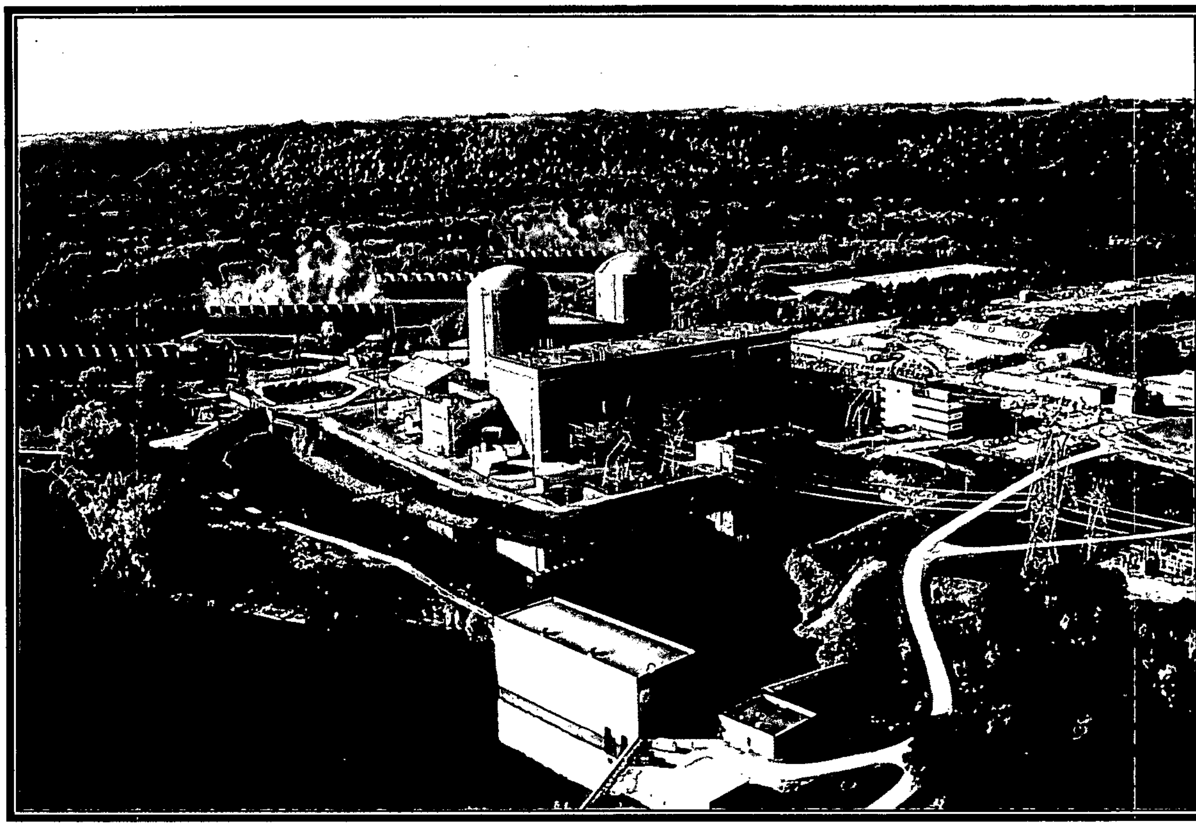
Xcel Energy

PRAIRIE ISLAND NUCLEAR GENERATING PLANT

LICENSE RENEWAL ENVIRONMENTAL REPORT
ADDITIONAL INFORMATION



Comprehensive Demonstration Study In Accordance with 316(b) of the Clean Water Act 40 CFR 9, 122, 123, 125, 126

To Fulfill Surface Water Request #101

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Xcel Energy Prairie Island Nuclear Generating Plant

IMPINGEMENT MORTALITY AND ENTRAINMENT CHARACTERIZATION STUDY

Submitted in Accordance with the NPDES Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities

NPDES Permit MN0004006

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Prepared by:

Xcel Energy
Environmental Services

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1) INTRODUCTION

The Prairie Island Nuclear Generating Plant (PINGP), Units 1 and 2, each employ a 2-loop pressurized water reactor. Full commercial operation began on December 16, 1973 for Unit 1 and on December 21, 1974 for Unit 2. Both units are licensed with the Nuclear Regulatory Commission (NRC) for operation at 1650 MWt per reactor, which is equivalent to a gross electrical output of 575 Mwe for each unit. Northern States Power Company d/b/a Xcel Energy (Xcel Energy) owns the facility, while Nuclear Management Company (NMC) operates the facility.

PINGP is located on the Mississippi River (River Mile 798) in Goodhue County near Red Wing, Minnesota (Figure 1). The site (approximately 578 acres) is located within the city limits of Red Wing, Minnesota on the West bank of the Mississippi River. The plant site is located about 26 miles SE of the Twin Cities Metropolitan Area.

Plant intake flow from the Mississippi River enters the Intake Screenhouse through eight 18.5 foot by 11.2 foot bay openings. The bottom of the inlet skimmer wall is at elevation 667.0 feet. Each bay is equipped with a raked trash rack and a traveling water screen with low-pressure fish wash sprays and high-pressure trash wash sprays. Traveling water screens are equipped with fish lift buckets to remove debris and organisms from the intake water. Each screen is 10 foot wide and extends from the operating deck (elevation 685 feet) to the floor (elevation 648.5 feet). Screen panels are replaceable. During the period of April 1 through August 31 fine mesh (0.5 mm) screens are used. The remainder of the year 3/8 inch (9.5 mm) coarse mesh screens are in service. The screens are capable of operation at several different speeds, as necessitated by trash loading.

During fine mesh screen operation, the screens continuously run at 3 fpm when screen differential is 4 inches or less. During coarse screen operation, the traveling screens, fish spray wash system and trash spray wash system do not operate when the differential level is less than 4 inches. The screens will automatically rotate with sprays operating, 1-1/3 revolutions if 8 hours pass without screen operation. For both fine and coarse screen operation, if the differential level exceeds 4 inches, screen speed increases proportionally up to a maximum of 20 fpm at 8 inches differential level

Fish protection measures designed into the vertical traveling screens include fish collection buckets and low-pressure fish sprays. Aquatic organisms impinged on the traveling water screens are lifted in the collection buckets to the level of fish sprays and are then washed into a fish collection trough. Removal of the fish and organisms is accomplished on the upward travel side with a low pressure (10 psi) inside spray when fine mesh is used and with a low pressure (20 psi) outside spray when coarse mesh screen is used. Debris is removed by a backside interior high-pressure (50 psi for fine mesh and 100 psi for coarse mesh) spray system. The organisms and debris washed off the traveling water screens collect in a fish return trough and a debris trough that combine into a common trough and is returned to the river through a buried pipe approximately

2200 feet long. The pipe discharges into the Mississippi River at a point approximately 1500 feet south (downriver) of the intake screenhouse (Figure 2).

The circulating water flows from the intake canal into the plant screenhouse and to the suction of the circulating water pumps. Four circulating water pumps, two for each unit, supply water to the condensers to condense the turbine exhaust steam. Each pump has a capacity of 147,000 gpm at 45 ft total head. The condenser inner and outer pass discharge flows from each unit combine into a common header and are directed to the discharge basin (Figure 3). The discharge basin serves as a stilling surge basin for the condenser discharge and provides the suction head for the cooling tower pumps. Four cooling tower pumps take water from the discharge basin and discharge into individual cooling tower distribution pipes. Four crossflow cooling towers remove some of the heat from the circulating water.

The discharge canal directs the circulating water flow from the distribution basin to the discharge structure for return to the river via the sluice gates. Flow through the four submerged sluice gates ranges from 150 cfs to 1390 cfs. Discharge flow rates are limited during specified periods of the year as follows:

April 15-30	150-300 cfs
May 1-31	300 cfs
June 1-15	400 cfs
June 16-30	800 cfs

The remaining periods of the year flow is limited by the design intake flow of 1410 cfs.

Xcel has selected Compliance Alternative (2) of 40CFR 125.94 (a) to meet the impingement and entrainment reduction requirements for PINGP. Alternative (2) requires that Xcel Energy demonstrate that existing design and construction technologies, operational measures, and/or restoration measures at Prairie Island meet the impingement and entrainment performance standards.

Xcel Energy will submit a comprehensive demonstration study (CDS) in accordance with 316 (b) of the Clean Water Act. The CDS will demonstrate that the location, design, construction, and capacity of the cooling water intake structure at Prairie Island reflects the best technology available for minimizing adverse environmental impact.

Xcel Energy will submit results of Impingement Mortality and Entrainment (IM&E) Characterization Studies conducted before and after construction of the intake screenhouse. The IM&E study will include taxonomic identifications and characterizations of all life stages of fish, shellfish, and any species protected under Federal, State, or Tribal Law that are in the vicinity of the cooling water intake structure and susceptible of impingement and entrainment.

2) HISTORICAL FISH SURVEYS

Xcel Energy has completed several adult fishery studies since the original 316(b) study information was obtained. Historical fisheries studies conducted before and after completion of original 316(b) study have included trawling, gill netting, seining, trap netting, and electrofishing.

Trawling was conducted seasonally in the plant intake area, discharge canal, and two stations in North Lake from 1973 to 1980. A minimum of 15 minutes of trawling in two or more runs was completed in each station. A total of 38 species representing 14 families were collected during trawling (Table 1). The three dominant species collected during trawling for all years combined are freshwater drum, gizzard shad, and white crappie.

Gill netting was conducted only during the spring and fall sampling seasons from 1973 to 1980. Standard 250 x 6 foot experimental gill nets were used. Eight nominal 24-hour sets were made in each section by making two nominal 24-hour sets at four stations. A total of 39 species representing 14 families were identified during gill netting (Table 2). The three most commonly collected species during gill netting were gizzard shad, white bass, and sauger.

Seining was conducted from 1973 to 1984. Shoreline seining was restricted to areas with water depth less than 2 meters. Sampling areas too deep to wade were seined by using a boat to pull the offshore end of the seine. Where river currents existed, the seine was pulled downstream. The seine used from 1974 to 1984 was ¼ inch knotless nylon 50 feet long by 4 feet deep, with a 4 x 4 x 4 foot bag. The seine used in 1973 was 100 foot long x 8 foot deep. Seining accounted for 61 species representing 14 families (Table 3). The three dominant species for all years combined were emerald shiner, gizzard shad, and white bass.

Trap netting was conducted in the vicinity of PINGP from 1973 to 1980. River trap nets were set for four nominal 24-hour periods. A total of 47 species representing 16 families were collected during trap netting (Table 4). The three dominant species for all years combined were freshwater drum, black crappie, and white bass.

Xcel Energy has conducted an electrofishing study on the Mississippi River in the vicinity of PINGP since 1973. The ongoing study provides more than 30 years of data on the fish populations in the river.

To fulfill part of the continuing environmental monitoring requirements of PINGP, the Mississippi River fisheries population is sampled by electrofishing near Red Wing, Minnesota, May through October. The study area extends from 3.6 miles upstream of the plant (River mile 802) to 10.8 miles downstream of the plant (River mile 787.5), (Figure

4). The original objective of the study was to "determine existing ecological characteristics before plant operation and to assess any significant changes to the aquatic environment after operation" (NSP 1972). The objective was changed slightly after the plant became operational in 1973; to "determine environmental effects of the PINGP on the fish community in the Mississippi River and it's backwaters" (NSP, 1973). Presently, the objective is to monitor and assess the status of the fishery in the vicinity of the PINGP (NSP, 1994). Parameters analyzed and compared to previous years include species composition, length-weight regressions, percent contribution (fish/hr), length-frequency distributions, and catch per unit effort (CPUE) for selected species.

Electrofishing methods and materials have changed over the 30 plus years of the study as equipment has improved and slight plant modifications (i.e. new intake structure/discharge canal) have occurred. Fish are now collected using a Smith-Root SR-18 Electrofishing boat equipped with a 5.0 GPP electrofishing unit. The power source is a 5.0 GPP generator. The 5000 watt generator has a maximum output of 16 amps, and a range of 0-1000 volts. The generator has the capability to be either pulsed AC or DC with a pulse frequency of 7.5, 15, 30, 60, and 120 Hz. The anode consists of two umbrella arrays, each with six dropper cables. The 18 foot boat and dropper cables hung from the front of the boat serve as the cathode. Collection occurs during daylight hours with a pulsed direct current. Due to the constantly changing river conditions, Electrofisher output is varied to enhance the effectiveness.

Sampling is done monthly, May through October, within four established sectors of the study area (see Figure 4). The runs within each sector are similar to previous years sampling to ensure a similar set of relative data indices for yearly comparison. At the end of each "run", the elapsed shocking time is recorded from a digital timer, which only tallied the seconds that the electrical field was energized. A run is terminated after approximately 450 seconds shocking time or when the end of the prescribed run is reached.

Stunned fish are captured with one-inch stretch mesh landing nets equipped with eight-foot insulated handles. Starting in 1981, all cyprinids (besides carp), small percids, and all white bass, gizzard shad, and freshwater drum less than 160 mm are not sampled. Captured fish are placed in live-wells and supplied with river water constantly until the end of each run. At the end of each run fish are identified, measured to the nearest millimeter (total length), weighed to the nearest 10 grams, and released. Parameters used to describe the fisheries include species composition, length-weight regressions, percent contribution, length-frequency distributions, and catch per unit effort (CPUE). It is assumed that population dynamics and spatial distribution is represented by CPUE.

Since 1973 there have been 71 species representing 20 different families collected while electrofishing (Table 5). After 1980 when sampling criteria changed, 50 species from 18 families have been identified while electrofishing in the Prairie Island plant vicinity. Currently, approximately 40 species are sampled each year.

Dominant species for the study period (30+ years) has been dependant on what type of gear was used for sampling. Overall, carp, freshwater drum and white bass have been the most dominant. Important pan fish include black and white crappies, and bluegill. Important game fish include sauger, walleye, and smallmouth bass. The most dominant cyprinid besides carp is emerald shiner. Other species with occasional high catch rates include shorthead redhorse, quillback carpsucker and channel catfish. Gizzard shad have been highly variable in the catch, with higher percentages occurring when y-o-y fish were sampled. Electrofishing has been the only collection method used since 1988. Since that time, the top four species have been carp, white bass, freshwater drum and shorthead redhorse.

Overall (all methods combined) a total of 79 species representing 20 families have been collected during surveys conducted in the vicinity of PINGP since 1973.

3) MUSSEL SURVEYS

A mussel survey was conducted in the vicinity of PINGP by biologists from Xcel Energy and Minnesota Department of Natural Resources. The survey was conducted prior to proposed construction of the intake screenhouse and discharge at PINGP to determine whether *Lampsilis higginsii* or any other endangered mussels were present in the area.

Sampling methods included brailing with a crowfoot bar, wading, and snorkeling. Sampling was conducted from September 4 through 17, 1980.

A total of 248 mussels representing 21 species were collected (Table 6). Two species were found as relic shells only and one species was collected only from the traveling screen wash. No live specimens of *Lampsilis higginsii* or any other endangered species were collected. The survey indicated a viable mussel fauna exists in the vicinity of PINGP. A copy of the survey is provided is Appendix A.

Distribution and relative abundance of Upper Mississippi River mussels species for navigation Pool 3 as provided by Kelner (2003) is presented in Table 7. Kelner (2003) lists a total of 27 live species collected from Pool 3 with historical collections of 13 additional species. *Amblema plicata, Fusconaia flava*, and *Obliquaria reflexa* were considered abundant in collections.

4) POTENTIAL THREATENED AND ENGDANGERED SPECIES

Tables 8 and 9 provide a listing of Minnesota and Wisconsin endangered, threatened, and special concern fish and mussel species. Review of present and historical surveys will be utilized to identify any species protected under Federal, State, or Tribal Law that are in the vicinity of the cooling water intake structure and susceptible to impingement and entrainment. Two state listed Endangered mussel species (*Lampsilis higginsi* and *Quadrula fragosa*) also have Federal status of Endangered.

Seven fish species listed by Minnesota and/or Wisconsin have been collected in surveys conducted in the vicinity of PINGP since 1973. Lake sturgeon were collected during electrofishing surveys (2003) and trap-netting (1977). Blue sucker have been identified in electrofishing collections (1982, 1983, 1986-1989, 1991-2005) and trap-netting (1987). Goldeye have been collected during electrofishing (1985, 1988, 1993, 1996-1999, 2003-2005), trap-netting (1974, 1976-1978, 1982, 1983, 1987), trawling (1974, 1980), gill-netting 1973-1980), and seining (1980). Redfin shiner were identified in electrofishing samples (1975, 1976) and seining collections (1975). River redhorse have been collected during electrofishing 17 of the 33 sampling years (1982, 1983, 1986, 1987, 1989-1992, 1994, 1995, 1998-2005) and five years during trap-netting (1974, 1981, 1984-1986). Greater redhorse was identified in electrofishing surveys conducted during 1984, 1988, 1990, 1997, 1998, 2001, and 2003. Paddlefish have been collected twice during electrofishing surveys (1997, 2005).

Goldeye was the only listed species collected during impingement sampling conducted from 1973 to 1984. Goldeye were identified in impingement samples from 1973 to 1980 and 1983.

One state listed mussel species (*Elliptio dilatata*) was identified during the 1980 mussel survey conducted in the vicinity of PINGP. *Elliptio dilatata* is listed as Special Concern by the Minnesota Department of Natural Resources and is not listed by the Wisconsin Department of Natural Resources. Relic shells of *Fusconaia ebena* were identified during the 1980 mussel survey. *Fusconaia ebena* is listed as Endangered by both Minnesota and Wisconsin. Based on the summary provided by Kelner (2003) (Table 7), no live specimens of *Fusconaia ebena* have been documented in the past 25 years in Pool 3. Federally listed Endangered mussel species *Lampsilis higginsi* and *Quadrula fragosa* have not been documented in live collections from Pool 3 during the past 25 years (see Table 7).

On July 29, 2003, members from the U.S. Fish and Wildlife Service, Minnesota Department of Natural Resources, and Army Corps of Engineers placed 195 sub-adult *Lampsilis higginsii* to a site in lower Mississippi River Pool 3 at Sturgeon Lake (approximately River Mile 799) (Kelner etal, 2004). In addition, 1,400 *Lampsilis higginsii* were placed at the same site in 2005 and 744 were placed at the site and scattered between the site and approximately ½ mile downstream in 2006 (Kelner, pers comm., 2006). *Lampsilis higginsii* were relocated to the Sturgeon Lake site as part of an ongoing multi-agency coordinated reintroduction effort.

