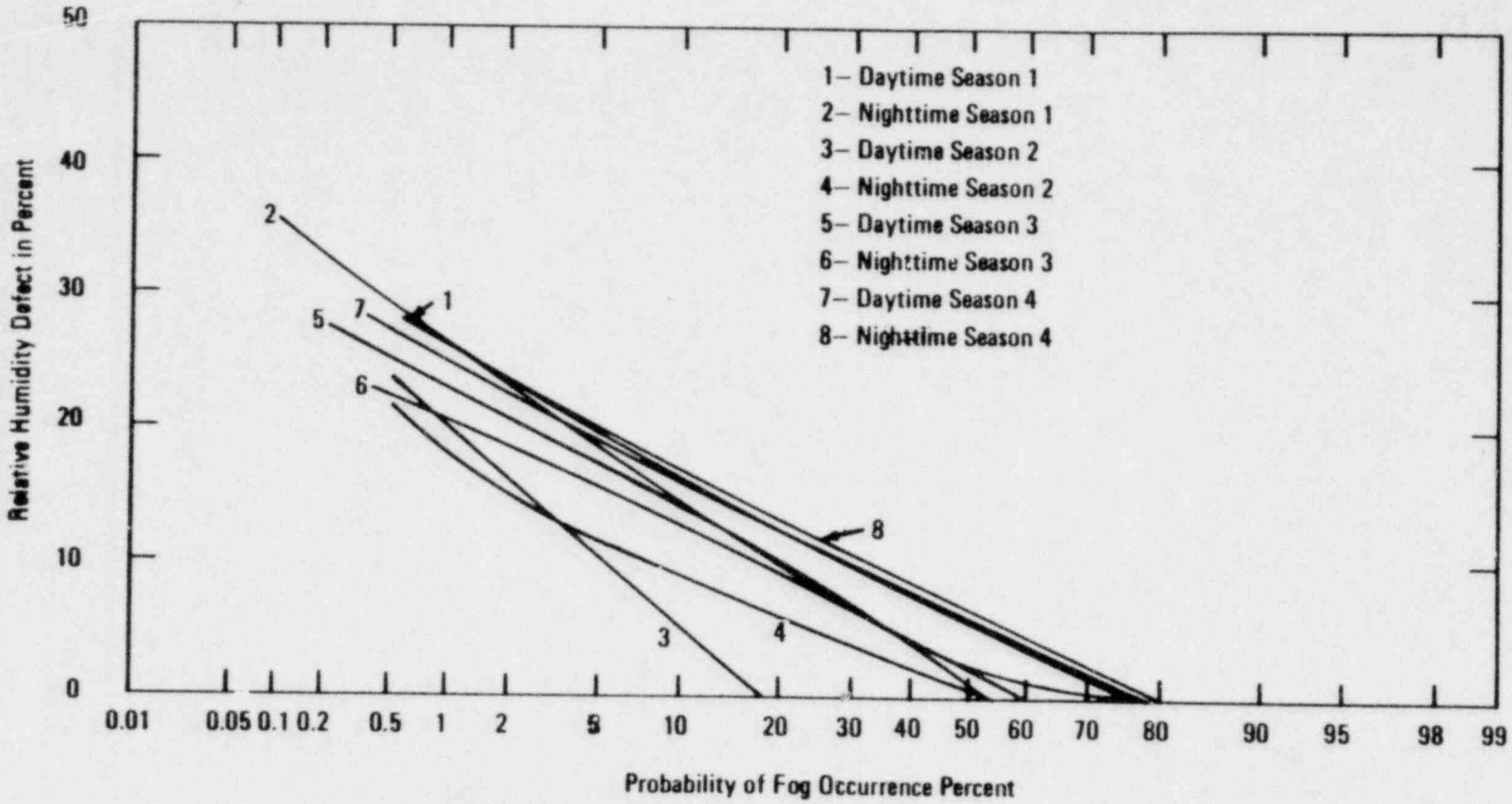


Figure 8 PROBABILITY OF FOG versus RELATIVE HUMIDITY

TOLEDO AIRPORT ('59–'63) SEASONS 1–4

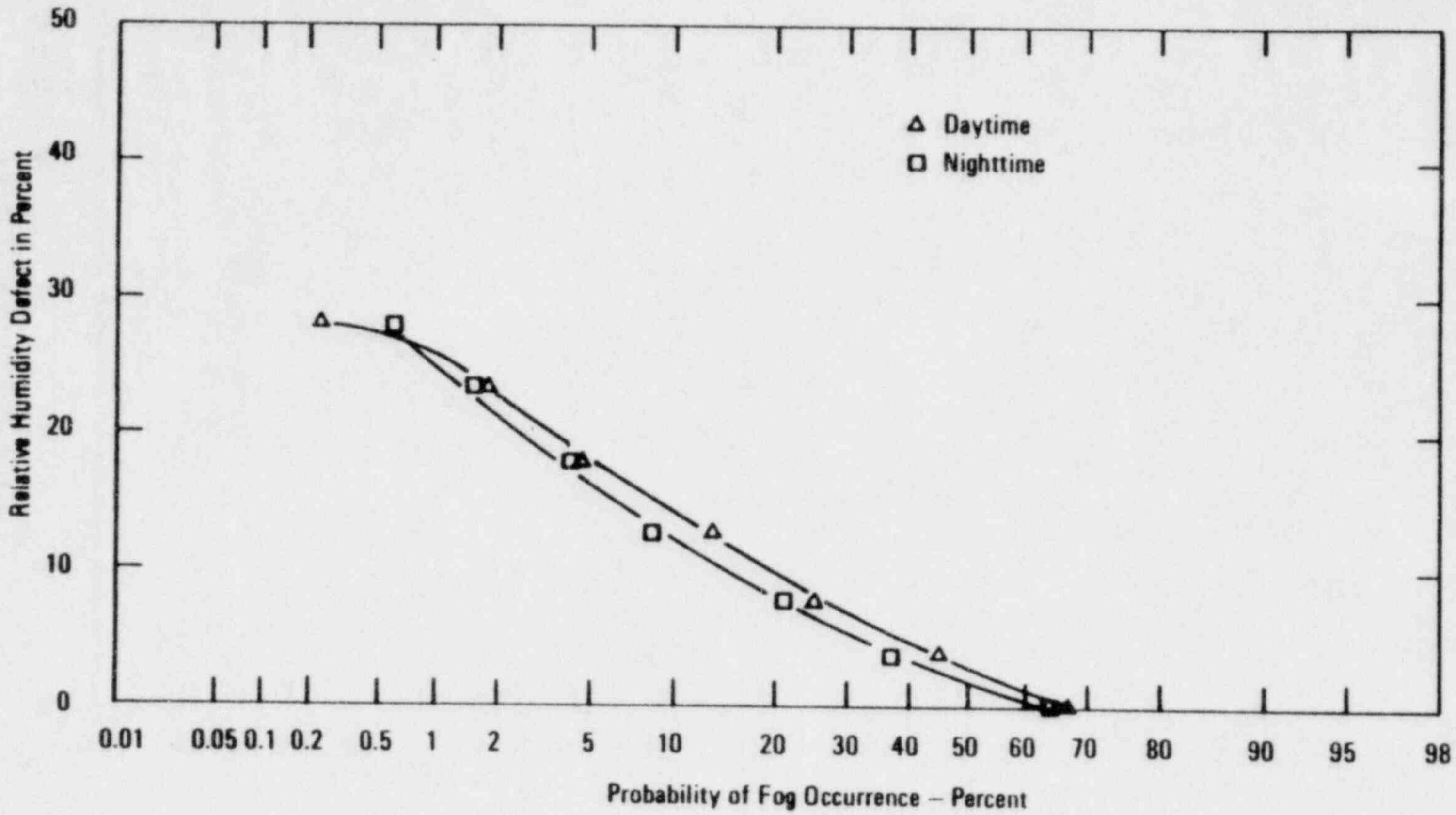


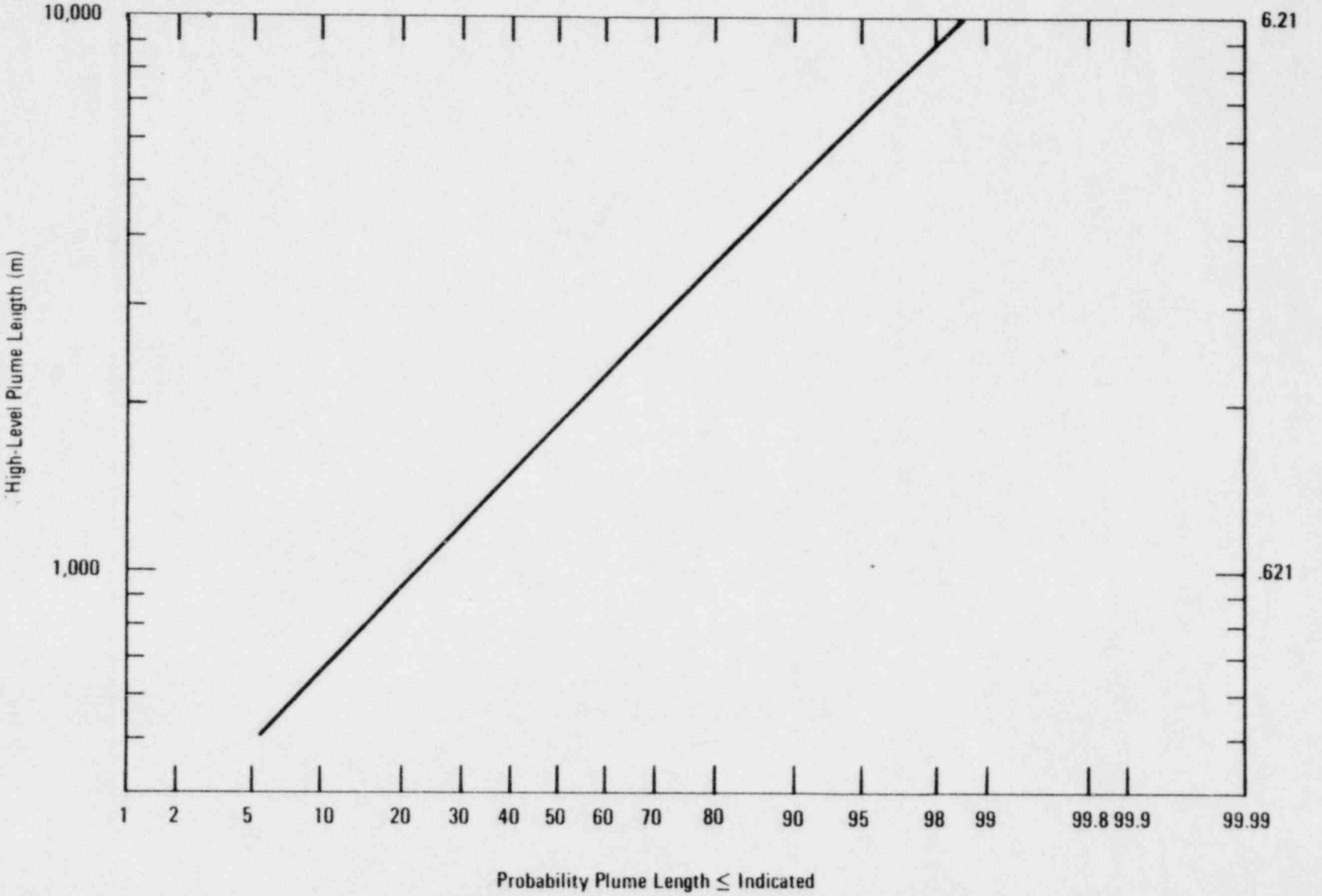
Figure 9 PROBABILITY OF FOG versus RELATIVE HUMIDITY
TOLEDO AIRPORT ('59 – '63) ANNUAL AVERAGE

Figure 10

HIGH LEVEL PLUME LENGTH

ANNUAL

(Based on '59 – '63 Toledo Airport Data)



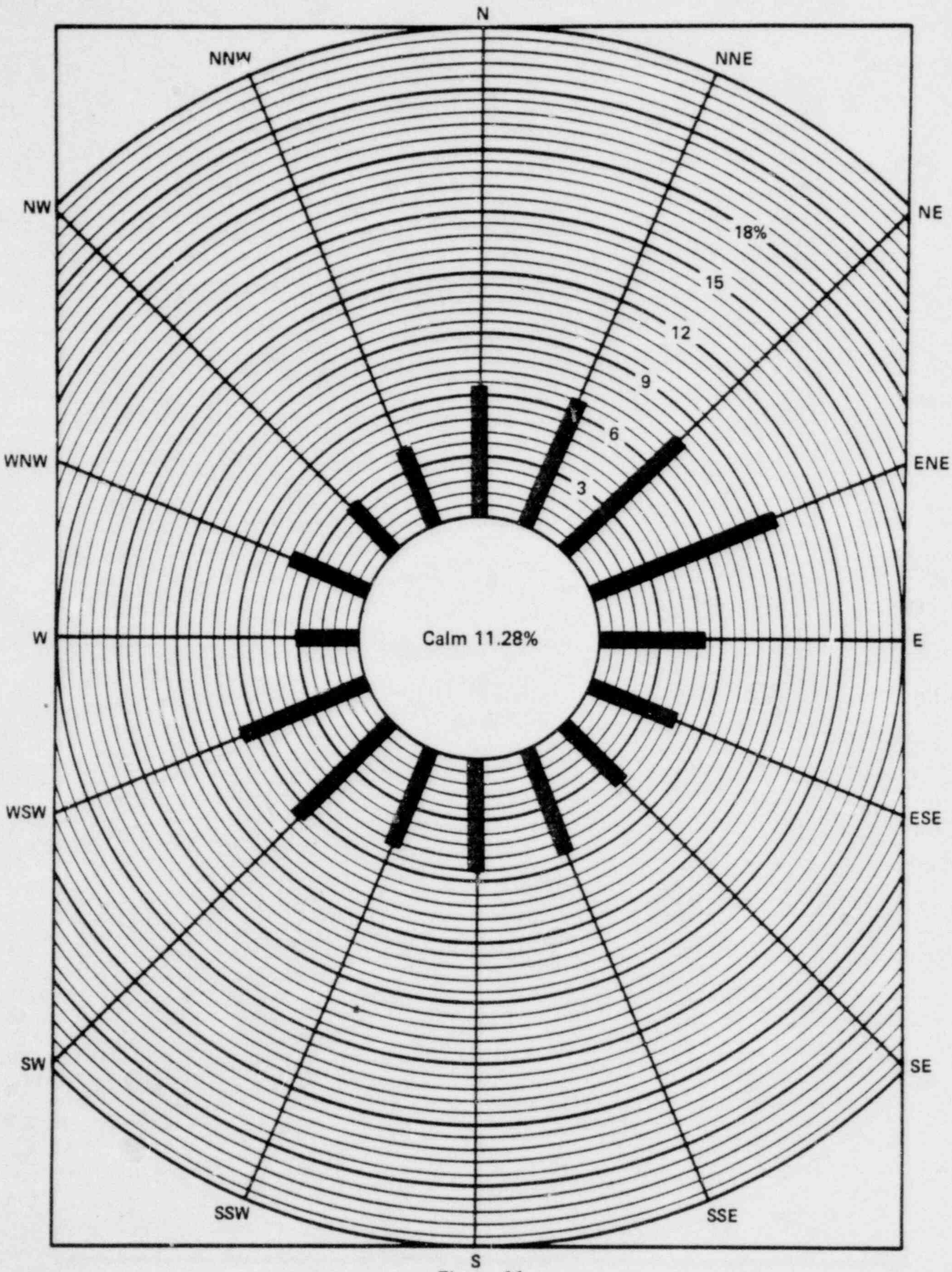


Figure 11
ANNUAL WIND ROSE
(Based on fog cases only)
TOLEDO AIRPORT – 20 FT. LEVEL
('59 – '63)

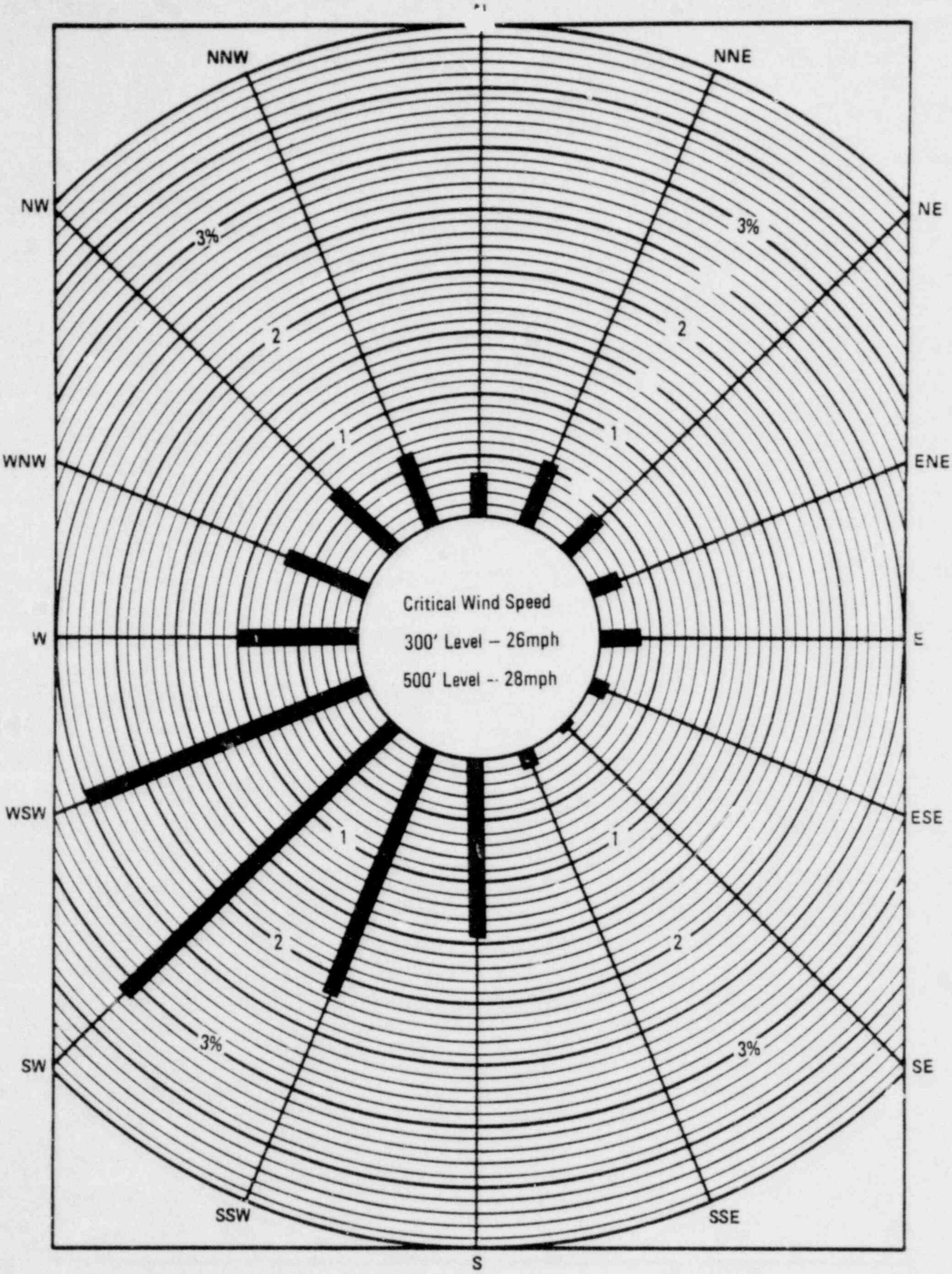


Figure 12
TOLEDO–EDISON , DAVIS–BESSE ANNUAL (68–70)
FREQUENCY OF DOWNWASH CONDITIONS
BY WIND DIRECTION

(Based on 300' Site Data)

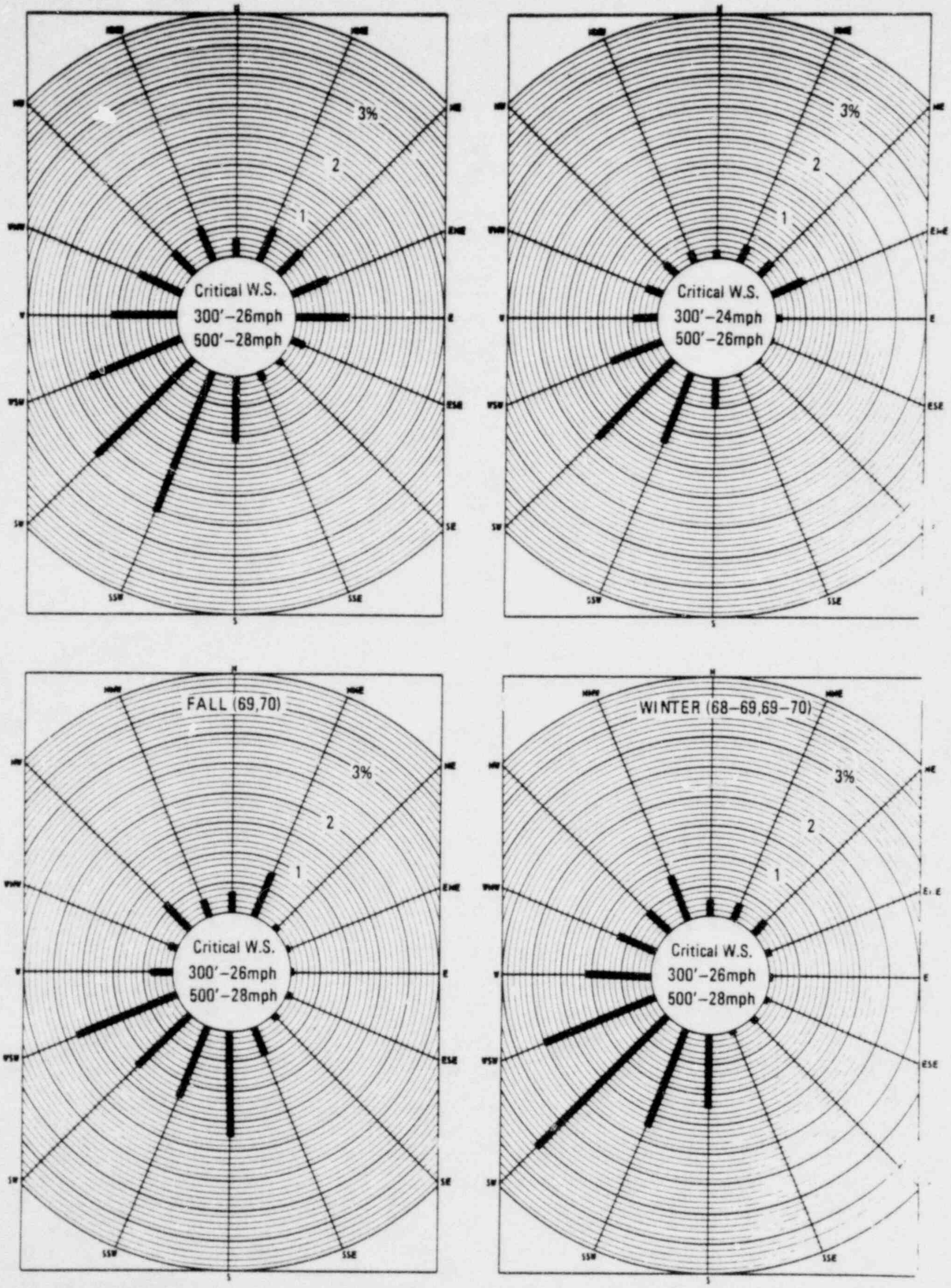


Figure 13

TOLEDO–EDISON , DAVIS–BESSE

FREQUENCY OF DOWNWASH CONDITIONS

BY WIND DIRECTION

8 EFFECTS OF ACCIDENTS

8.1 INTRODUCTION

Several postulated events and abnormal conditions have been examined to determine the most probable environmental consequences. A spectrum of events, according to expected frequency of occurrence and severity, has been considered. These events range in severity from small isolated activity releases up to the accidents normally analyzed in the Safety Analysis Report. The accident analysis and environmental consequences are evaluated using realistic assumptions in accordance with the requirements of the AEC Guide, "Scope of Applicants Environmental Reports with Respect to Transportation, Transmission Lines, and Accidents," dated September 1, 1971. The highly conservative assumptions and calculations used in the safety evaluations in the Safety Analysis Report are not suitable for the enviornmental risks evaluation, because the probability of occurrence of the unfavorable combination of circumstances leading to the conservative assumptions is very low. Even though realistic assumptions were used, the fundamental constants used in the analyses still represent conservative values. The feedback coefficients are very conservative. In those analyses where beginning-of-core life parameters are appropriate, a positive moderator coefficient has been used although it is expected that the moderator coefficient will be zero or negative throughout the entire life of the core. The control rod worths are maximum calculated values. The values related to the Reactor Protection System and the Control Rod Drive System are conservative with respect to expected values. The control rod assembly time to two-thirds insertion is taken to be 1.4 seconds although experimental tests indicate this time will be less than 1.4 seconds. The tripped rod worth is the normal expected rod worth minus the maximum worth stuck rod. The trip delay time is the maximum expected value.

8.2 SMALL RELEASES OUTSIDE CONTAINMENT

8.2.1 ACCIDENT DISCUSSION

All liquid spills or leakages from the reactor coolant system in the auxiliary building drain to the sumps and ultimately to the miscellaneous waste drain tank. These are then processed through an evaporator, demineralizer and a filter prior to being released to the environment: All the releases to the environment are monitored and controlled.

Any evaporation of liquids goes to the auxiliary building ventilation system, and would contribute to airborne releases. Annual doses due to such release depend on specific activities which vary greatly with position in the makeup and purification and radwaste systems. Concentrations of radioisotopes used in the estimates of doses due to these minor releases are all conservatively assumed to be at primary coolant levels corresponding to 0.1 percent fuel failure.

A two gallon spill and a continuous 10 gallons per day leakage of the reactor coolant has been analysed.

8.2.2 ENVIRONMENTAL CONSEQUENCES

The environmental consequences of this occurrence were evaluated using source activities in Table 8A-2 of Appendix 8A. The dose calculational methods used in the evaluation are shown in Appendix 8B. The table below and Table 8-1 summarize the environmental consequences of the occurrence by listing the dose to an individual at the site boundary and the total population dose within a 50 mile radius of the reactor site.

TABLE

OCCURRENCE	SITE BOUNDARY DOSE (mRem) Thyroid	Whole Body	POPULATION DOSE (Man-Rem)
1. 2 Gallon Spill	8.3×10^{-2}	3.3×10^{-3}	1.8×10^{-3}
2. 10 GPD Leakage	2.8×10^{-4}	1.1×10^{-2}	C.14

8.3 RADWASTE SYSTEM FAILURES

Various system malfunctions and/or human errors can be postulated which may result in some radioactivity release to the environment. Only significant malfunctions are discussed here.

8.3.1 HEAT EXCHANGER LEAKS

8.3.1.1 Accident Discussions

Letdown coolers, Seal return coolers and various other heat exchangers handling reactor coolant are cooled by the component cooling water system. The component cooling water system is a closed cooling system which acts as an intermediate barrier between the ultimate heat sink - the service water system. The component cooling water system is provided with radiation monitors which close the atmospheric vent on the component cooling surge tank on receipt of a high radiation alarm. The tank is then vented to the radwaste system. It is estimated that less than 13 gallons of reactor coolant at an activity level equivalent to 0.1% failed fuel would leak into the component cooling system before it is detected by the radiation monitors.

8.3.1.2 Environmental Consequences

For the purposes of evaluating the environmental consequences of this occurrence, it was assumed that all the gaseous activity in 14 gallons of reactor coolant was discharged to the atmosphere via the component cooling surge tank vent. The dose calculational methods used in the evaluations are shown in Appendix 8B. The Table below and Table 8-1 summarize the environmental consequences of the occurrence by listing the dose to an individual at the site boundary and the total population dose within a 50 mile radius of the reactor site.

TABLE

PATH	SITE BOUNDARY DOSE (m-Rem) Thyroid	Whole Body	POPULATION DOSE (Man-Rem)
Release to Atmosphere Unfiltered	5.8×10^{-5}	2.2×10^{-2}	1.2×10^{-2}

8.3.2 UNCONTROLLED RELEASE OF CONTENTS OF A GAS DECAY TANK

8.3.2.1 Accident Discussion

It can be postulated that a relief valve on one of the gas decay tanks is stuck open thus releasing the contents of that tank. However, the system design precludes this since the relief valves do not directly vent to atmosphere. Instead these successively relieve to various other tanks. The only way the contents of a gas decay tank can be released to atmosphere is in case of a damage to the piping or leakage through the flanged connections for the relief valves or the manhole covers.

For this analysis the contents of one gas decay tank was assumed to be released to the atmosphere through the auxiliary building ventilation system after it has been passed through charcoal filters.

8.3.2.2 Environmental Consequences

The environmental consequences of this occurrence were evaluated using the source activities given in Table 8A-7 of Appendix 8A. The dose calculational methods used in the evaluation are shown in Appendix 8B. The Table below and Table 8-1 summarize the environmental consequences of the occurrence by listing the dose to an individual at the site boundary and the total population dose within a 50 mile radius of the reactor site.

TABLE

PATH	SITE BOUNDARY DOSE (mRem)		POPULATION DOSE (Man-Rem)
	Thyroid	Whole Body	
Release to Atmosphere via charcoal filters at 16,000CFM	1.6×10^{-4}	9.7	8.0

8.3.3 FAILURE OF PUMPS TO SHUT OFF

8.3.3.1 Accident Discussion

Due to control malfunction or human error any of the various pumps in the radwaste system may fail to shut off in time, thereby causing tanks to overflow. The only tank overflow that can have some impact on the environment is the overflow from either the borated water storage tank or the primary water storage tank. Environmental impact due to the complete rupture of these tanks has already been analysed. The tank will continue to overflow only for the time it takes operator to shut the pump off manually. For the purposes of this analysis, it was assumed that the pump continued running for 15 minutes, thereby spilling 2100 gallons of treated and processed water from the primary water storage tank to the station storm drains. The station storm drains discharge into the Toussaint River.

8.3.3.2 Environmental Consequences

The same conservative assumptions as used in the analysis of the rupture of the primary water storage tank have been used for this evaluation. The environmental consequences of this occurrence were evaluated using the equilibrium tritium level of 0.4 µC/CC. The dose calculational methods used in the evaluations are shown in Appendix 8B. The dose to an individual living along the edge of the Toussaint River was calculated to be 1.8×10^{-2} mRem.

8.4 EVENTS THAT RELEASE RADIOACTIVITY INTO THE REACTOR COOLANT SYSTEM

8.4.1 DESCRIPTION OF EVENT

Significant amounts of radioactivity will be released into the reactor coolant system only if there is a defect in the fuel cladding. This radioactivity release from the fuel to the reactor coolant system alone results in no direct environmental release. To calculate the environmental effects due to a fuel defect, the radioactivity must be assumed to leak from the reactor coolant system to the containment vessel, and then leak from the containment vessel to the atmosphere. For this analysis, a reactor coolant system leak rate of 100 gallon per day was used, which is more than expected. The leakage from the containment vessel to the atmosphere is directly dependent on the pressures inside and outside the containment vessel. The greatest leakage would occur if the containment vessel was being ventilated. If the containment vessel was isolated, the leakage from the building would be negligible due to essentially no differential pressure.

Events that release radioactivity into the reactor coolant system such as fuel failure amounting to 0.1% of the pins in the core may occur at a rate of less than once per fuel cycle. Failure amounting to 1.0% of the pins in the core is not expected during the station life.

8.4.2 RESULTS OF EVENT

In this analysis, two different amounts of fuel failure are assumed, 0.1% and 1.0%. All of the Kr and Xe and 25% of the iodine activity in the reactor coolant leakage is assumed to become airborne in the containment vessel due to leakage or ventilation.

Reactor coolant system leakage to the containment will be isolated in the containment during normal operation. When access is required, a containment purge system designed to exhaust 50,000 CFM from the containment to the atmosphere through roughing and HEPA filters reduces the containment atmosphere activity levels. In the event of significant iodine activity levels in the containment, the purge system is capable of exhausting at 16,000 CFM through roughing, HEPA and charcoal filters of the emergency ventilation system prior to release to the atmosphere. For the purpose of this analysis, four purges of the containment per operating year were assumed. For normal access for maintenance, the containment will be purged when the winds are most favorable so that the releases are directed towards the lake. However, sometimes a situation may arise that the containment is required to be purged for access without waiting for the favorable winds. Therefore, since the cows in the vicinity of the station can graze for only about 6 months in a year only one of the four purges per year, on the average, may contribute towards the thyroid dose by the grass-cow-milk chain.

All releases of activity to the atmosphere are assumed to go directly to the site boundary with no time delay. Credit is only taken for normal atmospheric dispersion based on annual average meteorological conditions.

8.4.3 ENVIRONMENTAL CONSEQUENCES

The environmental consequences of these events were evaluated using the source activities given in Tables 8A-2 and 8A-3 of Appendix 8A. The dose calculational methods used in the evaluation are shown in Appendix 8B. The Table below and Table 8-1 summarize the environmental consequences of these events by listing the dose to an individual at the site boundary and the total population dose within a 50 mile radius of the reactor site.

TABLE

PATH	% FAILED FUEL	ANNUAL SITE BOUNDARY DOSE (mRem) THYROID	WHOLE BODY	POPULATION DOSE (Man-Rem)
Containment Purges (16,000 CFM Filtered)	0.1	7.4×10^{-3}	0.027	0.21
Containment Purges (16,000 CFM Filtered)	1.0	7.4×10^{-2}	0.270	2.1

8.5 EVENTS THAT RELEASE RADIOACTIVITY INTO THE SECONDARY SYSTEM

8.5.1 DESCRIPTION OF EVENT

This event is similar to the previously described event that released radioactivity into the reactor coolant system with the additional assumption of a leak path in the steam generator tube sheet. Significant amounts of radioactivity will be released into the environment via the secondary system only if there is defective fuel and a steam generator leak.

The radioactivity that is released to the containment vessel due to reactor coolant leakage will be released to the atmosphere, as previously described. The radioactivity that leaks into the steam generator will be transported to the condenser from which the noble gases are released directly to the atmosphere, and the iodines are released to the atmosphere using a liquid-to-gas partition factor of 10^4 in the condenser. In this analysis the leak rate from the reactor coolant system to the secondary system through the steam generator and the leak rate from the reactor coolant system to the containment vessel are each assumed to be either 100 gallons per day or 720 gallons per day.

8.5.2 RESULTS OF EVENT

In this analysis, 0.1% and 1.0% fuel failure is assumed. Due to the extreme low probability of having 720 GPD steam generator tube leakage concurrent with 1.0% defective fuel, the combination is not considered for this analysis. All of the Kr and Xe and 0.01% of the iodine activity in the reactor coolant which leaks into the containment vessel is assumed to become airborne and eventually escape from the containment vessel due to leakage or ventilation. All of the Kr and Xe and 0.01% of the iodine activity in the reactor coolant which leaks into the secondary system is assumed to be released directly to the environment.

8.5.3 ENVIRONMENTAL CONSEQUENCES

The environmental consequences of these events were evaluated using the source activities given in Tables 8A-2 and 8A-3 of Appendix 8A. The dose Calculational methods used in the evaluation are shown in Appendix 8B. The table below and Table 8-1 summarize the environmental consequences of these events by listing the dose to an individual at the site boundary and the total population dose within a 50 mile radius of the reactor site.

TABLE

PATH	% FAILED FUEL	PRIMARY TO SECONDARY LEAKAGE GPD	ANNUAL SITE BOUNDARY DOSE (mRem) THYROID	WHOLE BODY	TOTAL POPULATION DOSE (Man-Rem)
Turbine Building					
Steam Jet Air Ejector and Ventilation System	0.1	100	1.7×10^{-3}	0.18	1.37
Steam Jet Air Ejector and Ventilation System	0.1	720	1.2×10^{-2}	1.3	9.9
Steam Jet Air Ejector and Ventilation System	1.0	100	1.7×10^{-2}	1.8	13.7

8.6 REFUELING ACCIDENTS INSIDE THE CONTAINMENT VESSEL

8.6.1 DESCRIPTION OF ACCIDENT

A mechanical damage type accident is considered to be the maximum potential source of activity release during refueling operations. In this accident, it is assumed that a fuel assembly which has been irradiated for three full cycles is removed from the core after 72 hours of decay. This decay time is considered to be the minimum time for cooldown of the reactor coolant system, removal of the reactor closure head, and removal of the first fuel assembly. It is then assumed that while the assembly is being handled underwater, an incident occurs resulting in damage to the cladding of a full outer row of fuel pins (15 pins). This might result from dropping the assembly in such a way that it falls flat against a sharp-edged surface.

Damage to the fuel pin cladding is assumed to release all fission product activity in the gap. Since the fuel pellets are cold, only the activity contained in the pellet-cladding gap will be released. Fuel assemblies are handled under a minimum of 10 feet of water, so that activity released from the assembly must pass upwards through the water before reaching the building atmosphere.

Since the spent fuel assemblies are always handled under water, a loss of coolant water is impossible. Even in the fuel transfer tube, a loss of coolant is impossible since there is only one valve and water is available on both sides of the valve.

8.6.2 RESULTS OF ACCIDENT

Although there is experimental evidence that a portion of the noble gases will remain in the water, no retention of noble gases is assumed. In experiments in which air-steam mixtures were bubbled through a water pond, Diffey [1] demonstrated decontamination factors of about 1000 for iodine. Similar results for iodine were demonstrated by Barthoux[2] and predicted by Eggleton[3]. Based on these references, a decontamination factor of 1,000 for the iodine has been used. The iodine and noble gas activities released to the containment vessel atmosphere eventually escape from the containment vessel due to leakage or ventilation. During refueling operations, the personnel and equipment hatches will most probably be open and the containment purge system in operation. Should such an accident occur, the purging can be stopped within approximately 10 seconds. Since there is no difference in pressures inside and outside the containment there should be no appreciable leakage through the hatches. The containment atmosphere will be purged following this accident through the charcoal filters as described previously.

8.6.3 ENVIRONMENTAL CONSEQUENCES

The environmental consequences of this accident were evaluated using the source activities given in Table 8A-6 of Appendix 8A. The dose calculational methods used in the evaluation are shown in Appendix 8B. The table below and Table 8-1 summarize the environmental consequences of the occurrence by listing the dose to an individual at the site boundary and the total population dose within a 50 mile radius of the reactor site.

TABLE

PATH	SITE BOUNDARY DOSE (mRem)		POPULATION DOSE (Man-Rem)
	THYROID	WHOLE BODY	
Containment Purge (16,000 CFM Filtered)	5.0×10^{-2}	2.4	1.6

8.7 ACCIDENTS TO SPENT FUEL OUTSIDE THE CONTAINMENT VESSEL

8.7.1 DESCRIPTION OF ACCIDENT

A mechanical damage type accident is considered to be the maximum potential source of activity release during fuel transfer or handling operations. In this accident, it is assumed that a fuel assembly which has been irradiated for three full cycles is removed from the core after 72 hours of decay. This decay time is considered to be the minimum time for cooldown of the reactor coolant system, removal of the reactor closure head, and removal of the first fuel assembly. It is then assumed that while the assembly is being handled under water, an accident occurs resulting in damage to the cladding of a full row of fuel pins (15 pins). This might result from dropping the assembly against a sharp-edged surface. Since the fuel pellets are cold, only the activity contained in the pellet-cladding gap of the 15 damaged fuel rods will be released. Fuel assemblies are handled under a minimum of 10 feet of water so that activity released from the assembly must pass upwards through the water before reaching the fuel handling building atmosphere.

The fuel handling area crane is electrically interlocked to prevent it from travelling over the spent fuel pool. Also, the spent fuel handling cask pit is separated from the spent fuel pool by a 3 feet thick concrete wall, thereby preventing the cask from tilting and falling on the spent fuel assemblies. Therefore, based on the design, any damage to the spent fuel assemblies by the spent fuel cask is precluded.

The spent fuel assemblies are shipped to the reprocessing plant in special casks. These casks are designed, constructed and licensed in accordance with requirements of 10 CFR 71. The station design precludes a free drop of the cask in excess of 30 feet. A transportation accident on site is not considered credible.

8.7.2 RESULT OF ACCIDENT

Although there is experimental evidence that a portion of the noble gases will remain in the water, no retention of noble gases is assumed. In experiments in which air-steam mixtures were bubbled through a water pond, Diffey[1] demonstrated decontamination factors of about 1000 for iodine. Similar results for iodine were demonstrated by Barthoux[2] and predicted by Eggleton[3]. Based on these references, a decontamination factor of 1,000 for the iodine has been used. The iodine and noble gas activities released to the building atmosphere is released directly to the environment through the building ventilation system which is conservatively assumed to discharge the activity as a puff-release. Charcoal filters in the exhaust ventilation system are assumed to provide an iodine decontamination factor of 100. The fuel handling area ventilation system is provided with capability of utilizing the charcoal filters in the emergency ventilation system in case of a fuel handling accident in which radioactive iodine may be released.

8.7.3 ENVIRONMENTAL CONSEQUENCES

The environmental consequences of this accident were evaluated using the source activities given in Table 8A-6 of Appendix 8A. The dose calculational methods used in the evaluation are shown in Appendix 8B. The table below and Table 8-1 summarize the environmental consequences of the occurrence by listing the dose to an individual at the site boundary and the total population dose within a 50 mile radius of the reactor site.

TABLE

PATH	SITE BOUNDARY DOSE (mRem) THYROID	SITE BOUNDARY DOSE (mRem) WHOLE BODY	POPULATION DOSE (Man-Rem)
Fuel Handling Area Ventilation (16,000 CFM Filtered)	6.1×10^{-2}	2.9	1.6

8.8 ACCIDENT INITIATION EVENTS CONSIDERED IN THE DESIGN BASIS EVALUATION IN THE SAFETY ANALYSIS REPORT

8.8.1 UNCOMPENSATED OPERATING REACTIVITY CHANGES

8.8.1.1 Accident Discussion

The analysis of uncompensated operating reactivity changes is concerned with the consequences of normal reactivity changes due to fuel depletion and changes in xenon concentration. The analysis shows a very slow change of the average core moderator temperature even for worst case feedback parameters. No fuel damage or other system damage will occur since the rate of reactivity addition and temperature change are less than the rate at which the automatic control system or operator can detect and compensate for the change [(1)]. The rate of reactivity change for this occurrence may range from 10^{-7} to 10^{-5} $\Delta k/k/\text{sec}$. These rates are more than a factor of 10 less than the reactivity addition rate for the rod withdrawal accident from power. Therefore a detailed analysis of the consequences is unnecessary.

8.8.1.2 Environmental Consequences

There is no activity release and thus no environmental consequences due to uncompensated operating reactivity changes.

8.8.2 STARTUP ACCIDENT

8.8.2.1 Accident Discussion

The start-up accident, which is a rod withdrawal from zero power, has been analyzed for a conservative range of rod withdrawal rates. The analysis demonstrates that for conservative values of moderator and Doppler coefficients that no fuel damage or other system damage will occur[(1)]. The peak thermal power* reached during a startup accident is always less than the thermal

---

(1) The Toledo Edison Co., Davis-Besse PSAR, 14.1.2.1.2. & 14.1.2.2.3

*The thermal power is defined as the amount of energy transferred from the fuel pin to the coolant. During a power excursion this energy is less than the neutron power and lags the neutron power.

power at rated power operation. The rod withdrawal accident is initiated from rated power conditions, hence the severity of the startup accident is less than the rod withdrawal from rated power. For this reason a detailed analysis of this occurrence is not presented.

8.8.2.2 Environmental Consequences

There is no activity release and thus no environmental consequences due to startup accident.

8.8.3 ROD WITHDRAWAL

8.8.3.1 Accident Discussion

The rod withdrawal from rated power is the most severe of the continuous reactivity addition transient type accident. This accident has been examined using standard methods and initial conditions consistent with normal station operation. The calculational assumptions and station parameters are shown in the table below. The initial steady-state power level used is 2650 MW(t) which is the rated power for the station. The system conditions corresponding to this condition are an average moderator temperature of 582.5°F and an operating pressure of 2200 psia. The normal reactor coolant flow rate of 131×10^6 #/hr has been used. The kinetics constants used in this analysis are typical of beginning-of-core-life conditions which for this type of accident represent the most severe assumption. The reactivity addition rate used for this analysis represents the maximum expected control rod group worth being withdrawn at twice its average rate and hence is a conservative value.

Rod Withdrawal Accident Parameters

High Flux Trip Level, %	105.5
Trip Delay Time (High Flux Trip), s	0.4
CRA Insertion Time (2/3 Insertion), s	1.4
Doppler Coefficient, Δk/k/°F	-1.17×10^{-5}
Moderator Coefficient, Δk/k/°F	0.5×10^{-4}
Control Rod Speed, in/min	30
One Rod Group Reactivity Addition Rate, Δk/k/s	1.09×10^{-4}
Tripped Rod Worth; % Δk/k	5.6
Maximum Group Worth, % Δk/k	1.5

8.8.3.2 Discussion of Results

The neutron power, core average fuel temperature and system pressure are shown in Figure 8-1. It is seen that the neutron power rises until the flux trip set-point is reached at which time the transient is terminated by the rapid insertion of control rods into the core. The maximum neutron power as shown in Figure 8-1 is 106%. Since the thermal power, which reaches a maximum of 104.5%, does not exceed the design thermal power of 112% and the reactor coolant system pressure does not exceed code pressure limits (2750 psia), it is concluded that no fuel or reactor coolant system damage occurs.

8.8.3.3 Environmental Consequences

Since there is no fuel or reactor coolant system damage, there are no additional environmental consequences as a result of this transient.

8.8.4 MODERATOR DILUTION ACCIDENT

8.8.4.1 Accident Discussion

An analysis has been performed to determine the effect of the addition of unborated water to the reactor coolant system. This has the effect of adding reactivity at a slow rate which produces a slow change in the average core moderator temperature. No fuel damage or system damage occurs. [1] For the purposes of comparison, the maximum reactivity addition rate for this occurrence is 1.2×10^{-5} $\Delta k/k/sec$. The reactivity addition rate is approximately a factor of 10 less than the reactivity addition rate for the rod withdrawal from rated power. Since the initial conditions are the same, this accident is less severe than the rod withdrawal accident and a detailed analysis in unnecessary.

8.8.4.2 Environmental Consequences

There is no activity release and thus no environmental consequences due to a moderator dilution accident.

(1) The Toledo Edison Co., Davis-Besse PSAR, 14.1.2.4.2

8.8.5 COLD WATER ACCIDENT

8.8.5.1 Accident Discussion

The absence of isolation valves eliminates the potential source of cold water, therefore, this is not a credible accident. (1)

---

(1) The Toledo Edison Co., Davis-Besse PSAR, 14.1.2.5

8.8.6 LOSS OF COOLANT FLOW (LOCF)

8.8.6.1 Accident Discussion

The LOCF accident is representative of the flow decrease type of accident. The LOCF accident has been analyzed for the situation where two pumps are lost with the reactor operating at rated power. The loss of one pump in each loop is considered because the reactor coolant pumps are supplied by two electrical busses, each of which supplies one pump in each loop. Upon the loss of power to either electrical bus a rapid transfer to the unaffected bus is made. In order to lose two pumps for a length of time sufficient to cause flow coastdown two failures must exist; (1) failure of a primary source, (2) failure of the automatic power switching mechanism. The double failure required to initiate this accident is considered very unlikely. The methods of analysis used are standard. The calculational and station parameter assumptions are shown in the table below. The station is assumed to be operating normally at rated power (2650 MWt), normal pressure and inlet temperature (2135 psia and 557°F). These values account for any error in the instrumentation or the control of the station and hence are conservative with respect to the expected values. The initial flow rate is the nominal flow rate.

Loss of Coolant Flow Accident Parameters

DNBR at rated power conditions	1.93
Initial pressure, psia	2135
Initial inlet temperature, F	557
Pump monitor trip delay time, s	0.620
Initial Flow, #/hr, x 10^6	131.32
Tripped Rod Worth, % $\Delta k/k$	5.6

8.8.6.2 Discussion of Results

The results of the thermal analysis are shown in Figure 8-2. This figure shows the Departure from Nucleate Boiling ratio (DNBR) as a function of time following the electrical failure of two pumps. Since the DNBR does not go below 1.3, it is concluded that no fuel or reactor coolant system damage occurs.

8.8.6.3 Environmental Consequences

Since there is no fuel or reactor coolant system damage there are no additional environmental consequences due to a loss of coolant flow.