5) IMPINGEMENT

5.1 PLANT SCREENHOUSE IMPINGEMENT 1973 TO 1984 (BASELINE)

Fish and other organisms impinged on the traveling screens of the PINGP cooling water intake have been monitored and reported annually since 1974. In addition, impingement sampling was conducted in 1973 during preoperational testing and after commercial production began. Impingement data included taxonomic composition, weekly impingement rates, seasonal impingement rates, and length frequencies of fish measured. Non-fish organisms impinged (e.g. crayfish, turtles, clams, and small mammals) were also reported.

Procedures for collection, identification, and enumeration of impinged organisms from 1973 to 1980 were similar. Trash baskets were emptied on Monday, Wednesday, and Friday each week. Debris and organisms were separated, fishes were taxonomically enumerated, and non-fish organisms were recorded. Fishes removed from the bar racks were also included in impingement data. Organisms alive after impingement were included in total impingement numbers and released.

Impingement samples were collected every other week during 1981 through 1984. Trash baskets were emptied Monday, Wednesday, and Friday each sampling week. Annual impingement loss was estimated by multiplying actual numbers of fish collected by two. Observations were made during weeks not sampled to assure no catastrophic losses occurred. Debris and organisms were separated, fish were taxonomically enumerated, and non-fish organisms were recorded.

A summary of total number and percent composition of predominant fish taxa impinged at the PINGP from 1973 to 1984 is presented in Table 10. Annual estimated number of fish impinged ranged from 24,967 in 1979 to 554,590 in 1977. Nearly 2 million fish were estimated to have been impinged during the 12 sample years. Gizzard shad was the most frequently impinged taxon from 1973 to 1984, representing nearly 80 percent of fish impinged for all sample years combined. Other species common in impingement samples included freshwater drum, white bass, and channel catfish.

A summary of non-fish species (excluding mammals, insects, and birds) is presented in Table 11. Shellfish included nine identified species of clams. Other species impinged included various species of turtles, crayfish, mudpuppies, and frogs.

5.2 INTAKE SCREENHOUSE IMPINGEMENT 1984 TO 1989 (VERIFICATION)

In 1983, a new screenhouse was constructed at the PINGP. There are presently two complete screening facilities operating at PINGP. The old, or original, traveling screens and screenhouse (plant screenhouse) were designed to prevent debris, fish, and other organisms from entering the plant via the cooling water intake. Debris and fish impinged on plant screenhouse screens are washed into a trash trough which flows into a trash collection basket. The new screenhouse and screens (intake screenhouse), completed in 1983, were designed and located to exclude fish from the warm circulating water system. Impingement and survival of fish at the new intake screenhouse was studied beginning in 1984.

The intake screenhouse vertical traveling screens employ fine mesh (0.5 mm) panels with continuous screen operation during the larval fish season (mid-April through August) and course mesh (9.5 mm) panels for the remainder of the year. During the larval season, fish impinged on the fine mesh screens are washed off the front side of the screen into a trough on the screenhouse operating deck. Flow in the front trough, which contains the impinged fish is returned to the Mississippi River downstream of the plant intake or can be diverted into fish collection tanks in the environmental laboratory.

During November 1983 through March 1984 impingement samples were collected from coarse mesh screens at the intake screenhouse. Total number of fish impinged was estimated by expanding the numbers collected during weekly samples over an entire month. In addition, fish collected were recorded as live or dead, live fish were held in aquaria for up to 96 hours. To determine the efficiency of the screen wash in removing fish on the front side of the coarse mesh screens, a dip net was used to collect material washed off the backside of screens. The results of the samples indicate the front spray wash system was nearly 80 percent effective in removing fish.

An estimated 12,637 fish from 17 taxa were collected on the intake coarse mesh screens (Table 12). Gizzard shad comprised more than 75 percent of the total. Other major taxa collected were channel catfish, freshwater drum, shiners, and crappies. Survival rates of fish collected from the intake coarse mesh screens ranged from 0 to 100 percent (Table 13). However, the small number of individuals collected for some taxa preclude any definitive statements regarding survival rates. Initial survival rates of dominant taxa collected ranged from a low of 7.9 percent for gizzard shad and to a high of 97.4 percent for channel catfish. It was noted that in a number of samples many gizzard shad collected had obviously died prior to collection (NSP, 1983). Excluding gizzard shad, initial survival rates averaged 79.1 percent. The majority of fish collected were juveniles less than 200 mm total length.

During sample years 1984 to 1989, sample collection of fish impinged on the fine mesh screens started in April and continued through August. Samples were collected 2 to 3 days a week by diverting 25 percent of the screen wash water into collection tanks in the basement of the environmental lab. Screen wash water flows by gravity from the screen wash trough, into a drop structure, and through an 18-inch diameter pipe into the environmental lab basement. Screen wash water was channeled from the 18-inch diameter pipe through a larval collection tank. The collection tank filters screen wash water through 0.5 mm mesh nylon screen material.

Three types of samples were collected to provide various data. Sample types included abundance, initial survival, and latent survival. Following a designated sampling duration, all fish and any debris were rinsed into two collection baskets located in the collection area of the tank (Figure 5). These baskets were then removed from the tank, the contents transferred to four-liter beakers, and transported to the fish handling and sorting area for further processing.

Initial survival samples were collected at night or early morning to determine night density of fish and eggs and initial survival of fish impinged on the fine mesh screens. Initial samples underwent a "first and second" sort. The first sort was designed to remove live and dead fish, with emphasis placed on removing all live fish in a time efficient manner. The second sort was designed to assure removal of all remaining fish and eggs. Abundance samples were collected during early to midmorning to estimate day density of fish and eggs impinged on the fine mesh screens. After the sample was collected, all fish, eggs, and debris were preserved in 10 percent buffered formalin solution containing rose bengal stain and were sorted after the stain had an opportunity to penetrate all organisms.

Latent survival samples were collected to determine the latent survival of fish impinged on the fine mesh screens. Samples were collected during early morning. After the sample was collected, aliquots were placed in Pyrex baking dishes and sorted over a light table. Only live fish were removed and placed in 250 ml wide mouth jars or six gallon aquaria containing filtered river water. Jars and aquaria were kept in acrylic plastic water baths receiving a constant supply of river water. This allowed fish to be maintained at ambient temperatures throughout the holding period. Fish collected for latent survival estimates were held for 48 or 96 hours and checked at selected time increments. Number of live and dead fish were recorded during each time interval.

During 1984, back wash samples from fine mesh screens were also collected. Back wash samples were collected while an abundance sample was collected. This sample was collected using a 0.5 mm mesh ichthyoplankton drift net placed in the high pressure trash removal return trough. Comparing data from the abundance and back wash samples was utilized to determine the efficiency of the low pressure front wash in removing fish impinged on the fine mesh screens. Twenty-four pairs of samples compared indicated that the front spray wash removal system was more than 98 percent efficient in removing fish from the front side of the fine mesh screens.

Quality assurance sample sorts were performed randomly on more than five percent of the initial and abundance samples collected in 1984. After staining, sort efficiency exceeded 98 percent for all samples.

Fish and egg densities were calculated on a day and night basis using data from abundance and initial survival samples, respectively. Estimates of the number of fish and fish eggs impinged on the fine mesh screens were calculated by averaging data from initial and abundance samples. These values were expanded to weekly and yearly impingement estimates. All fish and eggs collected were identified to the lowest practical taxon by life stage and developmental phase. Life stages included egg, larvae, juvenile, and adult.

The estimated number and percent composition of all taxa/life stage combinations collected during the months of April through August (1984 to 1988) are presented in Table 14. Estimates of the number of fish and eggs impinged on the fine mesh screens were calculated by averaging data from the initial and abundance samples. These values were expanded to weekly and yearly impingement estimates.

In 1984, more than ten million eggs and nearly 500 million fish were estimated to have been impinged on the fine mesh screens. Juvenile channel catfish, carp prolarvae, and juvenile cyprinids were the most abundant taxa/life stage combinations impinged. Impingement estimates in 1984, were believed to be a gross overestimate due to sampling equipment design. The equipment was redesigned in 1985 to allow for a more realistic impingement estimate (NSP, 1986). Estimates calculated for 1985 through 1988 are considered to be a realistic approximation of the number of organisms which would have passed through PINGP in the absence of the fine mesh screens.

More than 17 million eggs and nearly 25 million fish were estimated to have been impinged during 1985. Freshwater drum prolarvae, juvenile channel catfish, and cyprinid post larvae comprised 64 percent of all fish impinged. More than six million eggs and 55 million fish were estimated impinged during 1986. Two taxa/life stage combinations, carp and freshwater drum prolarvae, accounted for over one-half of all organisms impinged. During 1987, more than 14 million eggs and 62 million fish were estimated to have been impinged. Freshwater drum prolarvae comprised 27.7 percent of the total, followed by cyprinid postlarvae with 18.6 percent. More than 12 million eggs and 54 million fish were estimated to be impinged on fine mesh screens during 1988. Freshwater drum prolarvae comprised 42.6 percent of the total, followed by freshwater drum eggs and Cyprinidae postlarvae with 14.5 percent and 11.6 percent of the total, respectively.

During the months of April, May, and June operational measures to reduce intake flow are in place per the NPDES permit to minimize potential impacts to larval fish and eggs at the intake. Modes of operation and associated impacts were analyzed by Henningson, Durham, and Richardson, Inc. in 1979 in an alternate discharge study (HDR, 1979). The analysis determined that during April, May, and June PINGP could operate in a recycle mode with reduced intake flows to minimize potential impacts to larval fish and eggs. As ambient river temperatures increase in spring, the partial recycle mode is utilized to maintain condenser inlet temperatures below the design maximum of 85°F. As river temperatures increase and ichthyoplankton densities decrease, intake flows increase.

Operations at PINGP reflect this design with current operational measures as follows:
April 15-30 150-300 cfs
May 1-31 300 cfs
June 1-15 400 cfs
June 16-30 800 cfs
Through screen velocities during the period of April 15 to June 15 range from 0.29 ft/sec to 0.38 ft/sec. These through screen velocities during this sensitive larvae period are less than the 0.5 ft/sec performance standard for impingement mortality as stated in the 316(b) Phase II rule document. The remaining periods of the year flow is limited to the design intake flow of 1410 cfs.

Studies conducted by Stone and Webster (1977), stated that reduction of intake flows at PINGP during May and June would reduce mortality based on the decrease of impingement or entrainment of fish. Annual larval peak densities encountered at PINGP during 1984 to 1989 occur in May or June (ESE, 1996). In the development of the 316(b) Phase II rule, the EPA states that some facilities could achieve further reductions in impingement mortality and entrainment by providing for seasonal flow restrictions.

5.2.1 Survivorship 1984 to 1989

Based on the calculation baseline definition, only juvenile fish (or fish large enough to be impinged on 3/8-inch mesh) will be included for impingement mortality estimates. Data is presented for pro and post larvae stages to demonstrate survivorship of these life stages on fine mesh screens that otherwise would have been entrained. In addition, eggs that are impinged on the fine mesh screens (that would have been entrained) are now returned to the river via the fish collection system. Number of eggs estimated to have been impinged ranged from 6,504,222 to 17,534,761 during 1984 to 1988 (Table 14).

Summary of initial survival data for all taxa/life stage combinations collected from 1984 through 1989 are presented in Table 15. Juvenile survival of the six study years ranged from 66.1 to 89.7 percent with a combined survivorship of 71.5 percent (Table 16). Survivorship of juveniles is relatively high for all taxa impinged ranging from 25 percent (gizzard shad) to 100 percent (Bullhead spp. and walleye). It is apparent that overall, prolarvae and postlarvae exhibit lower survival while juveniles exhibit the highest survival. Catostomidae, channel catfish, and walleye exhibit relatively high survival for the life stages collected. Freshwater drum, gizzard shad, cyprinids, Lepomis, Pomoxis, and white bass exhibit relatively poor survival for prolarvae and postlarvae life stages. Survivorship of prolarvae and postlarvae for all years combined was 7.2 percent and 5.5 percent, respectively. Overall (all taxa/life stages combined) initial survival was 15.0 percent for all years combined, ranging from 4.4 percent in 1988 to 50.1 percent in 1984 (Table 16).

Although presented in this report, the annual 1988 survivorship data was not utilized in the original report by mutual agreement with MPCA due to extreme low flows and excessive amounts of zooplankton and phytoplankton in samples.

5.2.2 Sampling Mortality

Extreme low river flows and excessive debris conditions occurred during impingement sampling in 1988. It became apparent that sampling induced mortality was having a pronounced impact on initial survival estimates. Large amounts of zooplankton and phytoplankton appeared to be causing increased mortality of fish in the sampling tank and was substantially increasing sorting time (NSP, 1989). To address this concern, the larval survivorship study was adapted in 1989 and 1990 by introducing test fish into the sample collection system. To differentiate from naturally occurring larval fish in the samples, test fish were marked with a biological stain. The resultant survival of test fish was used to assess sampling induced mortality.

The effects of debris loading were studied to determine the relationship to survival of larval fish collected. Studies conducted in 1989 and 1990 document that high debris in the collection system caused introduced test fish to suffer increased mortality and indicated survivorship of larval fish collected from the vertical traveling screens was underestimated. It was also determined that survival estimates are dependent on the hardiness of species and developmental stage of the fish (NSP, 1989).

Results of studies conducted in 1989 and 1990 indicate that sampling induced mortality caused by excessive debris in samples ranged from approximately 3 to 44 percent mortality depending upon sample period and test fish species (Figure 6). Overall, test fish survival was 85 percent, suggesting that the sampling method may account for 15 percent mortality of all fish sampled from fine mesh screens and up to 10 percent mortality of juvenile fish (NSP, 1989).

6) ENTRAINMENT

6.1 BASELINE

Larval fish were sampled in the vicinity of Prairie Island by the Minnesota Department of Natural Resources from May to September during 1974 and 1975. This data was used to estimate total numbers of young fish passing through the Sturgeon Lake outlet. Larval tows were conducted at 4 to 8 sampling locations (Figure 7) using a conical net with one square meter frontal area with a mesh size of 787 microns or a conical net of 560 micron mesh with mouth diameter of one meter. Contents of the net were removed at the end of each run. Samples were preserved in five percent formalin solution and counted at a later date. No attempt was made to identify the larval fish.

Larval fish tows were made in an effort to determine when and where larval fish and eggs were most abundant. Abundance of larval fish in tow samples varied from week to week. It was determined that high numbers of ichthyoplankton probably indicated that certain species had good spawning success. In 1974, larval fish catches were highest during late July and early August. In 1975, maximum numbers of larval fish were caught during the first week June.

Entrainment studies were conducted by NUS Corporation for 316(b) demonstration studies in 1975 (NUS, 1976). Entrainment monitoring studies were conducted at Prairie Island between April 25 and September 5. Samples were collected during one 24-hour period each week. Samples were collected at three stations; in front of the bar rack, on the plant side of the skimmer wall, and in the middle of the recirculation canal.

All samples were collected with plankton nets constructed of 560 micron mesh. Each net was 2.5 m long attached to square 42.5 cm frame and fitted with a flow meter. All nets were fished as stationary drift nets. Between 3 and 7 nets were stacked vertically, depending on location and water depth. Samples were stained and preserved in formalin. Larvae were identified to species level when possible. The total number of eggs, larval fish and juvenile fish for each taxon entrained was calculated.

A total of 39 taxa, including at least 26 species from 12 families, were represented in collections (Table 17). Freshwater drum eggs accounted for 89 percent of the eggs and mooneye eggs less than 0.1 percent; the remainder of the eggs were unidentified. Emerald shiners were the most abundant young fish collected, followed by gizzard shad, unidentified suckers, white bass, carp and freshwater drum. These 6 taxa comprised nearly 80 percent of the catch of young fish (Table 18).

Peak egg density (27.5/100m^3) occurred on May 29; a secondary peak (3.34/100m^3) occurred on June 19. On both occasions the collections were dominated by freshwater drum eggs. Peak density (101/100m^3) of fish larvae occurred on May 29. Secondary peaks occurred on May 21 (72/100m^3) and June 26 (60/100m^3). On May 29, the collections were dominated by emerald shiner, white bass, and gizzard shad. Suckers (Catostomidae and *Ictiobus* spp.) were most abundant in May 21 samples, with gizzard shad and carp predominant on June 26.

Estimated Entrainment

Analysis of the impact of entrainment of fish eggs and larvae at Prairie Island is based on the simple population modeling approach, described by Horst (1975) in which the number of larvae entrained is converted to an estimate of the number of adult fish that would have been produced had the larvae not been entrained.

A total of 8,371,000 fish eggs and 61,645,000 larval and juvenile fish were estimated to be entrained by PINGP between May 12 and September 10, 1975. The number of larval and juvenile fish entrained represents about 6 percent of the total number of larvae and juveniles passing through the Sturgeon Lake outlet during the same period (based on MDNR data). Weekly estimates of entrained larvae and juveniles ranged from less than 1 percent to 85 percent of the estimated Sturgeon Lake production.

The entrained eggs and larvae represent a potential loss of about 2,830,000 adult fish from at least 28 taxa. The number of eggs and young entrained, the number of adults lost and the values for fecundity and survival used to calculate the losses are summarized in Table 19.

Over 99 percent of the potential adult fish loss consisted of 8 taxa of forage fish. Taxa of either sport or commercial importance (e.g., sauger, walleye, white bass, sunfish, crappies, freshwater drum, carp, buffaloes, and carpsuckers) represented less than 1 percent of the adults lost. Minnows (mainly emerald shiner) accounted for 80 percent of the potential adult loss. Darters (logperch, river darter, and Johnny darter) and unidentified percids comprised the next greatest proportion (18 percent) of the potential adult loss. Gizzard shad (0.1 percent) and trout perch (0.3 percent) were the remaining forage taxa.

Oak Ridge National Laboratory under contract with the MPCA conducted any analysis of the 316(b) demonstration study by NUS in 1976 (Oak Ridge, 1978). The analysis consisted of a critique of the 316(b) demonstration and an independent analysis of the PINGP intake system. With regard to entrainment, the analysis concluded that estimated losses of the white bass and sauger population due to entrainment through the old intake system may result in a significant impact on both species. The estimated entrainment loss for other species was considered to be of less concern. In addition, it was determined that fine mesh screens should be considered for inclusion in any alternative design at PINGP. Experience with fine mesh screens indicate that they have the capability of reducing the number of fish larvae entrained (Oak Ridge, 1978).

A field sampling program was undertaken from June 6 to June 17, 1978, to study the distribution of fish eggs and larvae at three sampling locations near alternative intake locations (Stone and Webster, 1978). The survey was conducted at the request of the

MPCA to permit a more quantitative evaluation of ichthyoplankton densities at alternative intake locations. The study was conducted for a two week period during June 1978 which was believed to be the peak portion of the ichthyoplankton season. The ichthyoplankton concentrations at the three locations were used to examine the relative benefits of each location (Figure 8). Density of organisms collected during this study is presented in Table 20. Gizzard shad prolarvae (22.14 percent) and postlarvae (28.39 percent) and freshwater drum eggs (26.96 percent) represented over 75 percent of the collections. Other taxa and life stages common in collections included freshwater drum prolarvae (7.82 percent), carp prolarvae (5.60 percent) and white bass prolarvae (2.98 percent).

6.2 VERIFICATION STUDIES

Stone and Webster (1977) conducted studies for alternative intake designs to reduce entrainment mortality at PINGP. One objective was to determine criteria for screen mesh size that is fine enough to screen a large percentage of eggs and larval stages of species considered to be important.

Data on egg diameter and larval hatching size for species entrained at PINGP are presented in Table 21. Based on this data, it was determined that 0.5 mesh screen would be required to adequately screen those organisms from the water entering the intake canal. Examination of the data indicates that 0.5 mm mesh should screen a wide range of eggs and larvae near PINGP.

The EPA Section 316(b) Phase II Technical Development Document summarized performance data for fine mesh screens at several sites and from laboratory tests. Seasonal use of fine mesh on two of four screens at the Brunswick Power Plant in North Carolina has shown 84 percent reduction in entrainment compared to the conventional screen systems. Similar results were obtained during pilot testing of 1 mm screens at the Chalk Point Generating Station in Maryland and at the Kintigh Generating Station in New Jersey. Tennessee Valley Authority pilot-scale studies showed reductions in striped bass larvae entrainment up to 99 percent using a 0.5 mm screen. Experiences at Big Bend Station show that fine mesh screens can reduce entrainment by 80 percent or more.

At PINGP, back wash samples from fine mesh screens were collected in 1984. Back wash samples were collected while an abundance (front wash) sample was collected. This sample was collected using a 0.5 mm mesh ichthyoplankton drift net placed in the high pressure trash removal return trough. Comparing data from the abundance and back wash samples was utilized to determine the efficiency of the low pressure front wash in removing fish impinged on the fine mesh screens. Twenty-four pairs of samples compared indicated that the front spray wash removal system was more than 98 percent efficient in removing fish from the front side of the fine mesh screens.

Impingement estimates calculated for 1985 through 1988 are considered to be a realistic approximation of the number of larval fish and eggs which would have been entrained through PINGP in the absence of the fine mesh screens. Entrainment studies in 1975 estimated that nearly 70 million larvae and eggs were entrained at PINGP. Impingement estimates from fine mesh screens for 1985 through 1988 were similar with estimated number of larvae and eggs impinged ranging from 42 million to 77 million (see Tables 14 and 19). Species composition of entrainment and impingement samples is also similar with freshwater drum, cyprinids, and gizzard shad representing a large percentage of samples (see Tables 14, 19, and 20).

7) SUMMARY

Impingement performance standards are defined as a reduction in impingement mortality for all life stages of fish and shellfish by 80 to 95 percent from the calculation baseline. Entrainment performance standards are defined as the reduction of entrainment of all life stages of fish and shellfish by 60 to 90 percent from the calculation baseline.

Calculation baseline means an estimate of impingement mortality and entrainment that would occur at the site assuming that:

a. The cooling water system has been designed as a once-through system;
b. The opening of the cooling water intake structure is located at, and the face of the standard 3/8-inch mesh traveling screen is oriented parallel to, the shoreline near the surface of the source waterbody;
c. The baseline practices, procedures, and structural configuration are those that your facility would maintain in the absence of any structural or operational controls including flow or velocity reductions, implemented in whole or in part for the purposes of reducing impingement mortality and entrainment.

During the period April 1 through August 31, Prairie Island is required to operate the intake vertical traveling screens in continuous mode and using fine-mesh (0.5 mm) screen material in order to minimize entrainment of larval fish, fish eggs, and other aquatic organisms. In addition, intake flows are limited from April 15 through June 30 in order to minimize the impingement of fish and fish larvae. During the remaining months (September through March) when entrainment of larval fish and eggs is not expected standard 3/8-inch mesh screens are installed. The fish handling and return system is in service during both time periods.

Based on the calculation baseline definition, only juvenile fish (or fish large enough to be impinged on 3/8-inch mesh) are included for impingement mortality estimates. The size range for juvenile fish impinged on fine mesh screens from 1984 to 1989 is presented on Table 22. Representative size ranges of fish impinged from Prairie Island (1973 to 1984), Black Dog (2005 to 2006) and Allen S. King (2004 to 2005) impingement samples are presented on Table 23.

Minimum size of fish collected from fine mesh screens identified as juveniles was typically less than 20 mm, whereas minimum size of fish impinged on 3/8-inch mesh screens was 20 mm or greater. Further, modal size ranges of fish impinged on PINGP 3/8-inch mesh screens from 1973 to 1984 were greater than juvenile fish represented from fine mesh screen samples. Modal size ranges of the five most common fish impinged on 3/8-inch mesh screens were: gizzard shad (100 to 159mm), freshwater drum (100 to 139mm), white bass (100 to 139mm), crappie (60 to 119mm), and channel catfish (120 to 179mm). In comparison, impingement mortality estimates calculated from fine mesh screens would be more conservative since minimum length of juvenile fish impinged on fine mesh screens during 1984 to 1988 were less than lengths for taxa collected from 3/8 inch mesh screens. Fish that may have been entrained during operation with 3/8-inch mesh screens are now impinged on fine mesh resulting in an increased percentage of survival.

Estimates of juvenile fish impinged on fine mesh screens is substantially higher than the estimated number of fish impinged when compared to the baseline data from 3/8-inch mesh screens. However, size of juvenile fish impinged on fine mesh screens is typically smaller and were most likely entrained through the 3/8-inch mesh screens. In addition, impingement from the plant screenhouse 3/8-inch mesh screens resulted in nearly 100 percent mortality as fish were returned via a trash trough and collected in fish baskets. Juvenile fish impinged on fine mesh are washed from screens with a low pressure spray system and returned to the river via a fish collection trough and return pipe. Overall survival of juvenile fish from fine mesh screens is 71.5 percent, without factoring in operational measures and sampling induced mortality.

During November 1983 through March 1984 impingement samples were collected from coarse mesh screens at the intake screenhouse. Initial survival rates of dominant taxa collected ranged from a low of 7.9 percent for gizzard shad and to a high of 97.4 percent for channel catfish. It was noted that in a number of samples many gizzard shad collected had obviously died prior to collection (NSP, 1983). Excluding gizzard shad, initial survival rates averaged 79.1 percent. The majority of fish collected were juveniles less than 200 mm total length.

Impingement estimates from fine mesh screens are much greater than estimates from 3/8-inch screens. This is the result of eggs, prolarvae, postlarvae, and smaller juvenile fish impinged on fine mesh screens. These life stages of fish ,which would normally be entrained through the cooling water system, are washed from fine mesh screens and returned to the river via the intake screenhouse fish return system. Impingement survival of prolarvae and postlarvae is much lower than juvenile fish, but is no longer 100 percent mortality that would be expected if these life stages were entrained through PINGP. In addition, with utilization of fine mesh screens, eggs are no longer entrained but washed from fine mesh screens and returned to the river.

Operational measures are also utilized at PINGP to limit impingement of all life stages of fish during peak larval density period (May and June). Intake flows are reduced to 20-30 percent of design flows to limit impingement during April, May, and June.

8) CONCLUSION

Based on survival studies, sampling induced mortality studies, and operational measures, PINGP meets the impingement standards set forth by the 316(b) rule. Survival of juvenile and larger fish sampled from fine mesh screens is 71.5 percent. In addition, studies to determine sampling induced mortality determined that nearly 10 percent of mortality to juvenile fish (15 percent mortality for all life stages) is caused by the sampling method. With sampling mortality factored in, over 80 percent survivorship is expected from PINGP fine mesh screens. If operational measures are factored in, it can be assumed that overall fish survivorship of the community is increased since fewer fish overall are being impinged. During the peak larval density period (May and June), PINGP intake flows are limited to 20 to 30 percent of design flow. The assumption can be made that during these months only one-third of the fish that would have been impinged (if operating at design flow) are being impinged resulting in increased overall survivorship.

Due to the use of 0.5 mm (fine) mesh screens at the intake screenhouse from April through August entrainment standards are met at Prairie Island. It has been documented from larval studies conducted at PINGP that 0.5 mesh screens collects eggs and larvae of all fish expected to be encountered in the naturally occurring drift from the Mississippi River community within the vicinity of the plant. In addition to preventing entrainment of eggs and larvae, fine mesh screens limit the establishment of a resident population of fish in the intake and recycle canals and subsequent potential for cold-shock mortality.

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TABLES

Table 1. Taxa Collected by Trawling Within the Vicinity of PINGP from 1973 to 1980.

Family	Species	1973	1974	1975	1976	1977	1978	1979	1980
Petromyzontidae	Silver lamprey				X			X	
Lepisosteidae	Shortnose gar		X		X	X	X	X	X
Amiidae	Bowfin						X	X	
Hiodontidae	Goldeye		X						X
	Mooneye		X						
Clupeidae	Gizzard shad	X	X	X	X	X	X	X	X
Cyprinidae	Carp	X	X	X	X	X	X	X	X
	Silver chub		X	X	X			X	X
	Pugnose minnow		X						X
	Emerald shiner		X	X	X	X		X	X
	River shiner			X					
	Spottail shiner		X	X	X	X	X	X	X
	Bullhead minnow		X					X	
Catostomidae	River carpsucker							X	X
	Quillback						X	X	
	White sucker							X	
	Smallmouth buffalo		X	X	X	X	X	X	X
	Bigmouth buffalo		X	X	X	X	X	X	X
	Shorthead redhorse	X		X			X	X	
	**Carpsucker spp		X	X				X	X
Ictaluridae	Black bullhead				X	X			
	Yellow bullhead						X		
	Channel catfish	X	X	X	X	X	X	X	X
	Tadpole madtom				X			X	X
Esocidae	Northern pike	X						X	
Percopsidae	Trout perch		X	X	X	X		X	X
Percichthyidae	White bass	X	X	X	X	X	X	X	X
Centrarchidae	Rock bass					X			X
	Pumpkinseed		X						
	Bluegill			X	X	X	X	X	X
	White crappie	X	X	X	X	X	X	X	X
	Black crappie		X	X	X	X	X	X	X
Percidae	Johnny darter				X			X	X
	Yellow perch		X		X	X		X	X
	Log perch							X	X
	Sauger	X	X	X	X	X	X	X	X
	Walleye	X	X	X	X	X	X	X	X
Sciaenidae	Freshwater drum	X	X	X	X	X	X	X	X
# Families (14)	**Total species (38)**	10	23	19	22	19	18	30	26

**Prior to 1978 carpsuckers were identified to genus only

Table 2. Taxa Collected by Gill Netting Within the Vicinity of PINGP from 1973 to 1980.

Family	Species	1973	1974	1975	1976	1977	1978	1979	1980
Petromyzontidae	Silver lamprey								x
Lepisosteidae	Longnose gar	x	x	x	x	x	x	x	x
	Shortnose gar	x	x	x	x	x	x		x
Amiidae	Bowfin		x	x	x	x	x	x	x
Hiodontidae	Goldeye	x	x	x	x	x	x	x	x
	Mooneye	x	x	x	x	x	x	x	x
Clupeidae	Gizzard shad	x	x	x	x	x	x	x	x
Cyprinidae	Carp	x	x	x	x	x	x	x	x
	Silver chub			x	x	x			
Catostomidae	River carpsucker							x	x
	Quillback						x	x	x
	Highfin carpsucker						x		
	White sucker		x					x	x
	Smallmouth buffalo	x	x	x	x	x	x	x	x
	Bigmouth buffalo		x	x	x	x	x	x	x
	Silver redhorse			x				x	x
	Shorthead redhorse	x	x	x	x	x	x	x	x
	**Carpsucker spp	x	x	x	x	x		x	x
Ictaluridae	Black bullhead		x	x	x	x	x	x	x
	Yellow bullhead		x			x	x	x	x
	Brown bullhead		x	x	x	x			
	Channel catfish	x	x	x	x	x	x	x	x
	Tadpole madtom					x			
	Flathead catfish				x		x		
Esocidae	Northern pike	x	x	x	x	x	x	x	x
Gadidae	Burbot			x	x				
Percichthyidae	White bass	x	x	x	x	x	x	x	x
Centrarchidae	Rock bass	x	x	x	x	x	x	x	x
	Green sunfish				x	x	x	x	
	Bluegill		x	x	x	x	x	x	x
	***Hybrid sunfish				x				x
	Smallmouth bass		x	x	x	x			x
	Largemouth bass					x	x		x
	White crappie		x	x	x	x	x	x	x
	Black crappie	x	x	x	x	x	x	x	x
Percidae	Yellow perch	x	x		x	x	x	x	x
	Sauger	x	x	x	x	x	x	x	x
	Walleye	x	x	x	x	x	x	x	x
Sciaenidae	Freshwater drum	x	x	x	x	x	x	x	x
# Families (14)	**Total species (39)**	18	27	27	30	30	28	28	32

**Prior to 1978 carpsuckers were identified to genus only.

***Most hybrid sunfish were likely *Lepomis cyanellus x Lepomis macrochirus*

Table 3. Taxa Collected by Seining Within the Vicinity of PINGP from 1973 to 1984.

Family	Species	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Lepisosteidae	Longnose gar			X				X					
	Shortnose gar	X	X	X	X	X	X	X					
Amiidae	Bowfin			X									
Hiodontidae	Goldeye								X				
	Mooneye	X			X								
Clupeidae	Gizzard shad	X	X	X	X	X	X	X	X	X	X	X	X
Cyprinidae	Carp	X	X	X	X	X	X	X	X	X	X	X	X
	Speckled chub				X								
	Silver chub	X	X	X	X	X	X		X	X	X	X	X
	Notropis spp	X	X										
	Golden shiner					X						X	
	Common shiner		X	X									
	Emerald shiner	X	X	X	X	X	X	X	X	X	X	X	X
	Rosyface shiner	X	X	X									
	Sand shiner								X		X	X	X
	Spotfin shiner	X	X	X	X	X	X	X	X	X	X	X	X
	River shiner	X	X	X	X	X	X	X	X	X	X	X	X
	Spottail shiner	X	X	X	X	X	X	X	X	X	X	X	X
	*Red shiner			X									
	Mimic shiner		X	X									
	Redfin shiner			X									
	Blacknose shiner		X										
	Minnows	X	X										
	Hornyhead chub	X											
	Brassy minnow		X	X									
	Pugnose minnow			X	X		X		X	X	X	X	X
	Silvery minnow	X											
	Fathead minnow									X	X	X	X
	Bullhead minnow	X	X	X	X	X	X	X	X	X	X	X	X
	Bluntnose minnow	X	X	X		X							
	Creek chub								X	X			
Catostomidae	River carpsucker										X		
	Quillback						X			X	X	X	
	White sucker			X			X	X			X		
	Smallmouth buffalo	X	X	X	X	X	X	X	X			X	
	Bigmouth buffalo	X	X	X		X	X	X	X	X	X	X	
	Silver redhorse	X			X								
	Shorthead redhorse	X	X	X	X		X		X	X	X	X	
	**Carpsucker spp	X	X	X	X	X	X	X	X	X	X	X	X
Ictaluridae	Yellow bullhead		X										
	Channel catfish		X	X	X	X	X		X	X	X	X	X
	Tadpole madtom	X		X	X		X	X	X				
Atherinidae	Brook silverside												X
Esocidae	Northern pike	X	X	X		X	X	X			X	X	X
Percopsidae	Trout perch	X	X	X	X	X							
Percichthyidae	White bass	X	X	X	X	X	X	X	X	X	X	X	X
Centrarchidae	Rock bass	X	X	X					X	X	X		X
	Green sunfish	X	X	X						X	X		
	Bluegill	X	X	X	X	X	X	X	X	X	X	X	X
	***Hybrid sunfish				X								
	Smallmouth bass	X	X	X	X	X	X	X	X	X	X	X	X
	Largemouth bass				X	X				X	X	X	X
	White crappie	X	X	X	X	X	X	X	X	X	X	X	X
	Black crappie	X	X		X	X	X	X	X	X	X	X	X
Percidae	Yellow perch	X	X	X	X	X	X	X	X	X		X	
	Sauger	X	X	X	X	X	X		X	X	X	X	X
	Walleye	X		X	X	X	X	X	X	X	X		X
	Log perch	X	X	X	X	X	X	X	X	X	X	X	X
	Johnny darter	X	X	X	X	X	X	X	X	X	X	X	X
	River darter				X								
Sciaenidae	Freshwater drum	X	X	X	X	X	X	X	X	X	X	X	X
# Families (14)	**Total species (61)**	37	37	*40	33	29	30	25	30	30	32	30	27

*Red shiner probably misidentified breeding male spotfin shiner (1975)

**Prior to 1978 carpsuckers were identified to genus only

***Most hybrid sunfish were likely *Lepomis cyanellus* x *Lepomis macrochirus*

Table 4. Taxa Collected by Trapnetting Within the Vicinity of PINGP from 1973 to 1987.