8.8.7 STUCK-OUT STUCK-IN OR DROPPED CONTROL ROD ACCIDENT

8.8.7.1 Accident Discussion

A stuck-out, stuck-in or dropped control rod may have the potential to alter the flux distribution in the core and cause design thermal values to be exceeded. The analysis for these conditions indicates that design power peaking ratios will not be exceeded and no fuel damage will occur. The transient resulting from dropping a control rod assembly while the reactor is at power has been analyzed and the results indicate that no fuel or other system damage will occur[1]. The transient analysis has shown that the thermal power decreases in response to the negative reactivity addition then slowly returns to, but does not exceed, the initial condition. Since the thermal power does not exceed the thermal power at rated power operation there is no fuel damage or system damage. For this reason a detailed analysis of this occurrence is not presented.

8.8.7.2 Environmental Consequences

There is no activity release and thus no environmental consequences due to the accident.

(1) The Toledo Edison Co., Davis-Besse PSAR, 14.1.2.7.2

8.8.8 LOSS OF ELECTRICAL LOAD

8.8.8.1 Accident Discussion

The station is designed to sustain this occurrence without Reactor Protection System action or a turbine trip. Since the turbine does not trip, all vital loads will continue to receive power from the station generator. Following a complete loss of load occurrence the turbine generator will undergo a frequency transient, however, the frequency will peak at less than the overspeed trip point and decay back to set frequency in 40 to 50 seconds. During this transient the turbine governor valves and the intercept valves begin to close and following closure, steam will be relieved to the condenser and to the atmosphere. Steam relief permits energy removal from the reactor coolant system to prevent a high pressure reactor trip. The initial runback is to 15 percent reactor power. After the turbine generator has been stabilized at auxiliary load and set frequency, the station operator may reduce reactor power to the auxiliary load as desired.

8.8.8.2 Discussion of Results

The loss of load occurrence does not result in fuel damage or other system damage[1]. Steam venting to the atmosphere occurs for about 3 minutes following loss of load from 100 percent initial power until the turbine bypass can handle all excess steam generated. The amount of steam relieved to the atmosphere is shown in the following table.

Loss-of-Load Results

Steam relieved to atmosphere	224,000 lb.

8.8.8.3 Environmental Consequences

The loss of electrical load will release no radioactivity to the atmosphere unless the steam generator is leaking reactor coolant into the secondary system. In order to provide a conservative evaluation of the environmental consequences of a loss of electrical load, it was assumed that the reactor had been operating with 0.1% failed fuel and with a 100 GPD leak in the steam generator tube sheet. The evaluation used the source activities given in Table 8A-2 of Appendix 8A and the dose calculational methods shown in Appendix 8B. The Table below and Table 8-1 summarize the environmental consequences of the occurrence by listing the dose to an individual at the site boundary and the total population dose within a 50 mile radius of the reactor site.

Path	Site Boundary Dose (mRem)		Population Dose (Man-Rem)
	Thyroid	Whole Body	
Steam Relieved to Atmosphere	1.3×10^{-2}	6.0×10^{-5}	3.3×10^{-5}

(1) The Toledo Edison Co., Davis-Besse PSAR 14.1.2.8.2

8.8.9 STEAM LINE FAILURE

8.8.9.1 Accident Discussion

It is assumed that a double ended main steam line break has occurred directly outside the containment vessel during rated power operation under end of core life conditions with 100 GPD tube leakage. The end of core life conditions are representative of a large negative moderator coefficient and a large negative Doppler coefficient, which will result in the maximum reactivity insertion for a given drop in fuel temperature. A 36 in. maximum steam line break size is assumed in the analysis since this represents the worst condition for the steam line failure accident.

Following the rupture, the increased steam flow out of the break and the increased steam generator levels caused by water flashing to steam at the reduced generator pressures will cause a rapid reactor coolant system cooldown and depressurization. The reactor coolant system cooldown causes a positive reacivity insertion and the reactor trips on high neutron flux at 6 sec. The reactor trip signal initiates rapid closure of the turbine stop valves, which isolate the unaffected generator from the steam line break.

Following closure of the turbine stop valves the unaffected generator will repressurize and its associated turbine bypass valve will open. The affected steam generator continues to blow down until main feedwater flow has been isolated. This allows the affected steam generator to blow dry, which prevents any further cooling of the reactor coolant system through the steam line break. Continued cooldown and depressurization is achieved by operator control of the turbine bypass valve on the unaffected steam generator. Following a 4.5 hour reactor coolant system cooldown and depressurization, the reactor coolant system reaches the cold shutdown condition, thus terminating any further tube leakage in the affected steam generator.

A steam line failure is not expected to occur during the station lifetime.

8.8.9.2 Discussion of Results

During the initial phase of the steam line failure, the unaffected steam generator blows steam through the main steam line crossover line and out the pipe break. This release is terminated when the main steam line stop valves close on reactor trip. The affected steam generator continues to blow steam out the break until the feedwater control valves have closed and the generator blows dry. Reactor coolant tube leakage continues in the affected steam generator until the reactor coolant system reaches ambient pressure after the 4.5 hour cooldown period.

Assuming a minimum trip rod worth of 5.6% Δk/k with the maximum worth rod stuck out, the core remains subcritical following reactor trip and no reactor core fuel damage or additional loss of reactor coolant system integrity occurs. The reactor coolant system response to the double-ended steam line break is shown in Figure 8-3. The assumptions and results are given in the following Table.

Steam Line Failure Assumptions and Results

Maximum pipe size (ID) assumed in analysis	36 in.
Assumed reactor coolant leak rate into generator with steam line break	100 GPD
High flux trip point	105.5%
Doppler coefficient (EOL)	-1.2×10^{-5} (Δk/k)/F
Moderator coefficient (EOL)	-3.0×10^{-4} (Δk/k)/F
Trip delay time (high flux trip)	0.4s
Control rod movement time to 2/3 insertion during trip	1.4s
Minimum subcritical margin during accident	2.6% Δk/k
Total steam release from affected steam generator	110,000 lb.
Total reactor coolant leakage to the secondary	120 lbs.
Total steam release from unaffected steam generator	29,000 lb.

8.8.9.3 Environmental Consequences

The steam line break accident will release no radioactivity to the atmosphere unless the steam generator is leaking reactor coolant into the secondary system. In order to provide a conservative evaluation of the environmental consequences of this accident, it was assumed that the reactor had been operating with 0.1% failed fuel and with a 100 GPD leak in the steam generator tube sheet. The evaluation used the source activities given in Table 8A-2 of Appendix 8A and the dose calculational methods shown in Appendix 8B. The table below and table 8-1 summarize the environmental consequences of the occurrence by listing the dose to an individual at the site boundary and the total population dose within a 50 mile radius of the reactor site.

TABLE

Path	Site Boundary Dose (mRem)		Population Dose (Man-Rem)
	Thyroid	Whole Body	
Steam Release to Atmosphere	0.51	3.6×10^{-3}	4.6×10^{-3}

1

8.8.10 STEAM LINE LEAKAGE

8.8.10.1 Accident Discussion

It is assumed that a 10 GPM steam leak in the secondary system has occurred during rated power operation. A steam leak of this size will have virtually no effect on reactor coolant system or secondary system operational parameters and is not considered as justification for shutting down the plant. The event has therefore been analyzed under continuous steady state full power operation.

8.8.10.2 Environmental Consequences

Steam line leakage will release no radioactivity to the atmosphere unless the steam generator is leaking reactor coolant into the secondary system. In order to provide a conservative evaluation of the environmental consequences of this leakage, it was assumed that the reactor had been operating with 0.1% failed fuel and with a 100 GPD leak in the steam generator tube sheet. The evaluation used the source activities given in Table 8A-2 of Appendix 8A and the dose calculational methods shown in Appendix 8B. The table below and Table 8-1 summarize the environmental consequences of the occurrence by listing the dose to an individual at the site boundary, and the total population dose within a 50 mile radius of the reactor site.

PATH	SITE BOUNDARY DOSE (mRem) THYROID	WHOLE BODY	POPULATION DOSE (Man-Rem)
Steam Release to Atmosphere	7.4×10^{-5}	0.11	1.4

8.8.11 STEAM GENERATOR TUBE FAILURE

8.8.11.1 Accident Discussion

It is assumed that a double ended steam generator tube rupture occurs during rated power operation. Approximately 0.4 minutes following the tube rupture the radiation monitor on the condenser off-gas air ejector reaches the high level set point and initiates a condenser off-gas high radiation alarm on the reactor console.

The operator manually trips the reactor at 1.0 minute following the rupture. Following reactor trip, the secondary system pressurizes and opens the atmospheric vent valve and the first bank of code safety valves. The operator initiates an accelerated reactor coolant system cooldown and depressurization at 2.0 minutes by fully opening the atmospheric vent valve on the non-leaking generator side while manually controlling the pressurizer level with the high pressure injection system. At 4.0 minutes following the rupture, the steam pressure on the affected steam generator side drops below the low level set points of the code safety valves and the atmospheric vent valve. At this point the operator closes and secures the atmospheric vent valve on the affected steam generator side and continues the cooldown in order to isolate affected steam generator flow to the condenser.

At 17.0 minutes following the rupture, the reactor coolant system is down to 500° F at 1065 psia and the operator closes the condenser dump valve on the affected secondary side thus completing final isolation of the leaking steam generator.

Cooldown and depressurization of the reactor coolant system is continued with steam relief to the condenser from the non-leaking steam generator.

8.8.11.2 Discussion of Results

Following reactor trip, the core remains subcritical for the duration of the accident, and no reactor core fuel or additional loss of reactor coolant system integrity occurs. The principal assumptions and results are given in the following Table.

Steam Generator Tube Rupture Assumptions and Results

Initial steam generator tube leak rate	435 GPM
Operator manually trips reactor at	1 min.
Operator takes action by initiating accelerated reactor coolant cooldown and depressurization at	2.0 min.
Final isolation of affected steam generator is achieved at	17 min.
Reactor coolant released to the generator prior to reactor trip (0.0 - 1.0 min.)	2,500 lb
Reactor coolant released to the generator while the affected side of the secondary system is venting to the atmosphere (1.0 to 4,0 min.)	7,500 lb
Additional reactor coolant released to the generator during the remainder of the accelerated cooldown period (4.0 to 17.0 min.)	30,000 lb
Total reactor coolant released to the generator prior to steam generator isolation (17 min.)	40,000 lb

8.8.11.3 Environmental Consequences

In order to provide a conservative evaluation of the environmental consequences of this failure, it was assumed that the reactor had been operating with 0.1% failed fuel and with a 100* GPD leak in the steam generator tube sheet. The evaluation used the source activities given in Table 8A-2 of Appendix 8A and the dose calculational methods shown in Appendix 8B. The table below and Table 8-1 summarize the environmental consequences of the occurrence by listing the dose to an individual at the site boundary and the total population dose within a 50 mile radius of the ractor site.

Table

Path	Site Boundary Dose (mRem)		Population Dose (Man-Rem)
	Thyroid	Whole Body	
Steam release to Atmosphere	1.7×10^{-2}	1.1	0.59

1

8.8.12 ROD EJECTION ACCIDENT

8.8.12.1 Accident Discussion

A reactivity excursion initiated by an uncontrolled rod withdrawal was shown to be safely terminated without adversely affecting the reactor core or the integrity of the reactor coolant system. In order for reactivity to be added to the core at a more rapid rate, physical failure of a pressure barrier component in the control rod drive assembly must occur. Such a failure could cause a pressure differential to act on a control rod assembly and rapidly eject the assembly from the core region. The power excursion due to the rapid increase in reactivity is limited by the Doppler effect and terminated by the high flux trip.

Since control rod assemblies are used to control load variations only, and boron dilution is used to compensate for fuel depletion, only a few control rod assemblies are inserted (some only partially) at rated power level. Thus, the severity of a rod ejection accident is inherently limited because the amount of reactivity available in the form of control rod worth is relatively small.

The severity of the rod ejection accident depends on the worth of the ejected rod and the reactor power level. The control rod group of greatest worth is the first in the entire rod pattern to be withdrawn. The maximum worth of a rod in this group can be as high as 3.0% $\Delta k/k$, but a rod would have this worth only when the reactor was subcritical by more than this amount. When the reactor is subcritical, the boron concentration is maintained at a level that ensures that the reactor is at least 1% subcritical with the control rod of greatest worth fully withdrawn from the core. Thus, a rod ejection will not cause a nuclear excursion when the reactor is subcritical and all the other rods are in the core. As criticality is approached, the worth of the remaining rods decreases, so that at criticality the maximum expected reactivity addition is about 0.3% $\Delta k/k$.

A rod ejection accident is not expected to occur during the station's lifetime.

8.8.12.2 <u>Discussion of Results</u>

Accident analysis using standard methods show that no fuel rods experience DNB as a result of the ejection of a 0.3% $\Delta k/k$ worth control rod.[1&2] This analysis is based on nominal initial conditions. Since no fuel rods experience DNB there is no fuel failure. The effects of the physical failure of a pressure barrier component in the control rod drive assembly are considered in the loss-of-coolant accident analysis.

8.8.12.3 <u>Environmental Consequences</u>

Since no fuel failure occurs during a rod ejection accident only the radioactivity in the reactor coolant is released to the containment vessel. The environmental consequences of this accident were evaluated based on operating with 0.1% defective fuel and using the reactor coolant activities given in Table 2 of Appendix 8A. The dose calculational methods used in the evaluation are the same as for the LOCA and are shown in Appendix 8B. The Table below and Table 8-1 summarize the environmental consequences of the occurrence by listing the dose to an individual at the site boundary and the total population dose within a 50 mile radius of the reactor site.

TABLE

PATH		SITE BOUNDARY DOSE (mRem)		POPULATION DOSE (Man-Rem)
		THYROID	WHOLE BODY	
Containment Purge (16,000 CFM, filtered)	0-2 hour	1.0×10^{-5}	5.6×10^{-5}	3.1×10^{-5}
	2-24 hour	5.5×10^{-2}	1.0×10^{-3}	8.3×10^{-4}
	1-30 days	2.9×10^{-5}	4.6×10^{-4}	3.5×10^{-3}

1

(1) Toledo Edison Company, Davis-Besse PSAR, 14.2.2.2.1, Part B.
(2) Toledo Edison Company, Davis-Besse PSAR, Figure 14-28.

8.8.13 LOSS-OF-COOLANT ACCIDENT (LOCA)

8.8.13.1 Accident Discussion

All components of the reactor coolant system have been designed and fabricated to ensure high integrity and thereby minimize the probability of their rupture. This is concluded for the following reasons:

1. The reactor coolant system piping meets all applicable codes and standards of design.
2. All components of the reactor coolant system are shown to behave in a ductile manner at normal operating temperatures.
3. Studies made to date indicate that detectable leakage will occur prior to gross failure for those portions of the reactor coolant system removed from discontinuities.
4. Stringent inspection techniques during the fabrication, erection and service of the reactor coolant system reduce the probability of material flaws.

In addition, emergency core cooling is provided to ensure that the core will continue to be cooled and will not lose its geometric configuration even if the reactor coolant system should fail and release coolant. This emergency core cooling standby safeguard is provided by the core flooding system and two full capacity, independent, emergency core cooling strings.

The basic design objective for the ECCS equipment is to terminate the temperature transient and thus maintain core geometry for a loss-of-coolant accident. This would be accomplished if the temperature transient were terminated before the melting point of the clad was reached.

Engineered safeguards are also provided to cool the containment vessel environment following a loss-of-coolant accident and thereby limit and reduce pressure in the containment.

In order to evaluate this accide , a range of rupture sizes from small leaks up to the complete severance of a 36-in. ID reactor coolant system line has been evaluated. A detailed core cooling analysis has been performed for a wide spectrum of breaks in the Safety Analysis Report.

A double-ended rupture of a hot leg, 14.1 sq ft, is assumed in this analysis. This postulated accident causes the most severe transient for the reactor and ECCS systems. All engineered safeguard equipment are assumed to function normally.

The fission product release to the containment vessel was assumed to be the total core gap activity. Of this release, 100 per cent of the noble gases and 50 percent of the iodines were assumed to be airborne, i.e., 50 percent of the iodines released was assumed to plate out within the containment vessel. A reduction factor for spray removal of 3.33 in the contribution of inorganic iodines to the 0-2 hr thyroid dose was assumed.

The activity released from the containment vessel was then calculated for a leak rate which is a function of the containment pressure. The functional form of the leak rate was assumed to be:

$$Lt = La \left(\frac{Pt}{Pa}\right)^{1/2}$$

Where Lt is the leak rate at time t,

Pt is the pressure at time t,

Pa is the peak containment pressure,

and La is the leak rate corresponding to the pressure Pa.

Based on the test results from the leak rate tests of various containment vessels, a realistic value of 0.05 weight percent per day was used for La.

The leakage from the containment vessel enters the shield building and penetration rooms which in the event of a LOCA are maintained at a negative pressure by the emergency ventilation system. All activity discharged to the environment passes through HEPA and tandem charcoal filters. The overall removal efficiency of the charcoal filters for iodine is assumed to be 99%. The emergency ventilation system has 16,000 CFM blower capability, i.e., two redundant 8,000 CFM systems. Of this total capability, only 3,000 CFM is estimated to be required to maintain the shield building at a negative pressure. The additional 13,000 CFM is used in the recirculation mode. This acts as a high efficiency clean up loop for the shield building.

In order to account for nonuniform mixing, the effective volume of the shield building atmosphere was taken to be one half the actual volume.

8.8.13.2 Discussion of Results

The design basis accident selected for emergency core cooling equipment sizing is based on reactor conditions at a power level of 2,772 MWt. The moderator temperature coefficient is expected to be zero or negative over the lifetime of the core. However, this analysis conservatively uses a positive moderator coefficient which places a more stringent requirement on emergency core cooling equipment. The analysis of core cooling during a loss-of-coolant accident is based upon the following conservative conditions:

1. End-of-life fuel temperatures.
2. A void shutdown (for cases where control rod insertion will be impeded by higher than normal core pressure drop during the blowdown) including the positive reactivity effects from initial void formation when a moderator coefficient of $+0.5 \times 10^{-4}$ $\Delta k/k/F$ is assumed.

3. The hot spot power generation is a factor of 3.28 times the average.

4. Instantaneous rupture of the pipe.

Figure 8-4 shows the hot spot clad temperature transient. All cases have a nominal clad surface heat transfer coefficient. Heat removal is zero until the effect of injection cooling is simulated. An h (heat transfer coefficient) of 40 provides fast cooling. The value of 40 is realistic for film boiling in a pool, the probable heat transfer mode for the submerged portion of the core.

The clad hot spot temperature excursion is terminated at 2,069 F. Only a minute amount (less than 1 percent) of zirconium-water reaction occurs, and the maximum temperature is at least 1,281 F below the clad melting point.

A loss-of-coolant accident is not expected to occur.

8.8.13.3 Environmental Consequences

The environmental consequences of this accident were evaluated using the source activities given in Table 8A-6 of Appendix 8A. The dose calculational methods used in the evaluation are shown in Appendix 8B. The table below and Table 8-1 summarize the environmental consequences of the occurrence by listing the dose to an individual at the site boundary and the total population dose within a 50 mile radius of the reactor site.

TABLE

TIME	SITE BOUNDARY DOSE (mRem)		POPULATION DOSE (Man-Rem)
	THYROID	WHOLE BODY	
0-2 Hrs.	9.9×10^{-2}	6.5×10^{-2}	3.6×10^{-2}
2-24 Hrs.	0.57	1.2	.99
1-30 Days	0.35	0.78	5.9

8.8.14 REACTOR COOLANT LEAKAGE

8.8.14.1 Accident Discussion

It is assumed that a 10 GPM reactor coolant leak to the containment vessel has occurred during rated power operation. In response to the 10 GPM leak, the reactor coolant system will exhibit a slight loss in pressure with a subsequently small decrease in pressurizer level. The slowly decreasing pressurizer level will initiate a demand for increased reactor coolant system makeup flow. The increase in makeup flow will approach the 10 GPM reactor coolant leak rate and thus stabilize the pressurizer level.

Since reactor coolant system makeup flow is operating at approximately 10 GPM greater than the return flow to the makeup tank, the water level in the makeup tank will reach the low level set point and initiate the makeup tank low level alarm on the reactor console.

Upon receiving the makeup tank low level alarm, the operator will check the makeup tank level chart recorder and determine the presence and approximate flow rate of the reactor coolant system leakage. After this procedure is completed, the operator will run the station back to the hot shutdown condition.

If repairs cannot be completed within 10 hours, the operator will initiate a reactor coolant system cooldown and depressurization. After an additional 15.3 hours, the reactor coolant system will be at cold shutdown conditions, thus terminating the reactor coolant system leakage.

8.8.14.2 Discussion of Results

Following reactor runback to the hot shutdown condition, the core remains subcritical for the duration of the accident, and no reactor core fuel damage or additional loss of reactor coolant system integrity occurs. Assumptions and reactor coolant leakage for the analysis are given in the following Table.

Assumptions and Leakage Resulting for 10 GPM R.C. Leak

Makeup tank initially operating at	Normal level
Normal reactor coolant system makeup flow rate	70 GPM
Reactor coolant released to building until makeup tank low level alarm is received at 1.5 hr	5200 lb
Reactor coolant released to building during assumed 0.2 hr operator action period	900 lb
Reactor coolant released to the building during the 10.0 hr investigation period	38000 lb
Reactor coolant released to the building during the 15.3 hr cooldown period	39000 lb
Total reactor coolant released to the building for the duration (27 hrs) of the accident	83100 lb

8.8.14.3 Environmental Consequences

The environmental consequences of this accident were evaluated using the source activities given in Table 8A-2 of Appendix 8A. The dose calculational methods used in the evaluation are shown in Appendix 8B and use the same reactor building leak rate as was used in the evaluation of events that release radioactivity into the reactor coolant system. The Table below and Table 8-1 summarize the environmental consequences of the occurrence by listing the dose to an individual at the site boundary and the total population dose within a 50 mile radius of the reactor site.

Table

Path	Site Boundary Dose (mRem)		Population Dose (Man-Rem)
	Thyroid	Whole Body	
Release to atmosphere via Containment Purge (16,000 CFM, filtered)	1.1×10^{-2}	4.0×10^{-2}	3.3×10^{-2}

8.8.15 WASTE GAS DECAY TANK RUPTURE

8.8.15.1 Description of Accident

Although the rupture of a waste gas decay tank is considered to be a very improbable event, the rupture of this tank would release more radioactivity to the environment than any other credible radwaste system accident. The rupture of a waste gas decay tank would release the entire contents of the tank to the auxiliary building atmosphere.

A waste gas tank rupture is not expected to occur during the station lifetime.

8.8.15.2 Results of Accident

The hypothesized accident releases all of the noble gas inventory and 1% of the iodine inventory of a waste gas decay tank to the atmosphere as a puff-release. The iodine release is only 1% of the tank inventory because the charcoal filters in the auxiliary building exhaust ventilation will provide a DF of at least 100.

8.8.15.3 Environmental Consequences

The environmental consequences of this accident were evaluated using the source activities given in Table 8A-7 of Appendix 8A. The dose calculational methods used in the evaluation are shown in Appendix 8B. The Table below and Table 8-1 summarize the environmental consequences of the occurrence by listing the dose to an individual at the site boundary and the total population dose within a 50 mile radius of the reactor site.

Table

Path	Site Boundary Dose (mRem)		Population Dose (Man-Rem)
	Thyroid	Whole Body	
To Atmosphere via Auxiliary Building Ventilation (16,000 CFM, Filtered)	2.4×10^{-4}	14.4	8.0

8.8.16 RUPTURE OF CLEAN WASTE RECEIVER TANK

8.8.16.1 Accident Discussion

The two clean waste receiver tanks are located in separate rooms. Entrance or pipe penetrations into these rooms are above the flood level due the rupture or a tank. Therefore, all the liquids released from this tank are contained in the seismic class I auxiliary building. Water in this tank has been degassed prior to its storage, therefore, there are no significant amount of gases except for nitrogen used for blanketing and traces of other radioactive gases that may have escaped degasification. These escaped gases are released through the station vent via the auxiliary building ventilation system.

8.8.16.2 Environmental Consequences

There is no activity release and thus no environmental consequences due to rupture of a clean waste receiver tank.

8.8.17 RUPTURE OF PRIMARY WATER STORAGE TANK

8.8.17.1 Accident Discussion

The primary water storage tank contains reactor coolant system water which has been processed through the clean liquid radwaste system. The water that has been processed through the radwaste system and has been monitored for radioactivity is stored in this tank either for reuse or for controlled release. Except for tritium, which cannot be removed by any purification process, this tank does not contain any other radioactivity. Over a period of time, due to recycle, this tank will contain the same level of tritium that in the reactor coolant system, which will be of the order of 0.4 μc/ml. Since this tank is located outdoors, its rupture would result in water flow into the station storm drains which discharge into the Toussaint River. There are no potable water intakes from this river. Based on the conservative assumptions, the dose to the people living near the edge of this river was calculated.

8.8.17.2 Environmental Consequences

The environmental consequences of this accident were evaluated using the equilibrium tritium level discussed above. The dose calculational methods used in the evaluations are shown in Appendix 8B. The dose to an individual living along the edge of Toussaint River was calculated to be 1.2 mRem.

8.8.18 BORATED WATER STORAGE TANK RUPTURE

8.8.18.1 Accident Discussion

The borated water storage tank is also an outdoor tank. This tank is designed to withstand a design basis earthquake which makes its rupture more improbable than the primary water storage tank. Tornado missiles can damage the tank but complete rupture is highly improbable. Although this tank will contain over 3 times as much water as the primary water storage tank, the average tritium concentration would be lower. As in the case of the rupture of the primary water storage tank, a rupture of the borated water storage tank will also spill water into the station storm drains which drain into the Toussaint River.

A complete rupture of this tank is not expected to occur during the station's lifetime.

8.8.18.2 Environmental Consequences

The same assumptions as used for the rupture of the primary water storage tank were used in this analysis. The environmental consequences of this accident were evaluated using an equilibrium tritium level of 0.3 μc/ml in the tank. The dose calculational methods used in the evaluation are shown in Appendix 8B. The dose to an individual living along the edge of the Toussaint River was calculated to be 2.28 mRem.

8.9 SUMMARY

In this section, various accidents and/or occurrences, as specified in the AEC Guide, "Scope of Applicants' Environmental Reports with Respect to Transportation, Transmission Lines and Accidents," September 1, 1971 have been analyzed. Table 8-1 summarizes the consequences of each accident and occurrence. The dose at the site boundary due to any of these accidents and/or occurrences is well below the 10 CFR 20 limits. No activities in the environs will be affected and no economic losses would occur. The resultant individual and population doses are so small that the risk of an accident does not constitute a significant environmental effect.

TABLE 8-1

No. of Class	Description of Accident	Site Boundary Dose (mRem) Thyroid	Site Boundary Dose (mRem) Whole Body	Population Dose Within 50 Mile Radius of Reactor (Man-Rem)
2	a. 2 Gallon Spill	8.3×10^{-2}	3.3×10^{-3}	0.0018
	b. 10 GPD Leakage of Reactor Coolant	2.8×10^{-4}	1.1×10^{-2}	0.14
3	a. Heat Exchangers Leaks	5.8×10^{-5}	2.2×10^{-2}	0.012
	b. Uncontrolled Release of Contents of a Gas Decay Tank	1.6×10^{-4}	9.7	8.0
	c. Failure of Pump to Shutoff		* 1.8×10^{-2}	
4	a. 100 GPD Reactor Coolant Leak into Containment, 0.1% failed fuel	7.4×10^{-3}	2.7×10^{-2}	0.21
	b. 100 GPD Reactor Coolant Leak into Containment, 1.0% failed fuel	7.4×10^{-2}	2.7×10^{-1}	2.1
5	a. 100 GPD Steam Generator Leak, 0.1% failed fuel	1.7×10^{-3}	0.18	1.37
	b. 100 GPD Steam Generator Leak 1.0% failed fuel	1.7×10^{-2}	1.8	13.7
	c. 720 GPD Steam Generator Leak 0.1% failed fuel	1.2×10^{-2}	1.3	9.9
6	Refueling Accident Inside Containment	5.0×10^{-2}	2.4	1.6
7	Accident to Spent Fuel Outside Containment	6.1×10^{-2}	2.9	1.6
8	a. Rupture of Reactor Coolant Pipe 1. Small Leakage, 10 gpm	1.1×10^{-2}	4.0×10^{-2}	0.033

TABLE 8-1 (Continued)

No. of Class	Description of Accident	Site Boundary Dose (mRem) Thyroid	Site Boundary Dose (mRem) Whole Body	Population Dose Within 50 Mile Radius of Reactor (Man-Rem)	
	2. Loss of Coolant Accident				
	(LOCA) 0- 2 hour	9.9×10^{-2}	6.5×10^{-2}	0.036	
	2-24 hour	0.57	1.2	0.99	
	1-30 days	0.35	0.78	5.9	
	b. Steam Line Rupture	0.51	3.6×10^{-3}	0.0046	1
	c. Steam Generator Tube Rupture	1.7×10^{-2}	1.1	0.59	1
	d. Steam Line Leak, 10 GPM	7.4×10^{-5}	0.11	1.4	
	e. Loss of Electric Load	1.3×10^{-2}	6.0×10^{-5}	3.3×10^{-5}	
	f. Rod Ejection Accident				
	0- 2 hour	1.0×10^{-5}	5.6×10^{-5}	3.1×10^{-5}	
	2-24 hour	5.5×10^{-2}	1.0×10^{-3}	0.00083	
	1-30 days	2.9×10^{-5}	4.6×10^{-4}	0.0035	1
	g. Rupture of Gas Decay Tank	2.4×10^{-4}	14.4	8.0	
	h. Rupture of Primary Water Storage Tank		* 1.2		
	i. Rupture of Borated Water Storage Tank		* 2.28		

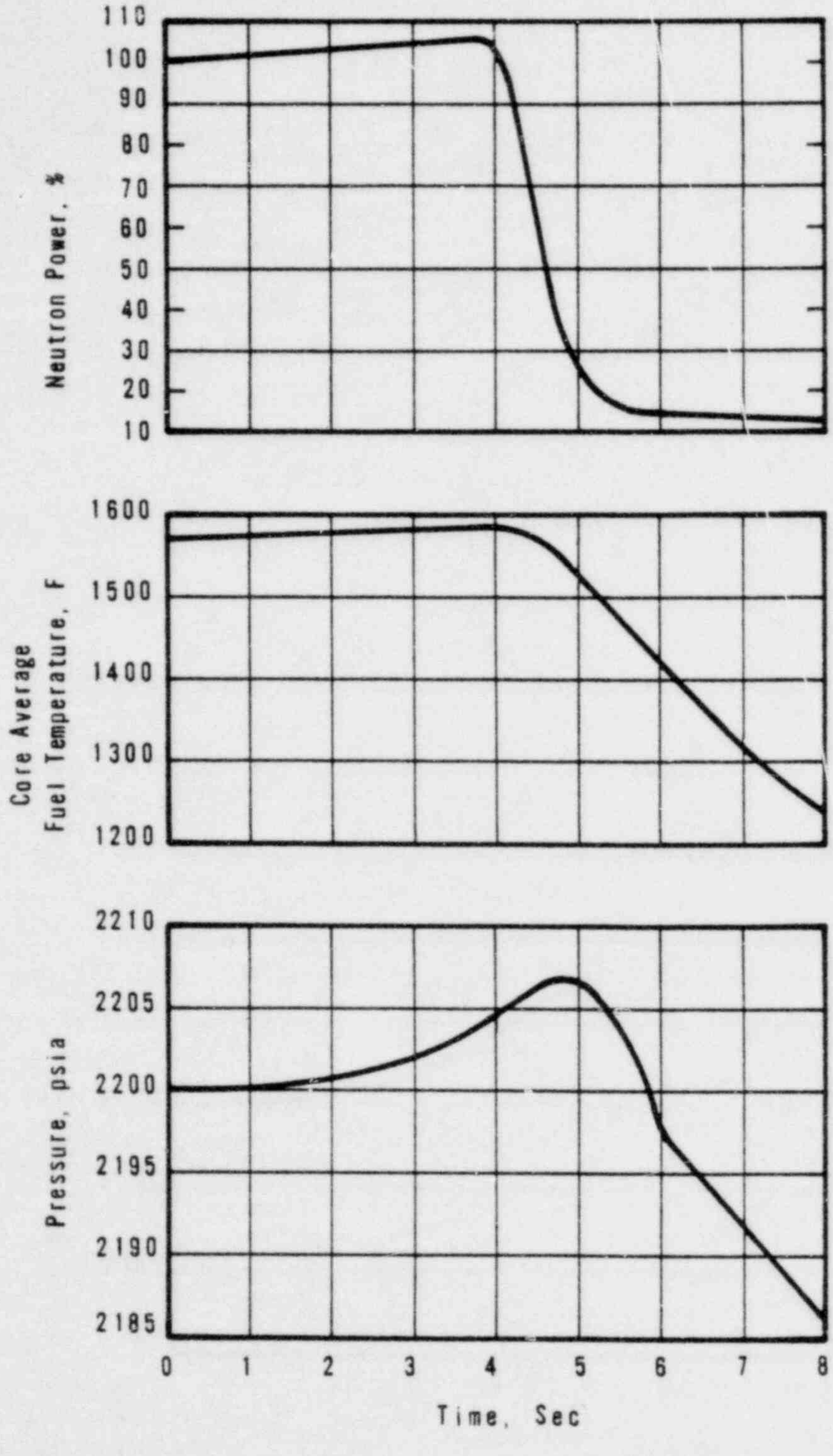
* Whole body dose to an individual living along the edge of the Toussaint River due to inhalation of tritium.

8.10 REFERENCES

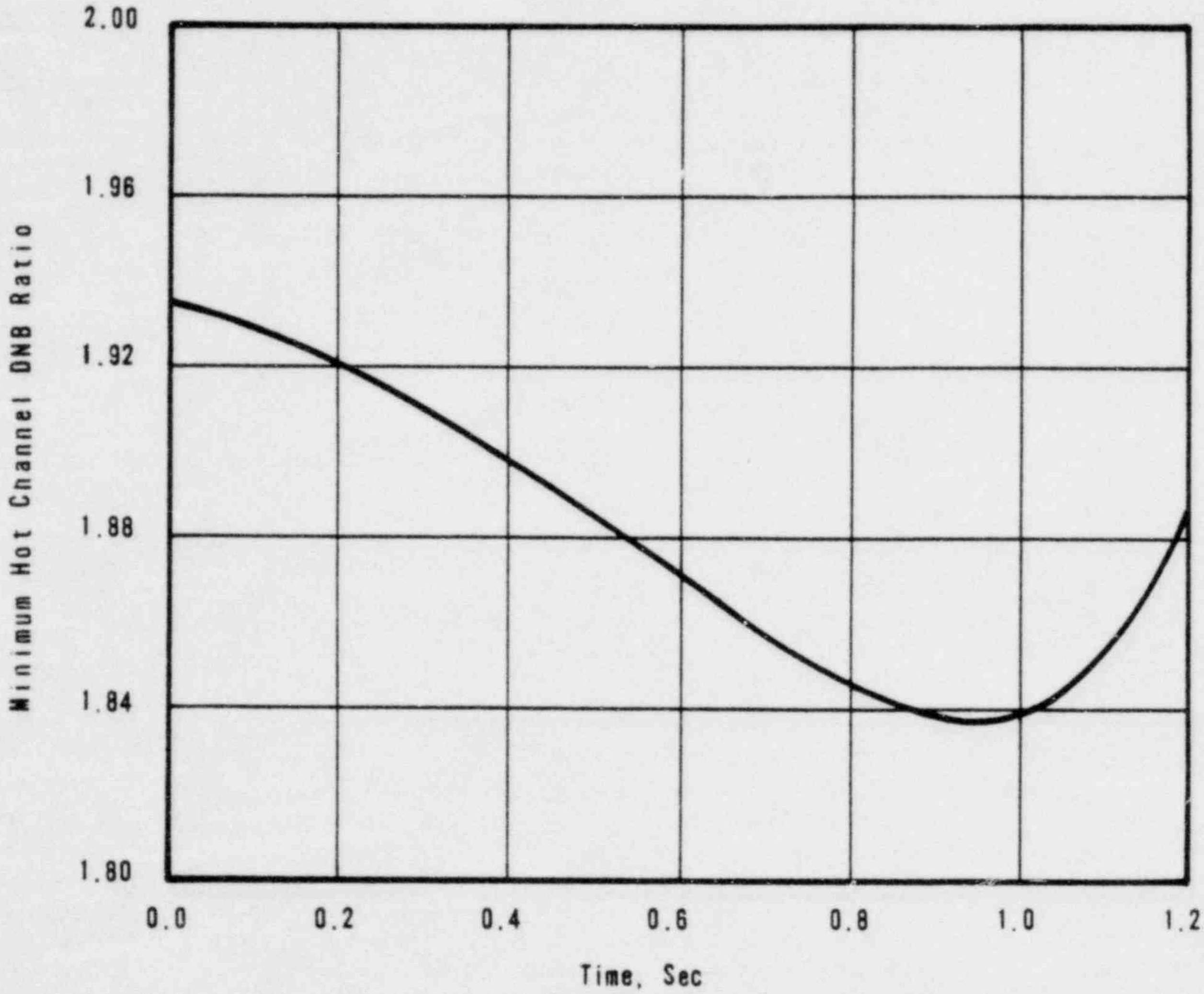
1. Diffey, H. R., et al., "Iodine Cleanup in a Steam Suppression System", International Symposium on Fission Product Release and Transport Under Accident Conditions, Oak Ridge, Tennessee, CONF-65047, Vol. 2, pp 776 - 804 (1965).

2. Barthoux, A. J., et al., "Diffusion of Active Iodine Through Water, With the Iodine Being Liberated in CO_2 Bubbles at High Temperatures, "AEC-TR-6149, June 1962.

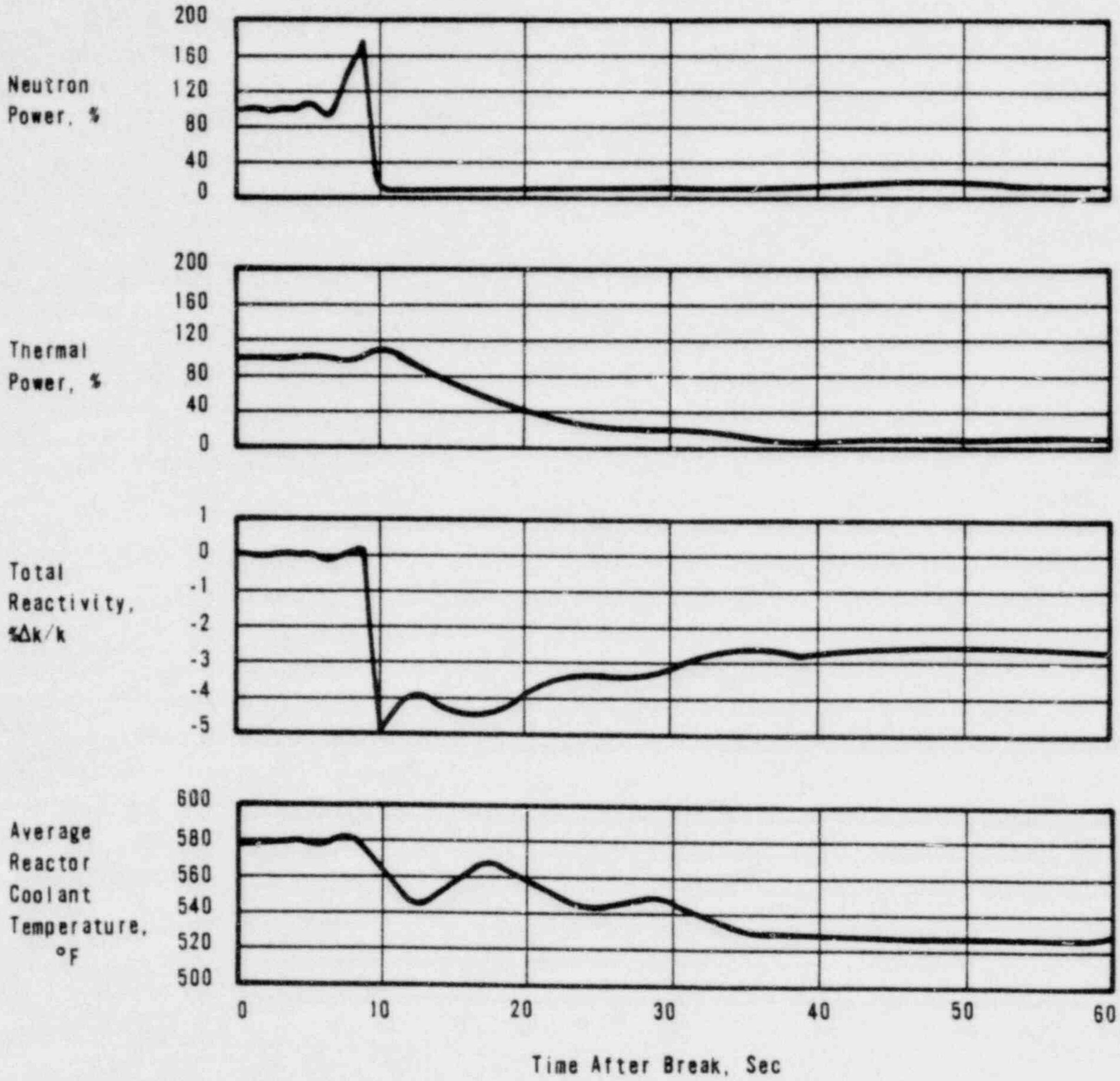
3. Eggleton, A. E. J., "A Theoretical Examination of Iodine-Water Partition Coefficients", AERE-R-4887, February 1967.



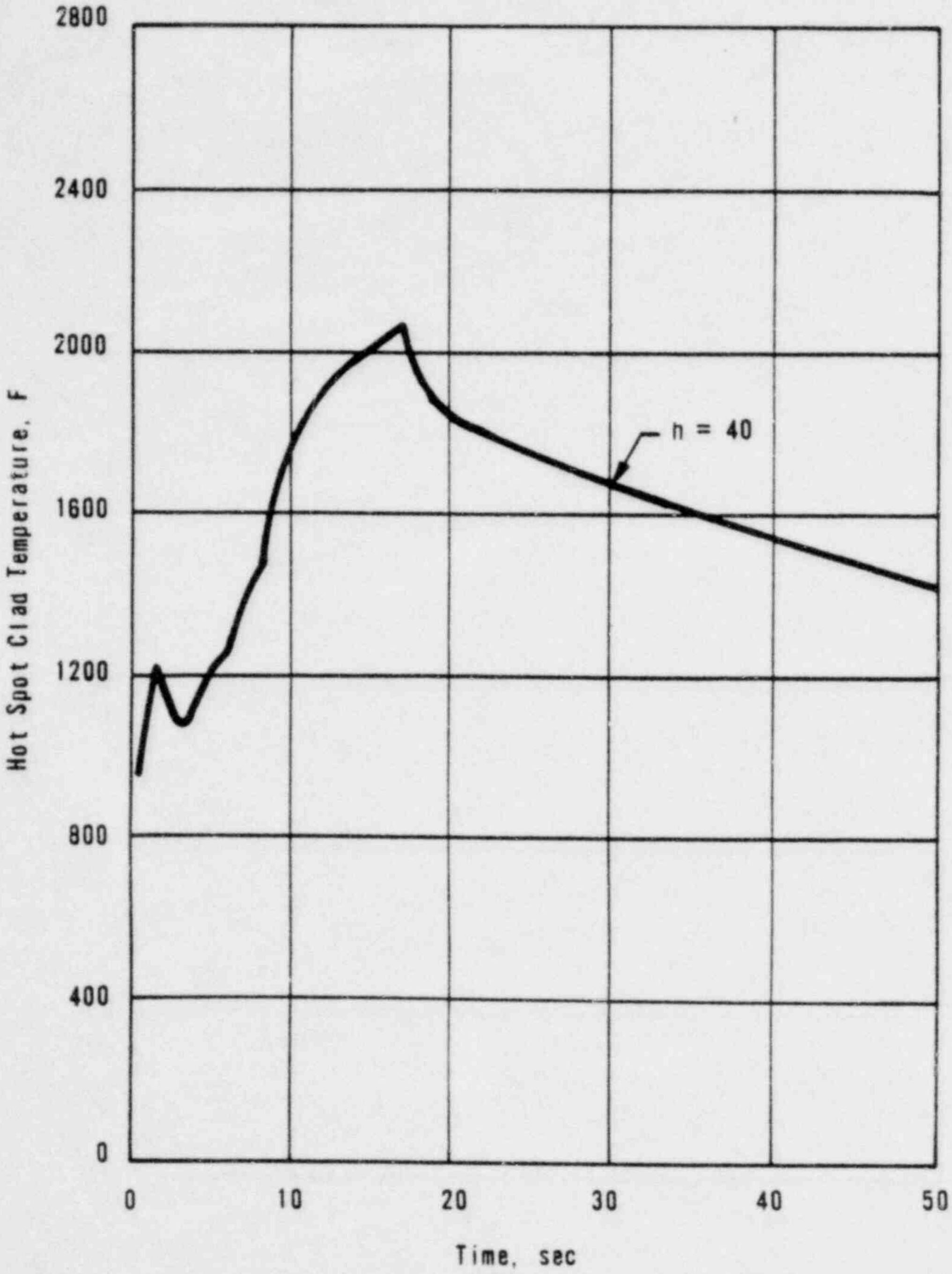
DAVIS-BESSE NUCLEAR POWER STATION
STATION PARAMETERS VERSUS TIME FOR A ROD
WITHDRAWAL FROM RATED POWER
FIGURE 8-1



DAVIS-BESSE NUCLEAR POWER STATION
DNBR VERSUS TIME FOR A TWO PUMP
COASTDOWN FROM RATED POWER
FIGURE 8-2



DAVIS-BESSE NUCLEAR POWER STATION
DOUBLE-ENDED RUPTURE OF 36-IN. STEAM
LINE BETWEEN STEAM GENERATOR AND
STEAM STOP VALVE
(WITH FEEDWATER ISOLATION)
FIGURE 8-3



DAVIS-BESSE NUCLEAR POWER STATION
HOT SPOT CLAD TEMPERATURE VERSUS TIME
FOR A 36-IN. ID DOUBLE ENDED HOT LEG RUPTURE
FIGURE 8-4

APPENDIX 8A

APPENDIX 8A

1 ACTIVITY SOURCES USED IN ACCIDENT ANALYSIS SECTION

The bases used to establish the specific activity of the radioactive sources used in the accident analyses are presented in this appendix along with a tabular summary of the activity of the significant isotopes for each basic source.

1.1 REACTOR COOLANT ACTIVITIES

The accumulation of activity in the reactor coolant has been computed assuming:

a. Base loaded operation at a power of 2772 MWt, which is the maximum rated power for B&W cores with 177 fuel elements.

b. No fission product leakage during the first 433 day core cycle nor the second 292 day core cycle.

c. At the start of and throughout the third core cycle, fission products leak from the fuel through cladding failures. All cladding failures and thus all fission product leakage is assumed to occur in only high burnup fuel, fuel that has been irradiated during the first two core cycles. Using this basis, the assumption of 0.1% failed fuel (0.1% of the fuel pins in the core have clad failures) is equivalent to leaking fission products from 0.3% of the high burnup fuel pins which have two previous cycles of irradiation.

d. The fission product activity in the reactor coolant is calculated with a digital computer code that solves the rate equations for the fission product buildup in the fuel, leakage into the coolant, and removal from the coolant by purification processes. The fission product activity calculation considers 178 isotopes in

70 decay chains, with a maximum chain length of 5 isotopes. The code calculates the isotopic activities considering the production by direct fission, the loss due to "burnup" (neutron activation), and the net effect of radioactive decay of the isotope and its "parent". Estimates indicate that about two- thirds of the fissions occur in U-235 and one-third in Pu-239, and the appropriate fission yields were used in the calculations.

e. The fission product isotopes in the fuel leak into the reactor coolant throughout the third cycle. The leak rates for each isotope are shown in Table 8A-1, in the form of "escape rate coefficients" (Sec^{-1}). The escape rate coefficients for the most important elements were determined from experiments using purposely defected fuel cladding [1,2,3,4]. The values of the escape rate coefficient for elements of lesser importance were estimated based on the chemical similarity with elements for which the escape rate coefficient was experimentally determined.

f. The reactor coolant purification system is assumed to operate at its normal flow rate of one reactor coolant system volume per day with a 99% removal efficiency for all isotopes except Mo, Y, Cs, Kr, Xe, and ^3H which are assumed to have a decontamination factor (DF) of unity. Since tellurium decay is the major source of iodine activity and since tellurium is known to rapidly plate-out on reactor coolant system surfaces, [5,6] the calculations assume that all the tellurium remains in the reactor coolant system and serves as a source of iodine.

g. The average bleed flow rate required to decrease the boron concentration at the proper rate is assumed to be processed to provide the DF's indicated in the following table:

	0-280 Days	281-292 Days
Kr, Xe	10^5	1
Mo, Y, Cs	∞	500
^3H	1	1
All others	∞	10

h. Tritium is produced during any core cycle by three major processes: ternary fission, neutron activation of boron, and neutron activation of lithium. The tritium activity in the reactor coolant due to neutron activation of lithium is based on 2 ppm of lithium (99.9% Li^7 and 0.1% Li^6) in the reactor coolant. The lithium is added to the reactor coolant for pH control, and 2 ppm Li corresponds to the maximum recommended lithium concentration. The tritium activity in the coolant due to activation of boron is based on a constantly decreasing boron concentration throughout the cycle. Since the initial cycle and the equilibrium cycle have different boron concentrations versus lifetime, the amount of tritium produced during these two cycles will be significantly different. Of the tritium produced by ternary fission, only a small fraction escapes from the fuel and enters the coolant: 1% by diffusion through the Zircaloy cladding and 0.1% leaking from fuel with cladding defects or failures. All tritium which enters the reactor coolant is expected to become rapidly associated with water molecules (T-O-H).

i. The corrosion product activity in the reactor coolant are based on extrapolating operating data from a similar PWR[7].

The results of the computed fission product activity in the reactor coolant are summarized in Tables 8A-1 and 8A-3 for 0.1% and 1.0% failed fuel. The rate of tritium addition to the reactor coolant is given in Table 8A-4, for both the initial cycle and the equilibrium cycle. The corrosion product activity in the reactor coolant is given in Table 8A-5.

1.2 GAP ACTIVITIES

The fission product activity in the gap between the fuel pellets and the cladding is calculated using the same computer code and the same bases (item 1-5) as was used to calculate the reactor coolant activities. The only difference between the two calculations is: (1) the fission products leak from the fuel to the gap instead of from the fuel to the coolart and (2) there is no removal by purification systems. Table 8A-6 lists the gap activities in the core at the end of the third core cycle (1017 day at 2772 MWt) and after 3, 50 and 120 days of decay.

1.3 WASTE GAS DECAY TANK ACTIVITY

The fission product activity in the waste gas decay tank was calculated assuming that all of the Kr and Xe and 1% of the iodine in the reactor coolant at the end of the third core cycle are removed from the coolant and stored in one waste gas decay tank. The basis of the 1% the iodine is that the reactor coolant must pass through the purification demineralizers before it is degassed, and the purification demineralizers provide a DF of 100 for iodine.*

Table 8A-7 lists the isotopic inventory of Kr, Xe, and iodine in the waste gas decay tank at the end of the third cycle; they neglect any decay that would occur during the degassing period or during storage. Table 8A-7 is based on the 292 day coolant activities in Table 8A-2 (0.1% failed fuel).

*(An additional DF will be obtained by the liquid-gas partitioning of iodine in the degasifer, evaporator, or storage tanks, but this DF has been neglected in preparing Table 8A-7).

1.4 REFERENCES

1. P.W. Frank, et al., Radiochemistry of Third PWR Fuel Material Test - X-1 Loop NRX Reactor, WAPD-TM-29. Feb. 1957.
2. J.D. Eichenberg, et al., Effects of Irradiation of Bulk UO_2, WAPD-183, Oct. 1957.
3. G.M. Allison and R. F. S. Robertson, The Behavior of Fission Products in Pressurized-Water Systems -- A Review of Defect Tests on UO_2 Fuel Elements at Chalk River, AECL-1338 (1961)
4. G.M. Allison and H.K. Roe, the Release of Fission Gases and Iodines From Detected UO_2 Fuel Elements of Different Lengths, AECL-2206, June 1965.
5. J.K. Dawson, et al., Chemical Aspects of Nuclear Reactors, Butterworths, London (1963), pp 352-4.
6. P.W. Frank, Calculation of Fission Product Activity in PWR Fron a Seed Plate Failure, WAPD-TM-83, Nov. 1957.
7. NACE, 1969 Conference Preprint, "Chemistry and Waste Management at the Connecticut Yankee Atomic Power Plant," p 21.

TABLE 8A-1

Escape Rate Coefficients

Nuclide	Coefficients
Kr, Xe	6.5×10^{-8}
Br, I, Cs, Rb	1.3×10^{-8}
Te, Se, Pd, Ag, Sb, Cd, In, Sn	1.0×10^{-9}
Mo, Nb, Tc, Ru, Rh	2.0×10^{-9}
Sr, Ba	1.0×10^{-11}
Y, La, Ce, Pr, Zn, Nd, Sm, Eu	1.6×10^{-12}

TABLE 8A-2

TOLEDO (NSS-14)
REACTOR COOLANT FISSION PRODUCT ACTIVITY IN µCi/cc (of Hot Coolant)
THIRD CYCLE - 2772 MWt - 0.1% FAILED FUEL

TIME, DAYS

Isotope	2	4	10	30	60	100	150	200	240	260	281	292
Kr-83m	0.020	0.020	0.021	→	→	→	→	→	→	→	→	→
Kr-85m	.11	→	→	→	→	→	→	→	→	→	→	→
Kr-85	.021	.038	.10	.29	.52	.72	.83	.78	.62	.48	.28	.33
Kr-87	.059	.059	.060	→	→	→	→	→	→	→	→	→
Kr-88	.19	.19	.20	→	→	→	→	→	→	→	→	→
Rb-88	0.19	→	→	→	→	→	→	→	→	→	→	→
Sr-89	2.5(-4)	2.8(-4)	2.9(-4)	3.0(-4)	3.2(-4)	3.2(-4)	3.2(-4)	→	→	→	→	→
Sr-90	1.2(-5)	1.3(-5)	1.4(-5)	1.4(-5)	1.5(-5)	1.6(-5)	1.6(-5)	1.7(-5)	1.8(-5)	1.8(-5)	1.9(-5)	1.9(-5)
Sr-91	2.0(-3)	→	→	→	→	→	→	→	→	→	→	→
Sr-92	6.2(-4)	→	→	→	→	→	→	→	→	→	→	→
Y-90	8.5(-6)	2.2(-5)	8.7(-5)	3.4(-4)	7.0(-4)	1.1(-3)	1.5(-3)	1.7(-3)	1.5(-3)	1.3(-3)	8.1(-4)	3.7(-4)
Y-91	1.2(-4)	2.4(-4)	6.5(-4)	1.8(-3)	3.0(-3)	4.0(-3)	4.3(-3)	4.2(-3)	3.7(-3)	3.1(-3)	2.2(-3)	1.2(-3)
Mo-99	.027	.073	.21	.29	→	→	→	.27	.27	.26	.26	.21
Xe-131m	.013	.022	.049	.10	.15	.16	.16	.15	.14	.13	.11	.14
Xe-133m	.011	.044	.15	.20	.20	.20	.20	.20	.19	.19	.18	.20
Xe-133	.87	2.0	7.2	16.4	17.8	17.7	17.6	17.3	16.7	15.8	14.3	17.4
Xe-135m	.062	.064	.066	→	→	→	→	→	→	→	→	→
Xe-135	.30	.34	.36	→	→	→	→	→	→	→	→	→
Xe-138	.036	.036	.037	→	→	→	→	→	.036	.036	.036	.037
I-131	.076	.10	.16	.22	.23	→	→	→	→	→	→	→
I-132	.025	.052	.11	.16	→	→	→	→	→	→	→	→
I-133	.18	.25	.27	→	→	→	→	→	→	→	→	→
I-134	.033	→	→	→	→	→	→	→	→	→	→	→
I-135	.13	.14	→	→	→	→	→	→	→	→	→	→
Cs-134	.004	.0075	.020	.061	.12	.18	.23	.24	.21	.18	.11	.054
Cs-136	.0028	.0053	.014	.036	.050	.053	.053	.051	.047	.043	.036	.024
Cs-137	.040	.075	.20	.61	1.2	1.8	2.3	2.4	2.1	1.8	1.1	.54
Cs-138	.052	.052	.053	→	→	→	→	→	.052	→	→	→
Ba-137m	.040	.070	.19	.56	1.1	1.6	2.1	2.2	2.0	1.6	1.)	0.50
Ba-139	5.4(-3)	→	→	→	→	→	→	→	→	→	→	→
Ba-140	2.0(-4)	2.4(-4)	2.9(-4)	3.6(-4)	3.9(-4)	4.0(-4)	→	→	→	→	→	→
La-140	6.5(-5)	8.8(-5)	1.1(-4)	1.4(-4)	1.6(-4)	→	→	→	→	→	→	→
Ce-144	3.7(-5)	4.2(-5)	4.3(-5)	4.4(-5)	4.5(-5)	4.6(-5)	4.7(-5)	4.7(-5)	4.8(-5)	→	→	→
Average Effective Puri. Rate*	1.17(-5)	1..7(-5)	1.16(-5)	→	→	→	→	→	→	→	→	1.17(-5)
Average Effective Bleed Rate*	9.09(-7)	8.86(-7)	3.86(-8)	4.14(-8)	4.54(-8)	5.38(-8)	6.74(-8)	9.55(-8)	1.52(-7)	2.49(-7)	4.35(-7)	1.14(-6)

* Vol. fraction per sec.

TABLE 8A-3

TOLEDO (NSS-14)
REACTOR COOLANT FISSION PRODUCT ACTIVITY IN µCi/cc (of Hot Coolant)
THIRD CYCLE - 2772 MWt - 1% FAILED FUEL

TIME, DAYS

Isotope	2	4	10	30	60	100	150	200	240	262	231	232
Kr-83m	0.20	0.21	0.21	→	→	→	→	→	→	→	→	→
Kr-85m	1.1	→	→	→	→	→	→	→	→	→	→	→
Kr-85	0.21	0.38	1.0	2.9	5.2	7.2	8.3	7.8	6.2	4.8	2.8	3.3
Kr-87	0.59	0.59	0.60	→	→	→	→	→	→	→	→	→
Kr-88	1.9	1.9	2.0	→	→	→	→	→	→	→	→	→
Rb-88	1.9	→	→	→	→	→	→	→	→	→	→	→
Sr-89	2.5(-3)	2.8(-3)	2.9(-3)	3.0(-3)	3.2(-3)	3.2(-3)	→	→	→	→	→	→
Sr-90	1.2(-4)	1.3(-4)	1.4(-4)	1.4(-4)	1.5(-4)	1.6(-4)	1.6(-4)	1.7(-4)	1.8(-4)	1.8(-4)	1.9(-4)	1.9(-4)
Sr-91	2.0(-2)	→	→	→	→	→	→	→	→	→	→	→
Sr-92	6.2(-3)	→	→	→	→	→	→	→	→	→	→	→
Y-90	8.5(-5)	2.2(-4)	8.7(-4)	3.4(-3)	7.0(-3)	1.1(-2)	1.5(-2)	1.7(-2)	1.5(-2)	1.3(-2)	8.1(-3)	3.7(-3)
Y-91	1.2(-3)	2.4(-3)	6.5(-3)	1.8(-2)	3.0(-2)	4.0(-2)	4.3(-2)	4.2(-2)	3.7(-2)	3.1(-2)	2.2(-2)	1.2(-2)
Mo-99	0.27	0.73	2.1	2.9	→	→	→	2.7	2.7	2.6	2.6	2.1
Xe-131m	0.13	0.22	0.49	1.0	1.5	1.6	1.6	1.5	1.4	1.3	1.1	1.4
Xe-133m	0.11	0.44	1.5	2.0	2.0	2.0	2.0	2.0	1.9	1.9	1.8	2.0
Xe-133	8.7	20	72	164	178	177	176	173	167	158	143	174
Xe-135m	0.62	0.64	0.66	→	→	→	→	→	→	→	→	→
Xe-135	3.0	3.4	3.6	→	→	→	→	→	→	→	→	→
Xe-138	0.36	0.36	0.37	→	→	→	→	→	0.36	0.36	0.36	0.37
I-131	0.76	1.0	1.6	2.2	2.3	→	→	→	→	→	→	→
I-132	0.25	0.52	1.1	1.6	→	→	→	→	→	→	→	→
I-133	1.8	2.5	2.7	→	→	→	→	→	→	→	→	→
I-134	0.33	→	→	→	→	→	→	→	→	→	→	→
I-135	1.3	1.4	→	→	→	→	→	→	→	→	→	→
Cs-134	0.04	0.075	0.20	0.61	1.2	1.8	2.3	2.4	2.2	1.8	1.1	0.54
Cs-136	0.028	0.053	0.14	0.36	0.50	0.53	0.53	0.51	0.47	0.43	0.36	0.24
Cs-137	0.40	0.75	2.0	6.1	12.	18.	23.	24.	21.	18.	11.	5.4
Cs-138	0.52	0.52	0.53	→	→	→	→	→	0.52	→	→	→
Ba-137m	0.40	0.70	1.9	5.6	11.	16.	21.	22.	20.	16.	10.	5.0
Ba-139	5.4(-2)	→	→	→	→	→	→	→	→	→	→	→
Ba-140	2.0(-3)	2.4(-3)	2.9(-3)	3.6(-3)	3.9(-3)	4.0(-3)	→	→	→	→	→	→
La-140	6.5(-4)	8.8(-4)	1.1(-3)	1.4(-3)	1.6(-3)	→	→	→	→	→	→	→
Ce-144	3.7(-4)	4.2(-4)	4.3(-4)	4.4(-4)	4.5(-4)	4.6(-4)	4.7(-4)	4.7(-4)	4.8(-4)	→	→	→
Average Effective Puri. Rate*	1.17(-5)	1.17(-5)	1.16(-5)	→	→	→	→	→	→	→	→	1.17(-5)
Average Effective Bleed Rate*	9.09(-7)	8.86(-7)	3.86(-8)	4.14(-8)	4.54(-8)	5.38(-8)	6.74(-8)	9.55(-8)	1.52(-7)	2.49(-7)	4.35(-7)	1.14(-6)

* Vol. fraction per sec.

TABLE 8A-4

Rate of Tritium Addition to Reactor Coolant

Source of Tritium	Initial Cycle Curies/Cycle	Equilibrium Cycle (Curies/Cycle)
Ternary Fission*	172	118
Boron Activation	235	132
Lithium Activation	141	96
Total Tritium Activity	548	346

* (1% Diffusion through clad plus 0.1% defective fuel)

TABLE 8A-5

Corrosion Product Acitvity in Reactor Coolant

Basis: The corrosion product activity is based on each cc of hot reactor coolant containing 0.1 mg of crud.

Corrosion Product	Half-Life	Activity μCi/cc
Co-58	71.3d	0.0091
Co-60	5.3y	0.0049
Cr-51	27.8d	0.0015
Mn-54	303d	0.00017
Fe-59	45.6d	0.00017
Zr-95	65.5d	0.012

TABLE 8A-6

Gap Activity in Core

Basis: These gap activities are for the average core conditions (no peaking) at the end of the third cycle (1017 days) with continuous full power operation at 2772 MWt. The core has 36,816 fuel pins in 177 fuel assemblies.

	Gap Activity in Core (Curies)			
	Decay Time (days)			
Isotope	0	3	50	120
Kr-83m	6.82(+3)	2.91(-6)	-	-
Kr-85m	3.61(+4)	3.87(-1)	-	-
Kr-85	7.45(+5)	7.45(+5)	7.39(+5)	7.29(+5)
Kr-87	1.98(+4)	-	-	-
Kr-88	6.36(+4)	9.57(-4)	-	-
Rb-88	6.49(+4)	1.07(-3)	-	-
Sr-89	8.31(+3)	8.00)+3)	4.32(+3)	1.73(+3)
Sr-90	3.15(+3)	3.15(+3)	3.14(+3)	3.13(+3)
Sr-91	1.08(+3)	6.42	-	-
Sr-92	2.39(+2)	1.11(-6)	-	-
Y-90	3.13(+3)	3.14(+3)	3.14(+3)	3.14(+3)
Y-91	2.33(+3)	2.26(+3)	1.29(+3)	5.63(+2)
Mo-99	9.90(+4)	4.76(+4)	4.86(-1)	-
Xe-131m	5.90(+4)	5.07(+4)	3.93(+3)	7.21(+1)
Xe-133m	6.74(+4)	2.82(+4)	2.01(-2)	-
Xe-133	6.07(+6)	4.13(+6)	8.61(+3)	8.65(-1)
Xe-135m	2.19(+4)	1.12(+1)	-	-
Xe-135	1.20(+5)	1.18(+3)	-	-
Xe-138	1.21(+4)	-	-	-

TABLE 8A-6 (contd.)

Gap Activity . Core (Curies)
Decay Time (days)

Isotope	0	3	50	120
1-131	9.50(+5)	7.33(+5)	1.25(+4)	2.89(+1)
1-132	6.09(+4)	2.34(_4)	9.13(-1)	-
1-133	1.99(+5)	1.74(+4)	-	-
1-134	1.14(+4)	-	-	-
1-135	6.28(+4)	3.58(+1)	-	-
Cs-134	3.56(+5)	3.56(+5)	3.55(+5)	3.52(+5)
Cs-136	1.94(+4)	1.65(+4)	1.32(+3)	3.08(+1)
Cs-137	3.56(+6)	3.56(+6)	3.55(+6)	3.53(+6)
Cs-138	1.74(+4)	-	-	-
Ba-137m	3.28(+6)	3.28(+6)	3.27(+6)	3.25(+6)
Ba-139	1.95(+3)	-	-	-
Ba-140	2.57(+3)	2.19(+3)	1.72(+2)	3.88
La-140	2.62(+3)	2.42(+3)	1.98(+2)	4.47
Ce-144	5.21(+3)	5.18(+3)	4.63(+3)	3.91(+3)

TABLE 8A-7

Waste Gas Decay Tank Source Activities

Basis: 1. Rupture of Tank and release of entire contents which are:

a. all noble gases in one reactor coolant volume at end of third cycle.

b. all iodine in 1 RCV after having passed through a DF of 100.

2. Reactor coolant volume = 3.34×10^8 cc.

3. Reactor coolant activities are based on operation with 0.1% defective fuel.

Isotope	Reactor Coolant Conc. μc/cc	Waste Gas Decay Tank Activity, Curies
Kr-83m	0.0206	6.88
Kr-85m	0.109	36.4
Kr-85	0.331	111.
Kr-87	0.0598	20.0
Kr-88	0.192	64.1
Xe-131m	0.139	46.4
Xe-133m	0.203	67.8
Xe-133	17.4	5810.
Xe-135m	0.0663	22.1
Xe-135	0.364	122.
I-131	0.229	0.765
I-132	0.161	0.538
I-133	0.269	0.898
I-134	0.0327	0.109
I-135	0.135	0.451

APPENDIX 8B

APPENDIX 8B

1 DOSE CALCULATIONAL METHODS

The dose calculational methods used in the evaluations of environmental consequences for the accidents and occurances discussed in section 8 are explained in this appendix.

1.1 ACCIDENT METEOROLOGY

For the determination of doses resulting from various occurrences and accidents at the Davis-Besse Nuclear station, a 50 percentile criterion was utilized to determine realistic atmospheric dilution conditions. The 50 percentile criterion was selected as being reasonable on the basis that it represents a condition which may be expected to be more severe 50% of the time and less severe the remaining 50% of the time; i.e., the expected condition. This value was determined by considering six atmospheric stability categories and the mean wind speeds associated with these stability categories. On-site data for the period June 1969 to November 1970 were used in this determination.[1] The frequency of occurrence of various stability conditions were used to establish that the most probable stability condition (including the effect of calms) is between Class D and Class E with a mean wind speed of 4.9 m/sec. This analysis established that the expected maximum value of X/Q at the site boundary is 4.0×10^{-5} sec./m^3. This determination is based on all wind directions. It should be noted that winds transporting releases from the Davis-Besse Plant offshore over the lake would occur approximately 60% of the time.

The value of X/Q is determined assuming a ground level release. All short duration releases are assumed to occur under conditions of invariant wind; i.e.. the wind direction is steady for the duration of the release. The same stability and wind conditions are used to determine the population dose to a

1. See Appendix 3A for data.

distance of 50 miles from the station. The population doses are based on the assumption that for the entire distance, wind direction is invariant. Thus, doses as a result of any given short duration release are delivered only in one 22 1/2 degree sector. The average value of X/Q across this 22 1/2 degreee sector was determined as a function of distance from the station. This average value of X/Q is then used to determine the dose to the population living at that distance and the total population dose is determined by summing the product of dose times the number of people receiving that dose for the entire 22 1/2 degree sector for a distance of 50 miles from the plant. For those accidents which result in a release over a long period of time (greater than 24 hours), credit is taken for the directional variability of the wind; i.e., over a long period of time it is not reasonable to assume that wind direction does not change. Therefore, releases beyond 24 hours are uniformly distributed into all sectors and the population dose delivered in a 22 1/2 degree sector was determined by multiplying the population dose that would be delivered by an invariant wind times the frequency of observation of the wind into that sector. Population dose was then determined for all populated sectors around the Davis-Besse Station.

For short-term releases, population dose was maximized by assuming that at the time of the accident the wind was blowing from the east sector. Population for the year 2000 was used as a basis. All individual doses were determined at the minimum site boundary distance of 730 meters. The meteorogical parameters used in the evaluation are shown in Table 8B-1.

1.2 DISCUSSION OF THE DOSE CALCULATION METHODS

The following assumptions and methods are used in the evaluation of the consequences of the occurances in section 8.

a. No correction is made for depletion of the effluent plume of radioactive iodine due to deposition on the ground, or for the radiological decay of iodine in transit.

b. For the first eight hours, the breathing rate of persons offsite is assumed to be 3.47×10^{-4} cubic meters per second. From 8 to 24 hours following the accident, the breathing rate is assumed to be 1.75×10^{-4} cubic meters per second. After that until the end of the accident, the rate is assumed to be 2.32×10^{-4} cubic meters per second. (These values were developed from the average daily breathing rate [2×10^{7} cm^3/day] assumed in the report of ICRP, Committee II-1959.)

c. The iodine dose conversion factors are given in ICRP Publication 2, Report of Committee II, "Permissible Dose for Internal Radiation," 1959.[1]

d. External whole body doses are calculated using "Infinite Cloud" assumptions, i.e., the dimensions of the cloud are assumed to be large compared to the distance that the gamma rays and beta particles travel. "Such a cloud would be considered an infinite cloud for a receptor at the center because any additional [gamma and] beta emitting material beyond the cloud dimensions would not alter the flux of [gamma rays and] beta particles to the receptor" (Meteorology and Atomic Energy, Section 7.4.1.1 - editorial additions made so that gamma and beta emitting material considered). Under these conditions the rate of energy absorption per unit volume is equal to the rate of energy released per unit volume.[2]

e. The appropriate average beta and gamma energies emitted per disintegration, as given in the Table of Isotopes; Sixth Edition; by C. M. Lederer, J. M. Hollander, I. Perlman; University of California, Berkeley; Lawrence Radiation Laboratory; are used.

f. Whole body doses due to the inhalation of tritium following the rupture of either the primary or borated water storage tanks are calculated using the following assumptions:

1. A "Standard Man" breaths for 24 hours in an atmosphere formed by wind that has traveled over the length of the area of tritiated water.
2. Body retention of inhaled water vapor = 95%
3. Effective half life of tritium in body = 12 days
4. Ratio of tritium ingested by inhalation and that absorbed through skin = 1:1

1 The following equation was used to calculate the thyroid dose:

$$D_{th} = R \; B_T \frac{X}{Q} \; DCF \; t$$

Where:

D_{th} = Thyroid dose (rem)

R = Release rate of activity (Ci/sec)

B_T = Breathing rate (m^3/sec)

$\frac{X}{Q}$ = Atmospheric dispersion factor (sec/m^3)

DCF = Thyroid dose conversion factor (rem/Ci)

t = Exposure time (sec)

2 Meteorology and Atomic Energy - 1968, Chapter 7, "Radioactive Cloud-dose Calculations," lists the following equations:

A. For an infinite uniform cloud containing χ curies of beta radioactivity per cubic meter the beta dose rate in air at the cloud center is:

$$_{\beta}D'_{\infty} = 0.457 \; \overline{E}_{\beta}\chi$$

The surface body dose rate from beta emitters in the infinite cloud can be approximated as being one-half this amount (i.e. $_{\beta}D'_{\infty} = 0.23\overline{E}'_{\beta}\chi$)

B. For gamma emitting material the dose rate in air at the cloud center is:

$$_{\gamma}D'_{\infty} = 0.507 \; \overline{E}_{\gamma}\chi$$

From a semi-infinite cloud, the gamma dose rate in air is:

$$_{\gamma}D' = 0.25\overline{E}_{\gamma}\chi$$

C. The whole body dose is then:

$$D_{WB} = ({}_{\beta}D'_{\infty} + {}_{\gamma}D'_{\infty})t$$

Where:

D_{WB} = whole body dose from an infinite cloud (rad)

${}_{\beta}D'_{\infty}$ = beta dose rate grom an infinite cloud (rad/sec)

${}_{\gamma}D'_{\infty}$ = gamma dose rate from an infinite cloud (rad/sec)

$\overline{E}_{\beta}$ = average beta energy per disintegration (Mev/dis)

$\overline{E}_{\gamma}$ = average gamma energy per disintegration (Mev/dis)

$\dot{\chi}$ = concentration of beta or gamma emitting isotope in the cloud (curie/m^3)

t = exposure time(sec)

TABLE 8B-1

PARAMETERS USED FOR DOSE EVALUATION

Site Boundary (Maximum)

0-24 hr $X/Q = 4.0 \times 10^{-5}$ sec/m^3

>24 hr $X/Q = 5.0 \times 10^{-6}$ sec/m^3

Population Dose

(maximum sector)	0-24 hr	$\sum_a (X/Q)\, P_a = 2.3 \times 10^{-2}$ man sec/m^3
	>24 hr	$\sum_a (X/Q)\, P_a = 2.9 \times 10^{-3}$ man sec/m^3
(all other sectors)	0-24 hr	$\sum_a (X/Q)\, P_a = 0$ man sec/m^3
	>24 hr	$\sum_a (X/Q)\, P_a = 8.5 \times 10^{-3}$ man sec/m^3

9 UNAVOIDABLE ADVERSE EFFECTS

There are some effects associated with the operation of the Davis-Besse Station that will be slightly adverse to the environment and that cannot be avoided, however they are few, are insignificant and have no overall significant adverse effect.

The cooling tower system will evaporate an average of 9,000 gpm from Lake Erie which is a negligible amount when compared with the amount of water flowing into or evaporating from Lake Erie. This vapor plume can, under infrequent conditions, reinforce the ground fog that occurs naturally. Under local and infrequent conditions, high winds could cause a downwash of the plume which might cause some local ground icing.

There will be a limited amount of heat discharged to Lake Erie, but this will have no adverse effect on the Lake biota.

Some radioactivity will be released in liquid and gaseous effluents, but it will add only an extremely small burden to the environment which is insignificant when compared to the radiation exposure from naturally occurring background radiation. The planned environmental monitoring program to be carried out by Applicants will confirm that these releases will have no significant adverse effect on the environment.

10

10 NEED FOR POWER

10.1 FORECASTS OF DEMAND

The extreme length of time required to place a new generating unit into service from the time of commitment requires extensive long-range planning. To provide a coordinated and economical expansion program requires an even longer period of planning. All of this planning is based on projections of future demands for electricity from the consumer. The validity of these projections determines the electri ul energy availability for the consumer and financial status of the electrical utility industry. Under-projecting results in generating capacity shortages for the consumer and over-projecting results in idle capacity with attendant added costs to the utility.

All of the capacity addition plans for the Applicants and CAPCO are based on individual company projections of future demand with the composite CAPCO demands determined from these projections.

To illustrate these projections and their validity, Figures 10-1 and 2 have been prepared. Figure 10-1 shows the Toledo Edison ten-year peak demand planning projection prepared in 1960 for the period 1960 through 1970. The actual system peak demand for 1960 through 1971 to date is also shown for comparison. The current ten-year projection prepared in 1970 is also shown for the period 1971 through 1980 and which forms the Toledo Edison system component of the CAPCO total demand projection shown on Figure 10-2 for the period 1970 through 1980.

The first combined CAPCO projection was made in 1967 for monthly demands during the 20-year period commencing September 1971. The September 1971 actual combined CAPCO peak demand was 8,747 MW which is only 178 MW or 2% below projection.

All of this illustrates the increasing consumer demand for electrical energy and the prudent and accurate forecasting of these needs on the part of Applicants and CAPCO to properly serve the consumers in their service area.

10.2 ELEMENTS OF DEMAND AND CONSUPTION

The historical demand for electrical energy on the Applicant's systems and forecast future demands can be categorized into three major sectors of consumers; namely, industrial, commercial, and residential.

Figures 10-3, 10-4 and 10-5 have been prepared to show this division in consumer demand. Figure 10-3 shows the annual peak demand, actual 1963 through 1971, and projected 1971 through 1975. Figure 10-4 shows the same information based on summer peak which is dominant from 1967 through 1975. Figure 10-5 is the consumer division of energy used in megawatt hours. Table 10-1 lists these sectors and percentages for the year 1971 peak demand to date and sales to date plus estimated sales for the balance of the year.

TABLE 10-1

	1971			
	Demand		Consumption	
	MKW	% of Peak	MMKWH	% of Total
Industrial	511	48.5	2,943	52.4
Commercial	240	22.8	752	13.4
Residential	230	21.8	1,376	24.5
Other*	73	6.9	547	9.7
Total	1,054	100.0	5,618	100.0

* Street Lighting, Public Authorities, and Municipal Systems.

10.2.2 INDUSTRIAL SECTOR

Currently the industrial sector of the service area accounts for the largest portion of the peak demand, being 511 MW or 48.5% in 1971. That same sector accounts for 2,943 MMKWH, or 52.4% of Toledo's sales for 1971.

The economic complexion of Toledo's service area is basically industrial. Changes in industrial activity lead to changes in total employment, population growth and commercial activity. During recent years expansions in the industrial sector have provided the momentum to create job opportunities for the growing population of the service area.

The industrial sector is also the most volatile sector of the local and the national economy. Toledo's sales to its industrial sector correlate with the vagaries of the nation's business cycles. To illustrate how dependent the economy of applicant's service area is on the national economy, Figure 10-6 was prepared. This shows the high degree of correlation between Toledo's industrial sales and a standard measure of national economic well-being, namely the Federal Reserve's Index of Industrial Production.

As the national Index of Industrial Production rises over time, job opportunities in the service area expand concurrently. These job opportunities, and job opportunities thereby created in other sectors of the economy are essential for a growing population.

Figure 10-6 also shows forecasts of Toledo's industrial sales and the Index of Industrial Production, which adds verification to the sales forecast. As national production expands, the industrial sector of the service area will require this additional power associated with these new job opportunities.

10.2.3 POWER NEEDED TO REDUCE ENVIRONMENTAL POLLUTION

There is another significant source of growth in demand for electric power. Massive amounts of power will be required to clean up our environment.

> "...more power is going to be needed to clean up the environment. Sewage-disposal plants use large amounts

of electricity. It takes a great deal of energy to beat an old automobile into a pancake, transport it to a central location, shred it into pieces and then recycle it. There are many similar examples."

Edward E. David, Jr., Science Advisor to President Nixon, as quoted in U.S. News and World Report, Oct. 18, 1971

This is true in the Toledo area, as both the private and public sectors are moving more rapidly to diminish damage to the environment associated with their respective activities. Here is a representative sample which points out the rapidly growing need for more power to clean up the environment:

- The large General Motors Company Foundry plant in Defiance has been shifting its production away from the use of fossil fuels in favor of electricity as a heat source to reduce pollution related to their production activities. During the period 1971 to 1976 their peak demand will increase from 60,000 KW to perhaps well over 100,000 KW, for the current plant expansion is to all-electric production. In addition, the foundry has installed approximately 5,000 KW of pollution abatement equipment to reduce stack emmissions.
- Kastle Iron and Metal recently installed a 2,000 horsepower electric shredder to prepare auto bodies and other junk for recycling.
- A number of canning plants have installed large pumps to dispose of effluents which formerly went into Northwest Ohio streams.
- The current expansion of the City of Toledo's sewage disposal plant to provide additional protection to the Maumee River and Lake Erie will require an additional 5,000 KW of generating capacity.

- A major petroleum refinery in Toledo Edison's system recently installed 1,250 kilowatts of pumping equipment to recirculate process water to eliminate thermal discharges.
- Owens-Illinois Glass Co. is conducting extensive research into the recycling of glass containers. The process involves the crushing and grinding of bottles with electrical equipment. The ground glass is used as pavement material.
- Dozens of electrically powered sewage lift stations and small package sewage-greatment plants are being installed in the Toledo area by municipalities that formerly dumped the sewage into creeks and streams.
- Lamson's, among the largest department store chains in the Toledo area, recently installed a large electric incinerator at its warehouse to dispose of all crating and packaging which is now being returned to the warehouse, rather than being used as land fill or burned openly.
- The Anderson's, a large local grain terminal and producer of goods used by the agricultural sector of Northwest Ohio, recently found a use for corn cobs which were formerly dumped or burned. The corn cobs are now ground and used as filler for fertilizer. This requires considerable electric power.

A complete list of new pollution abatement equipment recently installed or to be installed in the Toledo area by local governments and in the private sector would be long indeed. The fact that reducing environmental pollution will require large increased in power plant capacity is apparent. As the new environmental quality regulations take effect, hundreds of industries and municipalities will be upgrading their control systems, requiring massive new amounts of electric power.

10.2.4 RESIDENTIAL AND COMMERCIAL SECTORS

The residential sector accounts for 230 MW or 21.8% of the 1971 peak demand and is very sensitive to changes in industrial activity. The commercial sector is responsive to the residential sector and its growth generally lags changes in the residential and industrial sectors. The commercial sector accounted for 240 MW or 22.8% of the peak demand in 1971.

Contrary to the impression many opponents to nuclear power have expressed, the residential sector accounts for a small portion of the total demand, being only 21.8% of the system peak on Toledo Edison's system in 1971.

Studies have shown conclusively that the dominant determinant of the level of usage of electrical energy in the household is household income. As the incomes of households rise, the consumer demand for electricity consuming appliances also rise. Hence, the bulk of consumer demand for electric power is derived from the consumer demand for household appliances, which is in turn dependent on household income.

Additionally, a significant portion of the growth in the usage of electric power in the residential sector is due to demographic factors. Toledo Edison's studies have shown that new dwelling units which result from population growth and household formations use usbstantially more electric power than existing dwelling units. In the Toledo area, a representative sampling has shown that fully 35% of the increase in residential usage between 1969 and 1970 was due to newly constructed dwelling units, while the number of new residential customers increased by only 1.8% during the same period. As long as population grows, the use of electric power will increase in the residential sector.

The annual population growth rate over the past decade in the Toledo Edison service area was about 0.9%. However, the growth in residential customer units during this period in the residential sector has been about 1.6%. This is considerably less than the 6.4% growth rate in usage of electrical energy. This means that the increasing consumer demand in the household usage of electrical energy is dominated by a rise in the standard of living in the household.

In Lucas County, the county containing over 73% of the Toledo Edison service area population, the Office of Economic Opportunity estimates that there are over 18,000 families (one in eight) with incomes below $3,000, which is their criterion for the poverty threshold. "Survey of Buying Power," Sales Management estimates show that 25% of families in Lucas County have incomes of $5,000 or less per year with another 20% having incomes between $5,000 and $8,000.

Clearly, a large segment of the area population is not sharing in a high standard of living, which is a part of a good quality of life. This should be a matter of concern for those interested in making an urban area a better place in which to live. A shift of this segment into a higher standard of living will mean an increased usage of electricity. The only meaningful way such a shift can come about is through a higher income from employment which requires a rise in industrial and commercial activity, all of which increases the demand for electricity.

10.2.5 MAJOR INDUSTRIAL CONSUMERS

The ten major industrial users of power on the Applicants' systems with their electrical usage in 1970 and their employment are given below:

TOLEDO EDISON

Industrial Customer	KWH X 10^3	Employment (1)
General Motors - Total		
Central Foundry		
Chevrolet Transmission		
Standard Oil Refinery		
Sun Oil Refinery		
Libbey-Owens-Ford - Total		
East Broadway		
Rossford		
Johns-Manville - Total		
River Road		
Carpenter Road, Defiance		
Perry Street, Defiance		
Columbus Road, Defiance		
Doehler-Jarvis - Total		
Detroit Avenue		
Smead Avenue		
Owens-Illinois - Total		
Libbey Glass		
Technical Center		
Perrysburg		
American Motors - Total		
North Cove Blvd.		
Stickney Avenue		
Brush-Beryllium		
Dana Corporation		
Chrysler Corporation		
Total:	1,588.3	34,600

CLEVELAND ELECTRIC

Industrial Customer	KWH X 10^3	Employment (2)
Air Products		
Detrex Chem. Ind.		
Ford		
General Motors (Chev. Div.)		
J & L Steel		
NASA		
Reactive Metals		
Republic Steel		
TRW		
U.S. Steel		
Total:	2,819.0	39,071

(1) Chamber of Commerce Data for May 1971.

(2) Directory of Ohio Manufacturers, 1969, except NASA which is 1971.

10.3 DEMAND-CAPACITY SITUATION, 1974-1975

The Davis-Besse Nuclear Power Station is being built as a jointly-owned facility, 52.5% of its output will be owned by The Toledo Edison Company and 47.5% will be owned by The Cleveland Electric Illuminating Company. Both companies are members of the Central Area Power Coordinating Group (CAPCO). This Group is an operating and generating pool composed of the Applicants, Duquesne Light Company, and Ohio Edison Company. These four CAPCO companies supply electricity in the northern and central areas of Ohio and in the western part of Pennsylvania as shown on Figure 10-7.

The Davis-Besse Unit will be the fourth generating unit to be installed by CAPCO and it will be the second nuclear unit (Beaver Valley Unit 1 will be the first). The Davis-Besse Unit will become a part of the CAPCO pool generating capacity and it is needed to provide generating capability to meet anticipated load demand with adequate reserve generation for this pool. During the initial period of its operation, Ohio Edison will be entitled to 280 MW of output; Cleveland, 314 MW; and Toledo, 277 MW. Table 10-2 shows the December 1974 and June 1975 load-generation situation for CAPCO with and without Davis-Besse. The generating capacity figures shown in Table 10-2 include the output from Beaver Valley Unit 1 during both the December 1974 and June 1975 peak-load periods, and the June 1975 figures include Mansfield Unit 1, scheduled for April 1975. Prior to completion of Davis-Besse, Toledo is entitled to 175 MW from Beaver Valley Unit 1 and Cleveland, 10 MW.

Table 10-3 shows similar data for the Toledo Edison system and Table 10-4 shows data for the Cleveland Electric Illuminating system. The official CAPCO load and forecasts, dated March 18, 1970, were used in Tables 10-2, 3 and 4. This forecast data takes into account the long-range coordinated maintenance requirements and the allocation of generating capability to each company to provide adequate capacity for load and reserve during these maintenance periods. Table 10-2 data showing December 1974 and June 1975 which is the CAPCO 1975 peak-load month is summarized below:

	CAPCO % Reserve	
	December 1974	June 1975
Prior to Maintenance		
With Davis-Besse	21.9	17.6
Without Davis-Besse	14.0	10.1
With Maintenance		
With Davis-Besse	14.3	12.4
Without Davis-Besse	6.4	5.0

This clearly illustrates the need for Davis-Besse on the part of CAPCO and that without Davis-Besse, there would not be adequate reserve to provide reliable service to the consumers of the CAPCO companies. This is substantiated by the FPC comments on the Environmental Report contained in Appendix G of the Environmental Statement which deems a 20% reserve margin before maintenance considerations as requisite to provide pool reliability.

Tables 10-3 and 10-4, which are Applicants' components of Table 10-2, show that the Applicants' systems would have inadequate reserves without Davis-Besse in December 1974 and both are deficient in generating capability to meet load in June of 1975.

This clearly shows that without Davis-Besse, Applicants will be deficient in generating capability and that CAPCO as a group will have a serious deficiency in reserves and that generating capability equal to Davis-Besse would have to be found from other sources.

TABLE 10-2

CAPCO

PEAK LOAD WEEK

	December 1974		June 1975	
	With Davis-Besse	Without Davis-Besse	With Davis-Besse	Without Davis-Besse
Net Demonstrated Capability - MW	13,002	12,130	13,942	13,070
Net Concurrent System Capability - MW	12,850	11,978	13,572	12,700
Net Purchase from Other Systems - MW	536	536	261	261
Available Capability - MW	13,386	12,514	13,833	12,961
Scheduled Maintenance - MW	834	834	609	609
Available Capacity for Load - MW	12,552	11,680	13,224	12,352
Forecasted Peak Load Including Interruptable Loads - MW	10,980	10,980	11,767	11,767
Reserve Over Load				
With Scheduled Maintenance				
- MW	1,572	700	1,457	585
- %	14.3%	6.4%	12.4%	5.0%
With No Maintenance Provision				
- MW	2,406	1,534	2,066	1,194
- %	21.9%	14.0%	17.6%	10.1%

TABLE 10-3

TOLEDO EDISON

PEAK LOAD WEEK CORRESPONDING TO CAPCO

	December 1974		June 1975	
	With Davis-Besse	Without Davis-Besse	With Davis-Besse	Without Davis-Besse
Net Demonstrated Capability - MW	1,523	1,065	1,523	1,065
Net Concurrent System Capability - MW	1,497	1,039	1,467	1,010
Net Purchase from Other Systems - MW				
AEP	100	100	100	100
CAPCO	44	219(1)	31	206(1)
OVEC	27	27	16	16
Michigan Pool	200	200	-	-
CAPCO (Delivery)	(290)	(110)(2)	-	-
Available Capability - MW	1,578	1,475	1,614	1,332
Scheduled Maintenance - MW	6	6	114	114
Available Capacity for Load - MW	1,572	1,469	1,500	1,218
Forecasted Peak Load - MW	1,292	1,292	1,389	1,389
Reserve Over Load				
With Scheduled Maintenance				
- MW	280	177	111	(171)
- %	21.7%	13.7%	8.0%	(12.3%)
With No Maintenance Provision				
- MW	286	183	225	(57)
- %	22.1%	14.2%	16.2%	(4.1%)

(1) Includes 175 MW from Beaver Valley which is TECo's Entitlement for Period until Davis-Besse is available. This would reduce Duquesne's Reserve Over Load by 7.7% in December 1974 and 7.3% in June 1975.

(2) Delivery of 180 MW of Toledo Edison's share of Davis-Besse output to Ohio Edison Company eliminated.

TABLE 10-4

CLEVELAND ELECTRIC ILLUMINATING

PEAK LOAD WEEK CORRESPONDING TO CAPCO

	December 1974		June 1975	
	With Davis-Besse	Without Davis-Besse	With Davis-Besse	Without Davis-Besse
Net Demonstrated Capability - MW	4,146	3,732	4,203	3,789
Net Concurrent System Capability - MW	4,100	3,686	4,118	3,704
Net Purchase from Other Systems - MW				
AEP	-	-	-	-
CAPCO	18	28(1)	-	10(1)
OVEC	-	-	-	-
Michigan Pool	-	-	-	-
CAPCO (Delivery)	(450)	(350)(2)	(41)	(41)
Available Capability - MW	3,668	3,364	4,077	3,673
Scheduled Maintenance - MW	46	46	124	124
Available Capacity for Load - MW	3,622	3,318	3,953	3,549
Forecasted Peak Load Including Interruptable Loads - MW	3,380	3,380	3,720	3,720
Reserve Over Load				
With Scheduled Maintenance				
- MW	242	(62)	233	(171)
- %	7.2%	(1.8%)	6.3%	(4.6%)
With No Maintenance Provision				
- MW	288	(16)	357	(47)
- %	8.5%	(0.5%)	9.6%	(1.3%)

(1) Includes 10 MW from Beaver Valley which is CEI's Entitlement for Period until Davis-Besse is available. This would reduce Duquesne's Reserve Over Load by 0.4%.

(2) Delivery of 100 MW of CEI's share of Davis-Besse output to Ohio Edison Company eliminated.

10.4.1 ALTERNATE SOURCES OF POWER IN EVENT OF DELAY

Table 10-5 shows the Winter 1974-75 and Summer 1975 load-generation situation for ECAR. This data was obtained from a report, "Load Projections and Resource Planning," to the Federal Power Commission pursuant to FPC Docket R-362, Order 383-2, Appendix A, Items 1, 2, 3, and 4, April 1971. Additional generation data without Davis-Besse in both the Winter 1974-75 and Summer 1975 is included in Table 10-5. The load and capacity forecasts used in the Federal Power Commission Report in connection with the Environmental Statement are based on a September 1970 report to the FPC and are slightly lower than the similar data submitted in the April 1971 report and used in Table 10-5. Also, the capacity and reserves figures in the FPC comments did not consider scheduled maintenance outages. Even with these differences, the FPC comments substantiates CAPCO's need for Davis-Besse's capacity and the conclusion that CAPCO should not depend upon ECAR for any power during the Summer 1975. Additionally, the data in Table 10-5 assumes the availability of 4,173 MW of capacity from the following nuclear power units, all of which are subject to delays of availability as a result of application of the new procedures in Appendix D or for other reasons.

Cook	Unit 1 & 2
Beaver Valley	Unit 1
Fermi	Unit 2

The data in Table 10-5 also assumes the availability of 14,201 MW of new capacity from the following fossil and pumped storage units scheduled to be placed in service between January 1973 and Summer 1975, including 4,500 MW of capacity scheduled for the first six months of 1975, which could be subject to delay in completion:

In Service - 1973:

Conesville	Unit 4
Ludington	Unit 2, 3, 4, 5, & 6
E. W. Stout	Unit 7
Culley	Unit 3
Michigan City	Unit 12
Amos	Unit 3
Harrison	Unit 2
Monroe	Unit 4
Ghent	Unit 1

In Service - 1974:

Stuart	Unit 4
Mill Creek	Unit 2
Gavin	Unit 1
Karn	Unit 3

In Service First Six Months - 1975:

Gibson	Unit 1
Miami Fort	Unit 7
Harrison	Unit 3
Mansfield	Unit 1
Northern Indiana Public Service (Undesignated)	
Gavin	Unit 2

TABLE 10-5

ECAR

	Winter 1974-75		Summer 1975	
	With All Planned Units	Without Davis-Besse	With All Planned Units	Without Davis-Besse
Net Demonstrated Cap.(1) - MW	74,372	73,500	80,243	79,371
Net Seasonal Cap.(1) - MW	74,150	73,278	78,804	77,932
Net Sales (2) - MW	738	738	1,008	1,008
Available Capacity - MW	73,412	72,540	77,796	76,924
Scheduled Maintenance (3) - MW	3,710	3,710	1,576	1,576
Available Capacity for Load - MW	69,702	68,830	76,220	75,348
Forecasted Load Including Interruptable Loads - MW	57,467	57,467	62,941	62,941
Reserve Over Load				
With Scheduled Maintenance				
- MW	12,235	11,363	13,279	12,407
- %	21.4%	19.8%	21.1%	19.7%
With No Maintenance Provision				
- MW	15,945	15,073	14,855	13,983
- %	27.8%	26.2%	23.6%	22.2%

(1) Includes Cardinal #2, owned by Buckeye Power, Inc., and projected additional capacity to be owned by Buckeye Power, Inc.

(2) Includes delivery to Buckeye Power, Inc.

(3) Scheduled Maintenance figures for ECAR are not available; figures shown are estimated at 5% of Net Seasonal Capacity in Winter and 2% in Summer.

Since it would not be prudent for CAPCO to depend upon any firm capacity from ECAR in this situation, CAPCO would have to install additional generation within its system.

The inevitable result is that the necessary generating capability to make up for a delay of Davis-Besse must be supplied from the installation of gas turbines. At this time, it would be impossible to obtain and put into operation fossil fuel steam units. Aside from the very high additional expense involved, as shown below, there are other serious objections to gas turbines. The CAPCO companies already have 94 MW of diesel and gas turbine peaking units intalled and plans call for an additional 300 MW prior to the scheduled date of Davis-Besse operation. This represents the maximum desirable amount of this high operating cost peaking equipment which should be installed in proportion to total capacity of the Group for most efficient and economical service. Present CAPCO capacity planning is firm through 1979 and no additional gas turbine peaking units are scheduled between 1974 and 1979. Normal and prudent planning for a foreseeable period beyond 1979 would not include the addition of any sizeable quantity.

Since these gas turbine units have a lower efficiency than existing coal and oil-fired generation, the peaking units would be used only during peak-load periods. As a result, CAPCO's older coal and oil-fired units would operate at a higher capacity factor during the delay and generate more power during off-peak periods. This increased generation on existing units and the new peaking units would burn approximately 2,400,000 tons of coal and 102,000,000 gallons of fuel oil per year. This increased coal and oil-fired generation would release the following effluents to the atmosphere:

CO_2	6,300,000 Tons/Year
SO_2	124,000 Tons/Year

NO_x	104,000 Tons/Year
Fly Ash *	8,600 Tons/Year

* Based on an assumed average precipitator efficiency of 97% for the Applicants' older coal-fired units.