Family	Species	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Petromyzontidae	Silver lamprey		X		X	X		X								
	Chestnut lamprey						X						X			
Acipenseridae	Lake sturgeon					X										
Lepisosteidae	Longnose gar	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Shortnose gar	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Amiidae	Bowfin	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Hiodontidae	Goldeye		X		X	X	X				X	X				X
	Mooneye	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Anguillidae	American eel		X		X	X	X	X		X	X	X	X			
Clupeidae	Gizzard shad	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cyprinidae	Carp	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Emerald shiner							X								
Catostomidae	River carpsucker						X	X	X	X	X	X	X	X	X	X
	Quillback						X	X	X	X	X	X	X	X	X	X
	Highfin carpsucker													X		X
	White sucker	X	X	X	X	X	X	X	X	X	X	X	X	X		X
	Blue sucker															X
	Spotted sucker		X		X		X	X								
	Northern hogsucker						X									
	Smallmouth buffalo	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Bigmouth buffalo	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	River redhorse		X							X			X	X	X	
	Silver redhorse	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Golden redhorse								X	X			X	X		X
	Shorthead redhorse	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	**Carpsucker spp	X	X	X	X	X			X							
Ictaluridae	Black bullhead		X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Yellow bullhead	X	X		X	X	X	X	X	X						
	Brown bullhead	X	X	X	X	X	X		X	X		X		X		
	Channel catfish	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Flathead catfish		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Esocidae	Northern pike	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Gadidae	Burbot		X			X				X			X			
Percichthyidae	White bass	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Centrarchidae	Rock bass	X	X	X	X	X	X	X	X	X			X	X	X	X
	Green sunfish				X	X		X	X							
	Pumpkinseed	X					X									
	Bluegill	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	***Hybrid sunfish					X	X	X								
	Smallmouth bass		X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Largemouth bass		X		X	X	X	X		X	X	X	X			X
	White crappie	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Black crappie	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Percidae	Yellow perch	X	X	X	X	X	X	X	X	X	X	X	X			
	Sauger	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Walleye	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sciaenidae	Freshwater drum	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
# Families (16)	**Total species (47)**	26	35	27	34	36	37	35	32	34	29	30	33	30	26	31

**Prior to 1978 carpsuckers were identified to genus only

***Most hybrid sunfish were likely Lepomis cyanellus x Lepomis macrochirus

Table 5. Taxa Collected by Electrofishing Within the Vicinity of PINGP from 1973 to 2005. (Page 1 of 2)

Family	Species	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Petromyzontidae	Silver lamprey		X	X	X	X	X	X	X		X						X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
	Chestnut lamprey				X		X	X												X	X			X			X	X		X	X	X		
Acipenseridae	Lake sturgeon																															X		
Polyodontidae	Paddlefish																									X								X
Lepisosteidae	Longnose gar		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Shortnose gar		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Amiidae	Bowfin		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Hiodontidae	Goldeye													X			X					X			X	X	X	X				X	X	X
	Mooneye	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Anguillidae	American eel	X				X		X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X			X	X		X			X
Clupeidae	Gizzard shad	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cyprinidae	Carp	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Silver chub		X	X	X	X	X	X	X																									
	Pugnose minnow		X	X	X		X		X																									
	Golden shiner		X																															
	Common shiner		X					X																										
	Emerald shiner		X	X	X	X	X	X	X																									
	River shiner			X	X	X			X																									
	Rosyface shiner		X	X																														
	Spotfin shiner		X	X	X	X	X	X	X																									
	Redfin shiner			X	X																													
	Spottail shiner		X	X	X	X	X	X	X																									
	*Red shiner			X																														
	Silvery minnow		X																															
	Fathead minnow		X			X			X																									
	Bullhead minnow		X	X	X	X	X	X																										
	Bluntnose minnow		X	X				X																										
Catostomidae	River carpsucker						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Quillback						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Highfin carpsucker									X					X		X	X	X	X	X	X	X	X	X	X					X	X	X	X
	White sucker		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	
	Blue sucker										X	X			X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Spotted sucker												X		X		X	X			X												X	X
	Northern hogsucker								X		X	X														X			X					
	Smallmouth buffalo	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Bigmouth buffalo	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	River redhorse										X		X		X	X		X	X	X	X		X	X			X	X	X	X	X	X	X	X
	Silver redhorse	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Golden redhorse					X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 5. Taxa Collected by Electrofishing Within the Vicinity of PINGP from 1973 to 2005. (Page 2 of 2)

	Shorthead redhorse	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Greater redhorse												X				X		X							X	X			X		X		
	**Carpsucker spp	X	X	X	X	X	X	X	X									X																
Ictaluridae	Black bullhead					X		X	X	X		X		X			X				X							X	X		X			
	Yellow bullhead				X					X						X	X	X					X	X										
	Channel catfish	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Tadpole madtom							X																										
	Flathead catfish	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Atherinidae	Brook silverside					X																												
Esocidae	Northern pike	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Muskellunge																												X	X			X	
Salmonidae	Brown trout										X				X									X		X		X		X	X	X		X
Percopsidae	Trout perch			X	X				X																									
Gadidae	Burbot		X	X	X			X			X	X	X			X					X	X	X	X	X	X	X	X	X	X	X	X	X	X
Percichthyidae	White bass	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Centrarchidae	Rock bass	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Green sunfish	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Pumpkinseed	X	X	X														X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Orangespotted sunfish					X	X																				X		X	X			X	
	Bluegill	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Smallmouth bass	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Largemouth bass	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	White crappie	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Black crappie	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	***Hybrid sunfish		X		X		X	X	X																									
Percidae	Yellow perch	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X	X	X	X	X	X	X		X	X	X		X	X	X	X	X
	Johnny darter				X	X	X	X	X																									
	Sauger	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Walleye	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Saugeye																									X	X	X		X	X	X	X	X
	Log perch		X	X	X	X	X	X	X																									
Sciaenidae	Freshwater drum	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
# Families (20)	**Total species (71)**	25	44	*40	43	42	40	45	44	33	36	32	34	31	33	34	38	38	35	36	39	35	37	39	34	40	39	40	38	40	40	41	40	40

*Red shiner probably misidentified breeding male spotfin shiner (1975)

**Prior to 1978 carpsuckers were identified to genus only

***Most hybrid sunfish were likely Lepomis cyanellus x Lepomis macrochirus

Table 6. Frequency of Occurrence of Mussels Collected in the Vicinity of PINGP, 1980.

Taxa	# Collected
Amblema plicata	103
Obliquaria reflexa	35
Fusconaia undata	30
Truncilla donaciformis	22
Quadrula pustulosa	13
Truncilla truncata	9
Anodonta grandis	7
Fusconaia flava	6
Toxolasma parvus	6
Leptodea fragilis	4
Unidentified	2
Lampsilis radiata siliquoidea	2
Elliptio dilatata	2
Actinonaias carinata	1
Anodonta imbecillis	1 *
Anodonta corpulenta	1
Leptodea laevissima	1
Leptodea ovata ventricosa	1
Pleurobema cordatum	1
Proptera alata	1
Fusconaia ebena	0 **
Quadrula quadrula	0 **
Total	248

* Collected from traveling screen wash.
** Found as relic shells only.

Table 7. Relative Abundance of Upper Mississippi River Navigation Pool 3 Mussel Species.

Scientific Name	Common Name	Pool 3
Subfamily Cumberlandinae		
Cumberlandia monodo	Spectaclecase	H
Subfamily Ambleminae		
Amblema plicata	Three ridge	A
Cyclonaias tuberculat	Purple wartyback	H
Elliptio crassidens	Elephant ear	H
Elliptio dilatata	Spike	R
Fusconaia ebena	Ebonyshell	H
Fusconaia flava	Wabash pigtoe	A
Megalonaias nervosa	Washboard	R
Plethobasus cyphyus	Sheepnose	H
Pleurobema sintoxia	Round pigtoe	R
Quadrula fragosa	Winged mapleleaf	H
Quadrula metanevra	Monkeyface	H
Quadrula nodulata	Wartyback	C
Quadrula pustulosa	Pimpleback	C
Quadrula quadrula	Mapleleaf	C
Tritogonia verrucosa	Pistolgrip	H
Subfamily Anodontinae		
Alasmidonta marginat	Elktoe	R
Arcidens confragosus	Rock pocketbook	R
Lasmigona complanat	White heelsplitter	R
Pyganodon grandis	Giant floater	C
Simpsonaias ambigua	Salamander mussel	H
Strophitus undulatus	Strange floater	R
Utterbackia imbecillis	Paper pondshell	R
Subfamily Lampsilinae		
Actinonaias ligamenti	Mucket	R
Ellipsaria lineolata	Butterfly	R
Epioblasma triquetra	Snuffbox	H
Lampsilis cardium	Plain pocketbook	C
Lampsilis higginsi	Higgins eye	H
Lampsilis siliquoidea	Fatmucket	R
Lampsilis teres	Yellow sandshell	H
Leptodea fragilis	Fragile papershell	R
Ligumia recta	Black sandshell	R
Obliquaria reflexa	Threehorn wartyback	A
Obovaria olivaria	Hickorynut	R
Potamilus alatus	Pink heelsplitter	C
Potamilus ohiensis	Pink papershell	C
Toxolasma parvus	Lilliput	R
Truncilla donaciformis	Fawnsfoot	R
Truncilla truncata	Deertoe	C
Venustaconcha ellipsi	Ellipse	H
Live species		27
Historic		13
Total species		40

H=Records of occurrence but no live collections have been documented in the past 25 years.
R=Rare, does not usually appear in sample collections.
C=Commonly taken in most samples; can make up a large portion of some samples.
A=Abundantly taken in most samples.

Source: Kelner, 2003.

Table 8. Minnesota and Wisconsin Listing of Endangered, Threatened, and Special Concern Species.

FISH

Scientific Name	Common Name	Minnesota Status	Wisconsin Status
Acipenser fulvescens	Lake sturgeon	SC	NL
Alosa chrysochloris	Skipjack herring	SC	E
Ammocrypta asprella	Crystal darter	SC	E
Aphredoderus sayanus	Pirate perch	SC	NL
Coregonus kiyi	Kiyi	SC	NL
Coregonus zenithicus	Shortjaw cisco	SC	NL
Cycleptus elongatus	Blue sucker	SC	T
Erimystax x-punctata	Gravel chub	SC	E
Etheostama chlorosoma	Bluntnose darter	NL	E
Etheostoma microperca	Least darter	SC	NL
Fundulus dispar	Starhead topminnow	NL	E
Fundulus sciadicus	Plains topminnow	SC	NL
Hiodon asosoides	Goldeye	NL	E
Ichthyomyzon fossor	Northern brook lamprey	SC	NL
Ichthyomyzon gagei	Southern brook lamprey	SC	NL
Ictiobus niger	Black buffalo	SC	T
Lepomis megalotis	Longear sunfish	NL	T
Luxilus chrysocephalus	Striped shiner	NL	E
Lythrurus umbratisis	Redfin shiner	NL	T
Macrhybopsis aestivalis	Shoal chub	NL	T
Morone mississippiensis	Yellow bass	SC	NL
Moxostoma carinatum	River redhorse	NL	T
Moxostoma duquesnei	Black redhorse	NL	E
Moxostoma valenciennesi	Greater redhorse	NL	T
Notropis amnis	Pallid shiner	SC	E
Notropis anogenus	Pugnose shiner	SC	T
Notropis nubilus	Ozark minnow	NL	T
Notropis topeka	Topeka shiner	SC	NL
Noturus exilis	Slender madtom	SC	E
Percina evides	Gilt darter	SC	T
Polyodon spathula	Paddlefish	T	T

Status Designations:
E=Endangered
T=Threatened
SC=Special Concern
NL=Not Listed

Sources: Minnesota Department of Natural Resources.
Wisconsin Department of Natural Resources.

Table 9. Minnesota and Wisconsin Listing of Endangered, Threatened, and Special Concern Species.

Mussels

Scientific Name	Common Name	Minnesota Status	Wisconsin Status	Federal Status
Actinoaias ligamentina	Mucket	T	NL	
Alasmidonta marginata	Elktoe	T	NL	
Alasmidonta viridis	Slippershell mussel	NL	T	
Arcidens confragosus	Rock pocketbook	E	T	
Cumberlandia monodonta	Spectaclecase	T	E	
Cyclonaias tuberculata	Purple wartyback	T	E	
Ellipsaria lineolata	Butterfly	T	E	
Elliptio crassidens	Elephant ear	E	E	
Elliptio dilatata	Spike	SC	NL	
Epioblasma triquetra	Snuffbox	T	E	
Fusconaia ebena	Ebonyshell	E	E	
Lampsilis higginsi	Higgins eye	E	E	E
Lampsilis teres	Yellow sandshell	E	E	
Lasmigona compressa	Creek heelsplitter	SC	NL	
Lasmigona costata	Fluted-shell	SC	NL	
Ligumia recta	Black sandshell	SC	NL	
Megalonaias nervosa	Washboard	T	NL	
Obovaria olivaria	Hickorynut	SC	NL	
Plethobasus cyphyus	Sheepnose	E	E	
Pleurobema coccineum	Round pigtoe	T	NL	
Quadrula fragosa	Winged mapleleaf	E	E	E
Quadrula metanevra	Monkeyface	T	T	
Quadrula nodulata	Wartyback	E	T	
Simpsonaias ambigua	Salamander mussel	T	T	
Tritogonia verrucosa	Pistolgrip	T	T	
Venustaconcha ellipsiformis	Ellipse	T	T	
Villosa iris	Rainbow shell	NL	E	

Status Designations:
E=Endangered
T=Threatened
SC=Special Concern
NL=Not Listed

Sources: Minnesota Department of Natural Resources.
Wisconsin Department of Natural Resources.

Table 10. Total Number and Percent Composition of Fish Impinged at PINGP from 1973 to 1984*.

Taxa	1973 Number	1973 %	1974 Number	1974 %	1975 Number	1975 %	1976 Number	1976 %	1977 Number	1977 %	1978 Number	1978 %
Chestnut lamprey	2	0.00%	2	0.00%	9	0.01%	8	0.00%	3	0.00%	4	0.00%
Silver lamprey	11	0.02%	4	0.00%	36	0.04%	50	0.02%	27	0.00%	14	0.01%
Unidentified lamprey	0	0.00%	2	0.00%	3	0.00%	4	0.00%	1	0.00%	1	0.00%
Longnose gar	1	0.00%	6	0.00%	16	0.02%	12	0.00%	9	0.00%	0	0.00%
Shortnose gar	4	0.01%	2	0.00%	16	0.02%	30	0.01%	16	0.00%	1	0.00%
Gar species	0	0.00%	0	0.00%	2	0.00%	0	0.00%	1	0.00%	0	0.00%
Bowfin	15	0.02%	0	0.00%	17	0.02%	20	0.01%	12	0.00%	15	0.01%
American eel	0	0.00%	0	0.00%	0	0.00%	1	0.00%	1	0.00%	0	0.00%
Gizzard shad	65,000	93.90%	136,667	93.57%	70,506	75.55%	152,878	58.51%	456,949	82.39%	93,895	88.59%
Goldeye	1	0.00%	2	0.00%	5	0.01%	2	0.00%	1	0.00%	6	0.01%
Mooneye	2	0.00%	1	0.00%	26	0.03%	17	0.01%	14	0.00%	8	0.01%
Brown trout	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.00%	0	0.00%
Central mudminnow	2	0.00%	0	0.00%	10	0.01%	0	0.00%	0	0.00%	0	0.00%
Northern pike	27	0.04%	35	0.02%	110	0.12%	157	0.06%	14	0.00%	33	0.03%
Carp	14	0.02%	296	0.20%	427	0.46%	993	0.38%	122	0.02%	562	0.53%
Silver chub	94	0.14%	98	0.07%	259	0.28%	143	0.05%	14	0.00%	0	0.00%
minnow/shiner sp	581	0.84%	776	0.53%	2,231	2.39%	5,581	2.14%	374	0.07%	234	0.22%
Carpsucker sp	10	0.01%	79	0.05%	150	0.16%	115	0.04%	43	0.01%	82	0.08%
Carpsucker/buffalo sp	0	0.00%	0	0.00%	83	0.09%	6	0.00%	0	0.00%	0	0.00%
Smallmouth buffalo	17	0.02%	9	0.01%	11	0.01%	18	0.01%	7	0.00%	15	0.01%
Bigmouth buffalo	0	0.00%	3	0.00%	27	0.03%	146	0.06%	26	0.00%	414	0.39%
Buffalo species	0	0.00%	0	0.00%	1	0.00%	2	0.00%	12	0.00%	1	0.00%
Shorthead redhorse	7	0.01%	18	0.01%	34	0.04%	40	0.02%	19	0.00%	22	0.02%
Silver redhorse	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.00%	1	0.00%
Golden redhorse	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Redhorse species	0	0.00%	0	0.00%	0	0.00%	1	0.00%	0	0.00%	0	0.00%
Catostomid species	0	0.00%	0	0.00%	0	0.00%	1	0.00%	4	0.00%	1	0.00%
White sucker	0	0.00%	0	0.00%	15	0.02%	2	0.00%	1	0.00%	2	0.00%
Spotted sucker	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.00%
Black bullhead	887	1.28%	146	0.10%	2,797	3.00%	0	0.00%	0	0.00%	0	0.00%
Brown bullhead	6	0.01%	12	0.01%	38	0.04%	0	0.00%	0	0.00%	0	0.00%
Yellow bullhead	2	0.00%	0	0.00%	4	0.00%	0	0.00%	0	0.00%	0	0.00%
Bullhead species	0	0.00%	0	0.00%	811	0.87%	3,554	1.36%	274	0.05%	455	0.43%
Channel catfish	24	0.03%	637	0.44%	6,223	6.67%	8,457	3.24%	3,977	0.72%	2,032	1.92%
Tadpole madtom	58	0.08%	31	0.02%	33	0.04%	36	0.01%	64	0.01%	12	0.01%
Flathead catfish	12	0.02%	35	0.02%	90	0.10%	144	0.06%	73	0.01%	76	0.07%
Unidentified Ictalurid	0	0.00%	3	0.00%	12	0.01%	4	0.00%	4	0.00%	0	0.00%
Trout perch	22	0.03%	26	0.02%	49	0.05%	23	0.01%	13	0.00%	1	0.00%
Burbot	14	0.02%	19	0.01%	6	0.01%	31	0.01%	10	0.00%	3	0.00%
White bass	477	0.69%	1,367	0.94%	2,712	2.91%	44,638	17.08%	9,725	1.75%	2,096	1.98%
Rock bass	24	0.03%	57	0.04%	76	0.08%	99	0.04%	35	0.01%	38	0.04%
Green sunfish	7	0.01%	56	0.04%	111	0.12%	196	0.08%	189	0.03%	55	0.05%
Pumpkinseed	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%
Bluegill	147	0.21%	674	0.46%	242	0.26%	1,601	0.61%	2,317	0.42%	622	0.59%
BGxGSF	0	0.00%	0	0.00%	1	0.00%	1	0.00%	0	0.00%	0	0.00%
Orangespotted sunfish	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.00%	0	0.00%
Largemouth bass	0	0.00%	5	0.00%	0	0.00%	1	0.00%	0	0.00%	2	0.00%
Smallmouth bass	0	0.00%	13	0.01%	2	0.00%	14	0.01%	12	0.00%	10	0.01%
Crappie	445	0.64%	1,704	1.17%	2,030	2.18%	6,852	2.62%	5,530	1.00%	1,551	1.46%
Unidentified Centrarchid	0	0.00%	1	0.00%	6	0.01%	19	0.01%	1	0.00%	2	0.00%
Yellow perch	29	0.04%	13	0.01%	81	0.09%	30	0.01%	23	0.00%	19	0.02%
Logperch	41	0.06%	13	0.01%	15	0.02%	21	0.01%	5	0.00%	3	0.00%
Johnny darter	0	0.00%	0	0.00%	2	0.00%	1	0.00%	0	0.00%	0	0.00%
River darter	0	0.00%	0	0.00%	0	0.00%	2	0.00%	0	0.00%	0	0.00%
Unidentified darter	0	0.00%	0	0.00%	0	0.00%	1	0.00%	0	0.00%	0	0.00%
Sauger	8	0.01%	13	0.01%	97	0.10%	86	0.03%	14	0.00%	36	0.03%
Walleye	2	0.00%	5	0.00%	27	0.03%	118	0.05%	47	0.01%	36	0.03%
Sander species	89	0.13%	69	0.05%	73	0.08%	57	0.02%	22	0.00%	16	0.02%
Freshwater drum	1,144	1.65%	3,143	2.15%	3,789	4.06%	34,380	13.16%	74,422	13.42%	3,463	3.27%
Unidentified fish	0	0.00%	21	0.01%	3	0.00%	700	0.27%	160	0.03%	143	0.13%
Shovelnose sturgeon	0	0.00%	0	0.00%	0	0.00%	2	0.00%	0	0.00%	0	0.00%
TOTALS	69,226	100.00%	146,063	100.00%	93,324	100.00%	261,295	100.00%	554,590	100.00%	105,983	100.00%