Also, it would unnecessarily consume additional quantities of our nation's coal and oil reserves that are presently in short supply.

10.4.2 COST OF DELAY

10.4.2.1 Increase in Project Cost

The cost of construction delay at Davis-Besse would include the monthly interest cost of funds invested, the monthly escalation on all material and labor expenditures that are delayed, and a one-time cost to shut down the construction and to restart it at a later date. The monthly costs of a construction stoppage are as follows:

Interest Cost of Funds Invested 7.5%/Yr. on $44,730,000 invested up to 10/1/71 during delay	$ 280,000/Month
Escalation on Items Delayed 4%/Yr. on $83,499,000 for Nuclear Steam Supply System, nuclear fuel, and turbine-generator	$ 278,000/Month
8.7%/Yr. on $118,538,000 for remaining delayed purchases, field construction labor and overheads	$ 858,000/Month
Total Escalation	$1,266,000/Month
Maintenance and Security Vendor Warranty Extensions, Construction Skeleton Staff, and Miscellaneous Monthly Expenses	$ 250,000/Month
Total Monthly Cost	$1,666,000/Month

The escalation costs for the Nuclear Steam Supply System, nuclear fuel, and turbine-generator are based upon the price adjustment provisions for delayed shipments in the purchase agreements with the suppliers of these items. The escalation costs for the remaining delayed purchases, field construction labor and overheads are based on the construction experience of the Applicants and the Bechtel Company, who are the architect-engineers for this project. The one-time cost to shut down the construction and restart it at a later date is estimated at $4,100,000. A delay in the commercial startup of the station by 12 months, would add an estimated $24,100,000 to the initial cost of the station. This would increase the fixed charge on the station each year during its life by $4,338,000 (at 18% fixed charge rate) or by 0.68 mills/KWH (using an 80% capacity factor).

10.4.2.2 Costs Associated with Alternate Source of Power

In addition to added capital cost to the Davis-Besse project which would result from a delay in commercial operation, there are added costs to the Applicants and other CAPCO members that would be incurred in providing an alternate source of power for an estimated one-year delay in commercial operation of the Davis-Besse Station. These costs result from added fixed charges, operation and maintenance costs, and fuel costs. Such costs have been estimated for an alternative involving the addition of approximately 872 MW of gas turbine peaking units for operation in December 1974 and total $57,507,000. Details of these costs are given on Table 10-6.

TABLE 10-6

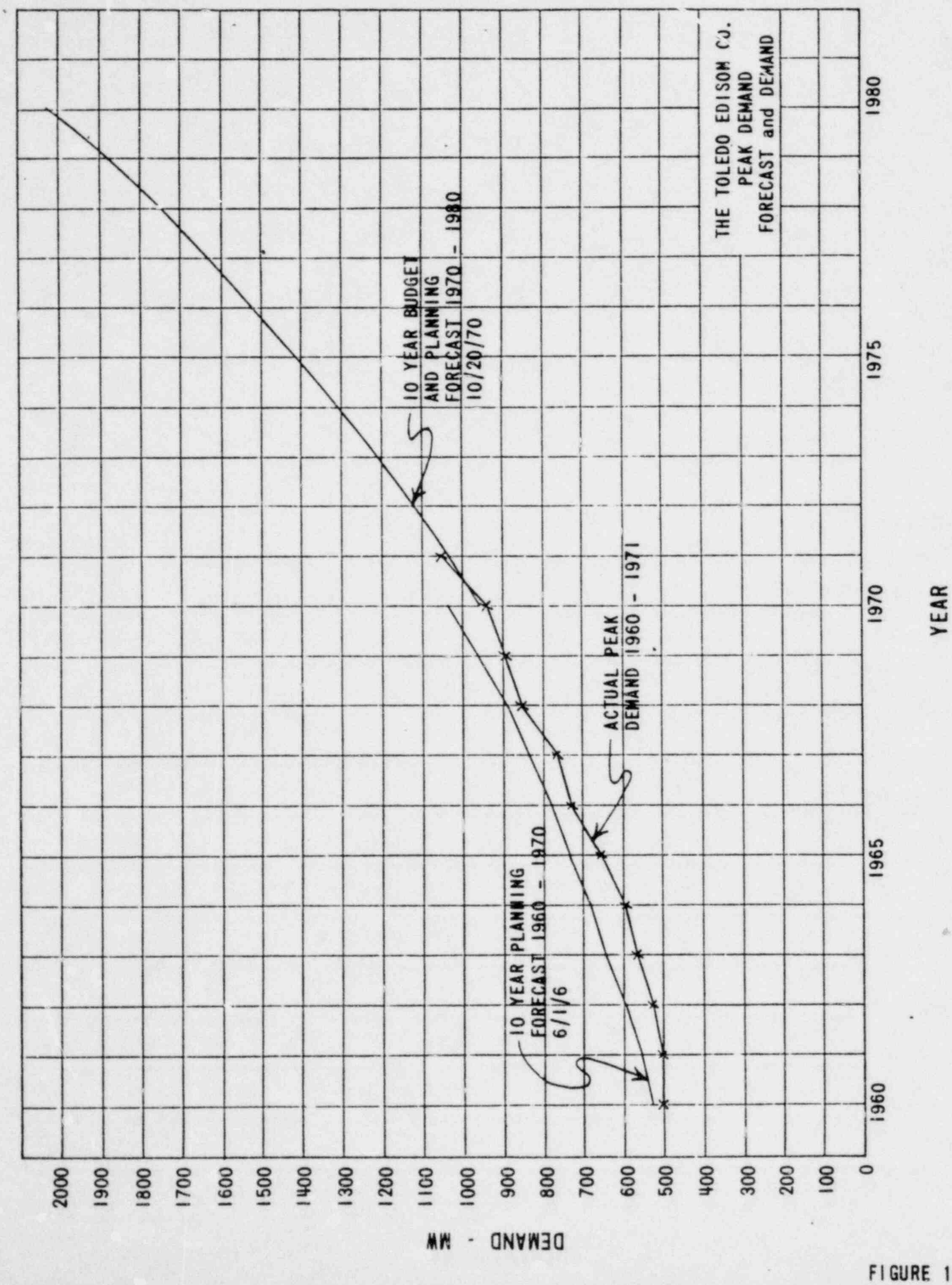
DELAY COSTS FOR GAS TURBINES ALTERNATE SOURCE OF POWER

Basic Data

Fixed Charge Rate - 18%
Present Worth Year - 1975
Present Worth Rate - 7.5%
Plant Depreciation Life - 25 Years
Current Davis-Besse Cost Estimate - $269,918,000
Current Cost Estimate For Gas Turbines - 95,920,000

Fixed Charge Costs		
Davis-Besse		
First Year Fixed Charge Saved if Delayed	($48,585,000)	
Present Worth of Last Year Fixed Charge	8,404,000	
Sum of Present Worths of Fixed Charges on Added $24,100,000 Capital Cost	44,982,000	
Added Fixed Charges on Davis-Besse Costs		$ 4,801,000
Gas Turbines		
Sum of Present Worths of First Three Years of Fixed Charges*	$48,266,000	
Sum of Present Worths of Last Three Years of Fixed Charges Eliminated*	(7,916,000)	
Sum of Present Worth of Savings of Three Years' Escalation Costs ($11,980,000)	(19,349,000)	
Added Fixed Charges for Gas Turbines		$21,001,000
Total Added Fixed Charge Costs		$25,802,000
Operation and Maintenance Costs		
Savings in O & M at Davis-Besse		($ 2,658,000)
Gas Turbines and Increased Coal Generation		
Gas Turbines	$ 2,880,000	
Coal Generation	3,860,000	
Total Added O & M Gas Turbines & Coal		$ 6,740,000
Total Added O & M		$ 4,082,000
Fuel Costs		
Davis-Besse Fuel Cost Displaced by Delay (For 6.397×10^9 KWH)		($14,437,000)
Gas Turbines and Increased Coal Generation		
Gas Turbines (For 0.960×10^9 KWH)	$12,960,000	
Coal (For 5.437×10^9 KWH)	29,100,000	
Total Added Fossil Fuel Cost		$42,060,000
Total Added Fuel Cost		$27,623,000
Total Cost of Delay		$57,507,000

* If gas turbines were installed to provide capability needed due to delay of Davis-Besse, the CAPCO units scheduled for 1975 and 1976 would not be delayed due to their advanced stage of procurement and construction and the first unit to be delayed would be the unit scheduled for 1977. This results in capacity added three years in advance of scheduled requirements to provide for a delay of Davis-Besse.



THE TOLEDO EDISON CO.
PEAK DEMAND
FORECAST and DEMAND
10 YEAR BUDGET
AND PLANNING
FORECAST 1970 - 1980
10/20/70
ACTUAL PEAK
DEMAND 1960 - 1971
10 YEAR PLANNING
FORECAST 1960 - 1970
6/1/6
DEMAND - MW
YEAR
1960
1965
1970
1975
1980
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000

FIGURE 10-1

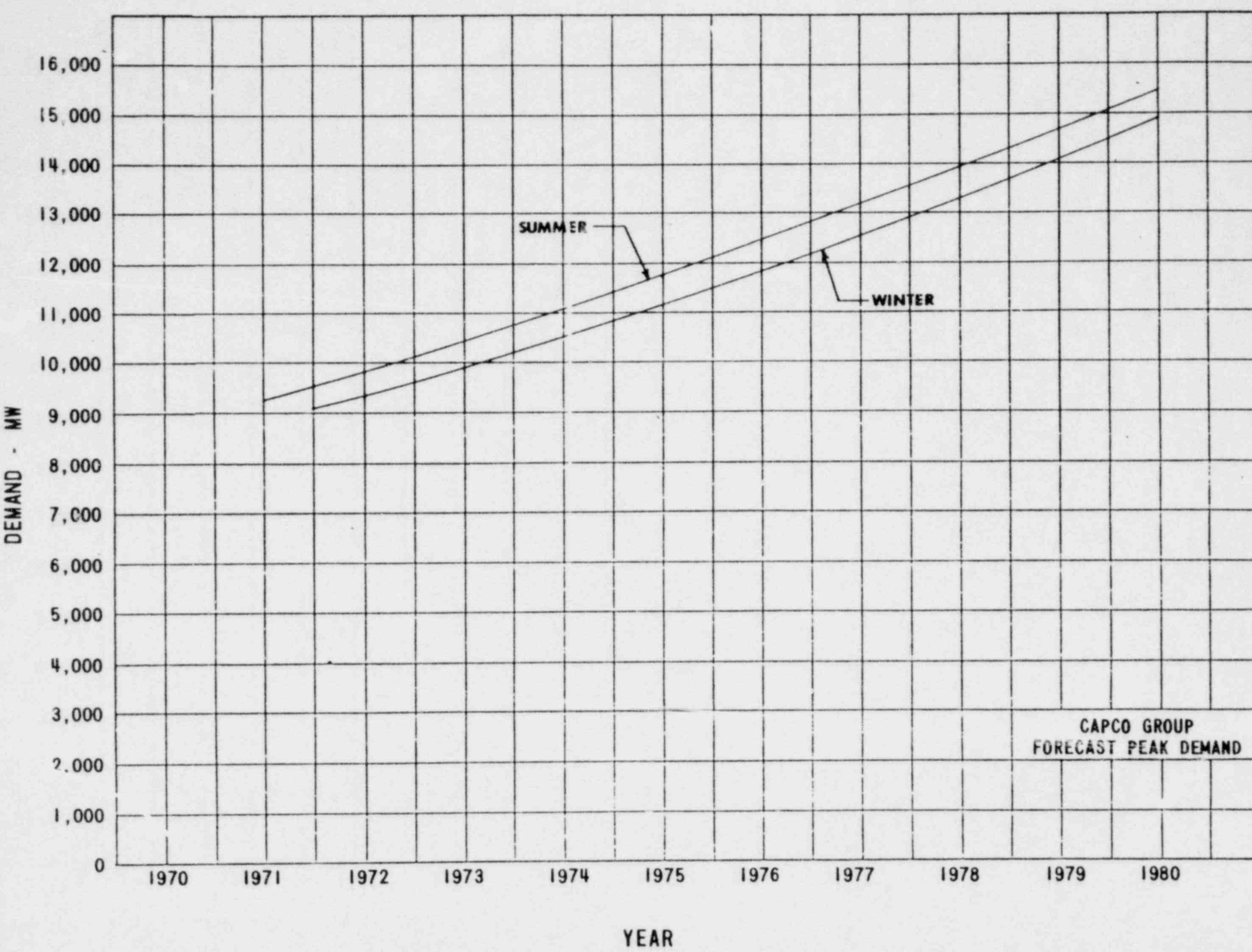

CAPCO GROUP
FORECAST PEAK DEMAND
SUMMER
WINTER
DEMAND - MW
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
YEAR

FIGURE 10-2

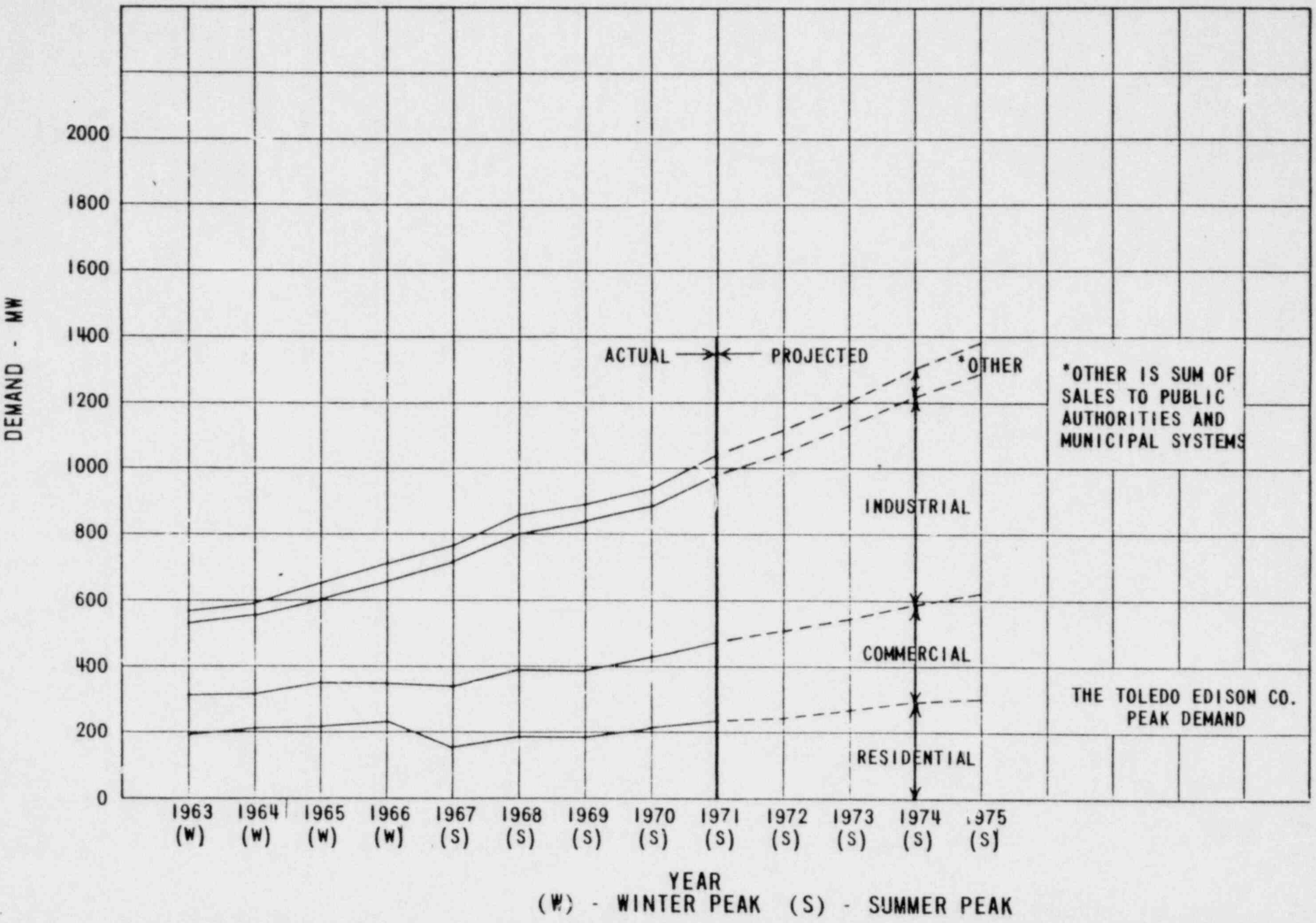

DEMAND - MW
2000
1800
1600
1400
1200
1000
800
600
400
200
0
ACTUAL
PROJECTED
*OTHER
INDUSTRIAL
COMMERCIAL
RESIDENTIAL
*OTHER IS SUM OF SALES TO PUBLIC AUTHORITIES AND MUNICIPAL SYSTEMS
THE TOLEDO EDISON CO. PEAK DEMAND
1963 (W)
1964 (W)
1965 (W)
1966 (W)
1967 (S)
1968 (S)
1969 (S)
1970 (S)
1971 (S)
1972 (S)
1973 (S)
1974 (S)
1975 (S)
YEAR
(W) - WINTER PEAK (S) - SUMMER PEAK

FIGURE 10-3

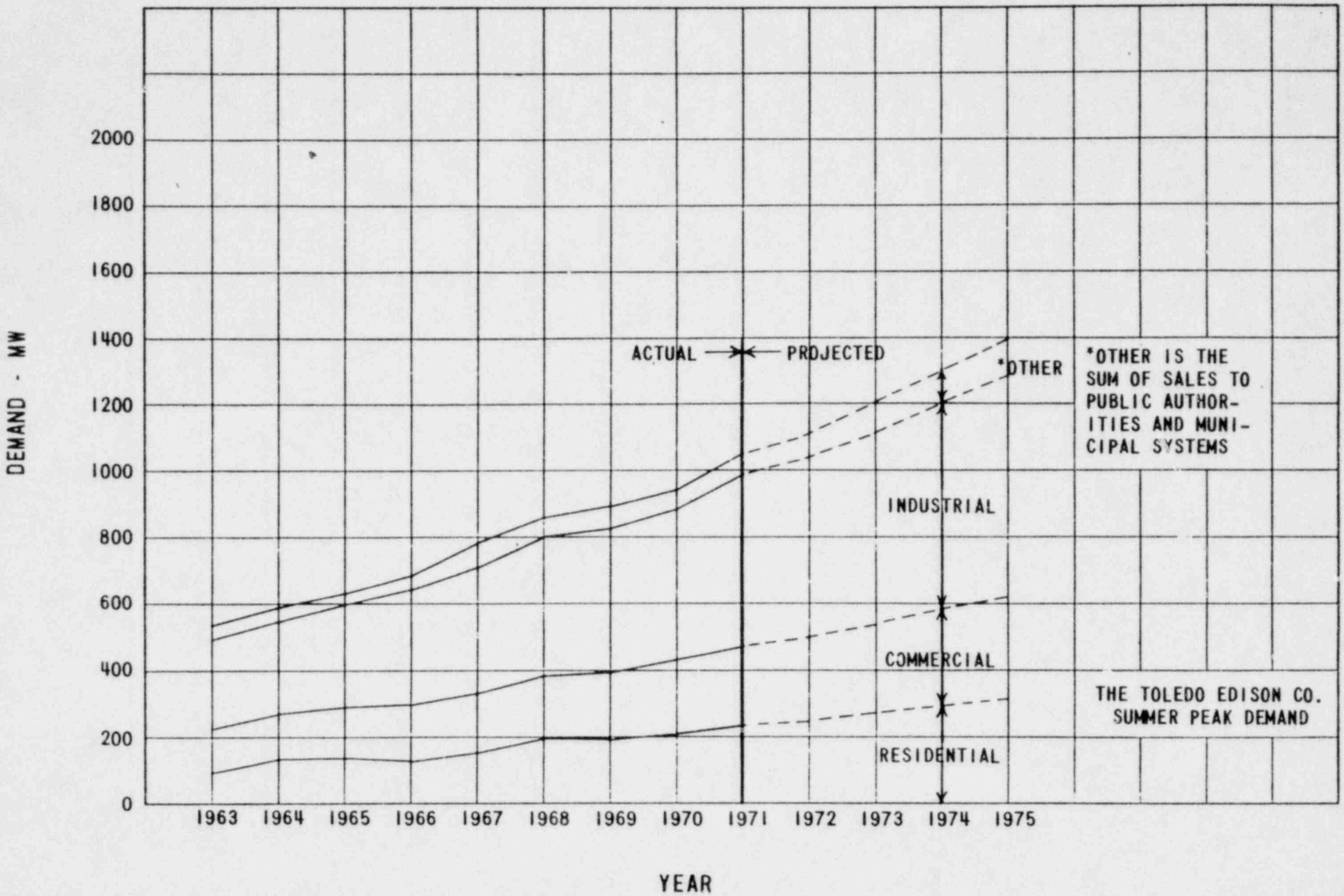
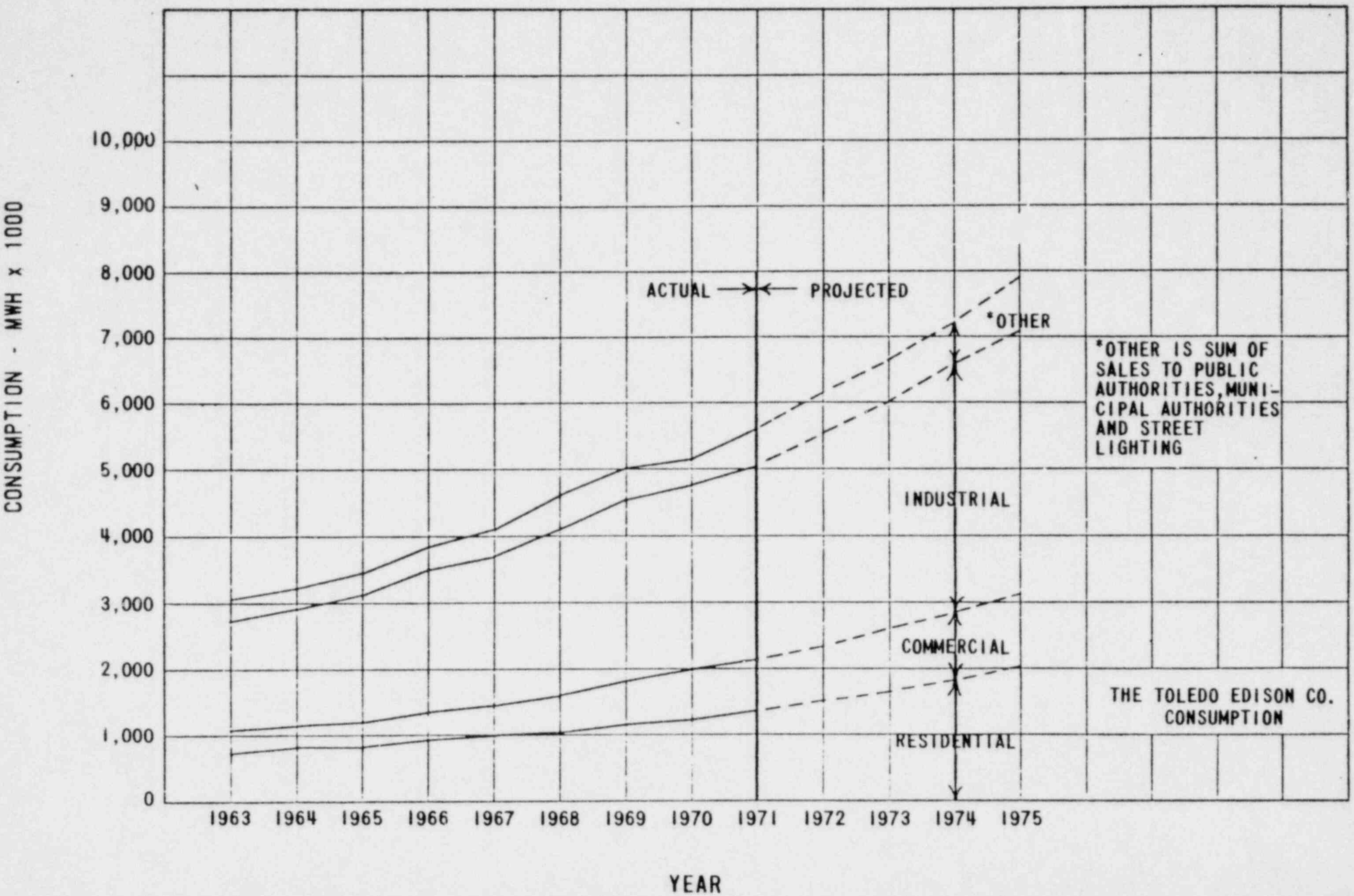
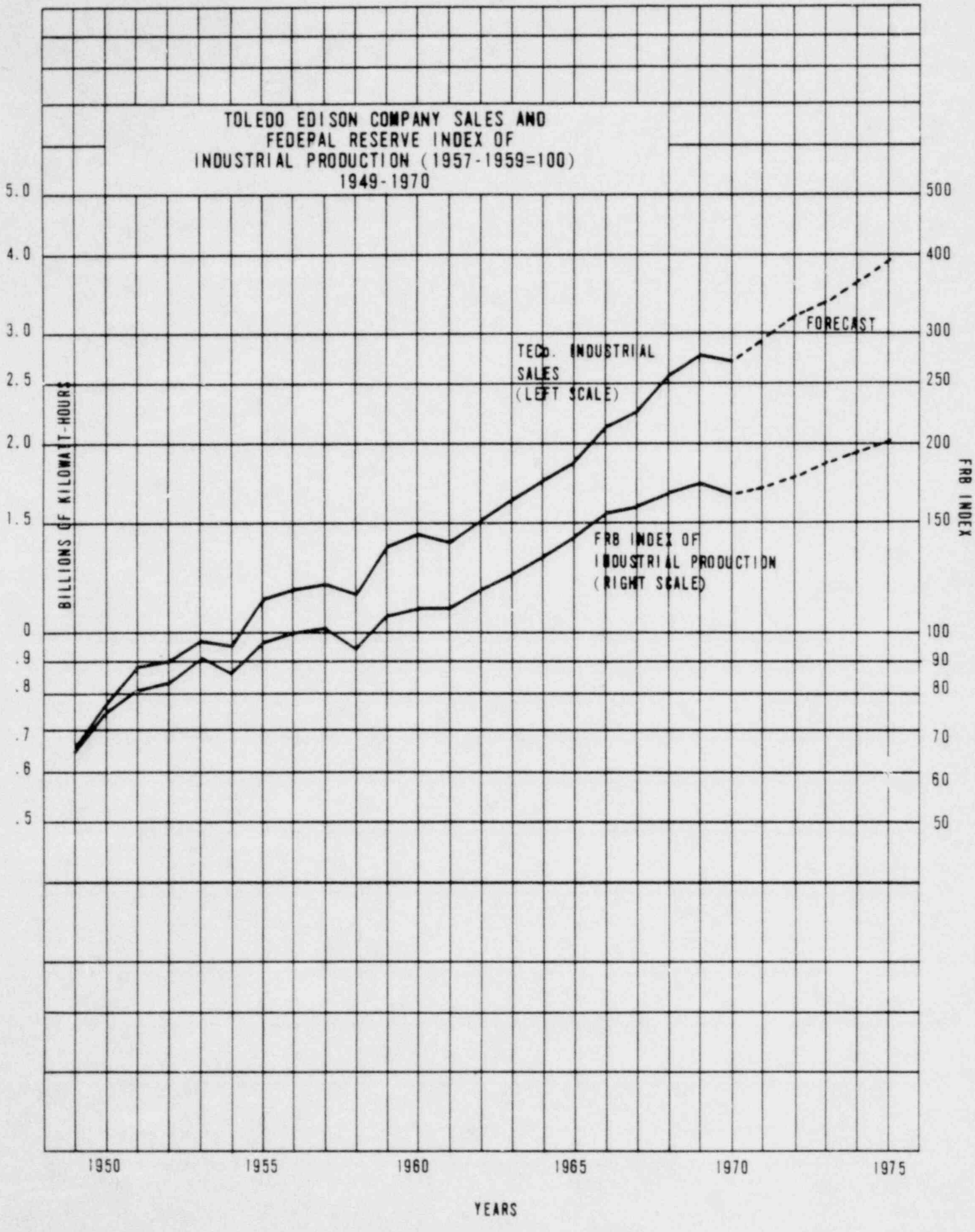

DEMAND - MW
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975
YEAR
ACTUAL
PROJECTED
*OTHER
INDUSTRIAL
COMMERCIAL
RESIDENTIAL
*OTHER IS THE SUM OF SALES TO PUBLIC AUTHORITIES AND MUNICIPAL SYSTEMS
THE TOLEDO EDISON CO.
SUMMER PEAK DEMAND

FIGURE 10-4



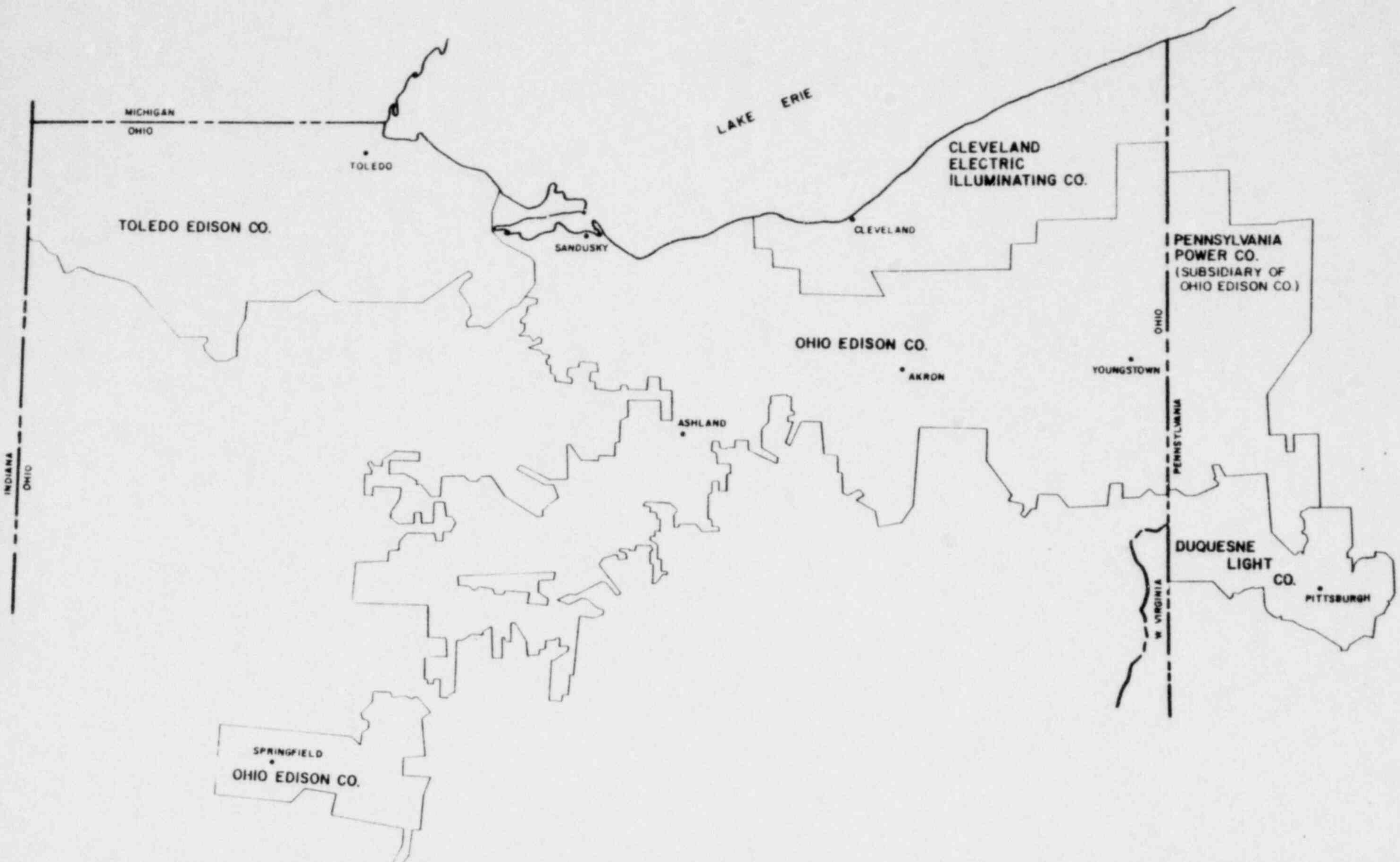
CONSUMPTION - MWH x 1000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
YEAR
ACTUAL
PROJECTED
*OTHER
*OTHER IS SUM OF SALES TO PUBLIC AUTHORITIES, MUNICIPAL AUTHORITIES AND STREET LIGHTING
INDUSTRIAL
COMMERCIAL
RESIDENTIAL
THE TOLEDO EDISON CO.
CONSUMPTION

FIGURE 10-5



TOLEDO EDISON COMPANY SALES AND
FEDEPAL RESERVE INDEX OF
INDUSTRIAL PRODUCTION (1957-1959=100)
1949-1970
BILLIONS OF KILOWATT-HOURS
FRB INDEX
5.0
4.0
3.0
2.5
2.0
1.5
0
.9
.8
.7
.6
.5
500
400
300
250
200
150
100
90
80
70
60
50
FORECAST
TECo. INDUSTRIAL
SALES
(LEFT SCALE)
FRB INDEX OF
INDUSTRIAL PRODUCTION
(RIGHT SCALE)
1950
1955
1960
1965
1970
1975
YEARS

FIGURE 10-6



DAVIS-BESSE NUCLEAR POWER STATION
AREA SERVED BY CAPCO
FIGURE 10-7

11

11 ALTERNATIVES

11.1 GENERAL

A number of alternatives are available at the concept stage of a project. As these alternatives are weighed, decisions made, and the project progresses, some of the earlier alternatives become difficult or impossible to adopt short of complete abandonment of the project. Other alternatives exist throughout the design and construction and even into the operating stage that can be implemented if required at most any stage.

This section discusses, in general terms, a number of alternatives for the Davis-Besse project which are in both categories and also some alternatives that have been suggested, but which are not available. In Section 14 of this Supplement, the costs and benefits of the first two categories are discussed in order to, for the first category, show that the choice has been a prudent and good one and for the second category, to evaluate the benefit, if any, which could be obtained from adopting the particular alternative.

11.2 POWER AND FUEL

11.2.1 GENERAL

It has been shown in Section 10 of this Supplement that there is an increasing demand for generating capability on the part of the consumers in the Applicants Service areas and in the country as a whole. It has also been shown that the level of usage of electrical energy and the demand is directly related to the level of the economy as a whole, to the general standard of living as a whole, and the specific standard of living of individual residential consumers.

Applicants are required to install additional generating capability to meet this increasing demand. The alternative is insufficient reserves to provide reliable service or a deficiency of generation to meet demand with a resulting curtailment of service, disruption to consumers, and danger to the health and safety of the public. This alternative is not acceptable to the consumer, the public, or regulatory agencies and governmental authorities, all in violation of legal duty to provide adequate and dependable service.

11.2.2 ALTERNATE SOURCES OF POWER

With no suitable alternate to providing added generating capability to meet an increasing demand, the question becomes one of where this capability can be obtained or provided for. New capacity can be added on a very local basis as the local demand increases, on a more expanded basis such as for the service area of each individual company, or on a relatively large area basis where the combined area increase in demand can closely match the full capability of the largest, most economical generating units available for installation. This later alternate has formed the basic planning concept that has resulted in the present plans for the Davis-Besse Station.

Applicants are members of the CAPCO Group who are installing new generating capability in large units which provide for the increased needs of the Group members in locations that are near where the loads occur. To provide for joint use of these units, the Group members are also installing transmission facilities to utilize the output of these pooled units and to provide mutual support and reliability of service for the consumers in the Group area. The only available alternative to the generating capacity of the Davis-Besse Station is the equivalent capability at some other location.

11.2.3 ALTERNATE LOCATIONS

The CAPCO planning for added generating capability calls for diversified generation sites generally located near the high-load areas in order to provide best stability to the Group system and best reliability for continuous service and also with regard to distribution of units to systems of each of the Group members. The pattern of planned new CAPCO Group units follows this closely with Davis-Besse being the fourth pooled unit located between the major load centers of Applicants with important load centers of Ohio Edison located between Applicants' major ones. Also important are adequate water supplies and transportation. The locations of the five announced pooled units beyond the in-service date of the Davis-Besse Station all give effect to these requirements.

The area in which an alternate location for the Davis-Besse Station could be considered and still meet the requirements of it being located between the Applicants' major load centers is very limited and is even more so when considering the desirability of having the station located in the Toledo Edison service area.

11.2.4 ALTERNATE FUEL

Natural gas is not available in sufficient quantities in this area of the country to be used as a fuel for generation of this amount. There are no hydroelectric generating sites in this area. Oil or coal is the only feasible alternate fuel. Oil in sufficient quantities in this area is not readily available and its high cost relative to coal rules out consideration of it for base-load generation.

Coal has in the past been the primary source of fuel for base-load generation in this area of the country.

Studies conducted prior to the decision on types of generation for the Davis-Besse Station however, showed clearly that nuclear fuel would provide the most economical generation for this base load capacity.

Coal in the past several years has come into short supply in the market due to the increasing demand and effects of much more stringent regulations in the mining process. Additionally, the restrictions on sulfur content of coal imposed by regulatory authorities has placed a high demand on the lower sulfur content coal. All of these factors, in addition to putting coal in short supply, has caused the price of coal to increase drastically in recent years.

11.2.5 ALTERNATE SITES

A location for the station on or near Lake Erie best meets the requirement of large quantities of water for an open condenser cooling system or consumptive use for a cooling tower system, together with the requirement to be in close proximity to navigable water for delivery of the reactor vessel.

The current Atomic Energy Commission guidelines ruled out consideration of the existing Bay Shore Station as a nuclear site due to its proximity to the population center of Toledo.

The lake shore area from Little Cedar Point to Port Clinton is largely held by the Federal or State Government for wildlife and recreation purposes or has heavily built up residential communities, with some privately-owned marsh areas. This results in the only potentially available areas being between the present site and Port Clinton with the present site being the most suitable site in this specific area. A purchase option on the Darby Marsh closer to Port Clinton was obtained and the details of the exchange agreement, whereby a large portion of the present site was obtained from the U. S. Bureau of Sports Fisheries in exchange for the Darby Marsh, are contained in the Environmental Report and Section 3.1 of this Supplement.

If an alternate fuel such as coal would have been selected for the generating unit represented by the Davis-Besse Station, this particular site would probably not have been selected since other site criteria would have applied.

11.2.6 ALTERNATE GENERATION FOR DAVIS-BESSE

All of the alternatives discussed previously in this section have been alternatives of some years ago and are not available for this project at this time. Imposition of any alternative discussed would mean abandonment of all or a major portion of work already done and expenditures already made or committed. To provide the required capacity represented by Davis-Besse, gas turbine peaking units would be required to be installed as the only type of generating capability that could be purchased and installed in the time available. The alternative to this is to permit the generating reserve of CAPCO to be reduced to an unacceptable low level until an additional large coal-fired unit could be installed.

11.3 TRANSMISSION

Alternatives considered for transmission are discussed in Appendix 4A. This includes alternate means of transmission and alternate routes. It should be noted that any alternative to the Davis-Besse project or location would not reduce the need for equivalent transmission construction.

11.4 RAILROAD

Alternate routes were available for location of the railroad spur into the Davis-Besse site. A route going directly south to the Penn-Central Railroad was considered as well as an extension of the existing spur into the Erie Industrial Park. This later alternate woute would have had a considerable impact on the area since this area is more heavily populated and has marsh areas to cross if the more populated areas were to be avoided. Other alternate routes would have about the same impact on farms as the present route.

To minimize inconvenience to landowners, the railroad spur location was planned to coincide with the main transmission corridor into the station and to follow one of the transmission right-of-ways the remainder of the distance to the railroad main line.

11.5 RADWASTE SYSTEMS

A number of alternative systems and system components are available to collect, treat, and control the radioactive liquid and gaseous wastes. Each of these systems and components have varying degrees of effectiveness and costs. The early design criteria established for the Davis-Besse Station called for extensive systems to collect and process these wastes to minimize the release of radioactivity to the environment. During the detail design, modifications to these systems have been made and the present design is a best balance between costs, minimum impact to the environment, and in-station safety.

In Section 14 of this Supplement, a number of alternatives are shown, some for less equipment than exists in the present design and some for additional equipment which is not anticipated to be included, but is shown for a clear presentation of cost and benefits. A description of the present design is given in Section 4.4 of this Supplement while alternates involving additional equipment are detailed in Section 14, together with costs and benefits relating to reduced release of radioactivity.

11.6 WATER USE AND DISCHARGE

The principal factor in water use and discharge for an installation such as the Davis-Besse Station is the means of releasing to the atmosphere the heat rejected from the condenser. The Davis-Besse Station was originally planned and preliminarily designed for the use of an open lake condenser cooling system with direct discharge to the lake of all rejected condenser heat. The present design and construction provides for rejection of almost entirely all of this heat directly to the atmosphere through the use of a single natural draft, evaporative-type cooling tower. The only heat rejected to the lake is contained in the cooling tower blowdown and is a completely insignificant quantity for a body of water such as Lake Erie. Alternatives, however, are available to further reduce this heat, and are discussed in Section 14, together with their costs and possible benefits.

There will be no chemical wastes discharged from Davis-Besse as such and any discharges, that might be termed as such, are non-toxic dissolved solids which have no adverse effect on the environment and almost the entire amount was contained in the intake water to the station and concentrated due to the evaporation of water from the cooling tower system water. The planned sewage treatment plant will provide better treatment for sanitary wastes than most modern municipal systems. No alternatives for chemical and sanitary wastes need to be considered due to the complete lack of adverse environmental effect resulting from them.

11.7 COOLING TOWER SYSTEM

The only alternative for a cooling tower system is a once-through condenser cooling system. The balancing of one alternative against another many times requires the acceptance of adverse effects of the alternate. In the case of the selection of a cooling tower system, there are some small but insignificant adverse effects on the environment which are unavoidable. These effects from the vapor plume are outlined in Section 7.4 and fully detailed in Appendix 7F. These effects have, however, been minimized by the use of a single taller tower rather than by the use of two smaller towers which Applicants had earlier studied.

It has been suggested that dry cooling towers be used for an installation such as Davis-Besse, however, present technology does not exist to provide such an installation for the Davis-Besse Station.

At the present time, no turbine-generator, with a capacity of 300 MW or greater, can operate at exhaust steam temperatures greater than the temperature corresponding to five inches mercury absolute. Temperatures that will be encountered

with the use of a dry cooling tower will correspond to approximately 10 to 15 inches mercury absolute.
One of the major equipment supplier of nuclear steam supply systems and nuclear turbines has indicated (1) that 3600 RPM turbine generators commonly used with conventional fossil fueled plants and exhausting at a pressure of 10 to 15 inches mercury absolute can probably be ready for shipment by 1977.

This manufacturer, however, states that steam turbine generator units for use in nuclear plants will not be available in the foreseeable future. Also pointed out is the fact that there are numerous hurdles involved in the development of a nuclear steam turbine such as:

1. Exhaust pressure up to 15" Hg. Abs.
2. Exhaust temperature very high.
3. Steam force loadings on blades are very high.
4. Possible flutter damage to last stage blades.
5. Possible water damage to blades with open contact type condenser.
6. Thermal cycling stresses much higher with changing load.
7. Distortion of the exhaust load and bearing supports due to high temperature transients.
8. Difficulties in providing adequate clearance control for mating parts.
9. Low pressure turbines will require completely new redesign to withstand the high transient temperatures.

12 THE RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES & LONG-TERM PRODUCTIVITY

As pointed out in the Environmental Report and in other sections of this supplement the Davis-Besse Station does not involve a short-term operation, but the maintenance of long-term productivity over the life of the station which has a design life of 40 years. The uranium that it will consume to produce heat for the generation of electricity does not represent a threat to the supply of uranium and the use of uranium for this purpose will conserve the fossil fuels, that otherwise would have been consumed, for more beneficial uses.

The station will utilize water and land during its life time, but these uses are entirely reasonable. The effect of water use will in no manner interfer with other general uses of Lake Erie, or the local lake and beach areas.

The land area occupied by the station structures and needed for construction and operation was farmland bordering on the marsh areas so no natural resource of this nature is being unduly used. The existence of the station is not anticipated to precipitate any changes in land use in the area and will be adding materially to the area tax base. Thus, the existence of the station provides for enhancement of the area without detrimental effect or reduction in the quality of the environment.

The fact is that there will be a long-term enhancement of the environment since, as pointed out, natural resources consisting of federally owned and managed water fowl refuges have been preserved and actually enlarged by this action. The U.S. Bureau of Sports Fisheries and Wildlife has had an additional area of about 500 acres added to that under its management for wildlife refuge purposes.

Additionally, the station will provide long-term enhancement of the environment through the supply for many years of a form of energy which has no significant adverse effect on the environment and which is used for purposes of enhancing the environment and in place of forms of energy which may adversely affect the environment.

13 RESOURCES COMMITTED

The principal resources committed involving the site itself are the approximately 160 acres of farmland that originally existed on the undeveloped site and that have been removed from this category by the requirements of site grading and station structures and approximately 24 acres of marsh which are now occupied by the intake canal. By contrast, over 600 acres of prime waterfowl marsh has been committed to the Federal Wildlife Refuge system on a long-term basis by reason of the exchange agreement under which a portion of the site was acquired.

A small amount of water will be removed from Lake Erie evaporated and released to the atmosphere. This is a small fraction of the normal evaporation from the lake surface and is an even smaller fraction of the total quantity of water flowing into Lake Erie in a year. This is not an irretrievable commitment, however, since by normal process, this moisture is returned to the surface in the form of rain.

The Davis-Besse Station will consume about 0.64 tons of U_{235} each year which will require the mining and processing of 180 tons of U_3O_8 to replenish the U_{235} that is consumed. By contrast, a coal-fired equivalent unit would consume approximately 2,000,000 tons of coal each year. At present, uranium has no beneficial use other than use in a nuclear reactor and is present in immediate supply and proven resources for a number of years.

In the reactor, plutonium is produced which in turn can be used as a nuclear fuel and can serve as a source of fuel for breeder reactors which, when developed on a commercial scale, will use the plutonium as fuel and in the nuclear process, produce greater quantities of plutonium than consumed, from the U_{238} isotope which has no other commercial value.

By contrast, an equivalent coal-fired unit would consume approximately 2,000,000 tons of coal each year. Coal has many other uses than as a fuel in a central station and is in short supply from economically recoverable known sources. Use of uranium in a power reactor can conserve the coal resources for use in other menner.

14

14. COST AND BENEFITS OF STATION AND ALTERNATIVES

14.1 GENERAL

This section contains a discussion of the benefits and costs resulting from the construction and operation of the Davis-Besse Nuclear Power Station and alternatives. Other sections have discussed the environmental effects and some of the benefits while Section 11 has outlined alternatives that would have been available during early planning for the project and alternatives that are available at this time. Where possible, costs and benefits are discussed in quantitative terms and where quantitative terms are not possible, qualitative discussion is used.

Applicants are convinced that the installation of the Davis-Besse Station is a proper response to the forecast of needs imposed by the consumer and general public and that construction and operation of the Davis-Besse Station will result in the greatest benefit to the consumer and to the environment while imposing an insignificant burden to the environment.

Applicants are also convinced that the design that now exists is a proper balance between costs and benefits and that imposition of further available alternates will not result in worthwhile benefits.

14.2 BENEFITS

The primary benefit of the Davis-Besse Station will be the availability of 872 MW of reliable base-load electric generating capability to meet the consumer demand in Applicants' service area. This generating capability will also produce the least expensive generation that is available for new installation on Applicants' systems and will result in lowest cost to the consumer. A number of secondary benefits have been or will be realized from the construction and operation and are as follows:

1. The preservation and improvement of all marsh areas on the site for wildlife and the addition to the National Wildlife Refuge System of over 500 acres of prime waterfowl habitat.
2. Additional revenue to local governments. Based on 1970 tax rates for the locality in which the Davis-Besse Station is located, approximately $4,100,000 property tax will be paid by Applicants to the local government. Of this total, the Benton-Carroll-Salem School District will receive $3,450,000, while Carroll Township general fund will receive $287,000 and Ottawa County general fund, $385,000. The school district receives only $800,000 annually from local property tax at the present time.
3. Employment of construction labor during the construction period is adding materially to the economy of a large local area from which the construction workers are drawn.

14.3 ENVIRONMENTAL COSTS

The environmental costs associated with the construction and operation are small and in comparison with the benefits are insignificant. These environmental costs are:

1. Slight and short-term disruption to the environment where construction activities are taking place. The site marsh areas are not disrupted.
2. A small aesthetic burden on the area from station structures and transmission lines.
3. Small consumptive use of lake water and discharge into the lake of small quantities of heated water. The discharge of heated water will not result in any adverse effect on the lake ecology.

4. A slight burden to the public from the extremely low level releases of radioactivity in the station effluents. As detailed in Section 7. , the radiation levels resulting from these releases and the resulting explosure to the public are insignificant in comparison to naturally occurring sources of radiation.
5. An additional possible, but extremely low, probability of low-level radiation exposure to the general public from accidents that could occur and release radioactivity.
6. The cooling tower plume may reinforce ground fogging or cause some ground icing that could be an inconvenience to a limited area on rare occasions.

14.4 COST AND BENEFITS OF ALTERNATIVES THAT WERE AVAILABLE DURING EARLY PLANNING

14.4.1 ALTERNATE SITE

The environmental costs of the Davis-Besse Station at its present location are so slight that any alternate site would not have eliminated them and would probably not have resulted in the benefits to the National Wildlife Refuge System.

14.4.2 ALTERNATE FUELS

As pointed out in Section 11.2.5, coal as an alternate fuel was the only feasible alternative for a base-load generating unit. The initial studies that led to selection of nuclear fuel showed that considering all capital costs, operating and maintenance costs and fuel costs, a nuclear unit would provide generation about 2 to 5% lower in cost.

Since these earlier studies, construction costs have risen which effects nuclear construction the most due to higher initial cost, but coal costs have risen much faster than nuclear with the result that nuclear base-load generation still maintains an economic edge over coal. The additional capital cost for equipment that is now being developed to remove SO_2 will add appreciably to the capital and operating costs of coal-fueled stations.

There are no environmental benefits for a coal-fueled station over a nuclear-fueled station and, in fact, there are environmental costs for a coal-fueled unit that can be quite high for a site such as the Davis-Besse site.

14.5 ALTERNATE FOR DAVIS-BESSE

As outlined in Section 11.2.6, the only available alternative to the Davis-Besse Station as it exists at this time involves abandonment of most of the sizeable expenditure to date of approximately $50,000,000 and a majority of the $148,000,000 committed to date and the installation of gas turbine units to provide the generating capability. This alternative not only adds to the cost of generation but adds a net loss to the applicants for the unrecoverable costs of funds already expended for the Davis-Besse station. The added cost of power generation from an alternate involving gas turbine peaking units instead of from Davis-Besse Station is estimated to be 7,600,000 annually for the generation involved.

This alternative would require the bulk of the generation to be done on applicants' older generating units due to the high costs of fuel for peaking units and the poorer efficiency of the cycle. In addition, this alternative would not eliminate adverse effects since these units would occupy much more area, contribute noise emit low level gaseous combustion products.

SUPPLEMENTAL COOLING POND TO REDUCE TEMPERATURE OF BLOWDOWN

The minimum area of cooling pond that will provide any significant cooling of the blowdown water discharged from the condenser cooling water system to the lake is about 40 acres which is the approximate pond area available on the site at the present time.

The areas consist borrow pits from which land fill has been removed for site construction and a quarry from which the rock has been removed. This alternative is the least expensive of all of the supplemental plans considered because the minimum amount of construction work in the form of excavation and grading is required for this arrangement.

A larger cooling pond of 100 acres will give added cooling to the blowdown discharge but the estimated cost is much greater because any additional acres would have to be excavated. The following summary table shows the cost of two alternates involving the use of cooling ponds and the reduction in temperatures and plume sizes of the discharge that can be attained with each.

Supplemental Cooling Pond to Reduce Temperature of Blowdown

	Blowdown No Pond	With Small Pond	With Large Pond
Water Flow-GPM	9200	9200	9200
Temp. Above Ambient	30	24	18
Btu to Lake x 10^6	138	110	83
Increase Flow with Dilution to	13,800	13,800	13,800
Final Temp Above Ambient Lake	20	16	12.0
5° F Plume-Area in Acres	.11	.09	.07
-Length in Feet	152	137	121
3° F Plume-Area in Acres	.34	.27	.20
-Length in Feet	264	235	202

	Blowdown No Pond	With Small Pond	With Large Pond
1° F Plume-Area in Acres	2.14	1.70	1.29
-Length in Feet	658	587	512

COST BENEFIT SUMMARY			
Total Cost Addition	Base	$630,000	$2,200,000
5° F Plume Area Reduction	Base	.02	.04
Cost Per Acre Reduced	Base	$31,000,000	$55,000,000

SUPPLEMENTAL COOLING TOWER TO REDUCE TEMPERATURE OF BLOWDOWN

If additional cooling tower equipment is used to further reduce the temperature and heat content of the blowdown from the main cooling tower that will be discharged to the lake, the cooling tower would have to be the mechanical draft type as opposed to the natural draft type because the water flow through it is not great enough to warrant use of the tall stack required for the natural draft tower.

Use of the mechanical draft tower means that large fans are required that must operate whenever the plant is operating and fan power and maintenance cost are relatively high compared to corresponding cost for a natural draft tower.

Two different towers of different sizes were analyzed to determine what the added cost would be to install either of them. The 5° F plume size reduction, associated with each tower, was also calculated to determine what the cost would be per acre if the 5° F plume size is reduced.

The results of this study are summarized in the following table.

Supplemental Cooling Tower
To Reduce Temperature of Blowdown

	(1) Blowdown Without Tower	(2) With Small Tower	(3) With Large Tower
Water Flow-GPM	9200	9200	9200
Temp. Above Ambient Lake	30	20	15
Btu to Lake x 10^6	138	92	69
Inc. GPM with Dilution to	13,800	13,800	13,800
Temp. Above Ambient Lake	20	14	10
5° F Plume - Area in Acres	.11	.08	.055
- Length in Feet	152	130	108
3° F Plume - Area in Acres	.34	.24	.170
- Length in Feet	264	222	186
1° F Plume - Area in Acres	2.14	1.50	1.07
- Length in Feet	658	552	466
COST BENEFIT SUMMARY			
Total Cost	Base	\$592,000	\$752,000
5° F Plume Area Reduction	Base	.03	.055
Cost Per Acre Reduced	Base	\$19,700,000	\$13,600,000

POWERED SPRAY MODULES TO REDUCE
TEMPERATURE OF BLOWDOWN TO THE LAKE

As discussed earlier, there are forty acres of existing borrow pits and rock quarry available for cooling ponds without sacrificing marsh or upland for this purpose. The forty acres if used as cooling pond area, would reduce heat input to the lake by reducing the temperature by approximately 25%.

Any further reduction in temperature and heat input to the lake would require a total of approximately 100 acres which means that an additional 60 acres would have to be excavated. The excavation cost alone would be approximately \$1,500,000 to remove and store 775,000 cu.yards of material. In addition to the high cost for this added 60 acres this area would be destroyed for further use as marsh land.

There is however, another alternative that will accomplish the same degree of cooling as can be attained with the 100 acre pond and it could utilize the existing 40 acres of pond area now available. This alternative consists of floating motor driven spray units that can be placed in one of the small borrow pits now at the site.

The use of these floating spray units would reduce the temperature of the blowdown discharged to Lake Erie as follows:

Supplemental Floating Spray Modules to
Reduce Temperature of Blowdown to Lake Erie

	Blowdown No Spray Modules	Blowdown With Spray Modules
Water Flow-GPM	9200	9200
Temp. Above Ambient Lake	30	15
BTU to Lake x 10^6	138	69
Increase Flow with Dilution to	13,800	13,800
Final Temp. to Lake-°F	20	10
5°F Plume-Area in Acres	.11	.055
-Length in Feet	152	108
3°F Plume-Area in Acres	.34	.170
-Length in Feet	264	186
1°F Plume-Area in Acres	2.14	1.07
-Length in Feet	658	466

COST BENEFIT SUMMARY

Total Cost Addition	Base	$700,000
5°F Plume Area Reduction	Base	.055
Cost Per Acre Reduced	Base	$13,000,000

The base area of the 5°F thermal plume that would be encountered with the present concept for Davis-Besse Station is so small that any further reduction in its size results in enormous cost per acre of reduction. In this case the cost is $13,000,000 per acre.

14.6 RADWASTE SYSTEMS

14.6.1 INTRODUCTION

The operation of a nuclear reactor for generation of electric power, because of the very nature of the fission process, also involves the creation of many megacuries of fission products. Even though efforts are made in the design and manufacture of fuel assemblies and during operation of the reactor itself, to prevent the leakage of these fission products from the fuel assembly, it has not been possible to prevent the escape of a small fraction of these fission products to the reactor coolant. The escape of these fission products occurs because no manufacturing process can be considered to be 100% perfect. Minor undetectable defects in material and in the manufacturing process after exposure in the reactor will occasionally allow fission products to leak from the fuel assemblies. In addition to these defects the use of zirconium as a cladding material also involves the generation of some fission products near the cold surface since naturally occurring zirconium contains some uranium which cannot easily be separated from the zirconium. Fission products which are generated in the fuel cladding itself or which leak through defects in the cladding will reach the reactor coolant system and will be released from that system in minor quantities as a result of normal operation of the nuclear reactor.

To control the quantity of these fission products released to the environment, nuclear power reactors are equipped with systems to remove as much of the fission products as possible before any contaminated fluids are released beyond the control of the station operator. The Davis-Besse Nuclear Power Station is equipped with systems to process gas and liquid station effluents to remove radioactive materials, and is also equipped with systems to collect and safely dispose of solid materials which may be contaminated with radioactivity.

Solids contaminated with radioactivity are collected and disposed of by off-site land burial at AEC-licensed sites. The solids, prior to burial, are sealed in containers designed to prevent the spread of the contained radioactivity and to prevent exposure to the public to excessive amounts of radiation. By proper management of collection and disposal facilities and by careful transport of these materials from the station to the disposal grounds, exposure to the public is minimized. The disposal of the solids material does commit a certain amount of land which could have been used for purposes other than the disposal of these materials. It is not possible to permit these lands to be used simultaneously by the general public. Consequently, the land used for radioactive waste disposal burial may be considered to be unavailable for other uses. It should be noted, however, that because of the method of burial, these lands are generally not irretrievably lost; and if some future method of safely disposing of these materials should be developed, the buried wastes could be retrieved and the land put to alternative uses.

The liquids and gases containing radioactive materials, cannot be handled in the same manner as radioactive solid wastes. There are various processes, however, which are used to reduce the amount of radioactivity contained in these waste streams prior to their release to the environment. Gases may be treated by filtration to remove particulate material, by passing through absorption beds to absorb certain fission products such as iodine, by holdup for decay, or by cryogenic processing equipment to separate radioactive noble gases. Other processes such as permeable selective membranes and fluorocarbon absorption systems are under development; however, these systems are not yet commercially available and the practicality of their use on a large scale has yet to be demonstrated. A gas stream, if the volume is not large, may be passed into a system of tanks and stored under pressure for a period prior to release from the station, to allow radioactive decay to occur, thereby reducing the amount of fission products released.

Liquids containing radioactive materials may be treated by filtration to remove insoluble materials, by ion-exchange to remove soluble materials and by evaporation to separate either soluble or insoluble materials. In addition, although no credit is taken for them, collection tanks are used in the station which inherently provide a certain period of decay, and thereby, assist in eliminating the dishcarge of short-lived radioactive materials.

An analysis of the various combinations of processes which could be used to treat the effluents from the avis-Besse Station and the costs associated with these systems has been made. The resultant impact, or reduction of impact, on the environment, expressed both as maximum individual exposure and population exposure, has been determined and is shown as a function of the cost of the system in Figure 14-1 and 14-2 for liquid releases and in Figures 14-3 and 14-4 for gaseous releases.

14.6.2 RADWASTE SYSTEM DESIGN ALTERNATES

14.6.2.2 Miscellaneous Liquid Radwaste System

This system, which is described in Section 4.4.1.2, is designed to collect, process, monitor and safely dispose of all potentially radioactive dirty and/or aerated liquid wastes. The present design of this system basically consists of two tanks for collecting wastes; an evaporator, demineralizer and filter for decontamination; two tanks for storing and monitoring the individual processed waste fractions; and all the necessary transfer pumps, instrumentation and interconnecting piping required for satisfactory operation.

In order to develop the cost-benefit curve, the following system design alternates were reviewed:

a. No active processing, i.e., direct release to environment (System 1).

b. Filtration and demineralization prior to release (System 2).

c. Evaporation, and filteration but no demineralization (PSAR Design - System 3).

d. Evaporation, filteration, and demineralization (Present design - System 4 - For more detail on this system, see Section 4.4.1.2 of this supplement).

e. Two evaporators in series, one filter, and one demineralizer (System 5).

14.6.2.3 <u>Clean Liquid Radwaste System</u>

This system, which is described in Section 4.4.1.1, is designed to collect, process, monitor and either store for reuse or dispose of all the reactor coolant system wastes. These wastes are generated as a result of fluctuations in the reactor coolant system volume or due to the required changes in the boron concentrations.

In the present design, the clean liquid wastes are processed through a degasifier, two filters in series, two demineralizers in series, and a boric acid evaporator. The waste is then monitored for radioactivity and purity prior to being stored for recycle or released to the environment. For the purposes of developing the cost - benefit curve, the following system design alternates were reviewed:

a. Minimum functional system with degasification, and filtration for undissolved particles (System 6).

b. Degasification, two sets of filters, and 1 demineralizer (System 7).

c. Degasification, two sets of filters, and two sets of demineralizers (System 8).

d. Degasification, two sets of filters, two sets of demineralizers and an evaporator (Present Design - System 9 - For more details see Section 4.4.1.1 of this supplement).

e. Degasification, two sets of filters, two sets of demineralizers, and two sets of evaporators in series (System 10).

14.6.2.4 Gaseous Radwaste System

The gaseous radwaste system, which is described in Section 4.4.1.3, processes potentially radioactive gases removed from the reactor coolant system water as it is processed through the clean liquid waste system and gases from the quench tank, makeup tank and reactor coolant drain tank. These gases are compressed into one of the three gas decay tanks. After a hold-up time for radioactive decay for most periods of generation of 60 days the gases are released to the station vent through a HEPA filter.

For the purposes of developing a cost-benefit curve, the following system design alternates were considered:

1. No hold-up for decay (System A).
2. Hold-up for 30 and 60 day decay (Present Design - System B - For more detail see Section 4.4.1.3 of this supplement).
3. Hold-up for 60 day decay (System C).
4. Recombiner plus hold-up for 5 years decay (System D).
5. Hold-up for decay plus addition of a cryogenic processing (System E). | 1

The cryogenic processing unit specified for use in design alternate No. 5 | 1
was one of the several types presently being developed. In general, it

separates the small amounts of radioactive noble gases from the much larger quantities of hydrogen and/or nitrogen. This is done by selective absorption of xenon and krypton on a cryogenically cooled media such as charcoal or molecular sieve or by cryogenic distillation. It is estimated that these processes are capable of reducing the xenon and krypton concentrations in a waste gas stream by a factor of at least 1,000. The radioactive gases removed, because of their small volume, can then be packaged for long term storage. Since after only 60 days of decay, most of the activity is due to the very long-lived Kr-85, it is not considered efficient to use this type of equipment simply to concentrate these gases so that they can be held longer for decay. Therefore, it is assumed that once the krypton and xenon are separated out, they would have to be stored permanently, either at the site or at a designated offsite repository. It should be noted that, at this time, the AEC and other regulatory agencies do not have a clearly defined policy on the storing and shipping of large quantities of compressed radioactive gases. This, combined with the fact that there are no similar units now in service, make the inclusion of this type of equipment somewhat speculative. The cost and effectiveness of such a system have been estimated however, to show the relative value of adding it to the present system.

14.6.3 COST-BENEFIT ANALYSIS

The various liquid radwaste systems described in the previous paragraphs were combined to determine the radioactivity discharged with liquid effluents from which the individual whole body dose and whole body dose to the population could be estimated. The dose routes considered for liquid releases were (a) fish ingestion and (b) drinking water.

System decontamination ability was based on the following decontamination factors for various system components:

Filters	-	10
Ion Exchangers	-	500 per unit
	-	1000 maximum all units
Evaporators	-	10^3 for iodine
	-	10^4 for all other non-volatile components

Ion exchangers were assumed to reduce only soluble fission products (except tritium) activity, filters were assumed to reduce only insoluble corrosion products activity while evaporators were assumed effective for both soluble and insoluble activity. In addition it was assumed that the minimum obtainable activity concentration in a liquid stream was 10^{-8} μCi/cc.

The various combinations of systems considered are identified by the numbers associated with each point on Figures 14-1 and 14-2. These numbers refer to the system numbers given in paragraphs 14.6.2.1 and 14.6.2.2.

As can be seen from these figures, a substantial reduction in the station contribution to the whole body dose is obtained by the addition of processing equipment presently in the station design. However, as the effluent concentration and consequently whole body exposure decreases, the incremental reduction in dose becomes insignificant and even substantial expenditures for additional equipment will not result in further significant dose reduction.

Figure 14-3 and 14-4 show the dose reduction obtainable with each of the five gas processing system designs along with the incremental cost to obtain the dose reduction from these systems. It should be noted that the most significant dose contribution results from containment purging even though it is based on being processed through the emergency ventilation system described in Section 4.4.1.5.

This dose contribution cannot be further reduced by the addition of processing methods currently available. This figure also demonstrates that gaseous releases will be reduced to levels which are considered as low as practicable considering current processing technology.

Table 14-1 shows the total dose resulting from natural background and from the station contributed sources considering various combinations for the liquid and gaseous radwaste systems along with system costs. As can be seen, the effluents from the extensive radwaste treatment systems, as now planned for the Davis-Besse Station, will contribute an extremely small fractional increase to the total radiation stress that is imposed upon individuals and the population from naturally occurring background radiation which is present whether the station exists or not. Additional expenditures for further equipment and systems would not result in any significant reduction to the exposure levels resulting from station operation which will be so low as to be barely detectable and of less magnitude than changes to individual exposure resulting from normal changes in work or living patterns.

TABLE 14-1 1

TOTAL DOSE FROM NATURAL BACKGROUND AND PLANT CONTRIBUTED RADIATION

WASTE TREATMENT SYSTEM COMBINATION	TOTAL SYSTEM COST IN DOLLARS	TOTAL EXPOSURE LEVELS INCLUDING NATURAL BACKGROUND RADIATION: TO THE MAXIMUM INDIVIDUAL[4] mRem/yr	TOTAL EXPOSURE LEVELS INCLUDING NATURAL BACKGROUND RADIATION: TO THE POPULATION[2], 0-50 mi Man-Rem/yr
1,6,A	1,780,000	100825.027	337239.
2,8,A	2,492,000	262.027	334202.2
2,9,B	3,776,000	165.527	334101.62
4,9,B[1]	4,178,000	126.186	334100.438
5,9,D	4,959,000	126.175	334100.389
5,10,E	6,354,000	126.155	334100.308
If there is no station built	zero	125[3]	334100.

(1) Present systems.

(2) Based on 1980 population of 2,670,000 within 50 miles of station.

(3) Average radiation dose due to naturally occurring radiation sources.

(4) Based on the extremely conservative assumptions that fish and drinking water ingestion is from undiluted station discharge water. 1

14.7 COST BENEFIT OF WATER USE THERMAL DISCHARGES AND ALTERNATIVES

14.7.1 THERMAL DISCHARGES

It is extremely difficult to develop a cost benefit analysis for thermal discharges from installation such as the Davis-Besse Nuclear Power Station due primarily to the fact that there has been no significant damage shown which has resulted from the discharge of warmed water to a lake or river from a properly designed comparably sized installation using a once-through cooling system.

The Applicants over the past three or four years, have conducted limnology and thermal plume studies involving the services of two different consultants. Both of them have concluded that there would be no appreciable detrimental effects on lake biota resulting from the discharge of warmed water to Lake Erie, through the use of a once-through open type condenser cooling water system and any detectable detrimental effects would be very limited in extent and would be centered in the area immediately adjacent to the point of out fall. With the closed cycle cooling tower system to be used at Davis-Besse, the thermal discharges will be dramatically reduced from those of a once-through system. Therefore, since there is no benefit to be realized from added investment there is no meaningful cost benefit comparison that can be made.

In spite of the absence of proven environmental damage from a properly located and designed once-through cooling system installation, there are others that held that detrimental effects will result from discharge of warm water even at the low levels encountered with such an installation, that these detrimental effects to the environment will be proportional to the quantity of heat input, and that no heat input is the only foolproof answer to all supposed problems in this area.

Under the circumstances, if a cost benefit study is to be made, there must be some arbitrary selection of a temperature limitation with an area associated with it which is significant, so that cost studies can be made of the various alternatives available to attain any reduction in affected areas within this limitation.

As shown under 7.2.2.1, the latest Ohio criteria, unapproved Federally, contemplate a reasonable mixing zone and beyond such zone, the excess temperature shall not be more than 5° above the ambient water temperature. Without conceding that increases of more than 5° above the ambient may involve harm from heated water, we have chosen to prepare figures on the basis of a 5° plume, since they adequately show the extreme cost and lack of benefit in making provisions for dissipation of heat beyond the present plan.

It is possible to predict very closely the area of the water body that will be at a temperature of 5° F and higher for any quantity of water flowing to the lake at a particular temperature above the ambient lake temperature. For a given reduction in the area of this 5° F plume there is a total cost that is required to bring about any plume size reduction. These figures can be developed and they seem to provide the best basis for a cost benefit analysis.

The lowest cost arrangement, to the Applicants, for a condenser cooling water system, is the open type designed for low flow quantity and a high temperature rise. For the Davis-Besse Station the lowest cost Base condition was selected as an open system designed for a temperature rise across the condenser of 22° F with a flow of 560,000 GPM. This arrangement results in the greatest area for the 5° F plume which is approximately 2300 acres with a low velocity discharge. At 6.7 ft./sec. discharge velocity this plume area is 101.2 acres.

In the following sub-sections, the costs of alternatives involved with the discharge of heat into Lake Erie are discussed and the benefits of these alternatives given in regard to reduction of areas in the lake seeing a temperature of 5° F or larger. These costs and benefits are summarized on figure 14-5.

The conclusion of the limnology and thermal plume studies conducted by two separate and independent consultants was that no measurable damage would result from the discharge of warmed water from the Davie-Besse Station even with the once-through open type condenser cooling water system discharging 685,000 GPM at 18° F which was the initial design condition.

Dr. Pritchard's thermal plume studies of this initial design condition are included in this report as Appendix 14A entitled "Predictions of the Distribution of Excess Temperature in Lake Erie Resulting from the Discharge of Condenser Cooling Water from the Davis-Besse Nuclear Power Station", under the date of 1 August 1969.

Dr. Pritchard's further studies of thermal plumes, if they are bent in the north or south direction by transverse currents resulting from a shift in the wind away from the prevailing wind direction, are included in this report as Appendix 14B dated April 10, 1970.

The April 10 study (Appendix 14B) indicated that when the plume was bent in the northerly direction the nearby reefs approximately 3 1/2 miles from the point of outfall would see 1 1/2 to 2° F. When the plume was bent southward due to a shift in wind direction the mouth of the Toussaint River could see approximately 7° F.

These bent plumes would be of a temporary nature lasting not more than 48 hours; however, to further remove any doubt existing in the minds of some, the Applicants agreed to increase the circulating water flow in the open system to 1,027,000 GPM to reduce the initial excess temperature from 18° F to 12° F.

Even though authorities on the subject conclude that there is no damage that occurs at temperatures above 5°F,the Applicants have added the closed system with a cooling tower to reduce the thermal input to Lake Erie to a negligible amount. For example the above bent plume 3-1/2 miles or 18,500 feet long at an excess temperature of 1 1/2 to 2° F that would have existed with the open lake cooling system under extreme adverse wind conditions would now only be 500 feet long, or less, under these adverse wind conditions as indicated in Dr. Pritchard's June 1971 statement included in this supplement as Appendix 4B.

As indicated by Mr. Harlow of EPA in his statement before the Ohio Water Pollution Control Board on July 28, 1971 at the public hearing conducted by the board and included as Appendix 2H in which he stated "Recognizing that western Lake Erie is at a danger point with respect to temperature and is in a more critical stage of eutrophication than any other part of any of the Great Lakes, we were deeply concerned about the possible impact of the waste discharges as originally proposed."

Mr. Harlow later states "Since there are no federally-approved temperature standards for Lake Erie, it is premature to conclude that plant thermal discharges will be in compliance with Federal Water Quality Standards. However, if the temperature standards recently proposed by the Lake Michigan Enforcement Conference can be used as a guide, the thermal discharges defined by the applicants are well within those standards".

The temperature standards proposed by the Lake Michigan Enforcement Conference establish a 1000 foot distance for the maximum length of the 3° F plume. Reference to part 14.7.1.2 column (3) of this supplement shows that the length of the 3° F plume is 264 feet for Davis-Besse Station and the area covered by this 3° F plume is 1/3 acre.

The proposed standards also established a limit of 500,000,000 BTU/HR, as the total heat input rate. The maximum rate of heat input to Lake Erie from Davis-Besse Station with the present plan is 138,000,000 BTU/HR, which is little more than 1/4 of the proposed standard for Lake Michigan.

14.7.1.1 Once Through Open Type Condenser Cooling Water Systems

Prior to the selection of the closed system with a cooling tower to remove the major portion of the heat discharged from the condenser cooling water, numerous alternatives were studied in an effort to minimize the environmental effects from the discharge of this warm water to Lake Erie. The summary data for all of these studies is included in the first issue of the Report and General Plan for Davis-Besse Nuclear Power Station, Lake Erie Water Use and Discharge, dated December 1969 and submitted to the Department of Health, State of Ohio, on December 30, 1969. The appropriate portions of this Report and Plan showing these alternatives are included in this supplement as Appendix 14C.

There are two general arrangements, either of which can be used for the discharge of warm water from generating stations. One involves the discharge of water at low velocity, such as one foot per second, with the result that the warm water tends to float on top, but covers a relatively large area.

The other method utilizes a higher velocity imparted to the discharge water to induce jet entrainment mixing which greatly reduces the area of all warm water plumes at the higher temperatures. Because of the presence of reefs that are spawning areas for pickerel within distances of three to six miles from the point of discharge, it was considered advisable to adopt the method of jet entrainment mixing.

The open type once-through condenser cooling water system discharge for the Davis-Besse Station, prior to the addition of the cooling tower with the closed system was designed on the basis of the latter of the two concepts namely with the use of high velocity discharge to increase jet entrainment mixing and thus reduce areas of the high temperature plumes to a minimum. The following table shows that jet entrainment mixing greatly reduces the area of all plumes except the plume at the 0.5° F temperature.

The estimated cost and plume size differences between these two arrangements of discharge, with the once-through open type system designed for an 18° F temperature rise and 685,000 GPM flow, are as follows:

	Velocity of Discharge	
	(1) 1.0Ft/Sec.	(2) 6.7Ft/Sec.
Water Flow-GPM	685,000	685,000
Temp. Rise Above Lake-°F	18	18
Heat Discharge-Btu x 10^9	6.21	6.21
18° F Plume-Area, Acres	13	.3
-Length, Feet	1500	330
14° F Plume-Area, Acres	36	.9
-Length, Feet	2500	400
10° F Plume-Area, Acres	146	3.5
-Length, Feet	5000	800

	Velocity of Discharge (1) 1.0Ft/Sec.	Velocity of Discharge (2) 6.7Ft/Sec.
5° F Plume-Area, Acres	1974	88
-Length, Feet	18,600	3900
1° F Plume-Area, Acres	9068	6680
-Length, Feet	40,000	34,000
0.5° F Plume-Area, Acres	9436	57,163
-Length, Feet	41,000	100,000

COST BENEFIT SUMMARY

Total Cost Addition	Base	$1,400,000
5° F Plume Area Reduction	Base	1886
Cost Per Acre Reduced	Base	$740

The data given in column (1) of the above tabulation shows predicated plume sizes with the standard arrangement of warmed water discharge that has been used over the years, with the water entering and receiving the water body at low velocity resulting in a relatively thin surface layer. The extent of the higher temperature areas is much larger in this case.

The figures in column (2) above show corresponding areas of like temperatures with a high velocity discharge with jet entrainment mixing introduced to reduce the areas of the warmer water plumes. The plumes for this case are thicker than those in column (1) and in some cases they touch the lake bottom but the areas in all cases except those at the 1/2° F temperature are much smaller.

This results, for applications where high velocity discharges are used, in much smaller high temperature areas and a lower temperature difference between air and the warmed water in these reduced areas. Consequently, most of the cooling and release of heat to the atmosphere takes place in the area covered by 1° F and less. This accounts for the fact that the area of the 1/2° F plume for the low velocity case (1) is 40,560 acres and for case (2) the corresponding area is 100,000 acres.

As indicated above, the cost of offshore structures to provide the necessary restriction at the point of outfall to inpart the 6.7ft/sec. velocity to the discharge stream, amounts to $1,400,000. However, this investment confines all warm water at excess temperatures of 5° F and higher to an area of only 88 acres with the open system.

Without this provision, for jet entrainment mixing, the area of this plume would have been 1974 acres. The cost per acre to accomplish this reduction amounts to only $740 per acre. This provision was considered advisable by the Applicants and the Davis-Besse Project has been committed to the concept of the high velocity discharge with jet entrainment mixing beginning in 1969 since it was realized that the reduction in areas of the higher temperature plumes to a minimum would reduce any possible detrimental thermal effect to a minimum and that the increased area covered by the 1/2° F plume is not a change significant enough to produce any detrimental effect whatsoever.

14.7.1.2 Closed Cooling Tower System

The decision was made in July of 1970, to adopt a closed condenser cooling water system with a single natural draft cooling tower to reject 98% of the waste heat to the atmosphere by evaporative cooling.

A brief summary of discharge water flows, temperature rises above lake temperatures, heat inputs and plume sizes at excess temperatures of 1°, 3°, and 5° F resulting from these heat inputs are given in the following table. The data given in the right column with the cooling tower applies to the thermal discharge concept for Davis-Besse Station as it exists today following numerous refinements and adoption of alternatives since the cooling tower was added with the closed system.

THERMAL DISCHARGE TO LAKE ERIE
OPEN SYSTEM VS. CLOSED SYSTEM WITH COOLING TOWER

	Open Systems No Cooling Tower (1)	(2)	Closed System With Cooling Tower (3)
Water Flow-GPM	685,000	1,027,000	13,800
Temperature Rise-°F	18	12	20
Heat Input to Lake-Btu x 10^6	6210	6210	138
5° F Plume-Area in Acres	88	37	0.11
-Length, in Feet	3900	2532	152
3° F Plume-Area in Acres	400	340	0.34
-Length in Feet	9500	8500	264
1° F Plume-Area in Acres	6680	6635	2.14
-Length in Feet	34,120	34,000	658
COST BENEFIT SUMMARY			
Total Cost Addition	Base	$2,775,000	$9,013,000
5° F Plume Area Reduction	Base	51.00	87.89
Cost Per Acre Reduced	Base	$54,000	$101,000

14.7.1.2.1 Present Arrangement of Discharges

The discharge of blowdown water, from the closed condenser cooling water system, to the lake will be controlled to maintain total dissolved solids concentration at a factor of approximately two at all times under the existing plan of operation.

The water evaporation rate from the cooling tower will vary between summer and winter operation from a high of 10,400 gpm in the summer to a low of 7500 gpm during the coldest winter month and the blowdown from the cooling tower system will equal the evaporation to maintain this concentration factor of two.

In addition to the variation in volume of water discharged from the cooling water system, the difference between the temperature of the blowdown water discharged and that of the ambient Lake Erie water is also variable since the water temperature of the cooling tower outlet is determined by the wet bulb temperature of the air and it is not dependent on lake temperature.

The quantity of blowdown and its temperature is the determining factors for the total quantity of heat discharged from the closed condenser cooling water system. These two parameters, namely flow and temperature of the blowdown as it leaves the closed system, are independent variables that are dictated by weather conditions alone for any given concentration factor. In this case the station will be operated at a concentration factor of 2 at all time. Since the concentration factor is fixed the blowdown flow and temperature are dictated by weather conditions; however, after the blowdown leaves the condenser cooling water system these factors can be altered or reduced in a number of ways to achieve more desirable plume conditions prior to discharge of this effluent to the lake.

When considering the various alternatives available for reducing heat input to the lake or for altering any one of the parameters to attain a smaller plume size in the lake, it is generally true that the plan that will give the best improvement will be the most expensive to install and the following discussion of the various plans available together with a comparison of each with the others will illustrate this.

Tables 6 and 8 of Appendix 2 of this supplement show that the maximum condition of temperature difference between blowdown and ambient lake temperature occurs in the month of April as tabulated below.

For the Peak April Day-Maximum Annual

Blowdown Flow - GPM	9200
Temperature Difference Above Lake Temp.-°F	30
Maximum Heat in Blowdown-BTU/Hr. x 10^6	138

There are inexpensive ways in which the above parameters can be altered if this is desired in the effort to reduce the thermal effect on the receiving water body. The two most common methods of doing this are as follows:

1. Temperature dilution.
2. Increase concentration factor.

These two concepts have their advantages and also their disadvantages. These are discussed as follows.

14.7.1.2.2 Dilution Alternatives

As indicated below the temperature of the discharge can be reduced simply by increasing the volume rate of flow with the addition of lake water at lake temperature to the discharge circuit. This is referred to as temperature dilution.

Reducing initial temperature of the discharge will not reduce the area of the 1° F plume because the total heat content is not altered by the use of this plan. However, this plan offers a 50% reduction in the area of the 5° F plume size and a 25% reduction in the size of the 3° F plume. There is also a secondary advantage in that the total dissolved solids content is reduced with the addition of lake water at the ambient dissolved solids content. The present plans are to use dilution water up to a maximum flow rate of 20,000 GPM to control temperature of blowdown water to Lake Erie to a maximum of 20° F above ambient lake temperature. The effect of temperature dilution on all parameters including the 1°, 3°, and 5° plume sizes is given in the following table for two different volumes of dilution water flow:

TEMPERATURE DILUTION WITH LAKE WATER
MAXIMUM PERIOD DURING THE MONTH OF APRIL

	Before Dilution	After Dilution To 29°F	After Dilution To 10°F
Blowdown Discharge Flow-GPM	9200	9200	9200
Dilution Water Flow-GPM	-	4600	18400
Total Water Flow-GPM	9200	13800	27600
Temp. Difference Above Lake - °F	30	20	10
Total Heat Discharged - BTU/Hr x 10^6	138	138	138
Total Dissolved Solids - PPM	478	395	309
5°F Plume-Area in Acres	.26	.11	.05
-Length in Feet	234	152	103
3°F Plume-Area in Acres	.47	.34	.20
-Length in Feet	310	264	202
1°F Plume-Area in Acres	2.15	2.14	2.12
-Length in Feet	660	658	656
COST BENEFIT SUMMARY			
Total Cost Addition	Base	$400,000	$660,000
5°F Plume Acre Reduction	Base	.15	.21
Cost Per Acre Reduced	Base	$2,600,000	$3,100,000

14.7.1.2.3 Concentration Factor Adjustment Alternative

Concentration factor in the condenser cooling water system can be increased as a means of reducing heat input to the lake in the blowdown by reducing blowdown flow. However, this reduction in blowdown flow will be offset by an increase of service water discharge flow because of the excess service water that cannot be used for cooling tower make-up purposes.

The net result of reducing blowdown flow and increasing service water flow to the lake amounts to very little reduction of total heat discharged.

There are two major systems in the station that could result in heat discharges to the lake. They are (1) the closed condenser cooling water system and (2) the service water system. If both systems discharged to Lake Erie the total heat would be approximately equally divided between them most of the time. The presently proposed plan is to direct effluent from the service water system to the cooling tower for use as make-up for evaporative and drift losses, and in this case the heat from the service water system is dissipated to the atmosphere by the cooling tower.

At the operating concentration of two the service water flow is such that it can all be used for cooling tower make-up. If make-up flow requirements are reduced by increasing the concentration factor part of the service water that is excess must be diverted to the lake anyway so that the net reduction in total heat discharged to the lake is near zero.

An objection to the increase of concentration factor is that it can cause scale formation on the heat transfer surfaces of the main turbine condenser that could require an acid cleaning to remove it.

14.7.1.2.4 Supplemental Cooling of Blowdown Alternatives

The total heat input to Lake Erie will be highest during the spring months because a transition is taking place in air and lake water temperatures during this period when both temperatures are warming. During spring months when the lake water is still very cold the air temperature increases at a much faster rate than the lake water there will be some periods when it will be impossible to significantly reduce the temperature difference between the cooling tower blowdown water and the lake water since cooling cannot be done below the wet bulb temperature of the air which would be above ambient lake temperature.

However, during part of the year some additional temperature reduction can be made in the blowdown water from the cooling tower circuit which will reduce the temperature difference and the heat input to the lake.

Alternatives to reduce the blowdown temperature are:

1. Add a mechanical draft cooling tower in the blowdown circuit.
2. Interpose a cooling pond in the blowdown circuit.
3. Interpose a group of water sprays and collecting basin in the blowdown circuit.

These alternatives reduce the temperature input to the lake and also the ultimate heat quantity because the flow of water to the lake is not increased as is the case with temperature dilution. The reduction in heat input to the lake will vary in proportion to the temperature reduction in the blowdown from any of the above supplemental cooling devices.

The cooling tower and cooling pond concepts were studied in two sizes to give a comparison of total cost with the reduction in temperature that can be attained for each size.

TABLE 2

DAVIS-BESSE NUCLEAR POWER STATION

CONDENSER COOLING WATER SYSTEM ALTERNATE ARRANGEMENTS - DESIGN PARAMETERS AND PERFORMANCE DATA

I OPEN CYCLE COOLING SYSTEMS	Temp Rise To Lake °F Rise	Total Flow To Lake GPM	Plume Size for 5° Isotherm: Length Ft.	Area: Acres	Area: Sq. Miles	Condenser: Water Flow GPM	Condenser: Size Square Feet	At 75° Lake Water Temp: Cond. Vac. In. Hg.	At 75° Lake Water Temp: Capacity KW Net	Average Annual: Capacity KW Net	Average Annual: Heat Rate Btu Per KWH Net
A. No Supplemental Cooling											
1. 22° Temperature Rise	22°	560,000	4,200	101.2	0.158	560,000	541,000	2.25	870,500	875,700	10,330
2. 18° Temperature Rise	18°	685,000	3,984	88.4	0.138	685,000	466,000	2.25	869,900	875,100	10,337
3. 18° Temp.Rise:Dilute	12°	1,027,500	2,532	36.7	0.057	685,000	466,000	2.25	869,700	874,900	10,340
4. 12° Temperature Rise	12°	1,027,500	2,532	36.7	0.057	1,027,500	397,000	2.25	868,300	873,500	10,357
B. Supplemental Cooling											
1. 22° Temp.Rise:Spray Modules	16°	560,000	2,400	33.1	0.052	560,000	466,000	2.25	854,200	869,400	10,405
2. 22° Temp.Rise:Spray Modules	13°	560,000	1,650	15.7	0.0245	560,000	466,000	2.25	851,000	866,200	10,444
3. 18° Temp.Rise:Spray Modules	12°	685,000	1,721	17.0	0.0265	685,000	466,000	2.25	851,000	866,200	10,444
4. 18° Temp.Rise:Spray Headers	12°	685,000	1,721	17.0	0.0265	685,000	466,000	2.25	852,500	867,700	10,426
5. 18° Temp.Rise:Forced Draft Towers	12°	685,000	1,721	17.0	0.0265	685,000	466,000	2.25	855,200	860,400	10,514

II CLOSED CYCLE COOLING SYSTEMS	Cooling Tower Dimensions: Dia. Ft.	Cooling Tower Dimensions: Ht. Ft.	Condenser Inlet Temp °F	Condenser Disch. Temp °F	Condenser: Water Flow GPM	Condenser: Size Square Feet	At 77° Wet Bulb Temp: Cond. Vac. In. Hg.	At 77° Wet Bulb Temp: Capacity KW Net	Average Annual: Capacity KW Net	Average Annual: Heat Rate Btu Per KWH Net
A. Natural Draft Cooling Towers										
1. 20° Temp.Rise:Small Towers-Large Condensers	355	291	98.0	118.0	616,000	727,000	3.75	840,400	862,400	10,490
2. 25° Temp.Rise:Medium Towers-Medium Condensers	390	370	91.5	116.5	495,000	659,500	3.59	845,600	865,700	10,450
3. 20° Temp.Rise:Large Towers-Small Condensers	400	370	91.4	111.4	616,000	551,000	3.50	844,600	863,600	10,475
4. 20° Temp.Rise:Large Towers-Large Condensers	400	370	91.4	111.4	616,000	741,000	3.12	850,600	864,400	10,466

NOTES: 1. All plume dimensions and areas are based on discharge velocity of 6.7 FPS for the open cycle systems.
2. All condenser vacuum, capacity, and heat rate values are based on maximum guaranteed turbine rating corresponding to the maximum net station capacity of 872 MWe at 1.75 In. Hg.

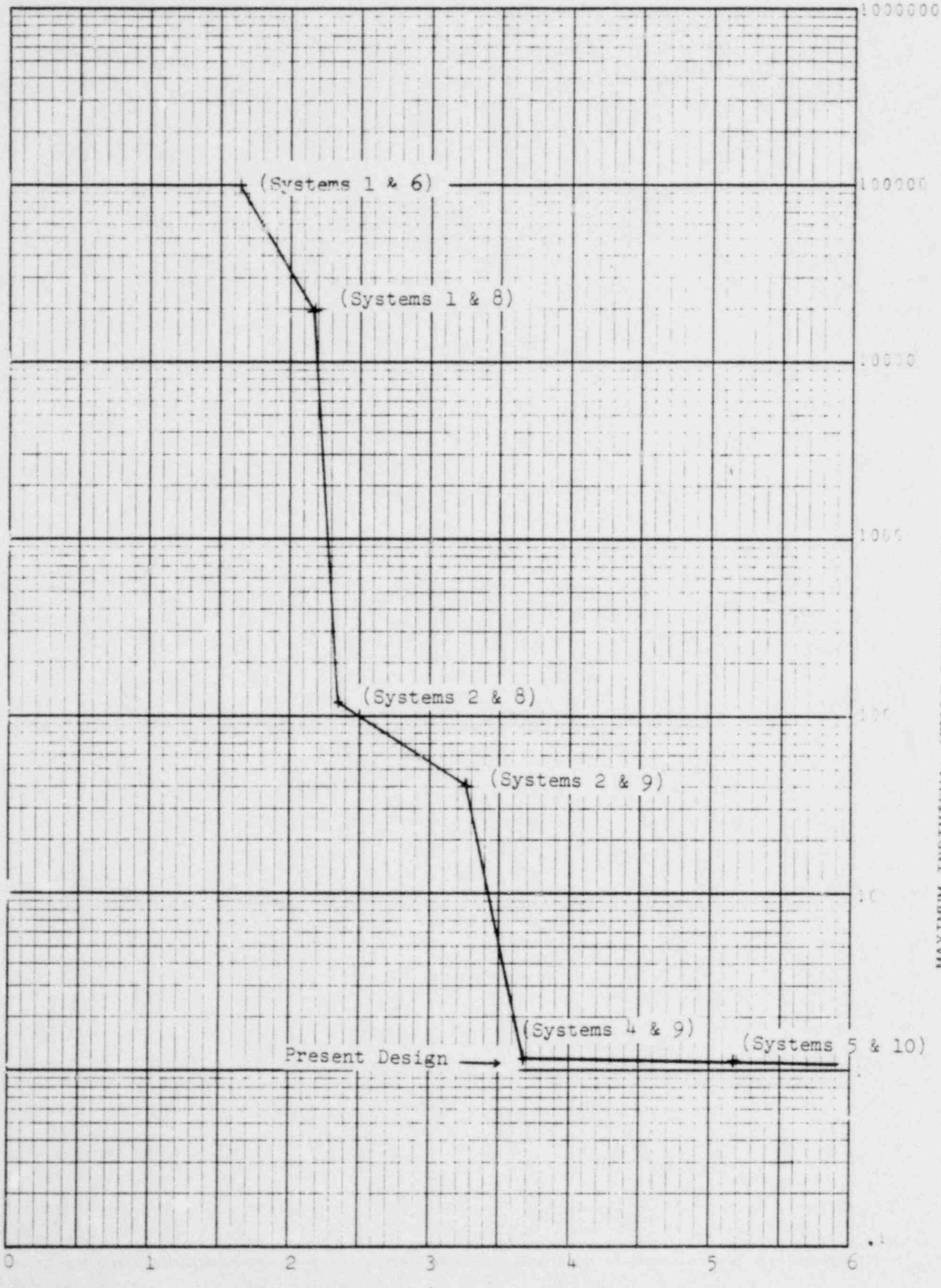
TABLE 3

DAVIS-BESSE NUCLEAR POWER STATION

CONDENSER COOLING WATER SYSTEM ALTERNATE ARRANGEMENTS - CAPITAL COST AND ANNUAL OPERATING COST PENALTIES

I OPEN CYCLE COOLING SYSTEMS	Temp Rise To Lake °F	At 75° Lake Water Temp: Capacity KW Net	At 75° Lake Water Temp: Capacity Penalty KW	Average Annual: Heat Rate Btu Per Net KWH	Average Annual: Heat Rate Penalty Btu/KWH	Capital Cost Penalty: Equipt. Cost Penalty	Capital Cost Penalty: Capacity Penalty @$280/KW	Capital Cost Penalty: Total Capital Cost Penalty	Fixed Charges & Annual Operating Cost Penalties: Fixed Charges @ 16.4%	Fixed Charges & Annual Operating Cost Penalties: Added Fuel Cost	Fixed Charges & Annual Operating Cost Penalties: Added Maint. and Insurance	Fixed Charges & Annual Operating Cost Penalties: Total Annual Cost
A. No Supplemental Cooling												
1. 22° Temperature Rise	22°	870,500	Base	10,330	Base	Base	Base	Base	Base	Base	Base	Base
2. 18° Temperature Rise	18°	869,900	600	10,337	7	$1,325,000	$168,000	$1,493,000	$245,000	$7,000	$ 0	$252,000
3. 18° Temp.Rise:Dilute	12°	869,700	800	10,340	10	4,100,000	224,000	4,324,000	710,000	10,000	1,000	721,000
4. 12° Temperature Rise	12°	868,300	2,200	10,357	27	4,250,000	616,000	4,866,000	798,000	20,000	0	818,000
B. Supplemental Cooling												
1. 22° Temp.Rise:Spray Modules	16°	864,200	6,300	10,405	75	5,250,000	1,764,000	7,014,000	1,150,000	75,000	3,000	1,228,000
2. 22° Temp.Rise:Spray Modules	13°	861,000	9,500	10,444	114	6,950,000	2,660,000	9,610,000	1,576,000	114,000	5,000	1,695,000
3. 18° Temp.Rise:Spray Modules	12°	861,000	9,500	10,444	114	8,150,000	2,660,000	10,810,000	1,773,000	114,000	5,000	1,892,000
4. 18° Temp.Rise:Spray Headers	12°	862,500	8,000	10,426	96	14,663,000	2,240,000	16,903,000	2,772,000	96,000	4,000	2,872,000
5. 18° Temp.Rise:Forced Draft Towers	12°	855,200	15,300	10,514	184	18,325,000	4,284,000	22,609,000	3,708,000	184,000	40,000	3,932,000