Taxa	1979 Number	1979 %	1980 Number	1980 %	1981** Number	1981** %	1982** Number	1982** %	1983** Number	1983** %	1984** Number	1984** %	Totals	%
Chestnut lamprey	3	0.01%	3	0.00%	0	0.00%	4	0.00%	0	0.00%	0	0.00%	38	0.00%
Silver lamprey	8	0.03%	11	0.01%	6	0.01%	4	0.00%	14	0.01%	2	0.00%	187	0.01%
Unidentified lamprey	0	0.00%	1	0.00%	2	0.00%	0	0.00%	0	0.00%	0	0.00%	14	0.00%
Longnose gar	3	0.01%	13	0.01%	2	0.00%	4	0.00%	12	0.01%	4	0.00%	82	0.00%
Shortnose gar	26	0.10%	15	0.01%	6	0.01%	6	0.00%	8	0.00%	0	0.00%	130	0.01%
Gar species	0	0.00%	2	0.00%	6	0.01%	6	0.00%	0	0.00%	0	0.00%	17	0.00%
Bowfin	14	0.06%	4	0.00%	12	0.02%	18	0.01%	10	0.00%	0	0.00%	137	0.01%
American eel	1	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	3	0.00%
Gizzard shad	9,381	37.57%	97,840	88.33%	47,966	88.21%	67,338	55.24%	171,972	77.30%	203,956	96.85%	1,574,348	79.69%
Goldeye	2	0.01%	1	0.00%	0	0.00%	0	0.00%	2	0.00%	0	0.00%	22	0.00%
Mooneye	13	0.05%	21	0.02%	2	0.00%	16	0.01%	18	0.01%	0	0.00%	138	0.01%
Brown trout	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.00%
Central mudminnow	0	0.00%	0	0.00%	0	0.00%	0	0.00%	4	0.00%	2	0.00%	18	0.00%
Northern pike	44	0.18%	249	0.22%	12	0.02%	28	0.02%	66	0.03%	0	0.00%	775	0.04%
Carp	320	1.28%	371	0.33%	190	0.35%	406	0.33%	230	0.10%	190	0.09%	4,121	0.21%
Silver chub	4	0.02%	6	0.01%	18	0.03%	46	0.04%	32	0.01%	2	0.00%	716	0.04%
minnow/shiner sp	311	1.25%	1,084	0.98%	220	0.40%	186	0.15%	262	0.12%	730	0.35%	12,570	0.64%
Carpsucker sp	187	0.75%	84	0.08%	94	0.17%	102	0.08%	34	0.02%	28	0.01%	1,008	0.05%
Carpsucker/buffalo sp	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	89	0.00%
Smallmouth buffalo	93	0.37%	7	0.01%	24	0.04%	22	0.02%	26	0.01%	4	0.00%	253	0.01%
Bigmouth buffalo	84	0.34%	42	0.04%	4	0.01%	26	0.02%	22	0.01%	10	0.00%	804	0.04%
Buffalo species	14	0.06%	3	0.00%	0	0.00%	0	0.00%	2	0.00%	2	0.00%	37	0.00%
Shorthead redhorse	16	0.06%	28	0.02%	12	0.02%	6	0.00%	8	0.00%	20	0.01%	228	0.01%
Silver redhorse	0	0.00%	2	0.00%	0	0.00%	2	0.00%	0	0.00%	0	0.00%	6	0.00%
Golden redhorse	0	0.00%	0	0.00%	0	0.00%	0	0.00%	2	0.00%	0	0.00%	2	0.00%
Redhorse species	0	0.00%	2	0.00%	2	0.00%	0	0.00%	2	0.00%	0	0.00%	7	0.00%
Catostomid species	5	0.02%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	11	0.00%
White sucker	2	0.01%	4	0.00%	0	0.00%	4	0.00%	8	0.00%	0	0.00%	38	0.00%
Spotted sucker	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.00%
Black bullhead	0	0.00%	0	0.00%	0	0.00%	22	0.02%	0	0.00%	0	0.00%	3,852	0.19%
Brown bullhead	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	56	0.00%
Yellow bullhead	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	6	0.00%
Bullhead species	99	0.40%	109	0.10%	8	0.01%	52	0.04%	148	0.07%	58	0.03%	5,568	0.28%
Channel catfish	3,588	14.37%	689	0.62%	502	0.92%	4,092	3.36%	3,458	1.55%	1,014	0.48%	34,693	1.76%
Tadpole madtom	17	0.07%	4	0.00%	4	0.01%	2	0.00%	4	0.00%	0	0.00%	265	0.01%
Flathead catfish	61	0.24%	18	0.02%	14	0.03%	128	0.11%	86	0.04%	32	0.02%	769	0.04%
Unidentified Ictalurid	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	23	0.00%
Trout perch	3	0.01%	1	0.00%	2	0.00%	2	0.00%	6	0.00%	18	0.01%	166	0.01%
Burbot	6	0.02%	8	0.01%	2	0.00%	4	0.00%	4	0.00%	6	0.00%	113	0.01%
White bass	2,094	8.39%	1,014	0.92%	1,724	3.17%	2,062	1.69%	1,312	0.59%	274	0.13%	69,495	3.52%
Rock bass	22	0.09%	25	0.02%	34	0.06%	20	0.02%	16	0.01%	2	0.00%	448	0.02%
Green sunfish	48	0.19%	19	0.02%	50	0.09%	48	0.04%	12	0.01%	140	0.07%	931	0.05%
Pumpkinseed	2	0.01%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	2	0.00%
Bluegill	398	1.59%	780	0.70%	270	0.50%	356	0.29%	708	0.32%	880	0.42%	8,995	0.46%
BGxGSF	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	2	0.00%
Orangespotted sunfish	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.00%
Largemouth bass	11	0.04%	0	0.00%	2	0.00%	0	0.00%	8	0.00%	2	0.00%	31	0.00%
Smallmouth bass	8	0.03%	8	0.01%	6	0.01%	8	0.01%	6	0.00%	0	0.00%	87	0.00%
Crappie	357	1.43%	905	0.82%	698	1.28%	666	0.55%	2,390	1.07%	218	0.10%	23,346	1.18%
Unidentified Centrarchid	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	29	0.00%
Yellow perch	27	0.11%	10	0.01%	12	0.02%	6	0.00%	26	0.01%	0	0.00%	276	0.01%
Logperch	11	0.04%	4	0.00%	2	0.00%	4	0.00%	2	0.00%	0	0.00%	121	0.01%
Johnny darter	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	3	0.00%
River darter	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	2	0.00%
Unidentified darter	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	0.00%
Sauger	27	0.11%	77	0.07%	42	0.08%	50	0.04%	86	0.04%	12	0.01%	548	0.03%
Walleye	33	0.13%	45	0.04%	20	0.04%	32	0.03%	44	0.02%	16	0.01%	425	0.02%
Sander species	3	0.01%	12	0.01%	16	0.03%	18	0.01%	0	0.00%	0	0.00%	375	0.02%
Freshwater drum	7,468	29.91%	7,198	6.50%	2,248	4.13%	45,960	37.70%	41,390	18.60%	2,944	1.40%	227,549	11.52%
Unidentified fish	153	0.61%	46	0.04%	142	0.26%	140	0.11%	38	0.02%	24	0.01%	1,570	0.08%
Shovelnose sturgeon	0	0.00%	1	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	3	0.00%
TOTALS	24,967	100.00%	110,764	100.00%	54,376	100.00%	121,896	100.00%	222,478	100.00%	210,590	100.00%	1,975,552	100.00%

* 1973 numbers represent fish impinged from March 21 through April 30 and November 20 through January 2, 1974.
** 1981 to 1984 number multiplied by 2 since sampling occurred every other week.

Table 11. PINGP Non-fish Species Sampled off Screens (mammals, insects and birds excluded) 1973-1984.

Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983+	1984*	Totals	%
Turtles														
Spiny softshell	9	32	59	365	403	94	35	244	89	20	15	22	1,387	32.2
Map		7	4	6	9	3	2	3	5	2	4		45	1.0
Painted					21	37	16	5	7	4	5		95	2.2
Western Painted	5	4	9	14									32	0.7
Eastern Painted							1						1	0.0
False map	1	1	2	1	1	1	1						8	0.2
Snapping	2	9	1	5	1	6				1			25	0.6
Unid turtle								3					3	0.1
Mussels														
Clams				372	36	33	127	251				185	1,004	23.3
Stout floater									6				6	0.1
Heelsplitter									3				3	0.1
Fawnfoot									2				2	0.0
Deer toe									1				1	0.0
Threeridge									1				1	0.0
Fragile papershell		2	5										7	0.2
Pink papershell		6	1						1				8	0.2
Pocket book											1		1	0.0
Paper floater									19	14	51		84	1.9
Corbicula											53		53	1.2
Unidentified clam		1	134						5				140	3.2
Other														
Crayfish	244	253	148	101	42	34	57	38	12	9	19	24	981	22.8
Mudpuppy	15	8	30	37	32	33	116	16	4	9	22	7	329	7.6
Leopard frog	25	11	11		1	1	7	5	2	2	1	3	69	1.6
Unid frog			2										2	0.0
Toad	1	1	7		1	1						1	12	0.3
Snake						2	2	1					5	0.1
Snail		2	2				1						5	0.1
Totals	302	337	415	901	547	245	365	566	157	61	171	242	4,309	

*Clams include: Fawns foot, corbicula, paper pond shells, floaters, fragile paper shells, unidentified
+Corbicula not counted or recorded consistently, due to sheer numbers

Table 12. Estimated Total Number of Fish Impinged on the PINGP Intake Coarse Mesh Screens from November 1983 through March 1984.

Taxa	Nov-83	Dec-83	Jan-84	Feb-84	Mar-84	Total	%
Silver lamprey	0	0	0	20	13	33	0.3
Gizzard shad	3,650	827	4,376	589	241	9,683	76.6
Minnow species	0	4	0	6	0	10	0.1
Shiner species	40	42	8	70	67	227	1.8
River carpsucker	0	0	0	0	7	7	0.1
Shorthead redhorse	0	4	4	0	7	15	0.1
Bullhead species	0	0	0	3	7	10	0.1
Channel catfish	250	319	144	177	235	1,125	8.9
Tadpole madtom	10	4	0	0	0	14	0.1
Flathead catfish	20	0	0	15	34	69	0.5
Trout perch	0	0	4	0	7	11	0.1
White bass	0	4	0	12	107	123	1.0
Green sunfish	0	21	4	0	0	25	0.2
Bluegill	20	0	16	17	27	80	0.6
Crappie species	80	21	4	35	80	220	1.7
Logperch	40	4	4	3	0	51	0.4
Freshwater drum	170	8	40	247	469	934	7.4
Total	4,280	1,258	4,604	1,194	1,301	12,637	

Table 13. Survival Rates of Fish Taxa Impinged on the PINGP Intake Coarse Mesh Screens from November 1983 through March 1984.

Taxa	Total # Collected	Initial Dead	Initial Live	Initial % Live	Live After 96 Hours	% Live 96 Hours
Silver lamprey	9	0	9	100.0%	7	77.8%
Gizzard shad	1,579	1,455	124	7.9%	17	1.1%
Minnow species	3	1	2	66.7%	1	33.3%
Shiner species	41	14	27	65.9%	11	26.8%
River carpsucker	1	1	0	0.0%	0	0.0%
Shorthead redhorse	3	0	3	100.0%	3	100.0%
Bullhead species	2	0	2	100.0%	2	100.0%
Channel catfish	194	5	189	97.4%	162	83.5%
Tadpole madtom	2	0	2	100.0%	1	50.0%
Flathead catfish	10	1	9	90.0%	4	40.0%
Trout perch	2	1	1	50.0%	0	0.0%
White bass	17	11	6	35.3%	0	0.0%
Green sunfish	5	1	4	80.0%	4	80.0%
Bluegill	13	6	7	53.8%	5	38.5%
Crappie species	32	6	26	81.3%	4	12.5%
Logperch	6	0	6	100.0%	6	100.0%
Freshwater drum	153	56	97	63.4%	17	11.1%
Total	2,072	1,558	514	24.8%	244	11.8%
Less Shad	493	103	390	79.1%	227	46.0%

Table 14. Estimated Number and Percent Composition of Fish and Eggs Impinged on Fine Mesh Screens During April through August 1984 to 1988.

		1984		1985		1986		1987		1988	
Taxa	Life Stage	Number	%	Number	%	Number	%	Number	%	Number	%
Centrarchidae	adult							672	0.00%		
Cyprinidae	adult	326,013	0.07%	2,688	0.01%	8,848	0.01%	14,700	0.02%	315,840	0.47%
Percidae	adult	43,680	0.01%					1,176	0.00%		
Trout perch	adult	26,880	0.01%								
Freshwater drum	egg	9,135,760	1.85%	17,010,668	40.04%	6,175,592	9.84%	11,672,852	15.13%	9,782,976	14.56%
Unidentified	egg	2,747,032	0.56%	524,093	1.23%	328,630	0.52%	2,598,570	3.37%	2,438,464	3.63%
Bullhead spp.	juvenile	24,080	0.00%	2,688	0.01%						
Burbot	juvenile					1,344	0.00%				
Carp	juvenile	1,151,017	0.23%	5,376	0.01%	24,528	0.04%	7,644	0.01%		
Catostomidae	juvenile	992,483	0.20%			22,736	0.04%	5,292	0.01%	1,344	0.00%
Channel catfish	juvenile	312,432,548	63.40%	2,459,504	5.79%	860,496	1.37%	235,494	0.31%	110,656	0.16%
Cyprinidae	juvenile	41,927,497	8.51%	207,712	0.49%	194,656	0.31%	1,046,346	1.36%	6,028,512	8.97%
Flathead catfish	juvenile	824,503	0.17%	32,256	0.08%	4,480	0.01%			2,688	0.00%
Freshwater drum	juvenile	2,786,320	0.57%	278,976	0.66%	653,352	1.04%	655,032	0.85%	331,968	0.49%
Gar spp.	juvenile					1,344	0.00%				
Gizzard shad	juvenile	124,972	0.03%	22,848	0.05%	38,080	0.06%	28,812	0.04%	5,376	0.01%
Lepomis spp.	juvenile	659,360	0.13%	33,600	0.08%	43,456	0.07%	10,584	0.01%	77,952	0.12%
Percidae	juvenile	504,035	0.10%	15,072	0.04%	8,512	0.01%	26,208	0.03%	4,032	0.01%
Pomoxis spp.	juvenile	403,170	0.08%			13,664	0.02%	4,116	0.01%		
Rock bass	juvenile	165,719	0.03%					1,176	0.00%		
Trout perch	juvenile	269,953	0.05%	14,112	0.03%	41,664	0.07%	2,352	0.00%		
Tadpole madtom	juvenile	423,986	0.09%	16,128	0.04%			1,176	0.00%		
White bass	juvenile	342,873	0.07%	8,064	0.02%	51,072	0.08%	101,598	0.13%	5,376	0.01%
Walleye	juvenile	6,720	0.00%			4,480	0.01%				
Burbot	postlarvae	448	0.00%	448	0.00%			448	0.00%	3,136	0.00%
Carp	postlarvae	1,174,154	0.24%	534,752	1.26%	4,172,200	6.65%	2,372,319	3.08%	552,608	0.82%
Catostomidae	postlarvae	342,222	0.07%	201,576	0.47%	113,120	0.18%	51,120	0.07%	15,232	0.02%
Centrarchidae	postlarvae			2,688	0.01%					8,736	0.01%
Coregonus spp.	postlarvae									448	0.00%
Cyprinidae	postlarvae	4,883,385	0.99%	2,080,416	4.90%	513,080	0.82%	14,342,980	18.59%	7,789,600	11.59%
Freshwater drum	postlarvae	5,131,250	1.04%	984,880	2.32%	2,007,544	3.20%	7,317,102	9.48%	3,525,984	5.25%
Gar spp.	postlarvae			2,688	0.01%	4,032	0.01%				
Gizzard shad	postlarvae	872,694	0.18%	598,800	1.41%	4,264,536	6.80%	3,627,968	4.70%	2,464,448	3.67%
Lepomis spp.	postlarvae	3,259,697	0.66%	237,216	0.56%	345,016	0.55%	98,952	0.13%	857,472	1.28%
Mooneye	postlarvae	1,344	0.00%								
Northern pike	postlarvae					10,483	0.02%				
Percidae	postlarvae	218,848	0.04%	66,832	0.16%	75,072	0.12%	162,524	0.21%	17,472	0.03%
Pomoxis spp.	postlarvae	208,992	0.04%	250,699	0.59%	237,040	0.38%	179,364	0.23%	61,824	0.09%
Rock bass	postlarvae	30,240	0.01%	4,928	0.01%	2,240	0.00%				
Sauger	postlarvae			3,011	0.01%			69,056	0.09%	4,480	0.01%
Sander spp.	postlarvae	2,688	0.00%								
Trout perch	postlarvae	2,464	0.00%			4,480	0.01%				
Unidentified	postlarvae	26,880	0.01%	2,016	0.00%	34,496	0.05%	69,732	0.09%	5,376	0.01%
White bass	postlarvae	1,156,512	0.23%	355,585	0.84%	1,482,336	2.36%	549,064	0.71%	637,952	0.95%
Walleye	postlarvae					17,920	0.03%	4,032	0.01%		
Bullhead spp.	prolarvae	13,440	0.00%								
Burbot	prolarvae	1,792	0.00%					23,744	0.03%	19,936	0.03%
Carp	prolarvae	69,566,744	14.12%	1,503,104	3.54%	16,422,806	26.17%	2,467,071	3.20%	536,032	0.80%
Catostomidae	prolarvae	4,654,935	0.94%	1,748,970	4.12%	7,758,013	12.36%	327,428	0.42%	145,600	0.22%
Channel catfish	prolarvae	15,854,289	3.22%	266,112	0.63%	20,608	0.03%	14,112	0.02%	18,816	0.03%
Centrarchidae	prolarvae			448	0.00%					9,408	0.01%
Cyprinidae	prolarvae	1,619,738	0.33%	651,264	1.53%	527,184	0.84%	6,980,864	9.05%	525,504	0.78%
Flathead catfish	prolarvae	185,808	0.04%								
Freshwater drum	prolarvae	6,210,510	1.26%	11,609,536	27.32%	15,306,928	24.39%	21,336,836	27.66%	28,620,928	42.60%
Gizzard shad	prolarvae	897,568	0.18%	114,032	0.27%	269,488	0.43%	168,252	0.22%	913,024	1.36%
Lepomis spp.	prolarvae	77,280	0.02%	58,688	0.14%	28,000	0.04%	65,856	0.09%	370,944	0.55%
Mooneye	prolarvae	68,992	0.01%	17,024	0.04%	71,296	0.11%	4,200	0.01%	448	0.00%
Percidae	prolarvae	227,528	0.05%	69,063	0.16%	160,334	0.26%	162,644	0.21%	41,440	0.06%
Pomoxis spp.	prolarvae	137,032	0.03%	84,896	0.20%	107,968	0.17%	13,524	0.02%	2,912	0.00%
Rock bass	prolarvae			1,344	0.00%	1,344	0.00%	588	0.00%		
Sauger	prolarvae	86,464	0.02%	25,626	0.06%	54,118	0.09%	16,800	0.02%	16,128	0.02%
Sander spp.	prolarvae	19,488	0.00%	2,573	0.01%	4,032	0.01%				
Trout perch	prolarvae	2,240	0.00%								
Tadpole madtom	prolarvae			1,344	0.00%					1,344	0.00%
Unidentified	prolarvae	158,368	0.03%	88,243	0.21%	135,232	0.22%	241,008	0.31%	433,216	0.64%
White bass	prolarvae	83,048	0.02%	149,648	0.35%	10,752	0.02%	56,592	0.07%	478,912	0.71%
Walleye	prolarvae	251,328	0.05%	13,978	0.03%	30,374	0.05%	6,720	0.01%	2,688	0.00%
Percidae	unidentified					6,048	0.01%				
Unidentified	unidentified	71,624	0.01%	120,816	0.28%	77,997	0.12%				
prolarvae		100,116,592	20.32%	16,405,893	38.61%	40,908,477	65.19%	31,886,239	41.33%	32,137,280	47.83%
postlarvae		17,311,818	3.51%	5,326,535	12.54%	13,283,595	21.17%	28,844,661	37.39%	15,944,768	23.73%
juvenile		363,039,236	73.67%	3,096,336	7.29%	1,963,864	3.13%	2,125,830	2.76%	6,567,904	9.78%
adult		396,573	0.08%	2,688	0.01%	8,848	0.01%	16,548	0.02%	315,840	0.47%
eggs		11,882,792	2.41%	17,534,761	41.27%	6,504,222	10.36%	14,271,422	18.50%	12,221,440	18.19%
unidentified		71,624	0.01%	120,816	0.28%	84,045	0.13%	0	0.00%	0	0.00%
TOTAL		492,818,635	100.00%	42,487,029	100.00%	62,753,051	100.00%	77,144,700	100.00%	67,187,232	100.00%