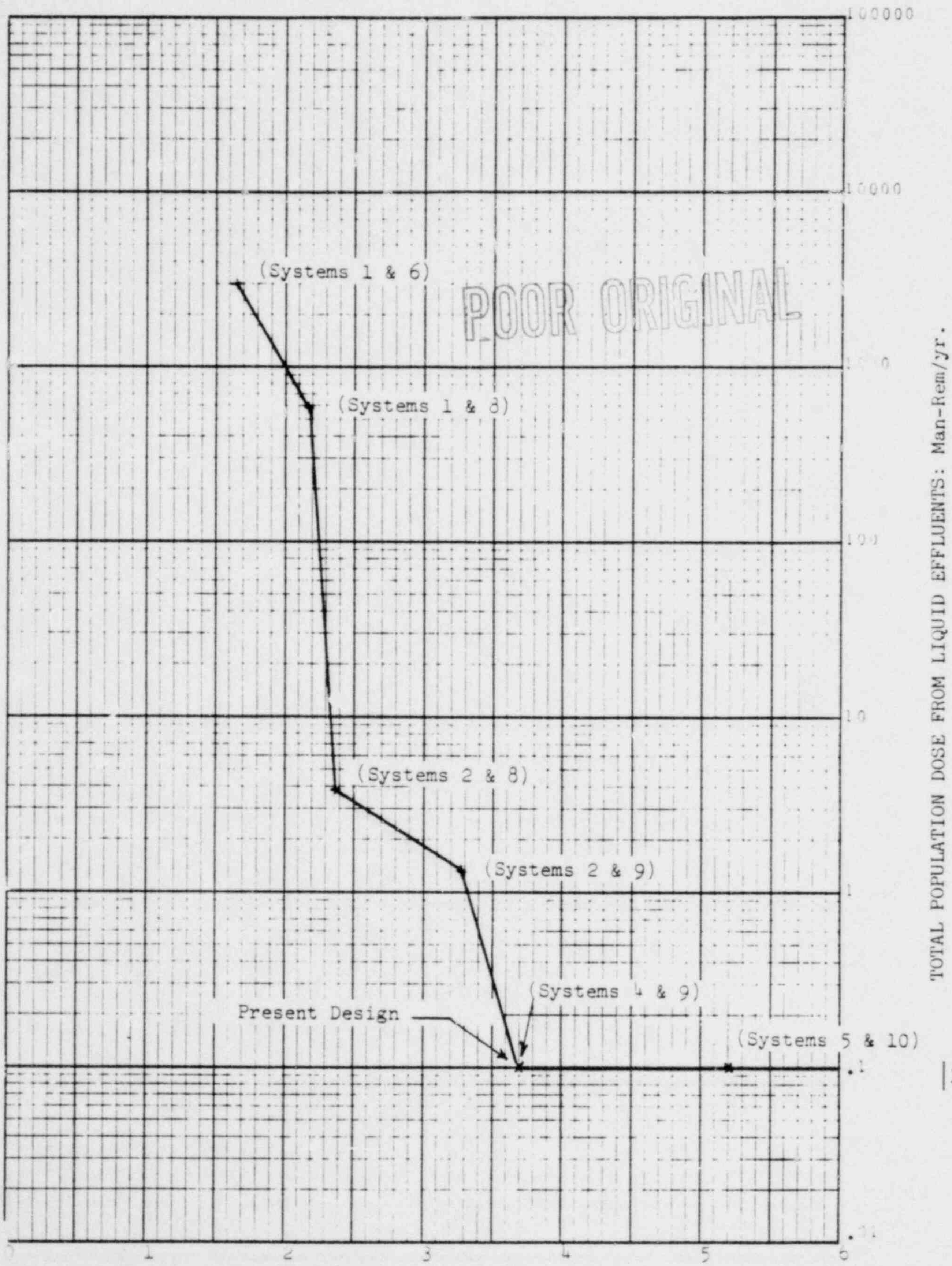
II CLOSED CYCLE COOLING SYSTEMS	At 77° Wet Bulb Temp.: Capacity KW Net	At 77° Wet Bulb Temp.: Capacity Penalty KW	Heat Rate Btu Per Net KWH	Heat Rate Penalty Btu/KWH	Equipt. Cost Penalty	Capacity Penalty @$280/KW	Total Capital Cost Penalty	Fixed Charges @ 16.4%	Added Fuel Cost	Added Maint. and Insurance	Total Annual Cost
A. Natural Draft Cooling Towers											
1. 20°Temp.Rise:Small Towers-Large Cond.	840,400	30,100	10,490	160	10,113,000	8,428,000	18,541,000	3,041,000	160,000	35,000	3,236,000
2. 25°Temp.Rise:Medium Towers-Medium Cond.	845,600	24,900	10,450	120	10,338,000	6,972,000	17,310,000	2,839,000	120,000	41,000	3,000,000
3. 20°Temp.Rise:Large Towers-Small Cond.	844,600	25,900	10,475	145	11,938,000	7,252,000	19,190,000	3,147,000	145,000	46,000	3,338,000
4. 20°Temp.Rise:Large Towers-Large Cond.	850,600	19,900	10,466	136	13,300,000	5,572,000	18,872,000	3,095,000	136,000	46,000	3,277,000



SYSTEM COST IN MILLIONS OF DOLLARS

Figure 14-1

Davis-Besse Nuclear Power Station
Liquid Radwaste System
Cost-Benefit Analysis



|1

$

SYSTEM COST IN MILLIONS OF DOLLARS

Davis-Besse Nuclear Power Station
Gaseous Radwaste System
Cost-Benefit Analysis

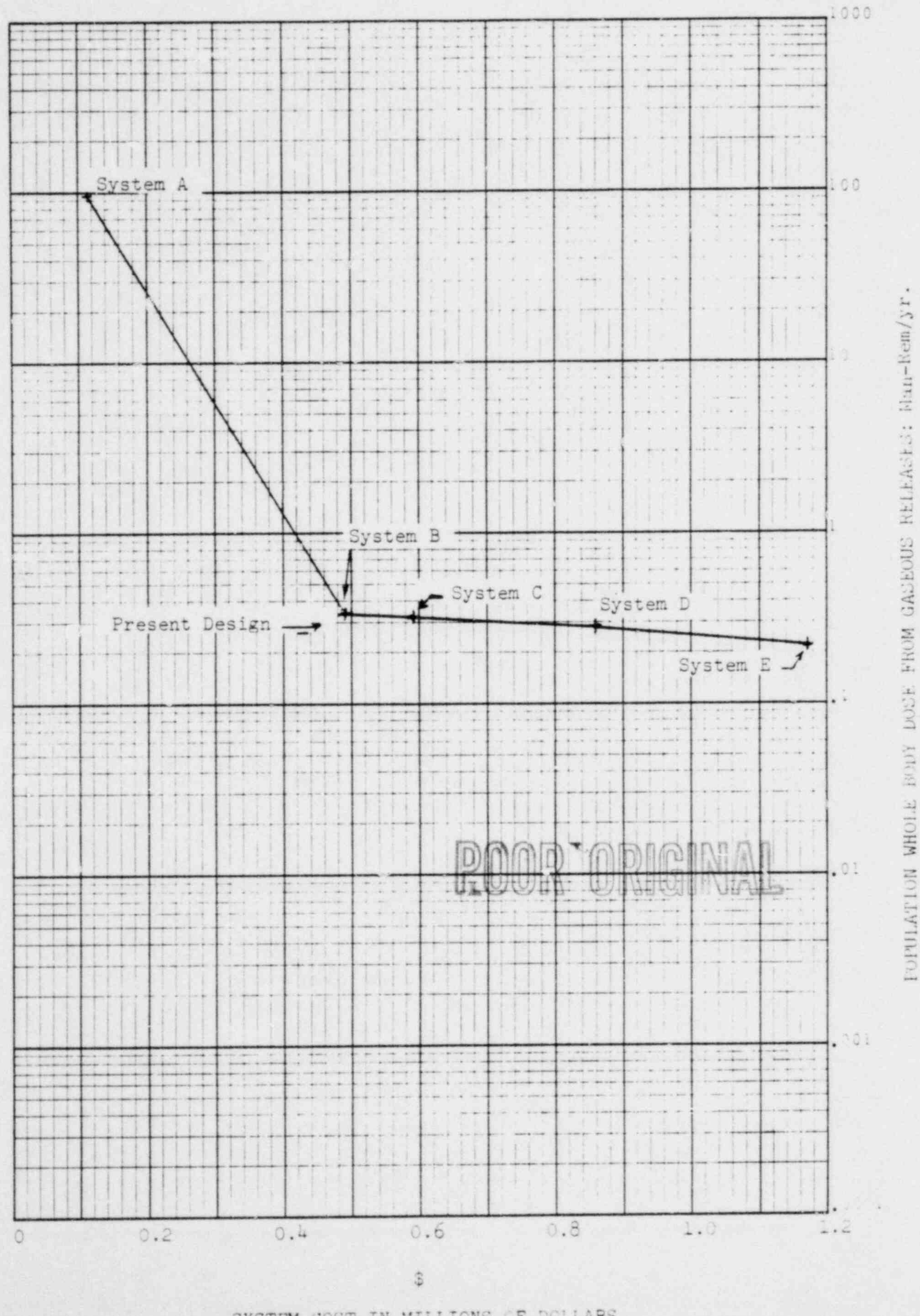


Figure 14-3

Davis-Besse Nuclear Power Station
Gaseous Radwaste System
Cost-Benefit Analysis

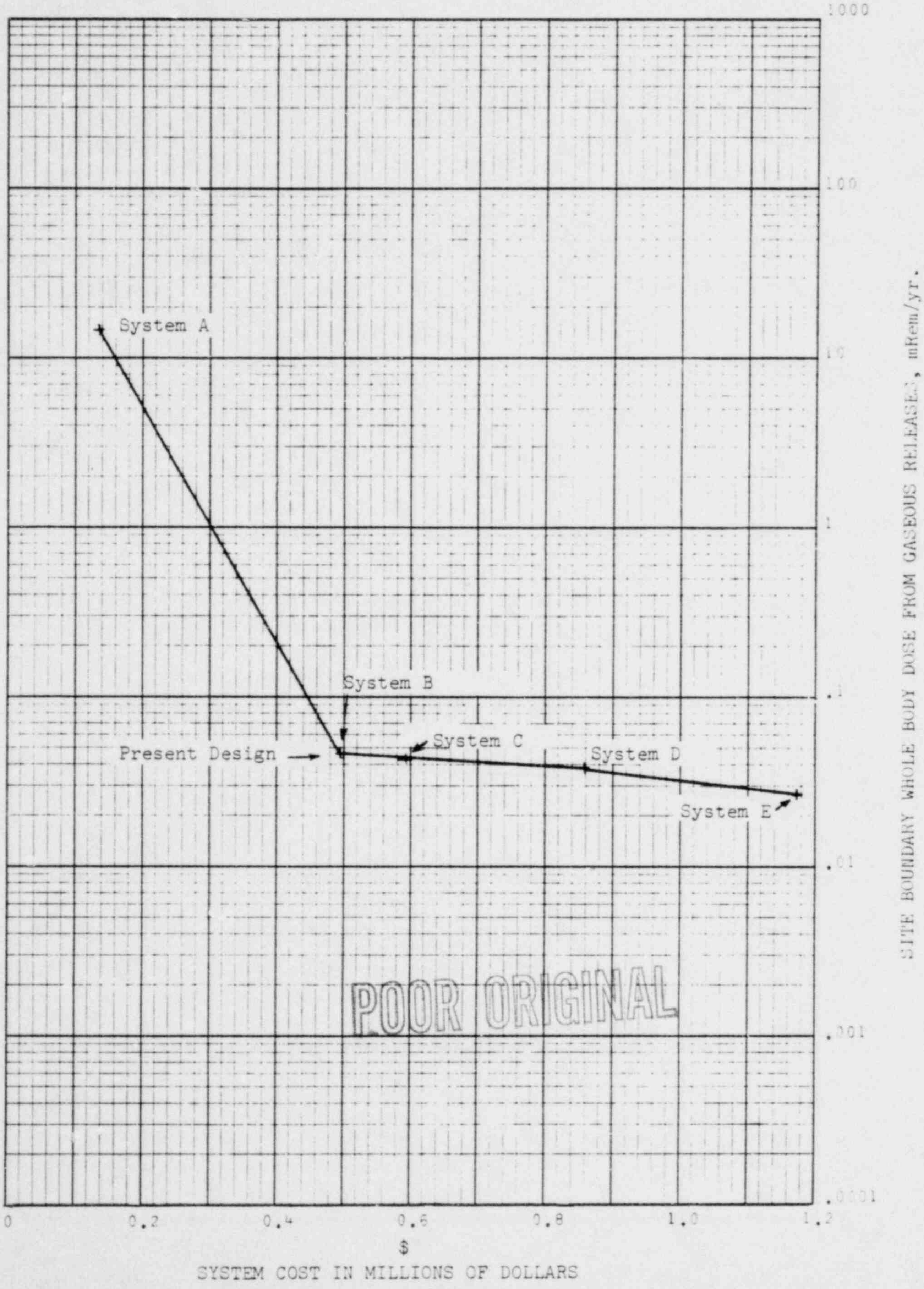


Figure 14-4

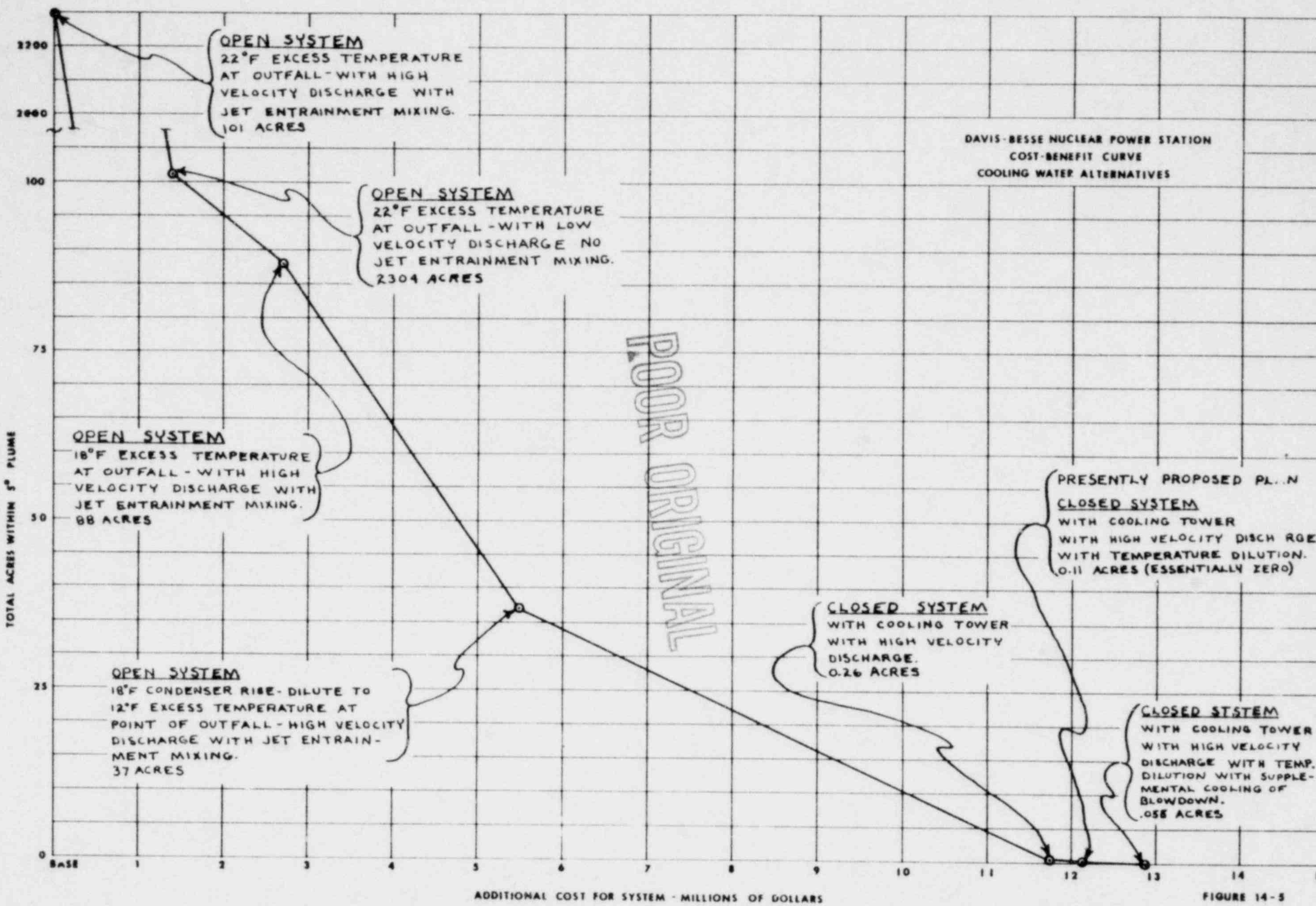

DAVIS-BESSE NUCLEAR POWER STATION
COST-BENEFIT CURVE
COOLING WATER ALTERNATIVES
OPEN SYSTEM
22°F EXCESS TEMPERATURE AT OUTFALL - WITH HIGH VELOCITY DISCHARGE WITH JET ENTRAINMENT MIXING.
101 ACRES
OPEN SYSTEM
22°F EXCESS TEMPERATURE AT OUTFALL - WITH LOW VELOCITY DISCHARGE NO JET ENTRAINMENT MIXING.
2304 ACRES
OPEN SYSTEM
18°F EXCESS TEMPERATURE AT OUTFALL - WITH HIGH VELOCITY DISCHARGE WITH JET ENTRAINMENT MIXING.
88 ACRES
OPEN SYSTEM
18°F CONDENSER RISE - DILUTE TO 12°F EXCESS TEMPERATURE AT POINT OF OUTFALL - HIGH VELOCITY DISCHARGE WITH JET ENTRAINMENT MIXING.
37 ACRES
CLOSED SYSTEM
WITH COOLING TOWER WITH HIGH VELOCITY DISCHARGE.
0.26 ACRES
PRESENTLY PROPOSED PL..N
CLOSED SYSTEM
WITH COOLING TOWER
WITH HIGH VELOCITY DISCH RGE
WITH TEMPERATURE DILUTION.
0.11 ACRES (ESSENTIALLY ZERO)
CLOSED STSTEM
WITH COOLING TOWER WITH HIGH VELOCITY DISCHARGE WITH TEMP. DILUTION WITH SUPPLEMENTAL COOLING OF BLOWDOWN.
.058 ACRES
TOTAL ACRES WITHIN 5° PLUME
2200
2000
100
75
50
25
0
BASE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
ADDITIONAL COST FOR SYSTEM - MILLIONS OF DOLLARS
POOR ORIGINAL

FIGURE 14-5

APPENDIX 14A

APPENDIX 14A

PRITCHARD - CARPENTER

CONSULTANTS

208 MacAlpine Road

Ellicott City, Maryland

PREDICTIONS OF THE DISTRIBUTION OF EXCESS TEMPERATURE IN LAKE ERIE RESULTING FROM THE DISCHARGE OF CONDENSER COOLING WATER FROM THE DAVIS-BESSE NUCLEAR POWER STATION

A Report

Prepared For

The Toledo Edison Company

Toledo, Ohio

August 1969

Predictions of the Distribution of Excess Temperature in Lake Erie Resulting from the Discharge of Condenser Cooling Water from the Davis-Besse Nuclear Power Station

Introduction

The Toledo Edison Company is in the process of the design of a nuclear power plant, called the Davis-Besse Nuclear Power Station, at Locust Point, on the south-west shore of Lake Erie, approximately 25 miles east-southeast of Toledo, Ohio. The first unit to be installed at this plant site is to be an 875 MWE generator which will reject at the condensers some 6.21×10^9 BTU $\cdot$ hr^{-1} under full load. This heat is taken up at the condensers by condenser cooling water withdrawn from Lake Erie through an intake structure and returned to the Lake, with its added heat content, via a discharge canal and discharge orifice structure.

This report is an analysis of the probable spacial distribution of excess temperature (i. e., the temperature elevation above the ambient, or natural lake temperatures which would be present if the plant were not operating) for four different conditions with respect to the temperature rise at the condenser, the volume rate of flow of circulating water, the addition of tempering flow prior to discharge, and the addition of supplemental cooling prior to discharge. In each of the four cases evaluated, it has been assumed that the discharge structure will terminate at a position where water depth, referred to mean lake level, is 6 feet. The discharge structure at this position is assumed to consist of an orifice 6 feet deep and 38 feet wide (except in two sub-cases, as will be noted). The advantage of this narrow orifice, producing a relatively high speed jet discharge, will be discussed later in this report. The other pertinent criteria for the four cases considered are as follows:

Case I: Condenser cooling water flow, 685,000 GPM
Temperature rise at condensers, 18°F

Case II: Condenser cooling water flow, 685,000 GPM
Temperature rise at condensers, 18°F
with supplemental cooling prior to discharge
to 12°F

Case III: Condenser cooling water flow, 685,000 GPM
Temperature rise at condensers, 18°F
with addition of tempering flow from Lake to
produce a discharge of 1,027,500 GPM at
temperature elevation of 12°F.

Case IV: Condenser cooling water flow, 1,027,500 GPM
Temperature rise at condensers, 12°F

Except in Case II, cooling in the discharge canal prior to discharge will not be significant. Therefore the rate of rejection of heat to the Lake in the heated discharge is taken, for Cases I, III and IV, to be 6.21×10^9 BTU $\cdot$ hr^{-1}. In Case II, supplemental cooling in the canal would result in a heat rejection rate to the Lake in the heated discharge of 4.14×10^9 BTU $\cdot$ hr^{-1}. In so far as the analysis of the probable distribution of excess temperature in the Lake is concerned, Case II is equivalent to treating the discharge from a 583 MWE plant rather than an 875 MWE plant.

Case III differs from Case IV in the following way. In Case III the volume rate of flow through the condensers is 685,000 GPM, with a temperature rise at the condensers of 18°F, and additional water is drawn from the Lake and mixed into the heated condenser cooling water flow after this flow has passed the condensers and prior to discharge back into the Lake, such that the volume rate of flow at the point of discharge is 1,027,500 GPM at a temperature rise above ambient of 12°F. In Case IV, all 1,027,500 GPM is considered to pass through the condensers, producing a temperature rise of 12°F. Thus, in both Case III and Case IV, the same amount of excess heat flux (6.21×10^9 BTU $\cdot$ hr^{-1}), carried in the same volume rate of flow (1,027,500 GPM), at the same excess temperature (12°F) is discharged to the Lake. In so far as the analysis of the distribution of excess temperature in the Lake is concerned, Cases III and IV represent the same input conditions, and are therefore treated as a single case, designated in the following as Case III-IV.

Processes Controlling the Distribution of Excess Temperature

Before proceeding with the numerical analysis for the several situations described above, it is desirable to describe the processes that control the distribution of excess temperature, and to establish the basis upon which the quantitative determinations are made.

There are three primary processes which lead to a decrease in the excess temperature in a thermal plume resulting from a discharge of heated water into a natural water body. First, there is an initial dilution of the heated discharge resulting from the mechanical mixing of the heated waters with the receiving waters as a result of the excess momentum in the discharge stream. There is then a second stage dilution resulting from the natural mixing, or turbulent diffusion processes. Third, there is a loss of heat with a consequent reduction in excess temperature, from the water body to the atmosphere.

Ultimately all the excess heat introduced into the Lake in the plant discharge is lost from the Lake waters to the atmosphere. However, as will be demonstrated in what follows, cooling alone cannot be depended upon to produce a reduction of excess temperatures to acceptable values within a sufficiently small area, for a discharge of the kind considered here.

The natural processes of turbulent diffusion are not very effective in producing a reduction in the excess temperatures near the source, because of the relatively large volume size of the source. The natural turbulent diffusion processes do become important at some considerable distance from the source; however, experience has shown that to effect a rapid decrease in the excess temperatures near the point of discharge, the initial mechanical dilution must be enhanced.

Initial mechanical dilution is enhanced by having the velocity of the discharged stream at the point of introduction into a lake or other natural water body be large compared to the natural water velocities in the adjacent lake waters. Even when no particular effort has been made to enhance this momentum jet entrainment, some initial mechanical dilution occurs, since normally the initial velocity of the discharge stream is somewhat larger than that of the natural water motions in the receiving water body. The characteristics of the discharge structure play a significant role in determining the distribution of excess temperature in the vicinity of every discharge of heated water. Consequently, it is not possible to employ observed temperature distributions from existing heated discharges in predicting the probable distribution of excess temperatures from a proposed site, however similar the natural conditions might be, unless the pertinent characteristics of the discharge structure for the existing and proposed plants are also taken into account.

Within the range of excess temperatures between the maximum value, that is, the excess temperature of the heated water at the point of discharge, down to a value corresponding to about 10% to 20% of the excess temperature at discharge, mechanical dilution resulting from momentum jet entrainment is the most important process in determining the distribution of excess temperature. Natural processes of turbulent diffusion are second in importance over this range, and become significant for a water body such as Lake Erie, for the type of discharge considered here, at an excess temperature corresponding to about 20% of the excess temperature at discharge. Cooling, or loss of heat to the atmosphere, contributes a second order correction to the distribution of excess temperature for excess temperatures greater than about 10% of the excess temperature at discharge. Surface heat loss becomes increasingly more important compared to the other processes at small values of the excess temperature, and is the dominant process for excess temperatures less than about 1°F.

The above statement may appear to be contradictory to the well established fact that surface loss of excess heat to the atmosphere per unit area is directly proportional to the excess temperature. What happens in fact is that the processes of momentum jet entrainment and natural turbulent diffusion lead to a decrease in the area of the water surface having high values of excess temperature to such an extent that, even though the rate of heat loss per unit area is high for high excess temperatures, the total loss of heat from such areas is relatively small. This feature will be treated in greater detail later in this report.

A brief description of the quantitative features of each of the three primary processes which control the distribution of excess temperature is given below.

1. Surface Cooling

Consider an increment volume of water introduced into the lake with the condenser cooling water discharge. This increment volume is considered to extend from the surface to some depth D_h, and to have unit surface area. The subject volume enters the lake with a certain amount of excess heat, that is, the heat rejected at the condensers, and consequently has an initial excess temperature, which will be designated as θ_o.

As the subject volume moves with the discharged thermal plume within the lake, its excess temperature will decrease due to horizontal mixing with cooler water through the side boundaries of the volume, and due to vertical mixing through the bottom boundary. Heat will also be lost to the atmosphere across the air-water interface. For the moment consider only this latter, surface cooling, process, neglecting any dilution of the excess heat by turbulent diffusion across the water faces of the volume.

The quantitative expression for the rate of loss of excess heat is obtained by taking the difference between the heat budget of the subject volume, and the heat budget which would apply to the volume if no excess heat had been added. That is, the time rate of change of heat content of the volume under natural conditions (assuming no heat rejected at the condensers) is given by

$$(1) \qquad \frac{\partial h}{\partial t} = q_s - q_{sr} + q_a - q_{ar} - q_b - q_e - q_c - q_{we}$$

where: h = heat content of the volume

q_s = solar radiation incident on the water surface

q_{sr} = reflected solar radiation at the water surface

q_a = incoming long-wave radiation from atmosphere incident on water surface

q_{ar} = reflected long-wave radiation at water surface

q_b = long-wave back radiation from water surface

q_e = rate at which heat is utilized for evaporation

q_c = rate at which heat is conducted from the water surface as sensible heat

q_{we} = rate at which heat is removed from the water body in the evaporated water.

The heat budget for the subject volume under conditions of added excess heat can be written as

(2) $$\frac{\partial h'}{\partial t} = q_s - q_{sr} + q_a - q_{ar} - q_b' - q_e' - q_c' - q_{we}'$$

where the primed terms are those which would be changed by the presence of excess heat. Note that the terms involving solar radiation and long-wave radiation from the atmosphere would be the same in both cases. Subtracting equation (1) from equation (2), gives

(3) $$\frac{\partial}{\partial t}(\Delta h) = -\Delta q_b - \Delta q_e - \Delta q_c$$

where $\Delta h = h' - h$; $\Delta q_b = q_b' - q_b$

$\Delta q = q_e' - q_e$; $\Delta q_c = q_c' - q_c$

and, where $q_{we}' - q_{we}$ can be shown to be negligible.

Now Δh is the excess heat content of the subject volume, and the left side of equation (3) represents the rate of loss of excess heat from the volume due to surface cooling. The three terms on the right side of equation (3) represent (a) the difference between the long-wave back radiation from the water surface for the heated and unheated situations, (b) the difference between evaporative heat loss for the heated and unheated situations, and (c) the difference between the conductive heat loss for the heated and unheated situations.

The long-wave back radiation from the water surface is a known function of surface temperature (i.e., the Stefan-Boltzmann law). Investigations such as the Lake Heffner Study (1) have provided quite reliable relationships giving the evaporation from a lake surface as a function of the wind velocity and the difference between the saturated vapor pressure at the temperature of the water surface and the actual vapor pressure in the air over the water. The conductive heat exchange at the surface can be shown to be related to the evaporative loss through a function called the Bowen's Ratio. Thus the terms on the right side of equation (3) can be computed given water temperatures and atmospheric parameters. It should be noted that when the difference between the evaporation under heated conditions and under unheated conditions is taken, the actual vapor pressure in the air over the water drops out of the relationship. Thus the evaporative loss of excess heat is independent of relative humidity, depending only on the difference between the saturated vapor pressures at the temperatures of the water surface for the heated and unheated situations.

Over the normal range of natural water temperatures (i.e., 40°F to 80°F) and of excess temperatures (i.e., 0°F to 20°F), the expressions for the three terms on the right side of equation (3) can be shown to be satisfactorily represented by a simple linear relationship having the form:

$$(4) \qquad \frac{\partial}{\partial t}\,(\Delta h) = -\mu\,\theta$$

where $\theta = (T_h - T_n)$ is the excess temperature of the subject volume (T_h designates the surface temperature for the heated situation and T_n the surface temperature for the natural, or unheated situation), and μ is a slowly varying coefficient dependent primarily on wind velocity, secondarily on natural water temperature, and only to a third order on excess temperature. Now the excess heat content of the subject volume at any time is given by

$$(5) \qquad \Delta h = \rho\, c_p\, D_h\, \theta$$

where ρ is the water density, c_p the specific heat, and D_h is, as noted earlier, the vertical thickness of the layer containing the excess heat. Substituting (5) into (4) gives

$$(6) \qquad \frac{\partial \theta}{\partial t} = -\frac{\underline{\gamma}}{D_h}\cdot\theta$$

where $\underline{\gamma} = \mu/\rho c_p$, and is called the surface cooling coefficient. Table I gives $\underline{\gamma}$, in $ft \cdot hr^{-1}$, as a function of wind velocity $\underline{W}$, natural water temperature $\underline{T_n}$ and excess temperature $\underline{\theta}$. It can be seen that $\underline{\gamma}$ depends primarily on $\underline{W}$ and $\underline{T_n}$, and hence equation (6) can be integrated to produce the following expression:

$$(7) \qquad \theta_\tau = \theta_o \exp\left(-\frac{\gamma\tau}{D_h}\right)$$

Table 1

The Surface Cooling Coefficient, γ (ft · hr^{-1}), as a Function of the Wind Speed, W (mph), the Natural Surface Water Temperature, T_n (°F), and the Excess Temperature, θ (°F)

W ↓ \ θ →	2°	6°	10°	14°	18°
		(For T_n = 40°F)			
2	0.0221	0.0240	0.0263	0.0292	0.0329
4	0.0303	0.0326	0.0352	0.0386	0.0427
6	0.0386	0.0412	0.0442	0.0478	0.0524
8	0.0468	0.0498	0.0531	0.0572	0.0620
10	0.0551	0.0584	0.0621	0.0666	0.0717
		(For T_n = 60°F)			
2	0.0276	0.0298	0.0377	0.0366	0.0416
4	0.0394	0.0423	0.0459	0.0505	0.0561
6	0.0514	0.0549	0.0590	0.0641	0.0704
8	0.0634	0.0674	0.0722	0.0779	0.0847
10	0.0754	0.0800	0.0854	0.0917	0.0991
		(For T_n = 80°F)			
2	0.0360	0.0388	0.0427	0.0482	0.0553
4	0.0546	0.0583	0.0633	0.0697	0.0778
6	0.0732	0.0780	0.0839	0.0914	0.1003
8	0.0919	0.0974	0.1045	0.1128	0.1229
10	0.1105	0.1172	0.1251	0.1344	0.1452

where θ_τ is the excess temperature after some time interval τ, and θ_o is the initial excess temperature. In the absence of any mixing with the receiving waters, then the surface area within any isoline of constant excess temperature, A_θ, is related to the time interval after discharge, τ, the depth interval containing the excess heat, D_h, and the volume rate of discharge of heated condenser cooling water, Q_c, such that:

$$\tau / D_h = A_\theta / Q_c$$

Hence equation (7) can be written

$$(8) \qquad \theta_A = \theta_o \exp \left(- \frac{\gamma A_\theta}{Q_c} \right)$$

Or, solving for A_θ, the surface area having excess temperatures equal to or greater than θ_A, we have

$$(9) \qquad A_\theta = \frac{Q_c}{\gamma} \ln \frac{\theta_o}{\theta_A}$$

This expression can be used to compute the area inside a given excess temperature isotherm for the case of surface cooling only -- i. e., no dilution by momentum jet entrainment or by natural processes of turbulent diffusion.

Publications containing background material pertinent to the subject of this section are included in the Reference List given at the end of this report. Of particular pertinence are Reference Numbers 1, 2, 3, 4 and 5.

2. Horizontal Turbulent Diffusion

The vertical stability at the bottom of the heated layer, resulting from the warm thermal plume spreading over the cooler receiving waters, will inhibit vertical mixing. Hence the primary natural process leading to dilution of the excess heat discharged with the condenser cooling water will be horizontal turbulent diffusion. A number of investigators have described the theoretical and observational information on horizontal diffusion from a two-dimensional point source (i.e., a vertical line source) in natural water bodies (6), (7), (8), (9). Consider a tracer material or a contaminant introduced as a continuous vertical line source of vertical thickness D, within a water layer of the same thickness bounded at the top and bottom by interfaces which prohibit or inhibit vertical motion and mixing (for example the water surface and the bottom, or the water surface and the thermocline), in a uniform horizontal current field. Both theory and experiment show that the peak concentration along the center-line of the plume of tracer which develops in the down-current direction will decrease as the inverse first power of distance from the source. The exact form of the transverse distribution across the plume as predicted by the several theories differs somewhat depending on which particular theoretical expression is employed. However, all theories predict that the lateral distribution in the plume will have a bell-like form, and experimental evidence indicates that the average lateral distribution in the plume is approximately Gaussian in form.

When the source is a relatively large continuous discharge, such as the discharge of condenser cooling water, natural turbulent diffusion initially acts only on the edges of the plume, and has little effect on decreasing the concentration of contaminant near the center of the plume until the transverse distribution has been altered from an initial relatively flat-topped form to a bell-shaped form. Thus the rate of decrease of the maximum concentration with distance along the centerline of the plume due to natural turbulent diffusion is, in the case of a large volume rate of discharge, very small for a considerable distance from the source. At sufficiently large distances from the source, however, the concentration distribution will approach that for a two-dimensional point source, and the maximum concentration will thereafter decrease as the inverse first power of distance.

Thus the natural processes of turbulent diffusion are ineffective in producing a rapid reduction in the excess temperature with distance in the vicinity of the point of discharge. In order to promote rapid reduction in excess temperature with distance close to the point of discharge, initial mechanical dilution must be enhanced.

3. Momentum Jet Entrainment

A number of experimental and theoretical studies have been conducted in recent years on the entrainment of diluting waters into both momentum jets and buoyant jets, particularly in reference to the design of effective submerged offshore diffusers for municipal sewage discharges into coastal waters (10), (11). A few studies have also involved the horizontal discharge of a heated effluent as a surface momentum jet (12), (13). The following briefly describes a relatively simple theory for the entrainment of diluting waters into a horizontal surface jet.

Consider the discharge of a heated effluent from a conduit extending into a large natural water body, and directed approximately at right angles to the shoreline. The width of the discharge orifice is designated by b_o, and the depth by h_o. It is assumed that the natural water depths are at least as large as h_o at the point of discharge, and increase with distance along the direction of discharge of the thermal plume.

The initial velocity of the jet at the point of discharge will be directed at right angles to the shoreline and will have an initial speed given by

$$u_j = Q_c / b_o h_o \tag{10}$$

where Q_c is the volume rate of flow of the condenser cooling water. Any natural flow in the receiving water body will usually be parallel to the shoreline. Thus the jet enters the receiving water body with an excess momentum in the direction at a right angle to the shoreline, and a deficiency in momentum along a direction parallel to shore. The jet must lose its excess momentum in the direction perpendicular to the shoreline and gain momentum in the direction parallel to the shoreline by entraining water of ambient momentum, and by being bent toward the direction of natural flow.

In the case of the proposed discharge from Locust Point into the waters of Lake Erie, existing evidence indicates that the natural current speeds are quite small. Hence we can neglect the deficiency in momentum in the jet in the direction parallel to the shoreline, and consider only the necessary entrainment to dilute the momentum of the jet along the axis of the jet.

If it is assumed, for purposes of keeping the mathematics of the problem tractable, that the distribution of both momentum and any other identifiable property (i.e., excess temperature) maintains a transverse distribution having a "top-hat" form, and set down the requirements for the integral conservation of momentum and of any other identifiable, conservative property of the jet, it can be shown that, along the centerline of the thermal plume,

$$\frac{\theta_\zeta}{\theta_o} = \left\{ \frac{\zeta_\theta}{\zeta_v} \right\}^{-1/2} \tag{11}$$

where θ_ζ is the excess temperature at a distance ζ_θ along the centerline of the jet, and θ_o is the initial excess temperature at the point of discharge. The length ζ_v is the distance from the vertical source of the jet, which is located approximately at the discharge orifice, to the point where the jet begins to entrain water, and hence to spread and to be diluted. That is, there is a certain distance, ζ_v, over which no dilution occurs, and hence equation (11) is defined only for $\zeta > \zeta_v$.

The vertual distance, ζ_v can be expressed in terms of the width of the orifice as

(12) $$\zeta_v = n \cdot b_o$$

where n represents an inverse spreading rate, and has been shown from experiment to be nearly constant and approximately equal to <u>6</u>. That is, the jet spreads by entrainment at the rate of 1 on 6.

Solving equation (11) for the distance ζ_θ along the centerline of the plume to the point where the excess temperature has been reduced to θ , we have, using (12)

(13) $$\zeta_\theta = \left\{ \frac{\theta_o}{\theta} \right\}^2 nb_o$$

Designating the rate of heat rejection at the condensers by Q_h, then

(14) $$\theta_o = \frac{Q_h}{\rho c_p Q_c}$$

and equation (13) can therefore be written in the form

$$(14) \qquad \zeta_\theta = \left\{\frac{Q_h}{\rho c_p Q_c}\right\}^2 \times \frac{nb_o}{\theta^2}$$

Also, $Q_c = u_j h_o b_o$

and hence equation (13) can be written in the following alternate forms.

$$(15) \qquad \zeta_\theta = \left\{\frac{\theta_o}{\theta}\right\}^2 \cdot \frac{Q_c}{h_o u_j} = \left\{\frac{Q_h}{\rho c_p \theta}\right\}^2 \cdot \frac{n}{Q_c h_o u_j}$$

The mathematical treatment of momentum entrainment in the jet also gives

$$(16) \qquad b = b_o \left\{\frac{\zeta}{\zeta_v}\right\} = b_o \left\{\frac{\zeta}{nb_o}\right\} = \frac{\zeta}{n}$$

where b is the width of the top-hat jet distribution at the distance ζ.

Keeping in mind that the above treatment deals with the distribution of excess temperature resulting from jet entrainment only, (i.e., surface cooling and natural diffusion are not taken into account), the above expressions can be used to make some general statements about the size of the thermal plume within the region where momentum jet entrainment is the dominant process. Momentum jet entrainment will be the dominant process in controlling the distribution of excess temperature out to greater dilutions, that is, to smaller values of excess temperature, the larger the velocity of the jet at discharge. However, for most practical cases this process will be the most important out to a dilution of at least 5:1, that is, to the point where the excess temperature has been reduced to 20% of the excess temperature at discharge. Thus in the following statements derived from the above equations the "size" of the thermal plume is defined by $\theta \geqslant 0.2\,\theta_o$.

(a) If θ_o is held constant (which also requires the ratio Q_h/Q_c to be constant) then the "size" of the thermal plume is directly proportional to b_o.

(b) If b_o is held constant, then the "size" of the thermal plume is directly proportional to θ_o^2, and hence to $\left\{Q_h/Q_c\right\}^2$.

(c) If Q_h is held constant, then the "size" of the thermal plume is directly proportional to the ratio b_o/Q_c^2, or inversely proportional to the product $Q_c h_o u_j$.

Procedures Used for Computing the Probable Distribution of Excess Temperature.

The relationships discussed in the previous section of this report were employed in a step-wise procedure for the determination of the probable distribution of excess temperature from the proposed Davis-Besse Nuclear Power Station. The following is a description of each step in the procedure.

1. Computation of the Areas Contained Within Given Excess Temperature Isotherms Assuming that the Only Process Controlling the Excess Temperature Distribution is Surface Cooling.

This computation is made for comparative purposes only, since it would be impossible to discharge the condenser cooling water back into the lake without some initial mechanical mixing, and subsequent turbulent diffusion would occur in any case. The results do indicate the size of a flow-through cooling pond which would be required for this plant under relatively unfavorable atmospheric cooling conditions.

The area, A_θ, having excess temperatures equal to or greater than a specified value, θ, is determined using the relationship

$$\{A_\theta\}_c = \frac{Q_c}{\gamma} \ln_e \frac{\theta_o}{\theta}$$

The values of the surface cooling coefficient, γ, used in these computations are for a wind speed of 6 mph and a natural water temperature of 70°F.

The computations for Case I are given in full in Table 2, as an example of the procedure followed.

2. Computation of Length and Width of, and Area Within, Excess Temperature Isolines for Momentum Jet Entrainment and Turbulent Diffusion (no surface cooling).

(a) The first step in this computation is to use the relationship

$$\xi_\theta = \left\{\frac{\theta_o}{\theta}\right\}^2 \cdot nb_o$$

Table 2

Computation of the Area Within a Given Excess Temperature Isoline Assuming Surface Cooling Only

$$\{A_\theta\}_C = \frac{Q_c}{\gamma} \ln_e \frac{\theta_o}{\theta}$$

For Case I: $\theta_o = 18°F$

$Q_c = 685,000$ GPM $= 1526$ cfs $= 5.494 \times 10^6\ ft^3 \cdot hr^{-1}$

γ from Table I for W = 6 mph, $T_n = 70°F$

Hence: $$\{A_\theta\}_C = \frac{5.494 \times 10^6\ (ft^3 \cdot hr^{-1})}{\gamma\ (ft \cdot hr^{-1})} \cdot \ln_e \frac{18}{\theta}$$

θ(°F)	γ (ft · hr^{-1})	$\frac{5.494 \times 10^6}{\gamma}$ (ft^2)	$\ln_e$ 18/θ	$\{A_\theta\}_C$ (ft^2)
16	8.01×10^{-2}	6.87×10^7	0.118	8.11×10^6
14	7.67×10^{-2}	7.17×10^7	0.251	1.80×10^7
12	7.35×10^{-2}	7.49×10^7	0.405	3.03×10^7
10	7.07×10^{-2}	7.78×10^7	0.588	4.57×10^7
8	6.80×10^{-2}	8.08×10^7	0.811	6.55×10^7
6	6.55×10^{-2}	8.39×10^7	1.099	9.21×10^7
4	6.36×10^{-2}	8.63×10^7	1.504	1.30×10^8
2	6.16×10^{-2}	8.92×10^7	2.197	1.96×10^8
1	6.07×10^{-2}	9.06×10^7	2.890	2.52×10^8
0.5	6.03×10^{-2}	9.11×10^7	3.584	3.27×10^8

to compute the distance, ζ_θ, along the axis of the plume from the discharge point to the position where the excess temperature has decreased to the value θ. Computations using this relationship are carried out at 2°F intervals of θ down to $\theta = 0.20\ \theta_o$. In these computations the spreading factor n, is taken as equal to 6.0, and b_o, the width of the discharge orifice is taken as 38 feet except where otherwise noted.

(b) For $\theta \leqslant 0.20\ \theta_o$, natural turbulent diffusion is assumed to be the dominant process, and hence θ should decrease as the inverse first power of distance. That is

$$\theta/\theta_o = k\,\zeta_\theta^{-1}$$

or

$$\zeta_\theta = k\left\{\frac{\theta_o}{\theta}\right\}$$

The value of the factor k is obtained by equating the expression for ζ_θ used in step (a) with the above expression, for $\theta = 0.2\ \theta_o$. That is

$$\left\{\frac{\theta_o}{\theta}\right\}^2 \cdot nb_o = k\left\{\frac{\theta_o}{\theta}\right\} \quad \text{for} \quad \left\{\frac{\theta_o}{\theta}\right\} = 5.0$$

$$\therefore\ k = n \cdot b_o \times 5 = 30 \cdot b_o \qquad (n = 6.0)$$

$$\text{and} \quad \zeta_\theta = \left\{\frac{\theta_o}{\theta}\right\} \cdot 30\,b_o \quad \text{for} \quad \theta \leqslant 0.2\ \theta_o$$

(c) The next step is to correct the computed values of the distance, ζ_0, to take into account the fact that the diluting water which is entrained into the thermal plume is not completely composed of water at natural temperature, but includes some water from the older areas of the plume with low but finite temperature elevations above the natural temperature. Based on experience elsewhere, the assumption is made that the diluting water for the thermal plume has an excess temperature of 0.5°F. The procedure involves first determining a corrected value of $\underline{\theta}$, corresponding to ζ_θ, assuming the diluting water mixed into the plume had an excess temperature of 0.5°F rather than 0.0°F. Since $\{\theta/\theta_o\}$ is the fraction of the mixture which is condenser cooling water, then $\left\{1 - \{\theta/\theta_o\}\right\}$ is the fraction of the mixture which is diluting water. Hence

$$\theta'_{0.5} = \{\theta/\theta_o\} \cdot \theta_o + \left\{1 - \{\theta/\theta_o\}\right\} \cdot 0.5$$

where $\theta'_{0.5}$ is the corrected excess temperature corresponding to the distance ζ_θ along the axis of the plume.

The corrected distance, which is designated by ℓ_θ, is obtained by interpolating the values of ζ_θ, to find the new distance corresponding to θ.

(d) Equation (16) shows that the width of the jet is directly proportional to the distance from the source along the centerline. This expression, however, derives from the simplifying assumption of a "top-hatted" transverse distribution. The actual transverse distribution is more bell-shaped. Instead of the proportionality factor being $1/n$, as given in equation (16), existing observations suggest that the mean width of an isotherm of excess temperature is more nearly 1/4 the length. Thus, in the computations use has been made of the relationship

$$\bar{b}_0 = \frac{\ell_\theta}{4}$$

where $\bar{b}_\theta$ is the mean width of the area containing excess temperatures equal to and greater than θ.

The area having excess temperatures equal to and greater than θ is then given by

$$(A_\theta)_M = \ell_\theta \cdot \bar{b}_\theta$$

The subscript $(\quad)_M$ has been used here to denote that the area has been determined assuming only <u>mixing</u> processes (that is, momentum entrainment and turbulent diffusion) are operative, and no surface cooling occurs.

Table 3 gives the details of the computations for the length, width and area associated with specific excess temperature values assuming momentum jet entrainment and turbulent diffusion, but no surface cooling.

3. <u>Computations to Correct the Areas Within Specified Excess Temperature Isolines Determined Assuming Mixing Processes Only so as to Include Surface Cooling.</u>

It is possible to correct the distribution of excess temperature computed under the assumption that the only controlling processes are momentum jet entrainment and natural turbulent diffusion, which together will henceforth be referred to simply as mixing processes, to take into account the loss of heat by surface cooling. The procedure is based on the relationship for the rate of loss of excess heat from an increment surface area $\Delta A_{\bar{\theta}}$, having a mean excess temperature $\bar{\theta}$

(17) $$\Delta \Gamma_{\bar{\theta}} = \rho c_p \gamma \bar{\theta} \Delta A_{\bar{\theta}}$$

Table 3

Computations of the Length, Width and Area for Specified Excess Temperature Isolines Assuming Momentum Jet Entrainment and Turbulent Diffusion (No Surface Cooling)

For Case I: $h_o = 6$ ft.; $b_o = 38$ ft.; $u_j = 6.7 \text{ ft} \cdot \text{sec}^{-1}$

$$\zeta_\theta = \left\{\frac{\theta_o}{\theta}\right\}^2 \cdot 6 \cdot b_o = 228\left\{\frac{18}{\theta}\right\}^2 \quad \text{for } \theta \geq 0.2\,\theta_o$$

and

$$\zeta_\theta = 30\, b_o \left\{\frac{\theta_o}{\theta}\right\} = 1.14 \times 10^3 \left\{\frac{18}{\theta}\right\} \quad \text{for } \theta \leq 0.2\,\theta_o$$

θ°F	$18/\theta$	ζ_θ (ft)	$\theta_{0.5}'$	ℓ_θ (ft)	$\bar{b}_\theta$ (ft)	$(A_\theta)_M$ (ft^2)
18	1.000	2.28×10^2	18	2.28×10^2	0.57×10^2	[illegible]$.30 \times 10^4$
16	1.125	2.89×10^2	16.05	2.91×10^2	0.73×10^2	2.12×10^4
14	1.285	3.77×10^2	14.11	3.85×10^2	0.96×10^2	3.70×10^4
12	1.50	5.13×10^2	12.17	5.33×10^2	1.33×10^2	[illegible]$.09 \times 10^4$
10	1.80	7.39×10^2	10.22	7.86×10^2	1.96×10^2	[illegible]$.54 \times 10^5$
8	2.25	1.15×10^3	8.28	1.28×10^3	3.20×10^2	[illegible]10×10^5
6	3.00	2.05×10^3	6.33	2.49×10^3	6.23×10^2	[illegible]55×10^6
4	4.50	4.62×10^3	4.39	5.76×10^3	1.44×10^3	[illegible] $\times 10^6$
[illegible]	9.00	1.03×10^4	2.45	1.50×10^4	3.75×10^3	5.62×10^7
1	[illegible].00	2.05×10^4	1.47	4.07×10^4	1.02×10^4	4.15×10^8
0.5	36.00	4.11×10^4	0.99	–	–	–

$$\theta_{0.5}' = \theta + \left\{1 - \theta/\theta_o\right\} 0.5 = \theta + \left\{1 - \frac{\theta}{18}\right\} 0.5$$

$\dot{\lambda}_\theta = \zeta_\theta$ corrected for dilution with water having excess temperature of 0.5°F

$\bar{b}_\theta = \ell_{\theta/4}$

Now designate:

A_{θ_n} = Area of the thermal plume inside the isoline of excess temperature θ_n (i.e., the area having excess temperatures $\geqslant \theta_n$)

Then

$$\Delta A_{\overline{\theta}_n} = A_{\theta_n} - A_{\theta_{n-1}}$$

and

$$\overline{\theta}_n = \frac{\theta_n + \theta_{n-1}}{2}$$

That is, $\Delta A_{\overline{\theta}_n}$ is the increment area between two adjacent isolines of excess temperature, and $\overline{\theta}_n$ is the mean excess temperature for that increment area.

The rate of loss of excess heat from the area between two adjacent isolines of excess temperature is then given by

(18) $$\left\{\Delta \Gamma_{\overline{\theta}_n}\right\}_M = \rho c_p \gamma \, \overline{\theta}_n \cdot \left\{\Delta A_{\overline{\theta}_n}\right\}_M$$

where the subscript $(\ )_M$ denotes that these parameters apply to the temperature distribution determined from mixing only. As a result of surface cooling, the areas and heat loss terms will be smaller than those determined from mixing alone. Using the subscript $(\ )_{M,C}$ to denote conditions after correction of the excess temperature distribution for surface cooling, then

(19) $$\left\{\Delta \Gamma_{\overline{\theta}_n}\right\}_{M,C} = \rho c_p \gamma \, \overline{\theta}_n \left\{\Delta A_{\overline{\theta}_n}\right\}_{M,C}$$

The loss of excess heat by surface cooling can be considered as a decrease in the source strength of the mixing heated effluent. Thus, if Q_h is the rate of heat rejection to the condenser cooling water, and hence the source strength at the point of discharge for the mixing thermal plume, then the effective source strength applicable to the θ_n isoline of excess temperature is given by

$$(20) \qquad Q_h \left\{ 1 - \frac{1}{Q_h} \sum_{i=1}^{n} \left(\Delta \Gamma_{\bar{\theta}_i} \right)_{M,C} \right\} = \left\{ Q_h \right\}_{\theta_n}$$

The increment area $\left\{ \Delta A_{\bar{\theta}_n} \right\}_{M,C}$ is then given by

$$\left\{ \Delta A_{\bar{\theta}_n} \right\}_{M,C} = \left\{ \Delta A_{\bar{\theta}_n} \right\}_M \frac{\left\{ Q_h \right\}_{\theta_n}}{Q_h}$$

or,

$$(21) \qquad \left\{ \Delta A_{\bar{\theta}_n} \right\}_{M,C} = \left\{ \Delta A_{\bar{\theta}_n} \right\}_M \frac{Q_h - \sum_{1}^{n} \left(\Delta \Gamma_{\bar{\theta}_i} \right)_{M,C}}{Q_h}$$

In order to compute the summation term on the right side of equation (6), it is, however, necessary to know $\left\{ \Delta A_{\bar{\theta}_i} \right\}_{M,C}$ for all $\underline{i}$ from 1 to n. Starting with the innermost isotherm in the thermal plume, a series-approximation procedure can be carried out, using as a first approximation of $\left\{ \Delta \Gamma_{\bar{\theta}_i} \right\}_{M,C}$ the value

$\left\{\Delta\Gamma_{\bar{\theta}_i}\right\}_M$ determined for mixing only. It can be shown that successive approximations converge to a constant value, which is the same as the single step computation using the relationship

$$(22) \qquad \left\{\Delta A_{\bar{\theta}_n}\right\}_{M,C} = \left\{\Delta A_{\bar{\theta}_n}\right\}_M \; \frac{Q_h - \sum_{i=1}^{n-1}\left\{\Delta\Gamma_{\bar{\theta}_i}\right\}_{M,C}}{Q_h + \left\{\Delta\Gamma_{\bar{\theta}_n}\right\}_M}$$

For the innermost isoline of excess temperature, the summation term on the right side of equation (22) is zero. Hence the corrected incremental area for n = 1 can be obtained immediately from equation (22), using $\left\{\Delta\Gamma_{\bar{\theta}_n}\right\}_M$ as computed from equation (18).

The corrected rate of heat loss for the area within the innermost isoline of excess temperature can be computed from the relationship

$$(23) \qquad \left\{\Delta\Gamma_{\bar{\theta}_n}\right\}_{M,C} = \frac{\left\{\Delta A_{\bar{\theta}_n}\right\}_{M,C}}{\left\{\Delta A_{\bar{\theta}_n}\right\}_M} \times \left\{\Delta\Gamma_{\bar{\theta}_n}\right\}_M$$

setting n = 1. This value of the corrected increment heat loss is then used as the summation term in equation (22) to allow the computation of the corrected incremental area bounded by the 1st and 2nd isoline of excess temperature. Equation (23) is then again used to compute the corrected heat loss term, which, added to the corresponding term computed for the area within the first isoline of excess temperature, provides the summation term in equation (22) for the determination of the corrected increment area bounded by the 2nd and 3rd isoline of excess temperature. This procedure is repeated until all incremental areas and heat loss terms have been corrected.

The corrected areas, $\left\{ A_{\theta_n} \right\}_{M, C}$ having excess temperatures equal to and greater than θ_n, are then obtained by simply summing the corrected incremental areas $\left\{ \Delta A_{\overline{\theta}_i} \right\}_{M, C}$ from $i = 1$ to $i = n$.

Table 4 shows the detailed computations of the areas within specific isotherms, as corrected for surface cooling, for Case I, as an example of the procedure described above.

Results

Computations as discussed above were made for each of the cases described in the introduction, plus some additional cases, representing modifications to the base cases, which are included for purposes of comparison. Table 5 summarizes the pertinent features of temperature rise, condenser cooling water flow, dimensions of discharge orifice, etc. applicable to each case considered.

THE JOHNS HOPKINS UNIVERSITY · BALTIMORE, MARYLAND 21218

CHESAPEAKE BAY INSTITUTE

8 December 1969

Mr. Lowell E. Roe, Chief Mechanical Engineer
The Toledo Edison Company
420 Madison Avenue
Toledo, Ohio 43601

Subject: Davis-Besse Nuclear Power Station
Circulating Water Studies (Bechtel Job 7749)

Dear Mr. Roe:

As requested in your recent telephone call, I have computed the probable distribution of excess temperature for two additional cases representing modifications of Case I as contained in my report dated August 1969. In one of these additional computations, which I have designated as Case I-C, all conditions are the same as Case I, except the surface cooling coefficients used correspond to a natural surface temperature of 80°F. The other new set of computations, designated as Case I-D, corresponds to a natural surface temperature of 35°F.

The enclosed table contains the results of these computations, expressed in terms of the area, in ft^2, having excess temperatures equal to or greater than specified values ranging from 18°F to 1°F. For ready comparison, the results for Case I are also shown in this table.

The computations of the probable distribution of excess temperature in the waters of Lake Erie adjacent to the proposed Davis-Besse Nuclear Power Station given here and also those contained in my report of August 1969 assumed that the natural currents in the Lake directed transverse to the direction of the jet discharge would have negligible speeds compared to the speed of the jet discharge. The effects of a transverse current on the trajectory and dilution rate in a jet are reasonably well known for a free-jet, that is, a jet discharge into a relatively large body of water at a point far away from any boundaries. Much less is known about the effects of a transverse current on a horizontal, surface jet discharge from a shoreline, or from an extension of the shoreline, such as provided by a pair of jetties forming a discharge canal. Some recent experimental data do give some indication of the influence of such a transverse current.

First of all, the jet plume will be bent over in the direction of flow of the transverse, longshore current. The inshore side of this bent jet thus becomes bounded by the shoreline, and the supply of new water for entrainment into the jet may be cut off on this inshore side. Consequently dilution of the excess heat will be at a slower rate in the presence of a transverse (longshore) current than in the absence of such a current, because the jet becomes essentially one-sided, rather than two-sided. The extent of such a reduction in dilution rate can not yet be determined from purely analytical considerations.

You also asked me to comment on the effects of a high discharge velocity on bottom scour and on boat safety. I should first of all point out that the discharge velocity assumed for most of the cases for which I have made computations of the probable excess temperature distribution, that is, 6.7 $ft \cdot sec^{-1}$, was not selected as the most effective velocity in order to minimize thermal effects. Actually, the important parameter is the width of the orifice through which the heat effluent is discharged to the lake. The velocity of 6.7 $ft \cdot sec^{-1}$ happened to be the velocity which resulted from the combined assumptions I made concerning volume rate of flow of the condenser cooling water, depth of water at the discharge orifice, and width of the orifice, for one of the preliminary computations of probable distribution of excess temperature. It was decided at one of our meetings at Bechtel to keep this velocity of discharge for most of the later computations of the distribution of excess temperature.

In any case, in order to minimize the area having high excess temperatures, the width of the discharge orifice should be made small, and consequently the velocity of discharge will be relatively large. For a given depth of water at the discharge orifice, the velocity of discharge will be inversely proportional to the width of the discharge orifice, while the length of the thermal plume to any designated excess temperature will be directly proportional to the width of the discharge orifice, and the area having excess temperatures equal to or greater than some designated value will be directly proportional to the square of the discharge orifice. These statements apply to the portion of heated plume where the excess temperature is primarily determined by dilution, and not by surface cooling processes. The consequence of a decision to change the width of the discharge orifice (and, consequently, the velocity of discharge) can thus be readily determined for any of the cases for which computations of the probable distribution of excess temperature have been made.

A discharge of the condenser cooling water flow from the Davis-Besse Nuclear Power Station at velocities in the range of 6 to 10 feet per second will probably produce local bottom scour out from the point of discharge. Evidence from model studies and of field observations of other sites indicates that the high velocities will be confined to the upper 10 feet or so. Further, the speed in the center of the plume of the discharge jet will decrease due to momentum entrainment in much the same way that the excess temperature is decreased. Thus, for Case I, the speed in the center of the discharge plume would be decreased to one-third its initial value, or to 2.2 $ft \cdot sec^{-1}$ at a distance of about 2000 feet from the discharge orifice; and would be decreased to one-ninth its initial value, or to 0.75 $ft \cdot sec^{-1}$ at a distance of 10,300 feet from the discharge orifice. These velocities would apply to the surface layers above 10 feet. It is highly unlikely that velocities sufficient to cause bottom scour would extend to depths greater than 15 feet at any distance from the source.

One additional factor which should be considered in selection of the final design velocity of discharge is the possible danger to small craft passing through the high speed portion of the discharge plume. The most danger would occur in the region of large velocity gradient along the sides of the jet plume. Considering the possible velocity changes which could occur, this problem should not be significant beyond about 1000 feet from the discharge. Some consideration should be given to devising ways to keep boats from cutting across the plume close to the point of discharge.

Please advise me if you require additional information. You might be interested to know that two power companies that my associate, Dr. Carpenter, has been advising are collecting information on the question of possible danger to small boat operations in the vicinity of a high velocity discharge of condenser cooling water. If and when any new information on this subject becomes available I will let you know.

Sincerely yours,

D. W. Pritchard

D. W. Pritchard
Director
Chesapeake Bay Institute

hc

Encl. Table (11/28/69)

Area (ft^2) Having Excess Temperatures Equal to or Greater Than Designated Values (Davis-Besse Nuclear Power Station)

Excess Temp. °F	Case[1] I	Case[2] I-C	Case[3] I-D
18	1.30×10^4	1.30×10^4	1.30×10^4
16	2.12×10^4	2.12×10^4	2.12×10^4
14	3.70×10^4	3.70×10^4	3.70×10^4
12	7.09×10^4	7.09×10^4	7.09×10^4
10	1.54×10^5	1.54×10^5	1.54×10^5
8	4.09×10^5	4.09×10^5	4.10×10^5
6	1.54×10^6	1.54×10^6	1.54×10^6
4	8.07×10^6	8.05×10^6	8.17×10^6
2	5.09×10^7	4.98×10^7	5.30×10^7
1	2.91×10^8	2.76×10^8	3.35×10^8

(1) One 875 MWE unit rejecting 6.21×10^9 BTU hr^{-1} to condenser cooling water flow of 1526 cfs. Excess temperature at point of discharge, 18°F. Discharge orifice, 38 ft. wide. Surface cooling for wind speed of 6 mph, natural surface water temperature of 70°F. (Refer to Report "Predictions of the Distribution of Excess Temperature in Lake Erie Resulting from the Discharge of Condenser Cooling Water From the Davis-Besse Nuclear Power Station", dated August, 1969).

(2) Same as Case I except surface cooling for natural surface water temperature of 80°F.

(3) Same as Case I except surface cooling for natural surface water temperature of 35°F.

Note: $\Delta A_{0.5}$ (See referenced report for definition) is, in each case: Case I, 2.20×10^9 ft^2; Case I-C, $1.77 \times 10^9 ft^2$; Case I-D, 4.50×10^9 ft^2.

APPENDIX 14B

APPENDIX 14B

PRITCHARD - CARPENTER

CONSULTANTS

208 MacAlpine Road

Ellicott City, Maryland

THE EFFECTS OF LONGSHORE CURRENTS ON THE DISTRIBUTION OF EXCESS TEMPERATURE IN LAKE ERIE ADJACENT TO THE DAVIS-BESSE NUCLEAR POWER STATION

A Report
Prepared For

The Toledo Edison Company
Toledo, Ohio

10 April 1970

PRITCHARD - CARPENTER, CONSULTANTS

The Effects of Longshore Currents on the Distribution of Excess Temperature in Lake Erie Adjacent to the Davis-Besse Nuclear Power Station

Introduction

In an earlier report (1) we presented the probable distribution of excess temperature in Lake Erie which will result from the discharge of condenser cooling water from the Davis-Besse Nuclear Power Station, in the absence of significant longshore currents in the adjacent lake waters. At the time that report was prepared, observations of currents in the waters of Lake Erie offshore from the plant site were not available. Studies reported by Ayers and Anderson (2) show that under certain wind conditions there are currents directed parallel to the shoreline, that is, transverse to the direction of jet discharge of the condenser cooling water, having speeds equal to and occasionally exceeding 10% of the velocity of the jet discharge from the proposed condenser cooling water discharge structure (i.e., on the order of $0.7\ ft \cdot sec^{-1}$).

When a heated effluent is discharged horizontally as a surface jet into a receiving body of water in which an ambient current is flowing transverse to the direction of discharge, the jet plume is bent in the down-current direction, ultimately becoming parallel to the direction of ambient current flow. If the jet discharge is made from the shoreline, or from an exposed structure extending out from shore, and the transverse flow is a longshore current, the jet plume will be bent over to become parallel to the shoreline. When the longshore current is sufficiently small compared to the speed of the jet discharge, or under certain conditions of shoreline configuration, the bending of the jet has only a small effect on the rate of dilution due to momentum entrainment. If the longshore current is of sufficient magnitude compared to the speed of the jet discharge, i.e., on the order of 10% or more, and the shoreline is relatively straight and uniform, the bent over jet plume becomes parallel to the ambient current flow sufficiently close to shore so that entrainment of diluting water is restricted to the offshore side of the plume. The rate of decrease in the excess temperature with distance from the point of discharge, due to dilution, is therefore less for such a bent jet than for a jet plume discharged into a large body of water under conditions of near zero transverse current speed.

Carter (3) has reported the results of model experiments conducted in a flowing water flume of the trajectory and dilution of a thermal plume discharged as a jet at right angles to an ambient flow in the flume. The results of the study by Carter will be used in the following treatment of the bent thermal plume from the proposed discharge of condenser cooling water from the Davis-Besse Nuclear Power Station.

The Bent Jet

The experiments conducted in the above referenced study covered a range in the ratio speed of jet discharge, u_j, to speed of the transverse ambient current, u_a, designated by $\underline{R}$ (i.e. $R = {}^{u}j/u_a$), of just under 2 to approximately 10. Carter developed semi-theoretical, semi-empirical relationships for the trajectory of the bent jet in terms of the width of the discharge orifice, $\underline{b_0}$, and the ratio $\underline{R}$.

Designating the distance in an offshore direction along the extension of the axis of the discharge orifice by $\underline{y}$, the distance alongshore in the direction of flow of the ambient transverse current by $\underline{x}$, the distance along the axis of the bent jet by $\underline{\zeta}$, and the initial angle of the jet discharge from the perpendicular to the axis of the discharge orifice by α_0 (i.e., $\alpha_0 = 90°$ would correspond to a discharge along the axis of the discharge orifice, and would occur for a zero transverse ambient current), then from the referenced report by Carter we can obtain, for any given value of R and b_o, the value of y_m, the maximum penetration offshore of the axis of the jet plume, at which point the plume direction becomes parallel to the transverse current; the value of x_m, the distance along shore corresponding to y_m; the initial angle of the jet discharge α_0 ; and the rate of dilution with distance along the axis of the plume.

The trajectory of the bent jet plume is a smooth semi-elipse extending from the discharge orifice where the initial direction is given by α_0, to the point x_m, y_m, and is thereafter along a line parallel to the ambient current flow. The rate of dilution with distance along the axis of the plume is proportional to the fourth route of distance. That is, if θ_0 is the initial excess temperature, and θ_ζ is the excess temperature at a distance along the axis of the plume ζ, then

$$\text{(1)} \qquad \frac{\theta_\zeta}{\theta_0} = \left(\frac{\zeta}{nb_0}\right)^{1/4}$$

for ζ greater than nb_o. Data from the experiments conducted by Carter give a value for n of approximately 2.6. This expression holds until the plume becomes parallel to shore, at which point the data suggest that the dilution rate increases such that:

$$\text{(2)} \qquad \frac{\theta}{\theta_0} = \left(\frac{\zeta}{mb_0}\right)^{1/2}$$

where m takes a value such that Equations (1) and (2) give the same dilution for the distance along the axis of the plume $\zeta = \zeta_m$, corresponding to the point x_m, y_m.

For values of R significantly greater than 10, it is probable that the rate of bending of the jet plume will not be sufficient to completely cut off entrainment from the inshore side of the bending jet. Thus the dilution rate for such cases will be intermediate between that for zero transverse current, and that for a transverse current having a speed approximately one-tenth that of the jet discharge.

The Thermal Plume off the Davis-Besse Nuclear Power Plant Site for an Ambient Longshore Current Directed Toward the Southeast.

Current measurements made in Lake Erie adjacent to the plant site, when corrected for direct wind drag on the exposed portion of the current drogue used in obtaining the measurements, indicate that the longshore current seldom exceeds 0.67 $ft \cdot sec^{-1}$, or one-tenth the speed of the proposed jet discharge. Thus the ratio R has a minimum value of:

$$R = u_j/u_a = \frac{6.7 \, ft \cdot sec^{-1}}{0.67 \, ft \cdot sec^{-1}} = 10$$

For this value of R, the referenced report by Carter (3) gives the following pertinent parameters for the bent jet plume:

$$x_m = 146.8 \, b_o$$

$$y_m = 74.0 \, b_o$$

$$\cos\alpha_o = 0.083 \quad \text{or } \alpha_o = 85° \, 15'$$

$$\zeta_m = 194.5 \, b_o \quad (\text{value of } \zeta \text{ at } x_m, y_m)$$

$$(\theta/\theta_o)_m = 0.34 \quad (\text{Dilution at } x_m, y_m)$$

The distance along the axis of the bent jet plume to a given dilution is given by:

(3) $$\zeta_\theta = 2.6 \, b_o \left\{\frac{\theta_o}{\theta}\right\}^4 \qquad \text{for } 2.6 \, b_o \le \zeta \le 194.5 \, b_o$$

and by:

(4) $$\zeta_\theta = 22.5 \, b_o \left\{\frac{\theta_o}{\theta}\right\}^2 \qquad \text{for } \zeta \ge 194.5 \, b_o$$

Inspection of the isotherms of excess temperature obtained in the flume experiments by Carter reveal that the lateral dimension of the area contained within a given isoline of excess temperature in the thermal plume is related to the length of the area along the axis of the plume (ζ_θ) as follows:

(a) The lateral dimension of the area contained within a given isoline in an up-current and/or offshore direction from the axis of the plume is approximately one-eighth of the length of the subject area along the axis of the plume.

(b) The lateral dimension of the area contained within a given isoline in a down-current and/or inshore direction from the axis of the plume is approximately three-eighths of the length of the subject area along the axis of the plume, for excess temperatures greater than the excess temperature at ζ_m (i.e., at x_m, y_m).

(c) For excess temperatures equal to and less than that at ζ_m (i.e., at x_m, y_m), the isolines of excess temperature extend to shore on the inshore side of the plume.

Table 1 (columns 2, 3 and 4) gives the dimensions of selected isolines of excess temperature obtained by using Equations (3) and (4) and the rules (a), (b) and (c) above. This computation is for a jet discharge of condenser cooling water having an initial excess temperature at discharge of 18°F, and a flow rate of 685,000 GPM (1526 cfs), corresponding to a heat rejection rate of 6.21×10^9 BTU·hr^{-1}.

Also given in Table 1 (columns 5, 6 and 7) are the dimensions of selected isolines of excess temperature after a correction for surface cooling has been made. The surface cooling coefficients used in obtaining the values given in Table 1 correspond to a wind velocity of 10 mph and an ambient lake temperature of 70°F. Note that this is a conservative assumption for the cooling rate, since longshore currents sufficient to bend the jet plume to the extent taken in this computation will occur only for winds exceeding 15 knots. The computations leading to this table were made essentially as described in our earlier report (1), except as modified in accordance with the discussion above.

Table 1

Dimensions of Excess Temperature Isotherms in a Bent Jet Thermal Plume Discharged from the Davis-Besse Nuclear Power Station for the case of an Ambient Transverse Current of 0.67 ft·sec^{-1}, and a jet discharge velocity of 6.7 ft·sec^{-1}.

	Dilution only			Dilution plus cooling		
θ°F	ζ_θ (ft)	b_θ (ft)	A_θ (H^2)	ζ_θ (ft)	b_θ (ft)	A_θ (ft^2)
14°	2.69×10^{2}	1.00×10^{2}	2.69×10^{4}	2.69×10^{2}	1.00×10^{2}	2.69×10^{4}
12°	5.01×10^{2}	1.89×10^{2}	9.46×10^{4}	5.00×10^{2}	1.89×10^{2}	9.45×10^{4}
10°	1.04×10^{3}	3.90×10^{2}	4.06×10^{5}	1.04×10^{3}	3.89×10^{2}	4.04×10^{5}
8°	2.53×10^{3}	9.50×10^{2}	2.40×10^{6}	2.50×10^{3}	9.36×10^{2}	2.34×10^{6}
6°	7.70×10^{3}	3.77×10^{3}	2.90×10^{7}	6.25×10^{3}	3.59×10^{2}	2.25×10^{7}
[illegible]°	1.73×10^{4}	4.97×10^{3}	8.59×10^{7}	1.34×10^{4}	4.49×10^{3}	6.01×10^{7}
2°	6.93×10^{4}	1.15×10^{4}	7.97×10^{8}	3.14×10^{4}	6.73×10^{3}	2.11×10^{8}
1°	2.77×10^{5}	3.74×10^{4}	1.04×10^{10}	4.32×10^{4}	8.21×10^{3}	3.54×10^{8}

Notes:

ζ_θ = length of the area within = the specified isotherm along the axis of the thermal plume.

b_θ = width of the area within the specified isotherm. The lateral extent of the isotherm in an upcurrent and/or offshore direction from the axis of the plume is equal to $\zeta_{\theta/8}$.
The lateral extent of the isotherm in a downcurrent and/or inshore direction from the axis of the plume is equal to $3\ \zeta_{\theta/8}$ for $\theta >$ 6°F, and is to the shoreline for $\theta \leq$ 6°F.

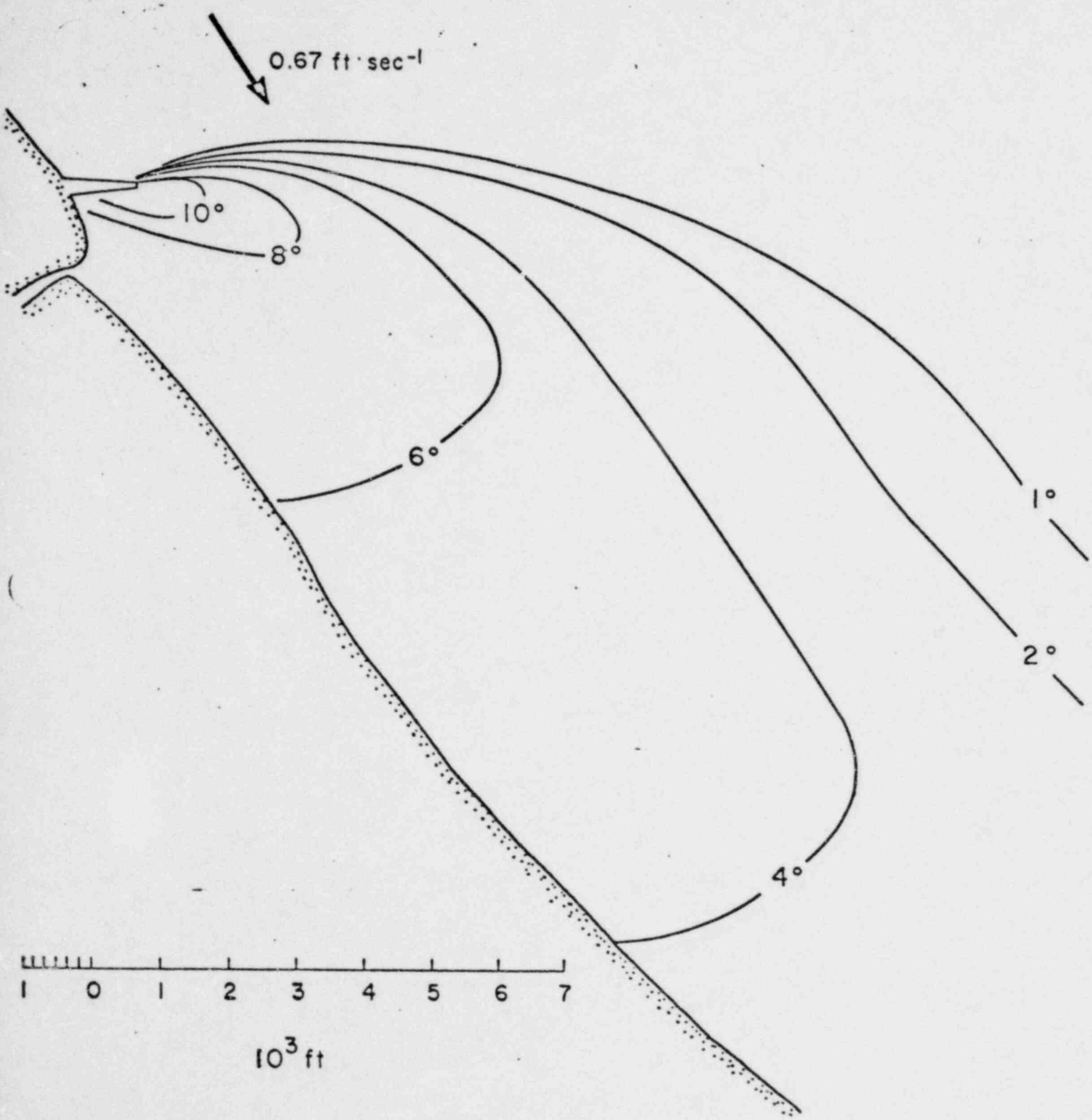
A_θ = Area contained within the specified isotherms.

The horizontal distribution of excess temperatures for this case is shown schematically in Figures 1 and 2, using the results of the computations for dilution plus cooling as given in Table 1, and the trajectory information developed from the referenced report by Carter (3). Note that since b_o, the width of the discharge orifice, is in this case 38 feet, the value of y_m, the distance off-shore at which the plume direction becomes parallel to the transverse current, is $y_m = 74 \times 38 = 2.81 \times 10^3$ ft. The corresponding distance along shore is $x_m = 146.8 \times 38 = 5.58 \times 10^3$ ft, and the corresponding length of the plume to this point is $\zeta_m = 194.5 \times 38 = 7.38 \times 10^3$ ft. The excess temperature at this point due to dilution alone is 0.34x18° = 6.12°F, which becomes 5.68°F after correcting for surface cooling.

Figure 1 shows the horizontal distribution of excess temperature isotherms in the bent jet plume for an ambient current speed of 0.67 $ft \cdot sec^{-1}$ directed toward the southeast, on a chart scale of 1:24,000. On this scale the predicted excess temperature distribution along shore in the vicinity of the mouth of the Toussaint River can be seen. Figure 2 shows the distribution of excess temperature for this case, on a chart scale of approximately 1:100,000. On this scale the extension of the thermal plume southeastward along the shoreline to excess temperature values of 2°F and 1°F can be seen.

The Thermal Plume off the Davis-Besse Nuclear Power Plant Site for an Ambient Longshore Current Directed Toward the Northwest.

Winds of 15 knots and higher from an east to southeast direction will produce longshore currents toward the northwest, and result in a bent jet thermal plume which will curve to become parallel to the ambient current. The distribution of excess temperature in this case departs slightly from a mirror image of the distribution for a southeastward directed longshore current, due to the fact that the direction of discharge is not exactly perpendicular to the shoreline, and the plume must execute a somewhat greater



F' ıre 1. Distribution of excess temperature for a transverse current of 0.67 ft· sec^{-1} directed toward the southeast.

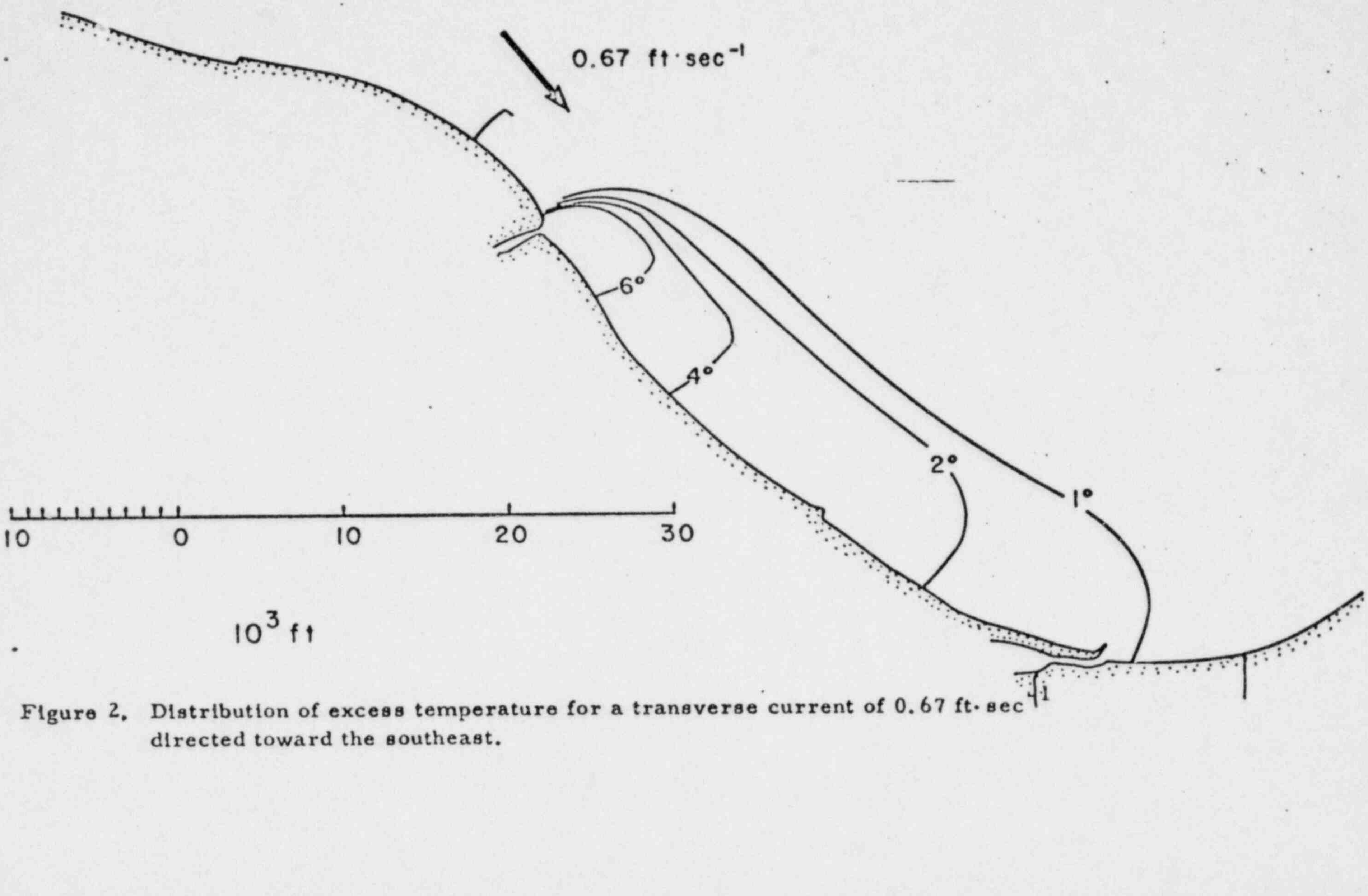


Figure 2. Distribution of excess temperature for a transverse current of 0.67 ft·sec^{-1} directed toward the southeast.

curve before becoming parallel to the ambient current. The dimensions of the isotherms as given in Table 1 also apply for all practical purposes, to this case.

Figure 3 shows the horizontal distribution of excess temperature in the upper 6 to 10 feet of the water column for this case of an ambient current directed toward the northwest, having a speed of 0.67 ft$\cdot$sec^{-1}, on a chart scale of 1:24,000. On this scale the possibility of recirculation of the condenser cooling water discharge at an excess temperature of about 5°F is shown.

Figure 4 shows the horizontal distribution of excess temperature for this case on a chart scale of approximately 1:100,000. On this scale it can be seen that, because the shoreline retreats somewhat southward, the 2°F and 1°F isolines of excess temperature do not extend as far along the shoreline in this case as in the case of the opposite-directed longshore current. That is, the axis of the plume is directed somewhat offshore from the southward retreating shoreline.

Excess Temperatures Over the Fish Spawning Reefs off-shore from the Plant Site.

In our earlier report (1), we showed that the thermal plume under conditions of near zero transverse currents has little effect on temperatures over the fish spawning reefs offshore from the plant site. At the very most, excess temperatures of 0.5°F might occur over Round Reef, Toussaint Reef and Crib Reef, with lower temperatures over the other fish spawning reefs, for the cases treated in the previous report.

The location of Locust Reef is shown on Figure 4. It is seen from this figure that the bent thermal plume for an ambient transverse current of 0.67 ft$\cdot$sec^{-1} directed toward the northwest will not extend over this reef, which is the nearest reef to this plume, at excess temperatures greater than about 0.5°F. It would thus appear that the thermal plume will produce

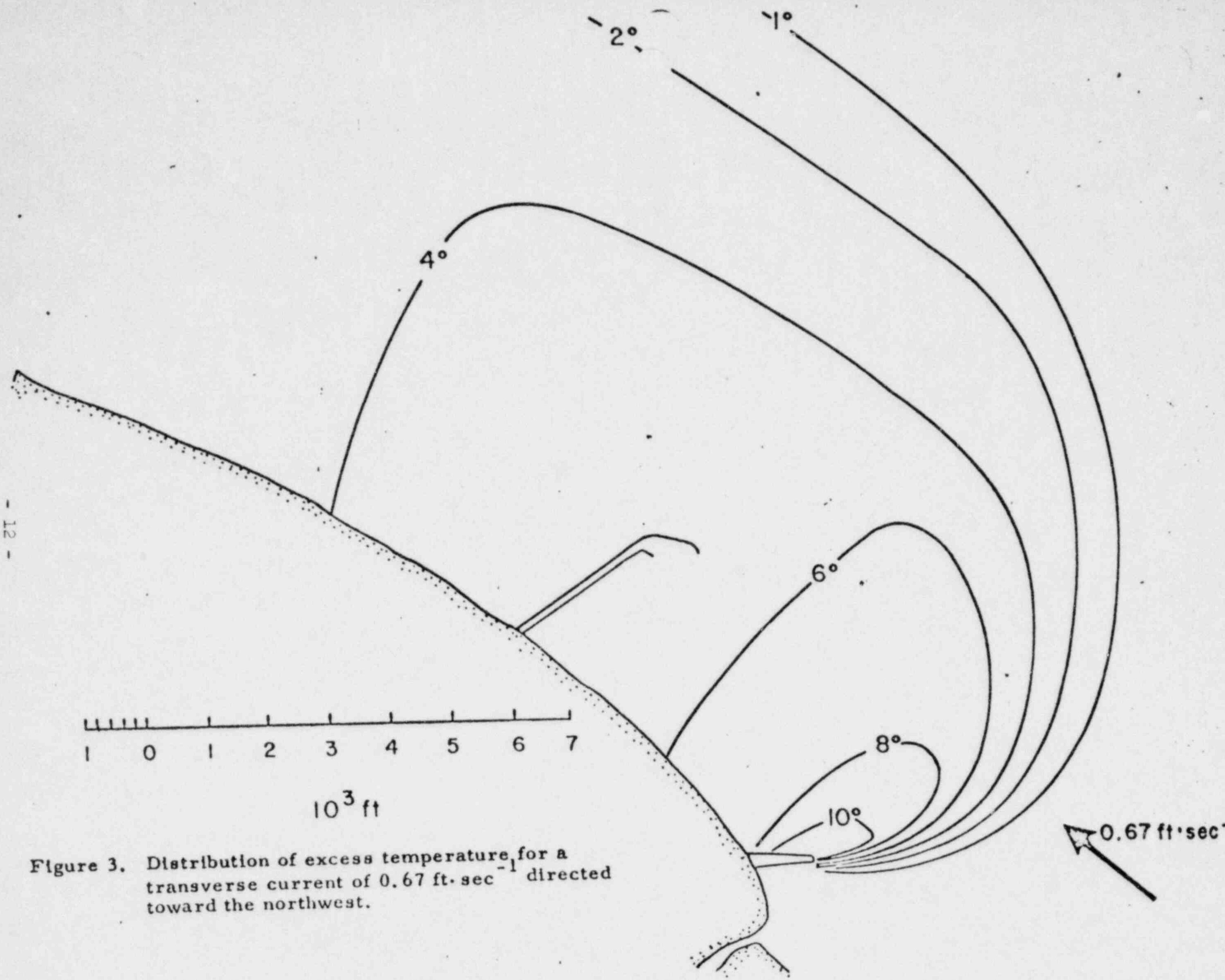


Figure 3. Distribution of excess temperature for a transverse current of 0.67 ft·sec^{-1} directed toward the northwest.

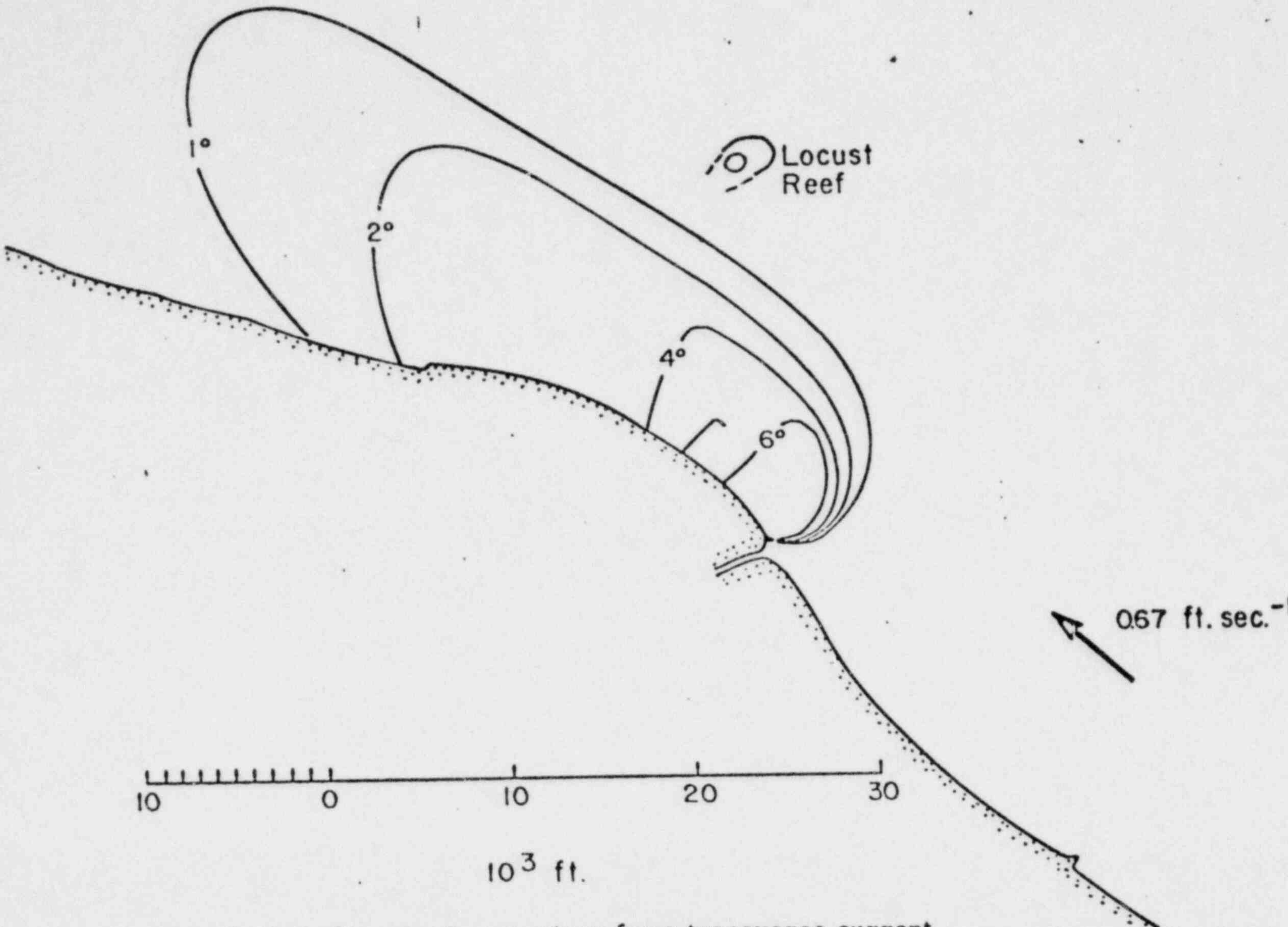


Figure 4. Distribution of excess temperature for a transverse current of 0.67 ft·sec^{-1} directed toward the northwest.

temperatures exceeding 0.5°F over the fish spawning reefs only for relatively weak transverse currents.

For transverse currents in the range 0.1 to 0.2 ft·sec^{-1} directed toward the northwest, the axis of the thermal plume will extend over the vicinity of Toussaint, Crib and Flat Reefs. The ratio $R = u_j/u_a$ will in this case be in the range 35 to 70. At these high values of R, the transverse current has little effect on dilution. Consequently the dimensions of the excess temperature isotherms will be essentially the same as given in our previous report for the case of zero transverse current. Figure 5 shows the horizontal distribution of excess temperature in the surface layers for this case of a transverse current of 0.1 to 0.2 ft·sec^{-1}toward the northwest. It is seen from this figure that the excess temperature in the water over Toussaint Reef, Crib Reef and Flat Reef will in this case be between 1°F and 2°F. For a somewhat smaller transverse current, the axis of the plume would extend over the vicinity of Round Reef and Niagara Reef. For this case the maximum excess temperatures in the water over Round Reef would also be between 1°F and 2°F, while the excess temperature over Niagara Reef would be close to 1°F.

For a transverse current of 0.3 to 0.4 ft·sec^{-1} directed toward the northwest, the thermal plume would be bent so that the axis would be in the vicinity of Locust Reef. The value of the ratio $R = u_j/u_a$ would in this case be approximately 20. At this value of R there would be some decrease in entrainment on the inshore side. The dilution rate would be intermediate between the case shown for R = 10, and the case of zero transverse current. The horizontal distribution of excess temperature for this case is shown in Figure 6. The maximum excess temperature in water over Locust Reef is seen from this figure to be approximately 2°F.

Thus the maximum excess temperature which would occur over any of the fish spawning reefs is 2°F. This temperature would occur over Locust Reef for the special case of a transverse ambient current of 0.3 to 0.4 ft·sec^{-1}

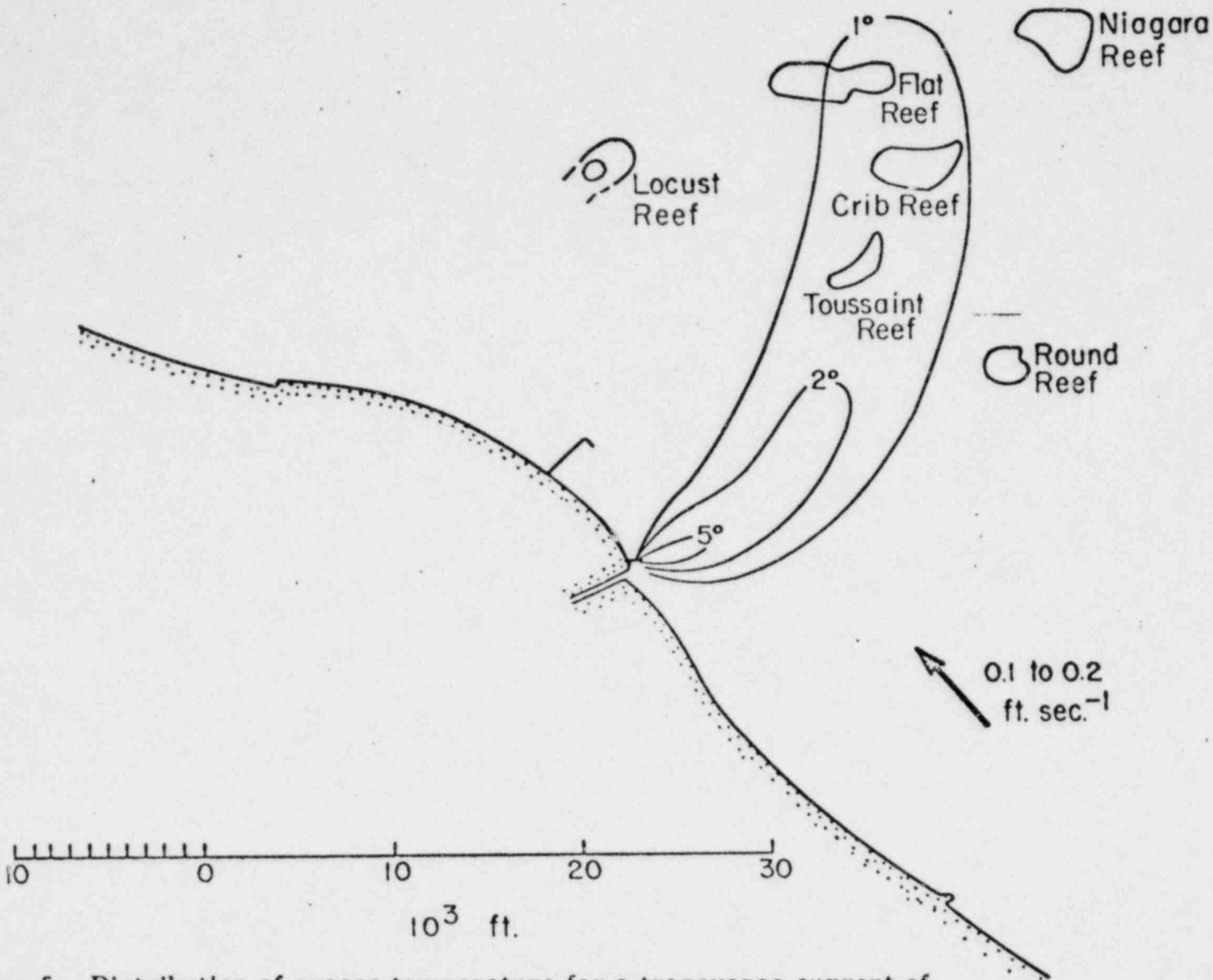


Figure 5. Distribution of excess temperature for a transverse current of 0.1 to 0.2 ft·sec^{-1} directed toward the northwest.