Table 15. Summary of Initial Survival Based on Taxa and Life Stage from 1984 to 1989.

Taxa	Life Stage	Dead	Live	Total	% Survival
Bullhead spp.	Juvenile	0	1	1	100.0%
Bullhead spp.	Prolarvae	0	1	1	100.0%
Burbot	Postlarvae	2	6	8	75.0%
Burbot	Prolarvae	5	2	7	28.6%
Carp	Juvenile	4	95	99	96.0%
Carp	Postlarvae	1,804	326	2,130	15.3%
Carp	Prolarvae	2,507	1,048	3,555	29.5%
Catostomidae	Juvenile	11	28	39	71.8%
Catostomidae	Postlarvae	154	104	258	40.3%
Catostomidae	Prolarvae	1,110	1,154	2,264	51.0%
Channel catfish	Juvenile	2,557	5,779	8,336	69.3%
Channel catfish	Prolarvae	87	235	322	73.0%
Centrarchidae	Postlarvae	1	0	1	0.0%
Centrarchidae	Prolarvae	1	0	1	0.0%
Coregonus spp.	Postlarvae	0	1	1	100.0%
Cyprinidae	Adult	4	65	69	94.2%
Cyprinidae	Juvenile	611	2,307	2,918	79.1%
Cyprinidae	Postlarvae	16,975	414	17,389	2.4%
Cyprinidae	Prolarvae	3,719	18	3,737	0.5%
Flathead catfish	Juvenile	3	47	50	94.0%
Flathead catfish	Prolarvae	0	5	5	100.0%
Freshwater drum	Juvenile	313	478	791	60.4%
Freshwater drum	Postlarvae	4,361	717	5,078	14.1%
Freshwater drum	Prolarvae	32,215	703	32,918	2.1%
Gar spp.	Postlarvae	1	0	1	0.0%
Gizzard shad	Juvenile	33	11	44	25.0%
Gizzard shad	Postlarvae	5,271	23	5,294	0.4%
Gizzard shad	Prolarvae	1,279	1	1,280	0.1%
Lepomis spp.	Juvenile	26	67	93	72.0%
Lepomis spp.	Postlarvae	544	12	556	2.2%
Lepomis spp.	Prolarvae	365	0	365	0.0%
Mooneye	Prolarvae	43	13	56	23.2%
Percidae	Adult	1	1	2	50.0%
Percidae	Juvenile	19	41	60	68.3%
Percidae	Postlarvae	286	39	325	12.0%
Percidae	Prolarvae	432	45	477	9.4%
Pomoxis spp.	Juvenile	2	31	33	93.9%
Pomoxis spp.	Postlarvae	297	12	309	3.9%
Pomoxis spp.	Prolarvae	85	0	85	0.0%
Rock bass	Juvenile	1	6	7	85.7%
Rock bass	Postlarvae	0	4	4	100.0%
Rock bass	Prolarvae	1	0	1	0.0%
Sauger	Postlarvae	53	23	76	30.3%
Sauger	Prolarvae	91	25	116	21.6%
Sander spp.	Prolarvae	16	3	19	15.8%
Trout perch	Juvenile	3	34	37	91.9%
Trout perch	Postlarvae	1	0	1	0.0%
Trout perch	Prolarvae	0	1	1	100.0%
Tadpole madtom	Juvenile	2	21	23	91.3%
Tadpole madtom	Prolarvae	0	2	2	100.0%
Unidentified	Postlarvae	77	0	77	0.0%
Unidentified	Prolarvae	1,060	0	1,060	0.0%
Unidentified	Unidentified	2,083	0	2,083	0.0%
White bass	Juvenile	26	67	93	72.0%
White bass	Postlarvae	1,586	160	1,746	9.2%
White bass	Prolarvae	618	5	623	0.8%
Walleye	Juvenile	0	2	2	100.0%
Walleye	Postlarvae	2	3	5	60.0%
Walleye	Prolarvae	179	122	301	40.5%
Overall		80,927	14,308	95,235	15.0%

Table 16. Percent Survival for Intake Screenhouse Impingement Samples by Lifestage from 1984 to 1989.

Life Stage	1984	1985	1986	1987	1988	1989	All Years
Prolarvae	26.9	12.3	7.3	2.7	0.9	8.5	7.2
Postlarvae	15.6	22.1	8.0	4.4	0.5	4.0	5.5
Juvenile	67.9	87.9	89.7	66.1	75.8	83.3	71.5
All lifestages	50.1	21.6	12.8	6.1	4.4	11.4	15.0

Table 17. Fish Eggs and Young Collected in Entrainment Sampling at Prairie Island, 1975.

Common Name	Scientific Name	Egg	Larvae	Juvenile
Gizzard shad	*Dorosoma cepedianum*		X	X
Lake whitefish	*Coregonus clupeaformis*		X	
Mooneye/Goldeye	*Hiodon spp.*		X	
Mooneye	*Hiodon tergisus*	X	X	
Northern pike	*Esox lucius*		X	
Minnow spp.	Cyprinidae		X	
Carp	*Cyprinus carpio*		X	X
Speckled chub	*Hybopsis aestivalis*			X
Emerald shiner	*Notropis athernoides*		X	X
Bullhead minnow	*Pimephales vigilax*			X
Suckers	Catostomidae		X	
White sucker	*Catostomus commersoni*		X	
Carpsucker spp.	*Carpiodes spp.*		X	
Buffalo spp.	*Ictiobus spp.*		X	
Redhorse spp.	*Moxostoma spp.*		X	
Channel catfish	*Ictalurus punctatus*		X	X
Tadpole madtom	*Noturus gyrinus*		X	
Flathead catfish	*Pylodictus olivaris*		X	X
Trout perch	*Percopsis omiscomaycus*		X	
Burbot	*Lota lota*		X	
White bass	*Morone chrysops*		X	X
Sunfishes	Centrarchidae		X	
Rock bass	*Ambloplites rupestris*		X	X
Pumpkinseed	*Lepomis gibbosus*		X	
Bluegill	*Lepomis macrochirus*		X	X
Unidentified sunfish	*Lepomis spp.*		X	X
Crappie spp.	*Pomoxis spp.*		X	
White crappie	*Pomoxis annularis*		X	
Black crappie	*Pomoxis nigromaculatus*		X	X
Perches	Percidae		X	
Johnny darter	*Etheostoma nigrum*		X	
Unidentified darters	*Etheostoma spp.*		X	X
Yellow perch	*Perca flavescens*		X	
Logperch	*Percina caprodes*		X	
River darter	*Percina shumardi*		X	
Unidentified darters	*Percina spp.*		X	
Sauger	*Sander canadense*		X	
Walleye	*Sander vitreum*		X	
Walleye/Sauger	*Sander spp.*		X	
Freshwater drum	*Aplodinotus grunniens*	X	X	X

Source: NUS, 1976.

Table 18. Mean Density and Percent of Catch of Young Fish Collected in Entrainment Sampling at Prairie Island, 1975.

Taxa	#/100m3	Percent
Notropis athernoides	4.36	22.30
Dorosoma cepedianum	4.00	20.50
Catostomidae	2.45	12.50
Morone chrysops	2.26	11.60
Cyprinus carpio	1.36	7.00
Aplodinotus grunniens	1.03	5.30
Ictiobus spp.	0.62	3.20
Sander canadense	0.55	2.80
Cyprinidae	0.51	2.60
Carpiodes spp.	0.44	2.20
Percina spp.	0.33	1.70
Hiodon tergisus	0.32	1.60
Lepomis spp.	0.26	1.30
Percidae	0.26	1.30
Percina shumardi	0.17	0.90
Pomoxis spp.	0.12	0.60
Ictalurus punctatus	0.09	0.50
Sander vitreum	0.09	0.50
Hiodon spp.	0.06	0.30
Perca flavescens	0.03	0.10
Sander spp.	0.03	0.10
Lepomis macrochirus	0.02	0.10
Percopsis omiscomaycus	0.01	*
Etheostoma nigrum	0.01	*
Etheostoma spp.	0.01	*
Percina caprodes	0.01	*
Pomoxis nigromaculatus	0.01	*
Coregonus clupeaformis	<0.01	*
Esox lucius	<0.01	*
Hybopsis aestivalis	<0.01	*
Pimephales vigilax	<0.01	*
Catostomus commersoni	<0.01	*
Moxostoma spp.	<0.01	*
Noturus gyrinus	<0.01	*
Pylodictus olivaris	<0.01	*
Ambloplites rupestris	<0.01	*
Lepomis macrochirus	<0.01	*
Pomoxis annularis	<0.01	*
Centrarchidae	<0.01	*
Unidentifiable	0.11	0.60
Unidentified	0.01	*

Source: NUS, 1976.

Table 19. Calculation of Loss of Adult Fish Due to Entrainment of Eggs, Larvae, and Juveniles at PINGP in 1975.

Taxa	Number Entrained	Fecundity	Survival Egg to Larva	Larvae Produced by One Female	Survival Larvae to Adult	Number of Adults Lost
Gizzard shad	10,370,000	1,560,000	0.005	7,800	0.0003	3,111
Lake whitefish	4,000	178,000	0.005	900	0.002	8
Mooneye	1,221,000	60,000	0.005	300	0.007	8,547
Northern pike	4,000	981,000	0.005	4,900	0.0004	2
Carp	3,257,000	7,360,000	0.005	36,800	0.00006	195
Emerald shiner	15,961,000	2,900	0.005	15	0.13	2,075,000
Minnow spp.	1,575,000	2,900	0.005	15	0.13	204,700
Carpsucker spp.	4,598,000	619,200	0.005	3,100	0.0006	2,759
White sucker	13,000	954,000	0.005	4,800	0.0004	5
Buffalo spp.	6,617,000	1,610,000	0.005	8,000	0.0002	1,323
Redhorse spp.	36,000	135,000	0.005	680	0.003	108
Channel catfish	325,000	214,800	0.75	160,000	0.00001	3
Tadpole madtom	3,000	200	0.75	150	0.01	30
Flathead catfish	16,000	108,300	0.75	500	0.004	64
Trout perch	25,000	1,400	0.005	7	0.3	7,500
White bass	7,297,000	3,390,000	0.005	17,000	0.0001	730
Rock bass	5,000	63,000	0.75	300	0.007	35
Pumpkinseed	122,000	16,425	0.75	12,000	0.0002	24
Bluegill	742,000	97,000	0.75	73,000	0.00003	22
Crappie spp.	480,000	462,200	0.75	35,000	0.00006	29
Johnny darter	67,000	1,600	0.75	1,200	0.002	134
Yellow perch	102,000	436,800	0.03	13,100	0.0001	10
Logperch	88,000	6,000	0.005	30	0.07	6,160
River darter	1,711,000	1,200	0.005	6	0.3	513,300
Sauger	1,881,000	159,500	0.005	800	0.003	5,643
Walleye	319,000	2,257,000	0.005	11,300	0.0002	64
Perches	956,000	477,000	0.005	2,400	0.0008	765
Freshwater drum						
Eggs	7,484,000	1,300,000	0.005	6,500	0.0003	11
Larvae/Juveniles	3,408,000	-	-	-	-	1,022
Unidentifiable larvae	403,000	-	-	-	-	-
Unidentifiable eggs	887,000	-	-	-	-	-
Unidentified larvae	39,000	-	-	-	-	-
Total Eggs	8,371,000				Total	2,831,304
Total Larvae/Juveniles	61,645,000				Forage	2,809,935
					Sport/Commercial	21,339

Source: NUS, 1976.

Table 20. Density (# organsims/100m3) of Fish and Eggs Collected During June 6 through 17, 1978 Stone and Webster Intake Study.

Taxa	Life Stage	Density Station 1	%	Density Station 2	%	Density Station 3	%	Denisty Total	%
Gizzard shad	prolarvae	120.13	15.05%	94.09	14.99%	625.13	26.44%	839.65	22.14%
Gizzard shad	postlarvae	22.43	2.81%	14.95	2.38%	1039.10	43.94%	1076.53	28.39%
Freshwater drum	eggs	375.86	47.09%	336.53	53.62%	308.87	13.06%	1022.27	26.96%
Freshwater drum	prolarvae	131.69	16.50%	78.51	12.51%	86.21	3.65%	296.70	7.82%
Freshwater drum	postlarvae	3.69	0.46%	4.96	0.79%	30.75	1.30%	39.41	1.04%
White bass	eggs	6.93	0.87%	0.00	0.00%	0.00	0.00%	6.94	0.18%
White bass	prolarvae	1.56	0.20%	0.19	0.03%	9.37	0.40%	11.12	0.29%
White bass	postlarvae	8.01	1.00%	14.01	2.23%	91.07	3.85%	113.12	2.98%
Emerald shiner	eggs	0.00	0.00%	0.00	0.00%	0.20	0.01%	0.20	0.01%
Emerald shiner	prolarvae	0.00	0.00%	0.00	0.00%	0.98	0.04%	0.98	0.03%
Emerald shiner	postlarvae	0.00	0.00%	0.32	0.05%	42.36	1.79%	42.68	1.13%
Carp	eggs	0.36	0.05%	0.00	0.00%	1.62	0.07%	1.98	0.05%
Carp	prolarvae	21.36	2.68%	76.44	12.18%	114.30	4.83%	212.25	5.60%
Carp	postlarvae	0.00	0.00%	0.36	0.06%	0.19	0.01%	0.55	0.01%
Darters	prolarvae	0.60	0.08%	0.35	0.06%	2.36	0.10%	3.31	0.09%
Darters	postlarvae	0.00	0.00%	0.00	0.00%	2.73	0.12%	2.73	0.07%
Cyprinids	eggs	29.32	3.67%	0.17	0.03%	0.00	0.00%	29.53	0.78%
Cyprinids	prolarvae	75.98	9.52%	6.39	1.02%	6.80	0.29%	89.28	2.35%
Cyprinids	postlarvae	0.20	0.03%	0.37	0.06%	2.53	0.11%	3.10	0.08%
Total Density		798.12		627.64		2364.57		3792.33	

Source: Stone and Webster, 1978.

Table 21. Egg Diameter and Larval Hatching Size for Species Entrained at PINGP.

Common Name	Scientific Name	Approximate Egg Diameter (mm)	Approximate Larval Hatching Size (mm)
Gizzard shad	Dorosoma cepedianum	0.8	3.2
Shiners	Notropis spp.	1.0-1.5	5.0
White bass	Morone chrysops	0.7-1.2	--
Darters	Etheostoma spp.	1.1-1.7	4.7-5.0
Walleye	Stizostedion vitreum	1.5-2.0	6.0-8.6
Freshwater drum	Aplodinotus grunniens	1.4-1.9	--
Northern pike	Esox lucius	2.2-3.4	6.0-10.0
Carp	Cyprinus carpio	1.0-2.0	3.0-6.4
Black bullhead	Ictaluras melas	3.0	--
Brown bullhead	Ictaluras nebulosus	3.0	6.0
Trout-perch	Percopsis omiscomaycus	1.2-1.8	6.0
Burbot	Lota lota	1.2-1.7	--
Largemouth bass	Micropterus salmoides	1.4-1.8	2.7-4.3
Smallmouth bass	Micropterus dolomieu	1.2-2.5	5.6-7.0
Bluegill	Lepomis macrochirus	0.9-1.4	2.-3.0
White crappie	Pomoxis annularis	0.9	3.0
Black crappie	Pomoxis nigromaculatus	1.0	3.0
Yellow perch	Perca flavescens	1.7-4.5	5.0-6.0

Source: Stone and Webster, 1977.

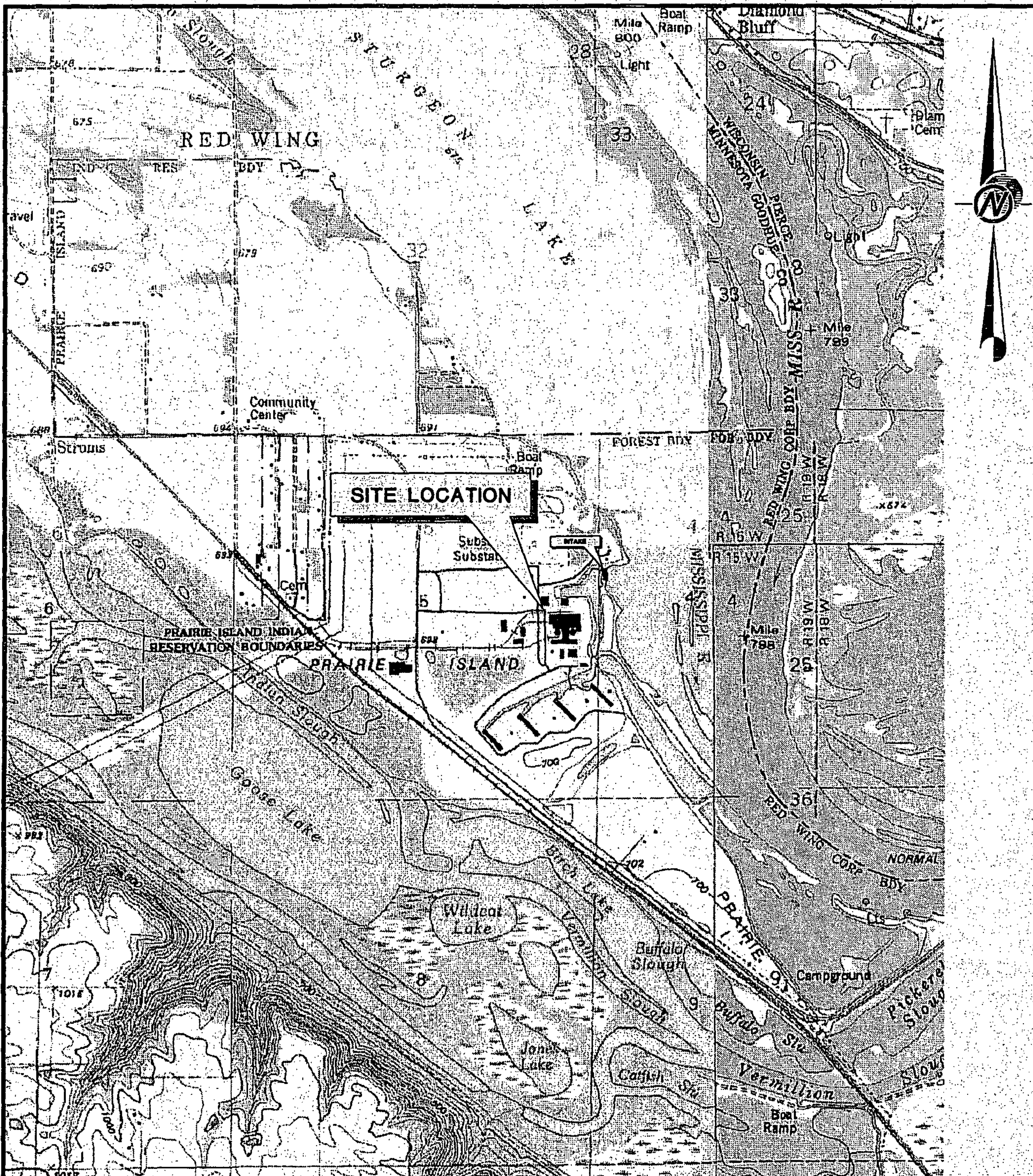
Table 22. Representative Total Length Ranges (mm) for Taxa/Life Stage Combinations Established in 1984 through 1988 Fine Mesh Impingement Studies at PINGP.

Taxa	Prolarvae	Post larvae	Juvenile
Channel catfish	11.0 - 18.0	N/A	15.0 - 51.0
Walleye	5.6 - 10.8	9.8 - 19.8	21.5 - 87.0
Sauger	5.1 - 10.6	8.2 - 14.6	--
Lepomis spp.	4.3 - 6.2	4.2 - 13.5	14.2 - 66.0
Pomoxis spp.	4.2 - 5.7	4.1 - 15.6	16.4 - 75.0
White bass	3.6 - 6.5	4.2 - 17.0	15.0 - 57.0
Rock bass	7.1 - 7.1	7.3 - 12.1	14.0 - 32.0
Trout perch	6.3 - 6.6	9.0 - 12.8	13.0 - 43.0
Mooneye	8.3 - 19.3	13.0 - 15.0	--
Burbot	3.8 - 7.6	--	84.0 - 84.0
Carp	4.8 - 8.5	5.9 - 18.5	19.7 - 59.0
Cyprinidae	3.1 - 6.2	5.0 - 17.0	12.9 - 60.0
Catostomidae	4.4 - 13.7	6.9 - 22.5	19.4 - 37.0
Freshwater drum	3.3 - 9.5	6.2 - 14.3	12.5 - 53.0
Flathead catfish	16.5 - 17.8	N/A	19.0 - 34.0
Tadpole madtom	10.8 - 11.8	N/A	14.5 - 21.0
Gizzard shad	3.6 - 5.6	5.5 - 21.7	19.0 - 50.0
Bullhead spp.	--	N/A	16.0 - 24.0

Table 23. Representative Total Length Ranges (mm) of Fish Collected from Impingement Samples at PINGP, A.S. King, and Black Dog Plants.

	PINGP 1973 - 1984	King 2004-2005	Black Dog 2005-2006
Taxa			
Longnose gar	80-839	150	60 - 503
Shortnose gar	140-939	--	73 - 222
Bowfin	140-799	--	--
Gizzard shad	20-499	28 - 419	32 - 443
Goldeye	80-419	--	--
Mooneye	100-419	--	84 - 142
Northern pike	80-979	229 - 296	473 - 546
Carp	20-859	110	34 - 235
Silver chub	40-199	140 - 141	119 - 150
minnow/shiner sp	20-179	35 - 87	28 - 124
Carpsucker sp	40-639	79	--
Carpsucker/buffalo sp	40-239	79	36 - 145
Smallmouth buffalo	40-659	49	35 - 156
Bigmouth buffalo	40-859	--	35 - 232
Buffalo sp	40-269	--	--
Shorthead redhorse	40-579	65 - 110	61 - 111
Silver redhorse	200-639	--	58
Redhorse sp	60-619	--	39 - 104
Sucker sp	40-219	--	--
White sucker	40-659	120	47 - 186
Black bullhead	40-319	123	47 - 177
Brown bullhead	80-339	122	51 - 228
Yellow bullhead	80-159	--	80 - 95
Bullhead sp	20-339	--	72 - 129
Channel catfish	20-759	46 - 68	42 - 324
Tadpole madtom	20-299	--	--
Flathead catfish	20-1119	83	47 - 138
Trout perch	40-359	73 - 120	--
Burbot	100-539	--	--
White bass	20-479	40 - 152	34 - 335
Rock bass	20-239	148	--
Green sunfish	20-359	48	32 - 112
Bluegill	20-339	43 - 168	30 - 126
Largemouth bass	60-459	98	32 - 320
Smalmouth bass	40-439	45 - 210	--
Crappie	20-439	39 - 234	21 - 242
Yellow perch	40-279	78 - 210	52 - 83
Logperch	40-179	60 - 100	--
Sauger	40-519	--	145
Walleye	60-799	--	45 - 550
Sauger/walleye	40-459	--	--
Freshwater drum	20-659	31 - 315	20 - 430

FIGURES



REFERENCE: U.S. GEOLOGIC SURVEY 7.5 MINUTE RED WING, MN TOPOGRAPHIC QUADRANGLE MAP, 1995, OBTAINED FROM www.teraserver-usa.com.

2000 0 2000

SCALE: APPROX. 1" TO 2000'

Golder Associates
Lansing, Michigan

SCALE	AS SHOWN	TITLE	**SITE LOCATION MAP** PRAIRIE ISLAND POWER PLANT RED WING, MN
DATE	05/02/06		
DESIGN	JJS		
CADD	JJS		
FILE No. 063-8266.0001 (1)	CHECK		
PROJECT No. 063-8266 REV. 0	REVIEW	XCEL ENERGY	FIGURE 1

Drawing file: 063-8266.0001.dwg Aug 02, 2006 - 5:35pm

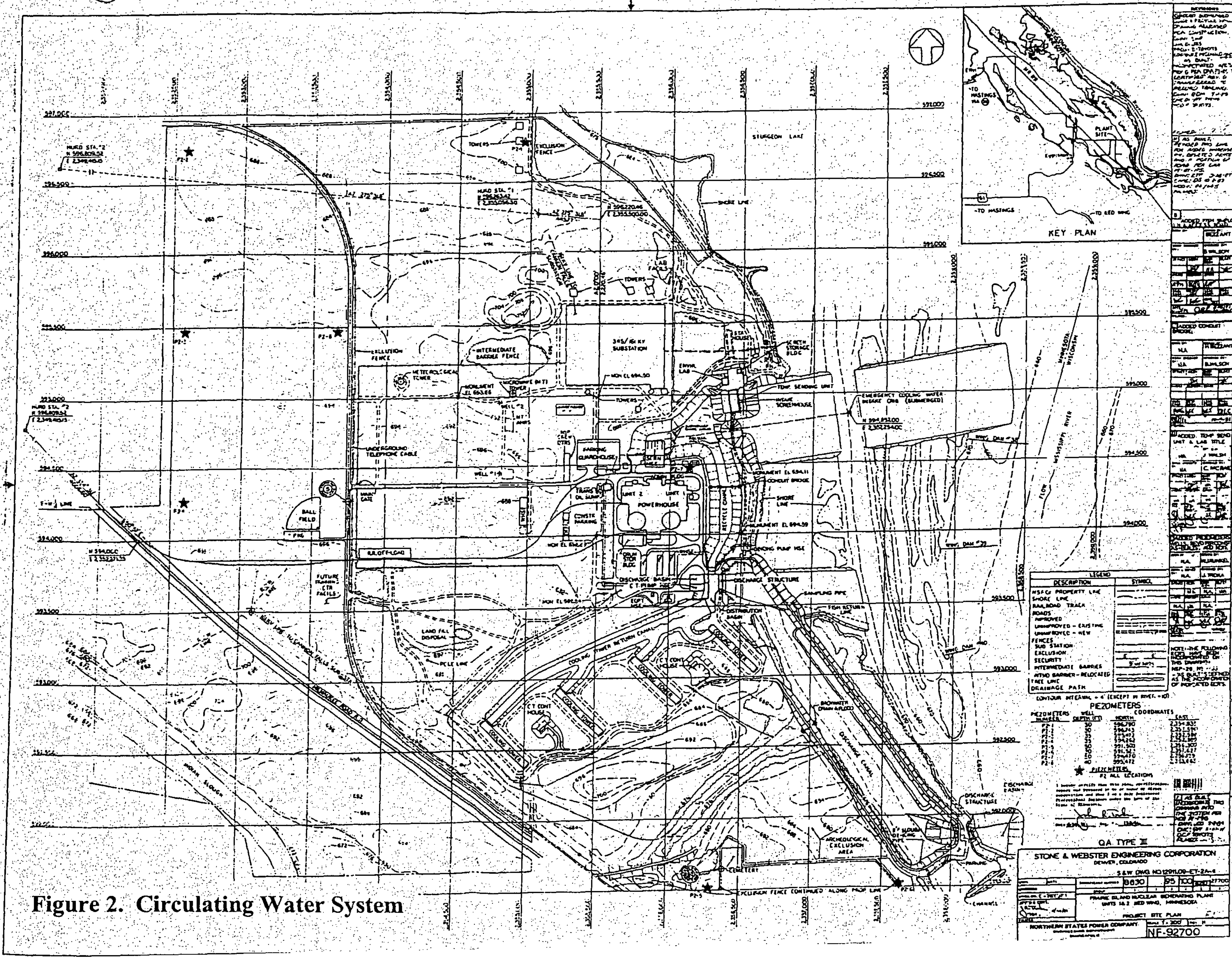


Figure 2. Circulating Water System

Figure 3. Location of Plant Screenhouse and Intake Screenhouse

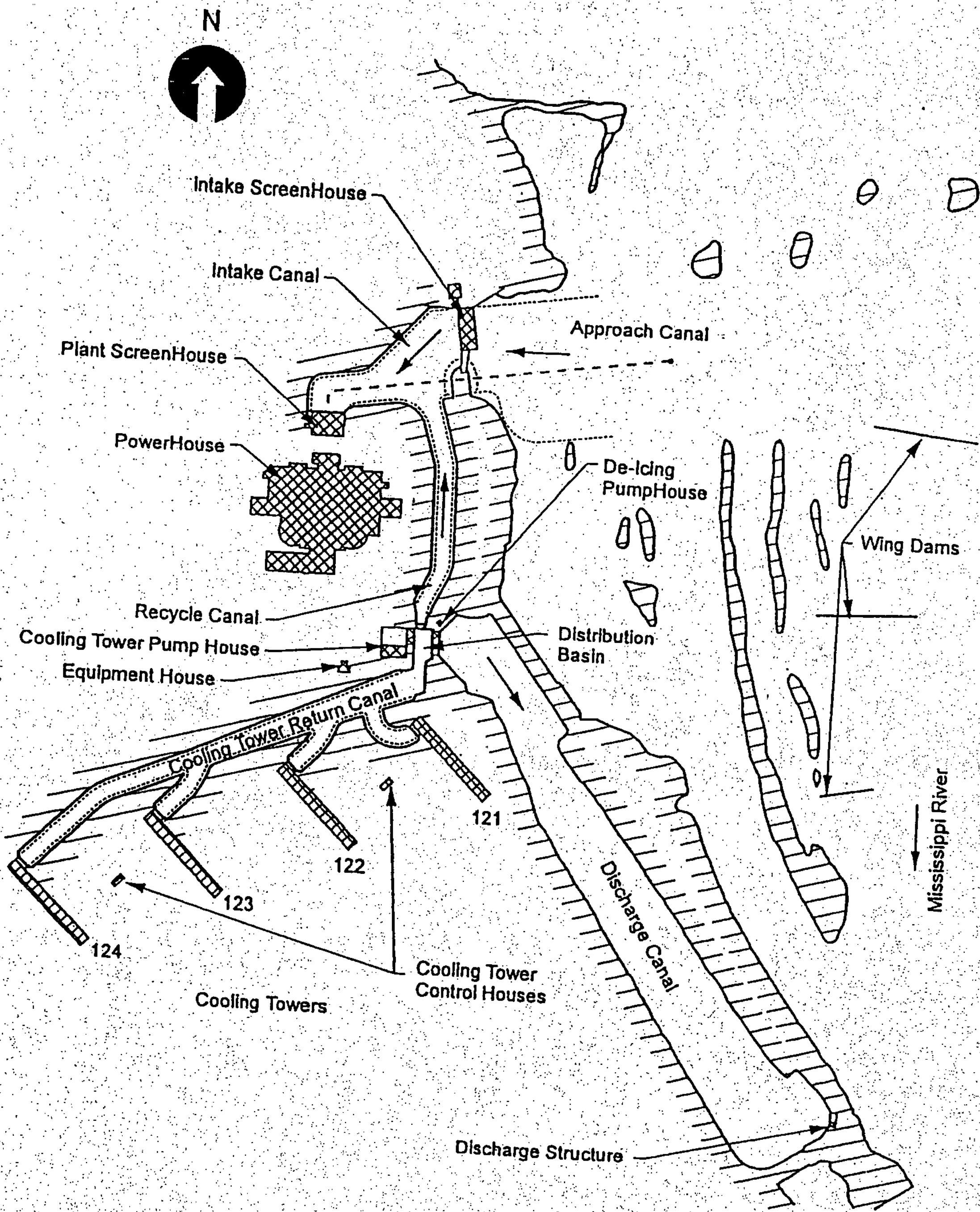
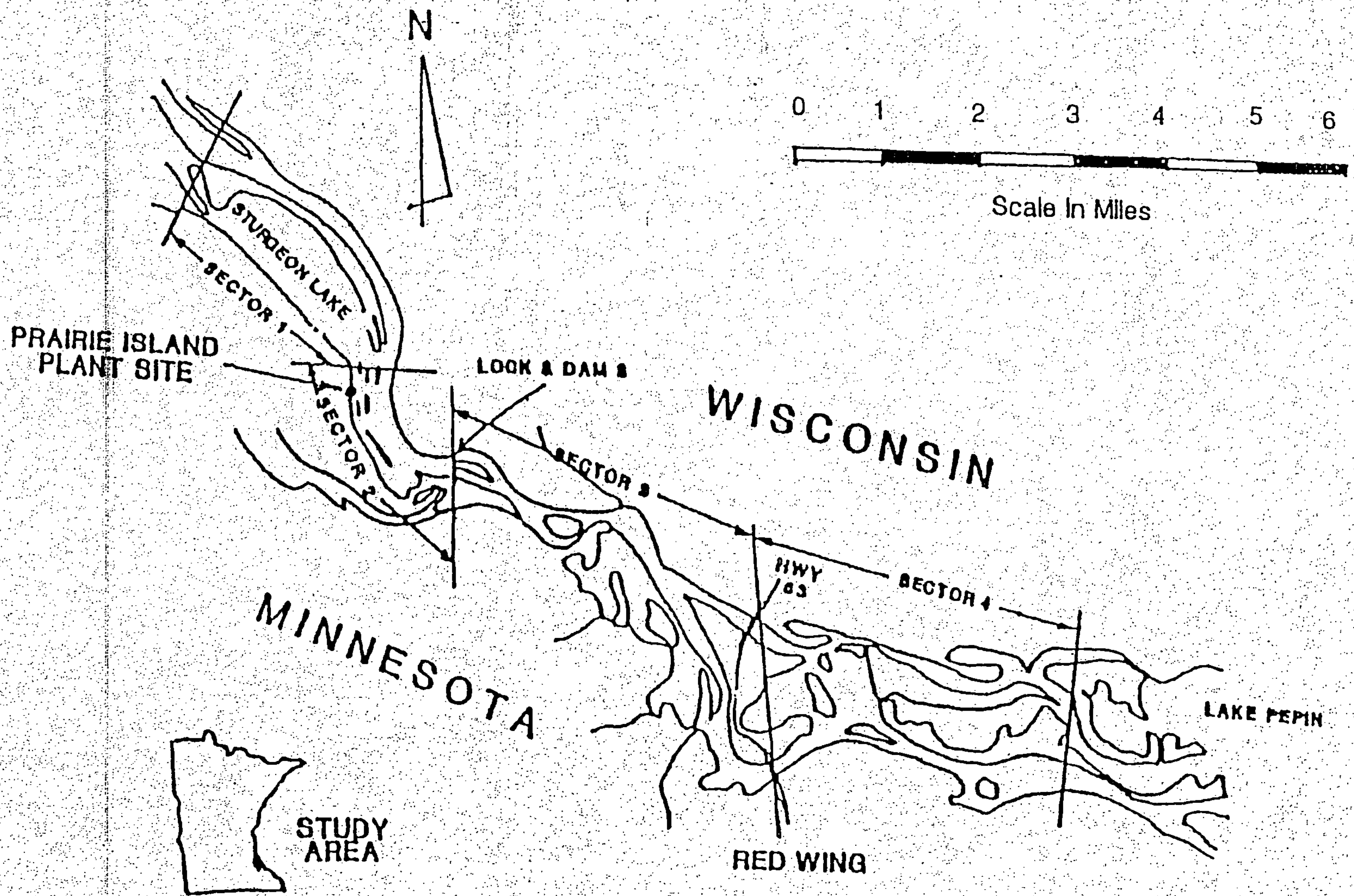