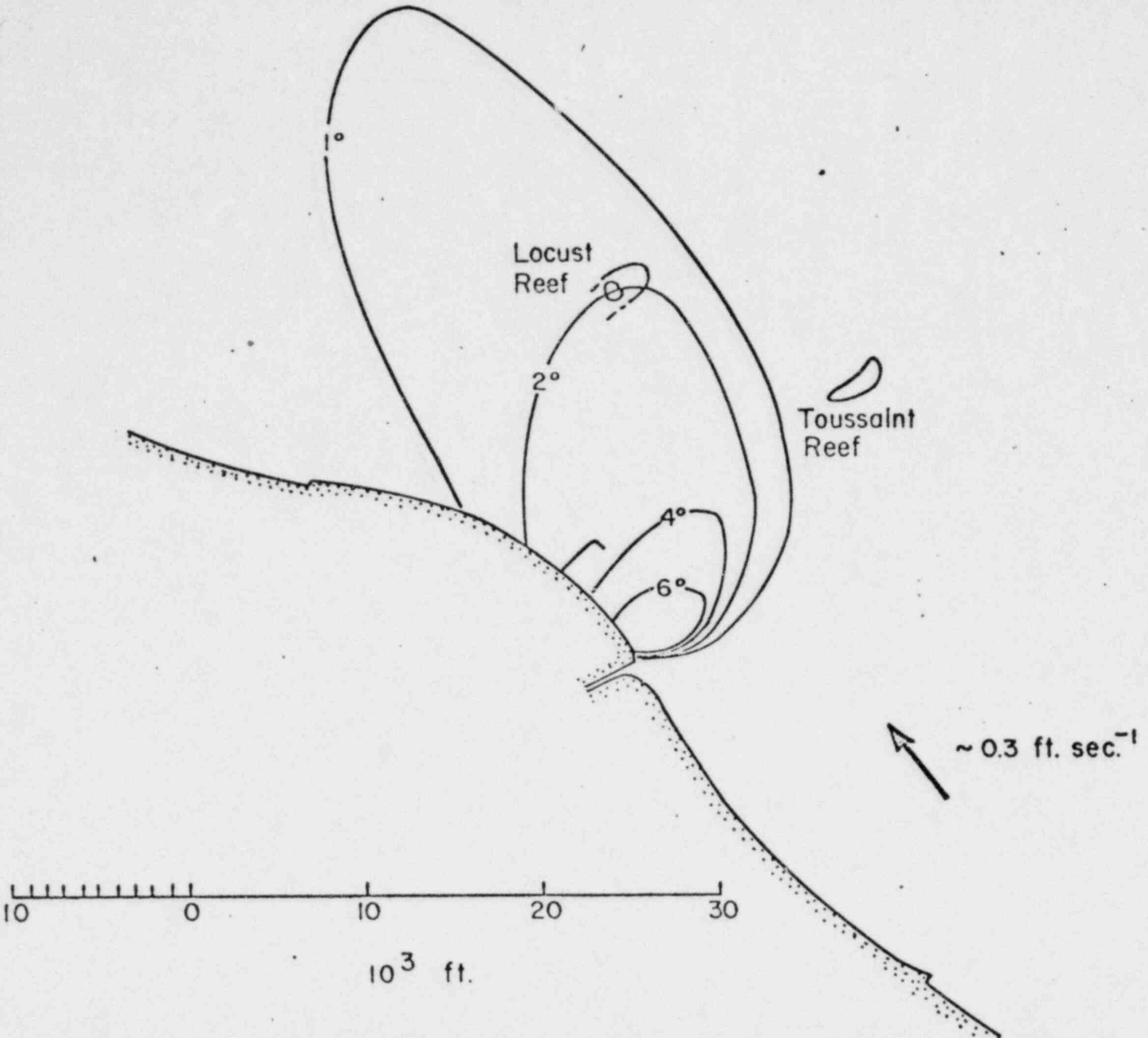


Figure 6. Distribution of excess temperature for a transverse current of approximately 0.3 ft$\cdot$sec^{-1} directed toward the northwest.

directed toward the northwest. The maximum excess temperatures which would occur in the Lake water over Flat Reef, Crib Reef and Toussaint Reef would be between 1°F and 2°F. These temperatures would prevail for the special case of a transverse current of 0.1 to 0.2 $ft \cdot sec^{-1}$ toward the northwest. The maximum excess temperature which would occur in the Lake water over Round Reef would also be in the range 1°F to 2°F, but would occur only in the special case of transverse currents directed toward the northwest at speeds less than 0.1 $ft \cdot sec^{-1}$. The maximum excess temperature which would occur in the lake water over Niagara Reef would be 1°F, and this temperature would also occur for the special case of a very weak transverse current directed toward the northwest. For most of the time, the excess temperature over any of these fish spawning reefs will be less than 1°F.

D. W. Pritchard
10 April 1970

References

1. PRITCHARD - CARPENTER, CONSULTANTS. Predictions of the distribution of excess temperature in Lake Erie resulting from the discharge of condenser cooling water from the Davis-Besse Nuclear Power Station. A report prepared for the Toledo Edison Company, August 1969.

2. Ayers, John C. and Robert F. Anderson. Hydrological surveys for the Locust Point Power Plant, Part II, Currents and Dilution. Special Report No. 45 of the Great Lakes Research Division, The University of Michigan, August 15, 1969.

3. Carter, H. H. A preliminary report on the characteristics of a heated jet discharged horizontally into a transverse current. Part I - constant depth. Technical Report 61, Chesapeake Bay Institute, The Johns Hopkins University. November 1969.

APPENDIX 14C

APPENDIX 14C

REPORT AND GENERAL PLAN

FOR

DAVIS-BESSE NUCLEAR POWER STATION

LAKE ERIE WATER USE AND DISCHARGE

Submitted To

THE DEPARTMENT OF HEALTH

STATE OF OHIO

By

THE TOLEDO EDISON COMPANY

December 1969

CONTENTS

F I G U R E S

TABLES

5 CONDENSER COOLING WATER SYSTEM STUDIES

5.1 GENERAL

All steam electric generating stations involve cycles in which a large portion of the heat produced by the steam generating equipment is not usable and it must be rejected to the environment. In a modern generating unit this amounts to about twice the thermal energy equivalent to the useful electrical energy produced.

A fossil fired unit rejects a portion of this heat directly to the atmosphere in the combustion gases. In the nuclear unit, there is no corresponding rejection of heat to the atmosphere. Both types of generating units reject heat to the condenser cooling water system. The nuclear unit rejects a larger quantity of heat which is about 50% greater than that of a fossil fueled unit of equal size due to its inherently lower initial steam pressure and temperature conditions. An illustration of the heat distribution for the two units is given in Figure 6 at the end of this section under the tab FIGURES.

For a given generating unit, a fixed quantity of heat must be released to the condenser cooling water system that is dependent on the unit size, cycle design and load at which it is operating. This quantity for the Davis-Besse unit is 6.21×10^9 BTU's per hour at ultimate full load. The temperature rise of cooling water passing through the condenser can be varied by design, but to do this, the water flow must also be varied because a constant amount of heat must be removed for a given load. An illustration of temperature rise versus water flow requirements for the Davis-Besse unit at full load is shown on Figure 7 at the end of this section under the tab FIGURES.

All of the heat added to the condenser cooling water must eventually be absorbed by the atmosphere either directly in a closed cycle cooling tower system or by a receiving body of water into which the condenser cooling water is discharged in an open cooling water system.

5.2 LAKE THERMAL PLUMES

Dr. Pritchard, of Johns Hopkins University, was retained by Toledo Edison to determine the dispersion pattern of warmed condenser cooling water after discharge into the lake. A resume of Dr. Pritchard's qualifications is given in Reference B. Dr. Pritchard's analytical work, covering a number of condenser cooling water discharge arrangements, is included in Appendix B of this report. This work was necessary to obtain the thermal plume configuration in the lake for each of the various alternate circulating water arrangements studied to determine an optimum overall arrangement that would have minimum effect on the lake, would not be harmful to the lake biota and ecology, and result in a satisfactory station arrangement at reasonable cost.

The distance traveled, and the area within the various isotherm lines of a thermal plume resulting from the discharge of warmed water into the lake, will vary in proportion to the quantity of heat added if the other conditions of the discharge remain constant. This is well illustrated in Appendix B of Dr. Pritchard's work by comparison of the isotherms for Case I (Figure 1) of Appendix B with Case II (Figure 3) of Appendix B where Case II includes supplemental cooling in the discharge to give a temperature and heat rejection rate smaller than those of Case I. All other conditions remain the same.

However, Dr. Pritchard's report also shows that these parameters within isotherm lines for a given heat load, water flow quantity and discharge temperature condition can be altered significantly by varying the velocity of the discharge at the point where it enters the lake. This is illustrated on Figure 8 at the end of this section under the tab FIGURES and by comparing Appendix B Cases I-B (Figure 2) at a 1.0 ft./sec. discharge velocity, with Case I (Figure 1) at a 6.7 ft./sec. discharge velocity and supplemental Case I-C (Figure 5) at a 10.1 ft./sec. discharge velocity. All of these cases are based on identical water flows, heat loads and discharge temperatures.

It can also be seen, in Appendix B, that the 10.1 ft./sec. velocity of Cases III and IV (Figure 3) with 12°F discharge temperature at 1,027,500 GPM and full heat input of 6.21×10^9 Btu/hr. gives the same thermal plume isotherms that are given for Case II (also Figure 3) which has 12° discharge temperature, with only 685,000 GPM water flow, two-thirds of the total heat but discharges at a 6.7 ft./sec. velocity.

With this means available for reducing the size of the thermal plume a condenser cooling water system can be selected and designed to provide a moderate flow of water through the system for a reasonable temperature rise across the condenser, with minimal effect on the lake. A summary of the various alternate arrangements, that were investigated, for the condenser cooling water system is given below. Refer to Tables 2 and 3 at the end of this section under the tab TABLES for detailed information.

5.3 ALTERNATE ARRANGEMENTS

A number of alternate condenser cooling water system arrangements were analyzed to determine performance characteristics, new investment costs, and operating costs of each.

Open systems, and also closed systems, were analyzed with the ultimate objective to determine which scheme will give the most reasonable plume configuration considering construction and annual operating cost penalties, with no adverse effect on the lake.

Alternate arrangements studied, for the condenser cooling water system, fall into three categories (1) open cycle without any supplemental cooling facilities, (2) open cycle with supplemental cooling facilities and (3) closed cycle with two natural draft cooling towers. These three categories are discussed in the following sections.

5.3.1 Open Cycle Systems - No Supplemental Cooling

These systems are the first category listed in tables 2 and 3 as follows:

I. OPEN CYCLE CONDENSER COOLING WATER SYSTEMS

A. No Supplemental Cooling

1. 22° Temperature rise - 22° Lake discharge
2. 18° Temperature rise - 18° Lake discharge
3. 18° Temperature rise - Dilution to 12° Lake discharge
4. 12° Temperature rise - 12° Lake discharge

In this type of system, all of the heat added to the condenser cooling water is transported, by the cooling water, to the lake for ultimate dissipation to the atmosphere. The only variations available are the temperature increase between the intake water and the discharge water with an inverse change in quantity of water required. This relationship is shown on table 2 at the end of this section under tab TABLES.

To attain a cooling water discharge temperature of $12^{\circ}F$ or less, above lake temperature, for a generating unit as large as the Davis-Besse unit, the condenser and related cooling water piping reach enormous proportions to the point where arrangement of the turbine building must be altered significantly.

The only feasible way by which 12° or less could be attained would be the use of condenser bypass pumps to increase the water flow rate from the intake canal directly to the discharge canal.

The greater the quantity of water used in the condenser cooling system, the larger the intake and discharge canals must be. Larger condensers require more pumps and additional pump power as shown on table 3 at the end of this section under the tab TABLES. Additional chlorine treatment is also required. These higher flows require added capital cost and operating expenditure as shown in Table 3 and decrease the marsh area available for wildlife due to the large canals.

The higher temperatures, (lower flow conditions) require a larger mixing zone in the lake to reduce the discharge plume to a given temperature.

Because all of the heat is rejected to the lake, the primary difference between any of the alternative temperature rise conditions is the size of the lake area required for a mixing zone to reduce the mixed temperature to a desired value and the initial temperature in the mixing zone at the configuration considering construction and annual operating cost penalties, with no adverse effect on the lake.

Alternate arrangements studied, for the condenser cooling water system, fall into three categories (1) open cycle without any supplemental cooling facilities, (2) open cycle with supplemental cooling facilities and (3) closed cycle with two natural draft cooling towers. These three categories are discussed in the following sections.

5.3.1 Open Cycle Systems - No Supplemental Cooling

These systems are the first category listed in tables 2 and 3 as follows:

I. OPEN CYCLE CONDENSER COOLING WATER SYSTEMS

A. No Supplemental Cooling

1. 22° Temperature rise - 22° Lake discharge
2. 18° Temperature rise - 18° Lake discharge
3. 18° Temperature rise - Dilution to 12° Lake discharge
4. 12° Temperature rise - 12° Lake discharge

In this type of system, all of the heat added to the condenser cooling water is transported, by the cooling water, to the lake for ultimate dissipation to the atmosphere. The only variations available are the temperature increase between the intake water and the discharge water with an inverse change in quantity of water required. This relationship is shown on table 2 at the end of this section under tab TABLES.

To attain a cooling water discharge temperature of $12^{\circ}F$ or less, above lake temperature, for a generating unit as large as the Davis-Besse unit, the condenser and related cooling water piping reach enormous proportions to the point where arrangement of the turbine building must be altered significantly.

The only feasible way by which 12° or less could be attained would be the use of condenser bypass pumps to increase the water flow rate from the intake canal directly to the discharge canal.

The greater the quantity of water used in the condenser cooling system, the larger the intake and discharge canals must be. Larger condensers require more pumps and additional pump power as shown on table 3 at the end of this section under the tab TABLES. Additional chlorine treatment is also required. These higher flows require added capital cost and operating expenditure as shown in Table 3 and decrease the marsh area available for wildlife due to the large canals.

discharge outfall. Proper design of the discharge can confine this mixing zone to a very small area as shown by Dr. Pritchard's studies given in Appendix B.

The open systems without supplemental cooling give somewhat larger 5° plumes, 2,532 to 4,200 feet long, than the other cycles but the cost is much lower and stations performance is much higher due to low pumping power requirements and higher station output because full advantage is taken of the lake water at low temperature.

Plume sizes at the boundary of the 5°F isotherm line for each of the four open systems studied are as follows:

	Temperature - °F		GPM Flow	Plume Size - 5°F	
	Cond.Rise	To Lake	To Lake	Length-Ft.	Acres
1.	22	22	560,000	4,200	101.2
2.	18	18	685,000	3,924	88.4
3.	18	12	1,027,500	2,532	36.7
4.	18	12	1,027,500	2,532	36.7

The 5° mixing zone of arrangement 2 above, which is the recommended arrangement, is 88.4 acres corresponding to only .0014% of the 6,340,000 acre total area of Lake Erie. This means that during a warm day, with a 70°F ambient lake water temperature and a six mile per hour wind velocity, only 88.4 acres of Lake Erie will be at 75°F temperature at the boundary with Davis-Besse Station operating at full load.

This means that during the very hot summer months of July and/or August when ambient lake temperature is at its maximum of 81°F and the wind is at the typical velocity of six miles per hour only 88.4 acres of Lake Erie will be at 86°F at the boundary when Davis-Besse Station is operating at full load.

Ambient lake temperatures and total plume boundary temperatures for different isotherms that will occur during periods of maximum ambient lake temperatures each month of the year, with Davis-Besse Station operating at full load, and corresponding plume sizes are given in Table 4 at the end of this section under the tab TABLES.

Reference to table 4 shows that during the period of maximum lake ambient temperature of 81°F the Davis-Besse Station, at full load, will only heat 1.63 acres to a temperature of 93°F at the boundary.

5.3.2 Open Cycle - With Supplemental Cooling

These systems are the second category listed in tables 2 and 3 as follows:

B. With Supplemental Cooling in the Discharge Canal
   1. 22° Temperature Rise: Spray Modules to 16°
   2. 22° Temperature Rise: Spray Modules to 13°
   3. 18° Temperature Rise: Spray Modules to 12°
   4. 18° Temperature Rise: Spray Headers to 12°
   5. 18° Temperature Rise: Forced Draft Cooling Towers to 12°

The addition of supplemental cooling equipment in the discharge canal gives a somewhat smaller plume size, 1,721 to 2,400 feet long, but station capability is reduced by 6,300 to 15,300 kw and heat rate is impaired by 75 to 184 Btu/KWH depending upon the particular arrangement. These economic penalties are given in table 3 at the end of this section of this report under the tab TABLES.

Plume sizes for 5°F isolines of each of the five open systems studied with supplemental cooling are as follows:

	Temperature		GPM Flow	Plume Size - 5°F	
	Cond.Rise	To Lake	To Lake	Length-Ft.	Acres
1.	22	16	560,000	2,400	33.1
2.	22	13	560,000	1,650	15.7
3.	18	12	685,000	1,721	17.0
4.	18	12	685,000	1,721	17.0
5.	18	12	685,000	1,721	17.0

With an open cycle system, the only way to reduce the amount of heat added to the lake is to provide supplemental cooling of the discharge water before it enters the lake. This could be accomplished with a spray system in the discharge canal or a cooling tower with all, or a portion, of the discharge water passing through it.

A major drawback associated with the spray modules and spray headers is the lack of reliable design and performance data for cooling systems of this size. Small spray ponds used on plants in the past of 5 to 50 mw capacity were constructed with a length over width ratio of 1.5 to 1 to give maximum exposure of the spray droplets to the cooling air. The corresponding ratio of length to width for a spray pond, consisting of the wide discharge canal, for Davis-Besse Station would be 30 to 1. This ratio leaves only the sides of the spray bank exposed to the cooling air stream with the ends essentially eliminated as effective cooling area.

The performance of arrangement 5 (Forced Draft Cooling Towers) is reasonably accurate and it is considered to be reliable because of the vast experience that is available on this method of cooling. However, the spray systems are entirely dependent on natural movement of air across the spray zone. An enormous size installation is required, to significantly cool this high volume of water making its performance so unpredictable that use of this concept has never been attempted for plants of the 800 MW size.

Any spray or cooling tower arrangement, to do adequate cooling, must receive the water to be cooled at a temperature which is higher than the wet bulb air temperature. To be most effective the temperature rise through the condenser should be 20-25°. As the temperature rise across the condenser is reduced the effectiveness of a spray or cooling tower system decreases.

Either of these methods for dissipating portions of the heat load to the atmosphere involve large quantities of water vapor and entrained moisture droplets at essentially a ground level release, and ground fogging problems would be quite severe under certain atmospheric conditions.

5.3.3 Closed Cycle - With Two Natural Draft Cooling Towers

These systems are the third category listed in tables 2 and 3 as follows:

II. CLOSED CYCLE COOLING SYSTEMS

A. Natural Draft Cooling Towers

1. 20° Temp. Rise: Small Towers-Large Condensers
2. 25° Temp. Rise: Medium Towers-Medium Condensers
3. 20° Temp. Rise: Large Towers-Small Condensers
4. 20° Temp. Rise: Large Towers-Large Condensers

In this type of system, the condenser cooling water passes through two cooling towers giving up all of its heat to the atmosphere through evaporative cooling and it is then recycled through the condenser. As pointed out previously, the cooled water temperature leaving the towers and entering the condenser must be well above the wet bulb air temperature.

To adequately cool the condenser cooling water, during hot weather periods, the warmed water leaving the condensers and entering the towers must be from 110°F for an average summer day to 120°F for a peak summer day when the wet bulb temperature is high.

The cooling range that can be accomplished in a cooling tower is approximately 20° to 25°F between the warmed water entering the tower and the cooled water leaving. This means that the cooling water must enter the condensers at temperatures ranging from 85° to 95°F during summer months, with the closed system, depending upon design and actual wet bulb temperature.

The higher condenser operating temperatures that would exist with this closed system arrangement materially reduce station performance resulting in severe capability and fuel cost penalties. Refer to tables 2 and 3 at the end of this section for detailed performance and cost penalties.

In summary these penalties are as follows:

CLOSED CYCLE COOLING SYSTEMS
With Two (2) Natural Draft Towers

	Arrangement	Penalty		
	Condenser Temp. Rise Tower Size & Condenser Size	Capacity KW	Heat Rate Btu/KW	Total Annual Cost
1.	20°F Rise: Sm. Twrs.-Lg. Conds.	30,100	160	$3,236,000
2.	25°F Rise: Med.Twrs.-Med.Conds.	24,900	120	3,000,000
3.	20°F Rise: Lg. Twrs.-Sm. Conds.	25,900	145	3,338,000
4.	20°F Rise: Lg. Twrs.-Lg. Conds.	19,900	136	3,277,000

Nearly all of the heat dissipation from cooling towers is by evaporative cooling, and makeup water must be continually added to the system. Under full load conditions the water evaporated amounts to about 7,200 GPM. To prevent excessive scale formation and corrosion to the cooling water system, a certain amount of the cooling water must be discharged. To provide for a reasonable concentration factor of four, this amounts to 2,800 GPM giving a total make-up water requirement of 10,000 GPM to provide for evaporative losses and blowdown.

Water in the closed system must be treated to prevent accelerated biological attack and corrosion to the filler material. Phosphate or chromate treatment cannot be used because these substances are in the blowdown water returned to the lake; consequently, an organic-zinc and sulphuric acid treatment would have to be used which would add some Biological Oxygen Demand to the blowdown water.

To date all large cooling towers, used on utility systems, have been constructed with filler material consisting of treated fir lumber. The natural draft induced by the 370 foot high chimney of a cooling tower makes it a serious fire hazard. Usually, if a fire occurs the entire wood fill is consumed before it can be brought under control. In the event fire occurs, in a cooling tower of a closed system, capacity must be reduced or the station must be shut down until the wood fill is replaced.

The Travelers Research Center (TRC) has been retained as a consultant to provide the necessary site meteorology data required by the AEC. TRC, at the request of Toledo Edison, has made an evaluation of the vapor plumes that would exist with cooling towers if they were used at the Davis-Besse Station. The TRC report is included at the end of this report as Appendix C.

This study shows that a highly visible, but elevated, plume would persist for 1.2 to 2.3 mi[illegible]ind from a cooling tower and in cold weather could persist for [illegible] as 20 miles in a down wind direction. It is estimated that these conditions would exist approximately 22 days per year or 6% of the time. This study also shows that surface icing from the plume could occur at ground level under certain conditions at a distance of 1.2 to 1.5 miles from the tower that would create extremely hazardous driving conditions along the highways nearby. The cooling towers of a closed system such as this must be operated year around or whenever the station is operating.

6 RECOMMENDATIONS

The recommended arrangement for the condenser cooling water system at the Davis-Besse Station is designated as No. I-A-2, in tables 2 and 3 at the end of this section. Temperature rise across the condenser will be 18°F with a cooling water flow of 685,000 GPM (1,526 cfs). This is the open cycle system with the cooling water discharging to the lake at a velocity of 6.7 ft./sec.

Tables 2 and 3 give performance and cost data for the recommended arrangement and show the relationship of this system to other systems analyzed.

The discharge velocity of 6.7 ft./sec. was selected because the plume resulting from the discharge at this velocity will be small enough to assure no detrimental effect on the lake biota and it will produce a smaller area of turbulence near the point of discharge than would be the case if the velocity were greater.

Figure 8 at the end of this section under the tab FIGURES is a curve showing how 5°F plume size varies in relation to discharge velocity at the entrance to the lake. Plume size is reduced very rapidly as velocity increases from one ft./sec. up to about six ft./sec. Gain in plume size reduction is very small for increases in velocity beyond 6.7 ft./second.

The resulting plume isotherm lines in the lake for the recommended arrangement are shown on Figure 9 at the end of this section under the tab FIGURES. They are identical with the values shown for Case I in Table 6-B and Figure 1 of Appendix B. This arrangement will result in a total area of Lake Erie having an excess temperature of 5°F, at the boundary, of 88.4 acres or only .0014% of the total surface of Lake Erie.

With this small thermal plume and its configuration, there will be no effect on the Niagara Reef area of any detectable excess temperature. The area immediately in front of the point of discharge into the lake will have bottom scour from the higher velocity of the discharge but in a short distance, this bottom scour action will disappear.

The thermal plumes shown on Figure 9 under the tab FIGURES, resulting from the proposed arrangement, will be bent by any wind induced currents in the offshore area; however, winds with a high enough velocity to produce currents will also sharply reduce the extent of the areas within the isotherm lines due to the higher surface cooling rate resulting from the higher wind speeds. The thermal plume configuration shown on Figure 9 is based on a typical wind speed of 6 mph.

These conditions for the condenser cooling water system were selected because they give the best balance between the various parameters to meet a number of conflicting objectives. With these proposed conditions, the quantity of water pumped through the station will not require excessive pipe sizes resulting in a good station arrangement at reasonable costs.

Total annual cost penalty of $252,000 over the most economical arrangement No. I-A-1 in Tables 2 and 3 is not considered to be excessive and an additional thirteen acres are eliminated from the 5°F thermal plume by accepting this penalty.

Marsh area required for the intake and discharge canals will not be excessively large and there will be no moisture vapor plumes or noise sources that would otherwise exist in this area if supplemental cooling equipment was provided. With proper design of the discharge into the lake, the resulting thermal plume will be confined to a very small area and its configuration will be such that there will be no harmful effect on the lake biota or ecology.

The nature of general biota and ecology in the area of the lake influenced by the thermal plume, is such that it will not be adversely affected. The Niagara Reef area, which is considered a critical area because of the walleye spawning grounds, will not be affected by any measurable thermal change resulting from operation of the station, and there will be no adverse effect on public health in any way.

7 CONCLUSIONS

The Toledo Edison Company is of the firm opinion that the construction and operation of the Davis-Besse Nuclear Power Station, within the conditions outlined in this report, will not cause undue changes in the ecology of Lake Erie in the vicinity of the station site and there will be no detrimental effect on public health. Sufficient information on the lake biota are being established and post operational surveys will be conducted to confirm that station operation is not affecting the biota or ecology.

The small 5° plume area of 88.4 acres, that will exist with the Davis-Besse Station operating at full load, complies with Ohio water quality standards. The length of this plume will be 3,924 feet and the width will be 982 feet. Maximum lake temperatures will occur during the months of July and/or August. This maximum temperature should not be greater than 81°F based on Dr. Ayers' work, and records from the Toledo water intake and the Port Clinton intake.

During the time of a maximum lake temperature of 81°F there will be only 88.4 acres at a boundary temperature of 86°F and only 1.63 acres at a boundary temperature of 93°F as shown in Table 4 at the end of this section under the tab TABLES. To further reduce the 88.4 acre size of the 5° plume that will exist, with the recommended arrangement No. I-A-2, would materially increase initial cost of the station and impose severe penalty on annual operating costs.

Possible reductions of plume size, and corresponding cost associated with each, are given in summary below. Additional data and information are shown on Tables 2 and 3.

PLUME SIZE REDUCTION AND COST TO ATTAIN THIS REDUCTION

I Open Cycle Systems	5° Plume Size and Reduction-Acres	Cost Penalty Total Capital	Cost Penalty Total Cost/Yr.
A. No Supplemental Cooling			
1. 22°F Rise-22°F to Lake	101.2	Base	Base
2. 18°F Rise-18°F to Lake	101.2 to 88.4	$1,493,000	$ 252,000
3. 18°F Rise Dilute to 12°F	101.2 to 36.7	4,324,000	721,000
4. 12°F Rise-12°F to Lake	101.2 to 36.7	4,866,000	818,000
B. With Supplemental Cooling			
1. 22°F Rise-16°F to Lake	101.2 to 33.1	7,014,000	1,228,000
2. 22°F Rise-13°F to Lake	101.2 to 15.7	9,610,000	1,695,000
3. 18°F Rise-12°F to Lake	101.2 to 17.0	10,810,000	1,892,000
4. 18°F Rise-12°F to Lake	101.2 to 17.0	16,903,000	2,872,000
5. 18°F Rise-12°F to Lake	101.2 to 17.0	22,609,000	3,932,000
II Closed Cycle Systems			
A. Natural Draft Cooling Towers			
1. 20°F Rise-0 to Lake	101.2 to 0	18,541,000	3,236,000
2. 25°F Rise-0 to Lake	101.2 to 0	17,310,000	3,000,000
3. 20°F Rise-0 to Lake	101.2 to 0	19,190,000	3,338,000
4. 20°F Rise-0 to Lake	101.2 to 0	18,872,000	3,277,000

PLUME AREA OF 5°F ISOTHERM
VS
DISCHARGE VELOCITY

CONDENSER COOLING WATER FLOW 685,000 GPM

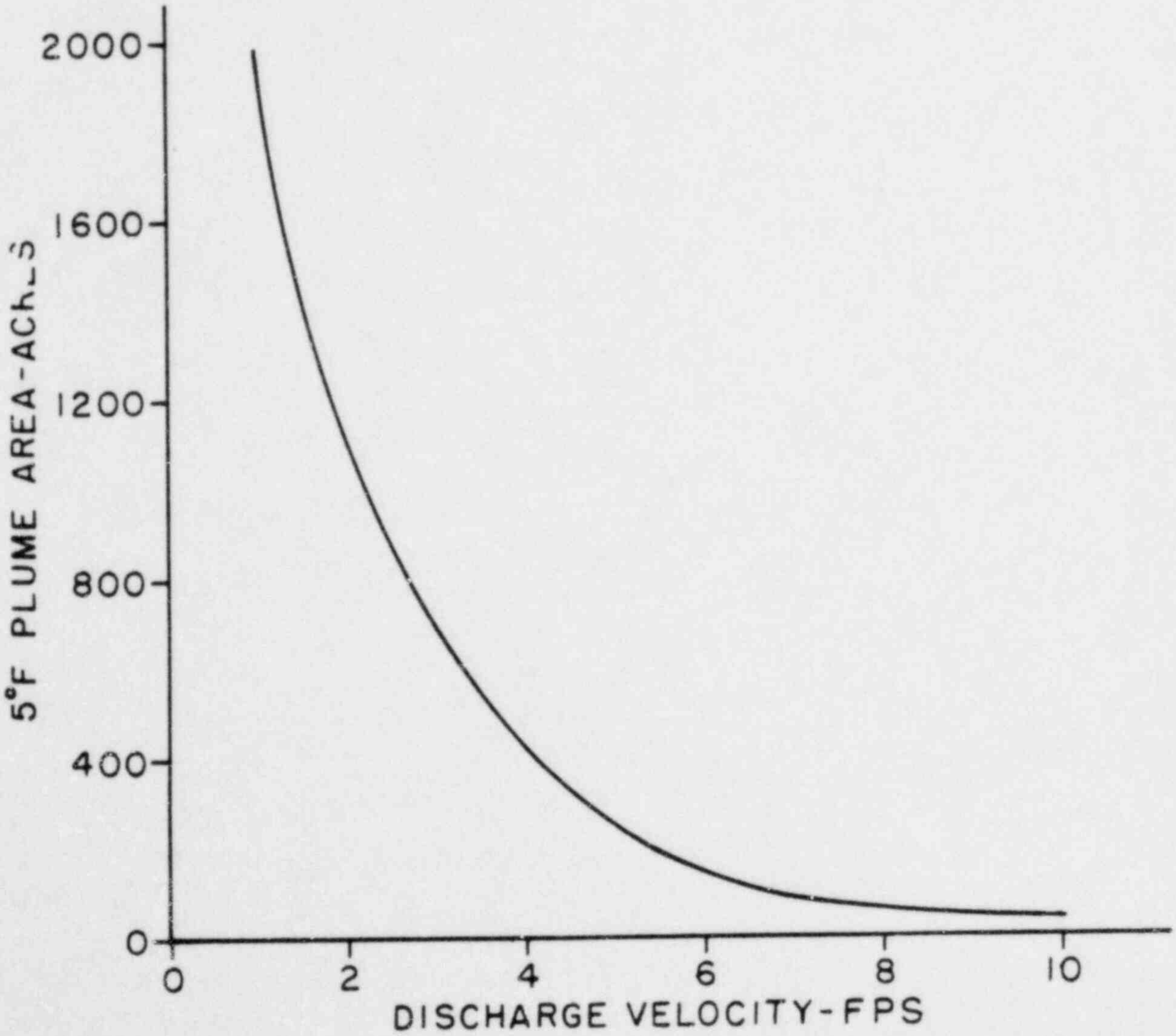
HEAT INPUT TO LAKE 6.21 X 10^9 BTU/HR

TEMPERATURE RISE ACROSS CONDENSER 18°F

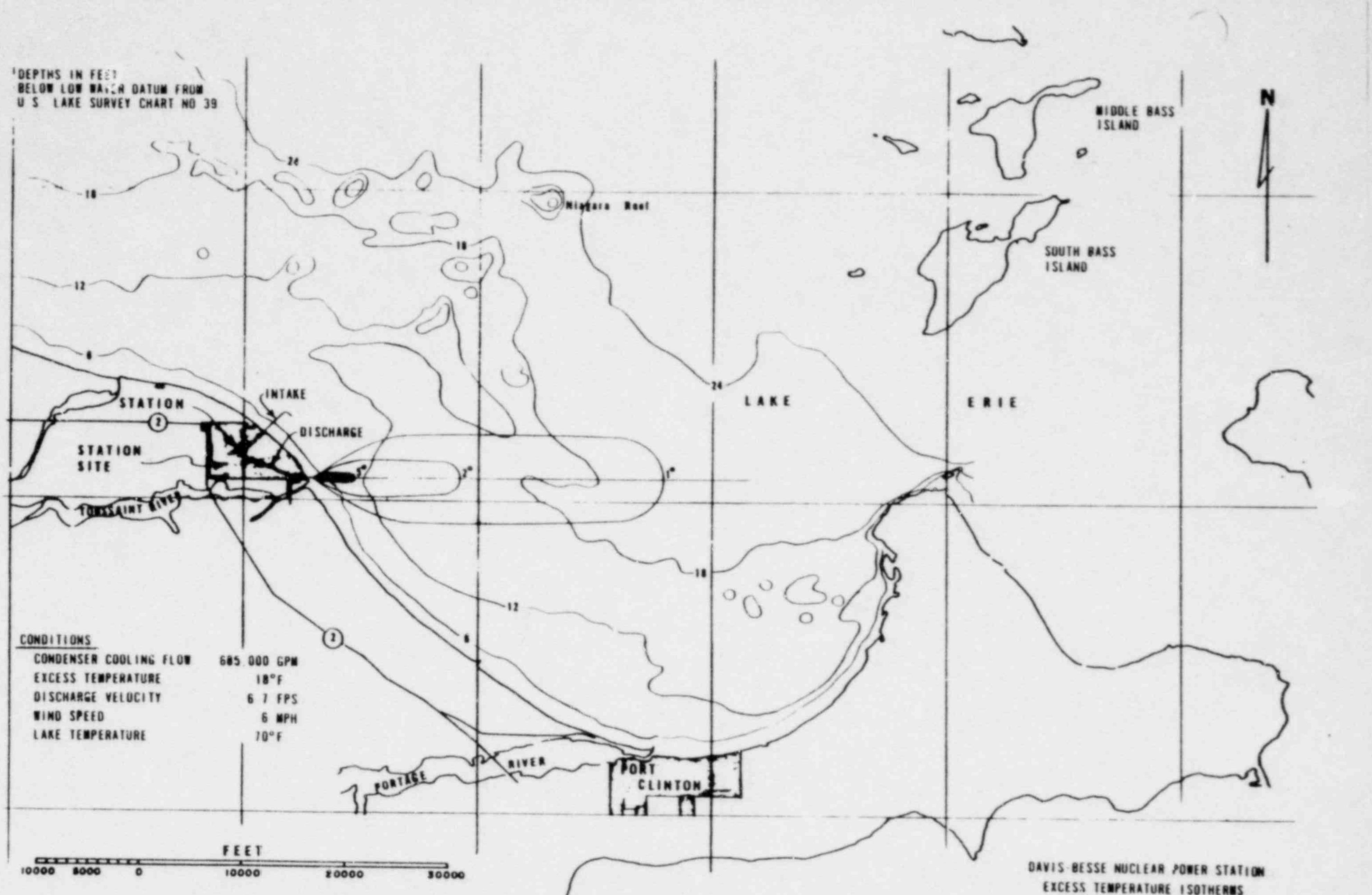
EXCESS TEMPERATURE IN DISCHARGE TO LAKE 18°F

WIND VELOCITY 6 MPH

TEMPERATURE OF LAKE WATER 70°F



DAVIS-BESSE NUCLEAR POWER STATION
PLUME AREA VS DISCHARGE VELOCITY
FIGURE 8



DAVIS-BESSE NUCLEAR POWER STATION
EXCESS TEMPERATURE ISOTHERMS
CONDENSER COOLING WATER
FIGURE 9

TABLE 2

DAVIS-BESSE NUCLEAR POWER STATION

CONDENSER COOLING WATER SYSTEM ALTERNATE ARRANGEMENTS - DESIGN PARAMETERS AND PERFORMANCE DATA

I OPEN CYCLE COOLING SYSTEMS	Temp Rise To Lake °F Rise	Total Flow To Lake GPM	Plume Size for 5° Isotherm			Condenser		At 75° Lake Water Temp		Average Annual	
			Length Ft.	Area Acres	Area Sq. Miles	Water Flow GPM	Size Square Feet	Cond. Vac. In. Hg.	Capacity KW Net	Capacity KW Net	Heat Rate Btu Per KWH Net
A. No Supplemental Cooling											
1. 22° Temperature Rise	22°	560,000	4,200	101.2	0.158	560,000	541,000	2.25	870,500	875,700	10,330
2. 18° Temperature Rise	18°	685,000	3,924	88.4	0.138	685,000	466,000	2.25	869,900	875,100	10,337
3. 18° Temp.Rise:Dilute	12°	1,027,500	2,532	36.7	0.057	685,000	466,000	2.25	869,700	874,900	10,340
4. 12° Temperature Rise	12°	1,027,500	2,532	36.7	0.057	1,027,500	397,000	2.25	868,300	873,500	10,357
B. Supplemental Cooling											
1. 22° Temp.Rise:Spray Modules	16°	560,000	2,400	33.1	0.052	560,000	466,000	2.25	864,200	869,400	10,405
2. 22° Temp.Rise:Spray Modules	13°	560,000	1,650	15.7	0.0245	560,000	466,000	2.25	861,000	866,200	10,444
3. 18° Temp.Rise:Spray Modules	12°	685,000	1,721	17.0	0.0265	685,000	466,000	2.25	861,000	866,200	10,444
4. 18° Temp.Rise:Spray Headers	12°	685,000	1,721	17.0	0.0265	685,000	466,000	2.25	862,500	867,700	10,426
5. 18° Temp.Rise:Forced Draft Towers	12°	685,000	1,721	17.0	0.0265	685,000	466,000	2.25	855,200	860,400	10,514

II CLOSED CYCLE COOLING SYSTEMS	Cooling Tower Dimensions		Condenser				At 77° Wet Bulb Temp			
	Dia. Ft.	Ht. Ft.	Inlet Temp °F	Disch. Temp °F			Cond. Vac. In. Hg.	Capacity KW Net		
A. Natural Draft Cooling Towers										
1. 20° Temp.Rise:Small Towers-Large Condensers	355	291	98.0	118.0	616,000	727,000	3.75	840,400	862,400	10,490
2. 25° Temp.Rise:Medium Towers-Medium Condensers	390	370	91.5	116.5	495,000	659,500	3.59	845,600	865,700	10,450
3. 20° Temp.Rise:Large Towers-Small Condensers	400	370	91.4	111.4	616,000	551,000	3.50	844,[illegible]00	863,600	10,475
4. 20° Temp.Rise:Large Towers-Large Condensers	400	370	91.4	111.4	616,000	741,000	3.12	850,600	864,400	10,466

NOTES: 1. All plume dimensions and areas are based on discharge velocity of 6.7 FPS for the open cycle systems.
2. All condenser vacuum, capacity, and heat rate values are based on maximum guaranteed turbine rating corresponding to the maximum net station capacity of 872 MWe at 1.75 In. Hg.

TABLE 3

DAVIS-BESSE NUCLEAR POWER STATION

CONDENSER COOLING WATER SYSTEM ALTERNATE ARRANGEMENTS - CAPITAL COST AND ANNUAL OPERATING COST PENALTIES

	Temp Rise To Lake °F	At 75° Lake Water Temp		Average Annual		Capital Cost Penalty			Fixed Charges & Annual Operating Cost Penalties			
		Capacity KW Net	Capacity Penalty KW	Heat Rate Btu Per Net KWH	Heat Rate Penalty Btu/KWH	Equipt. Cost Penalty	Capacity Penalty @$280/KW	Total Capital Cost Penalty	Fixed Charges @ 16.4%	Added Fuel Cost	Added Maint. and Insurance	Total Annual Cost
I OPEN CYCLE COOLING SYSTEMS												
A. No Supplemental Cooling												
1. 22° Temperature Rise	22°	870,500	Base	10,330	Base	Base	Base	Base	Base	Base	Base	Base
2. 18° Temperature Rise	18°	869,900	600	10,337	7	$1,325,000	$168,000	$1,493,000	$245,000	$7,000	$ 0	$252,000
3. 18° Temp.Rise:Dilute	12°	869,700	800	10,340	10	4,100,000	224,000	4,324,000	710,000	10,000	1,000	721,000
4. 12° Temperature Rise	12°	868,300	2,200	10,357	27	4,250,000	616,000	4,866,000	798,000	20,000	0	818,000
B. Supplemental Cooling												
1. 22° Temp.Rise:Spray Modules	16°	864,200	6,300	10,405	75	5,250,000	1,764,000	7,014,000	1,150,000	75,000	3,000	1,228,000
2. 22° Temp.Rise:Spray Modules	13°	861,000	9,500	10,444	114	6,950,000	2,660,000	9,610,000	1,576,000	114,000	5,000	1,695,000
3. 18° Temp.Rise:Spray Modules	12°	861,000	9,500	10,444	114	8,150,000	2,660,000	10,810,000	1,773,000	114,000	5,000	1,892,000
4. 18° Temp.Rise:Spray Headers	12°	862,500	8,000	10,426	96	14,663,000	2,240,000	16,903,000	2,772,000	96,000	4,000	2,872,000
5. 18° Temp.Rise:Forced Draft Towers	12°	855,200	15,300	10,514	184	18,325,000	4,284,000	22,609,000	3,708,000	184,000	40,000	3,932,000
II CLOSED CYCLE COOLING SYSTEMS		At 77° Wet Bulb Temp.										
		Capacity KW Net	Capacity Penalty KW									
A. Natural Draft Cooling Towers												
1. 20°Temp.Rise:Small Towers-Large Cond.		840,400	30,100	10,490	160	10,113,000	8,428,000	18,541,000	3,041,000	160,000	35,000	3,236,000
2. 25°Temp.Rise:Medium Towers-Medium Cond.		845,600	24,900	10,450	120	10,338,000	6,972,000	17,310,000	2,839,000	120,000	41,000	3,000,000
3. 20°Temp.Rise:Large Towers-Small Cond.		844,600	25,900	10,475	145	11,938,000	7,252,000	19,190,000	3,147,000	145,000	46,000	3,338,000
4. 20°Temp.Rise:Large Towers-Large Cond.		850,600	19,900	10,466	136	13,300,000	5,572,000	18,872,000	3,095,000	136,000	46,000	3,277,000

TABLE 4

DAVIS-BESSE NUCLEAR POWER STATION

PLUME SIZE AND TOTAL TEMPERATURE AT THE BOUNDARY OF THE VARIOUS ISOTHERMS OCCURRING DURING PERIOD OF MAXIMUM MONTHLY TEMPERATURE OF LAKE ERIE WITH DAVIS-BESSE STATION OPERATING AT FULL LOAD

Condenser Cooling Water Arrangement No. I-A-2 (Case I in Appendix B)

Plume Boundary Temp. - °F	Maximum Monthly Temp. - °F *	Jan. 37	Feb. 36	March 40	April 54	May 64	June 75	July 81	Aug. 81	Sept. 77	Oct. 64	Nov. 50	Dec. 40
18	Total Temp. Incl. Excess - °F	55	54	58	72	82	93	99	99	95	82	68	58
	Acres in Plume of Total Temp.	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30
	Acres - % of Lake Erie	.000005	.000005	.000005	.000005	.000005	.000005	.000005	.000005	.000005	.000005	.000005	.000005
16	Total Temp. Incl. Excess - °F	53	52	56	70	80	91	97	97	93	80	66	56
	Acres in Plume of Total Temp.	.49	.49	.49	.49	.49	.49	.49	.49	.49	.49	.49	.49
	Acres - % of Lake Erie	.000008	.000008	.000008	.000008	.000008	.000008	.000008	.000008	.000008	.000008	.000008	.000008
4	Total Temp. Incl. Excess - °F	51	50	54	68	78	89	95	95	91	78	64	54
	Acres in Plume of Total Temp.	.85	.85	.85	.85	.85	.85	.85	.85	.85	.85	.85	.85
	Acres - % of Lake Erie	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001	.00001
2	Total Temp. Incl. Excess - °F	49	48	52	66	76	87	93	93	89	76	62	52
	Acres in Plume of Total Temp.	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63
	Acres - % of Lake Erie	.00003	.00003	.00003	.00003	.00003	.00003	.00003	.00003	.00003	.00003	.00003	.00003
0	Total Temp. Incl. Excess - °F	47	46	50	64	74	85	91	91	87	74	60	50
	Acres in Plume of Total Temp.	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54
	Acres - % of Lake Erie	.00006	.00006	.00006	.00006	.00006	.00006	.00006	.00006	.00006	.00006	.00006	.00006
8	Total Temp. Incl. Excess - °F	45	44	48	62	72	83	89	89	85	72	58	48
	Acres in Plume of Total Temp.	9.39	9.39	9.39	9.39	9.39	9.39	9.39	9.39	9.39	9.39	9.39	9.39
	Acres - % of Lake Erie	.00015	.00015	.00015	.00015	.00015	.00015	.00015	.00015	.00015	.00015	.00015	.00015
6	Total Temp. Incl. Excess - °F	43	42	46	60	70	81	87	87	83	70	56	46
	Acres in Plume of Total Temp.	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4
	Acres - % of Lake Erie	.00056	.00056	.00056	.00056	.00056	.00056	.00056	.00056	.00056	.00056	.00056	.00056
5	Total Temp. Incl. Excess - °F	42	41	45	59	69	80	86	86	82	69	55	45
	Acres in Plume of Total Temp.	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4
	Acres - % of Lake Erie	.0014	.0014	.0014	.0014	.0014	.0014	.0014	.0014	.0014	.0014	.0014	.0014
4	Total Temp. Incl. Excess - °F	41	40	44	58	68	79	85	85	81	68	54	44
	Acres Covered by Total Temp.	185	185	185	185	185	185	185	185	185	185	185	185
	Acres - % of Lake Erie	.0029	.0029	.0029	.0029	.0029	.0029	.0029	.0029	.0029	.0029	.0029	.0029
2	Total Temp. Incl. Excess - °F	39	38	42	56	66	77	83	83	79	66	52	42
	Acres Covered by Total Temp.	1169	1169	1169	1169	1169	1169	1169	1169	1169	1169	1169	1169
	Acres - % of Lake Erie	.0184	.0184	.0184	[illegible]	.0184	.0184	.0184	.0184	.0184	.0184	.0184	.0184
1	Total Temp. Incl. Excess - °F	38	37	41	55	65	76	82	82	78	65	51	41
	Acres Covered by Total Temp.	6680	6680	6680	6680	6680	6680	6680	6680	6680	6680	6680	6680
	Acres - % of Lake Erie	.1054	.1054	.1054	.1054	.1054	.1054	.1054	.1054	.1054	.1054	.1054	.1054

NOTES:
1. *Maximum Monthly Temperatures are the highest temperatures recorded for the individual months over the past 12 year period.
2. All plume sizes are based on discharge velocity of 6.7 FPS and a 6 MPH wind velocity.

TABLE 5

DAVIS-BESSE NUCLEAR POWER STATION

AVERAGE AUGUST WATER TEMPERATURES AT TOLEDO AND PORT CLINTON MUNICIPAL WATER INTAKE STRUCTURES

Toledo Temp-°F	Year	Port Clinton Temp-°F
75	1969	76
75	1968	76
72	1967	72
73	1966	72
72	1965	72
73	1964	71
72	1963	71
73	1962	75
75	1961	75
75	1960	74
79	1959	79
74	1958	77
73	1957	74
70	1956	Not Available
77	1955	Not Available
73	1954	Not Available
75	1953	Not Available
73	1952	Not Available
73	1951	Not Available
73	1950	Not Available
77	1949	Not Available
73	1948	Not Available
77	1947	Not Available
73	1946	Not Available
75	1945	Not Available
75	1944	Not Available
75	1943	Not Available
75	1942	Not Available