Figure 4. PINGP Fisheries Study Area



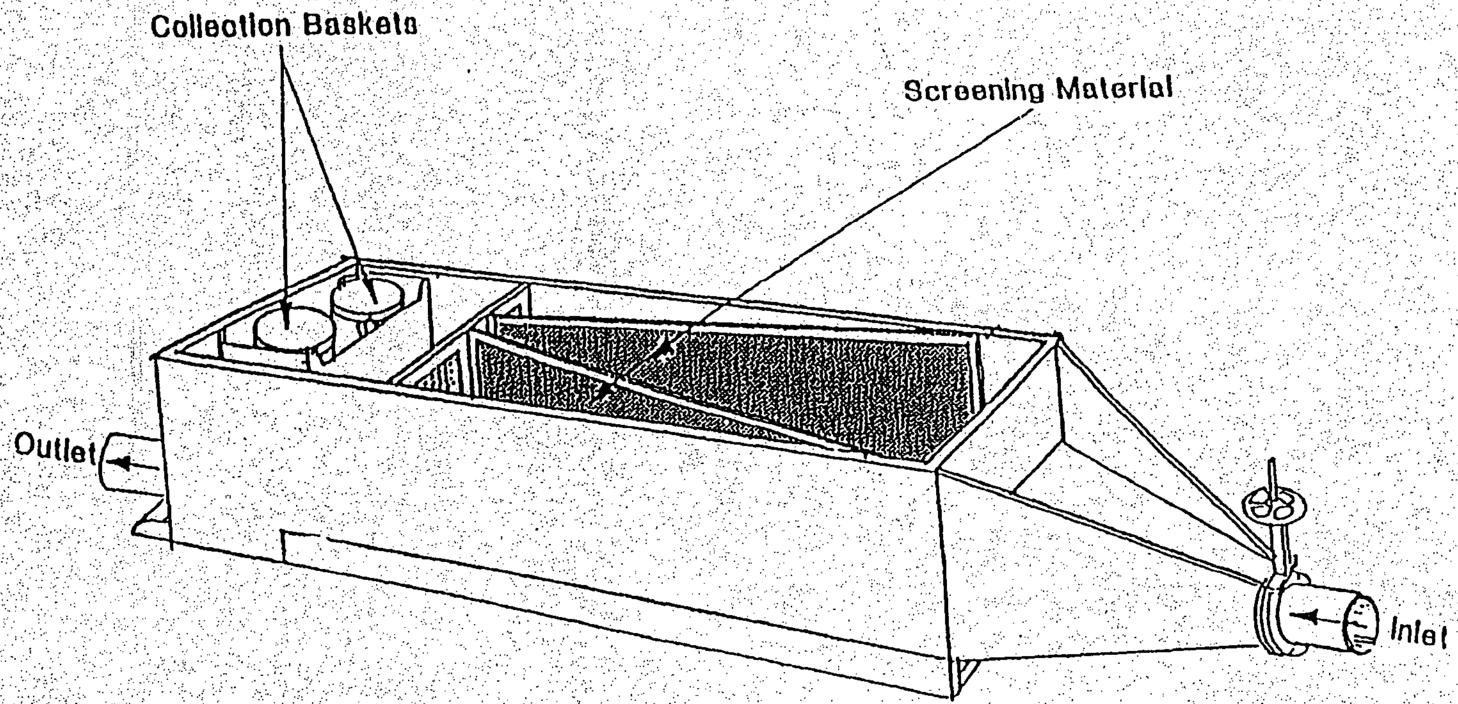


Figure 5. Larval Fish Collection Tank

Figure 6. Test Fish Survival

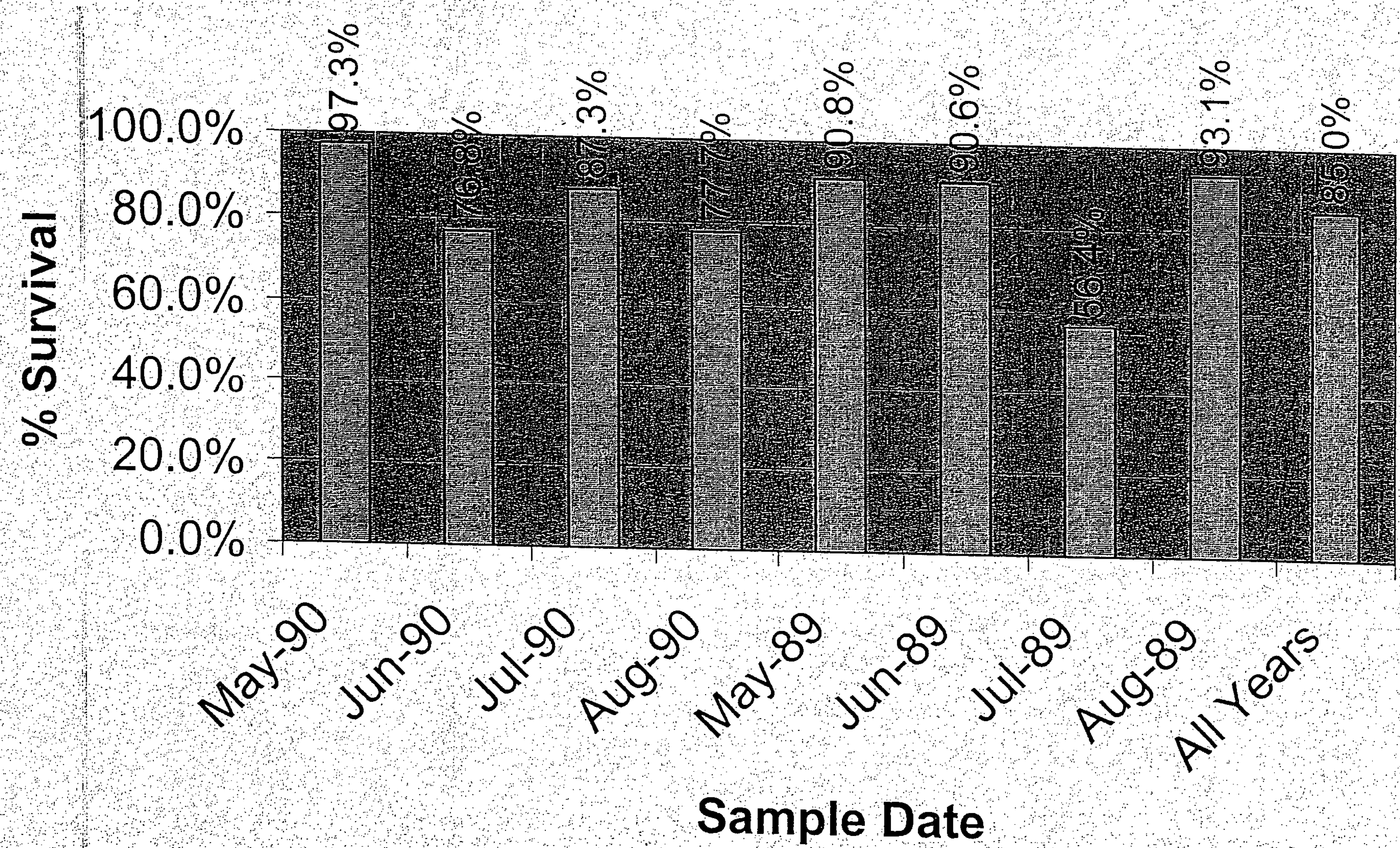
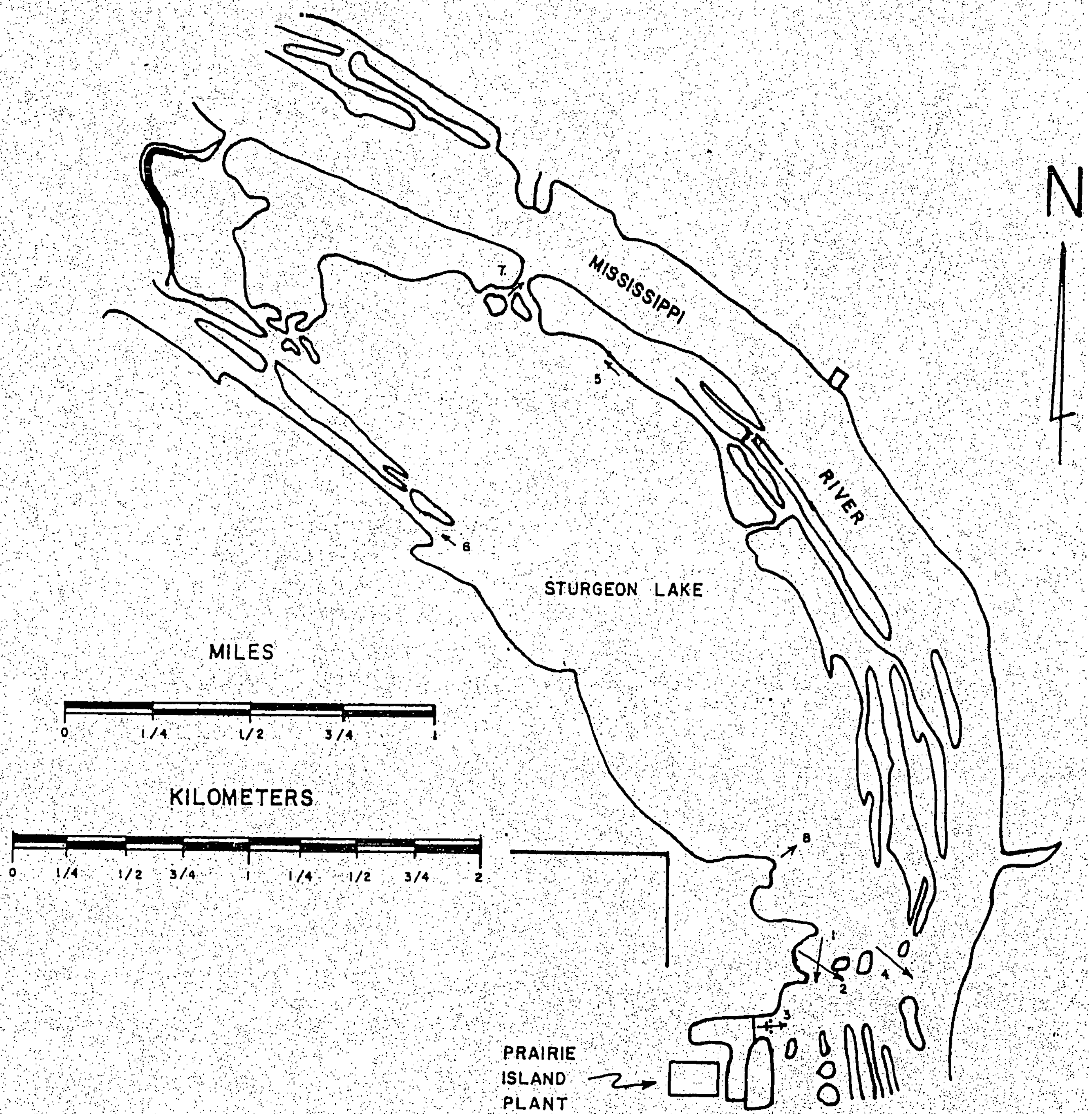


Figure 7. Location of Larval Fish Towing Stations at PINGP, 1975



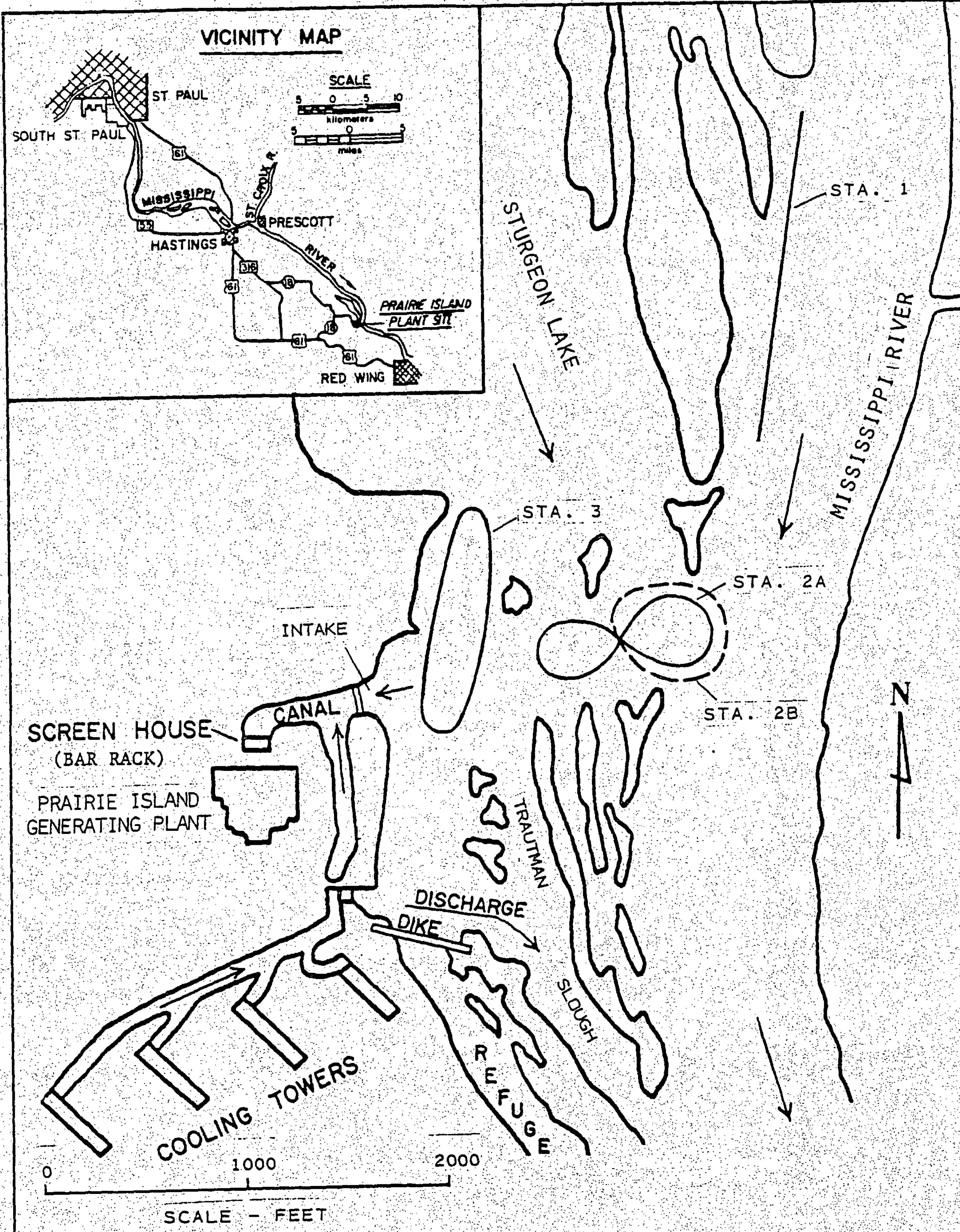


Figure 8. Location of Ichthyoplankton Sampling Stations, 1978.

NOTE: ↑ WATER FLOW

REFERENCE: NSP, 1975, VOL I, FIGURE 1 AND
NSP, 1976, VOL II, FIGURE 2.6-1

APPENDIX A
PINGP MUSSEL SURVEY

Prairie Island Modificatn Intake Discha General

NSP

NORTHERN STATES POWER COMPANY

MINNEAPOLIS, MINNESOTA 55401

January 8, 1981

Col Wm J Badger, District Engineer
St Paul District Corps of Engineers
1210 U S Post Office & Custom House
St Paul, Minnesota 55101

PRAIRIE ISLAND NUCLEAR GENERATING PLANT
Mussel Survey
C/E Reference NCSCO-RF (80-112-13)

Enclosed is a copy of a Mussel survey, dated December 1980, conducted by NSP and the Department of Natural Resources in the vicinity of the Prairie Island Nuclear Plant.

E H Schentzel

E H Schentzel
Assistant Administrator
Regulatory Liaison

ah

enclosure

cc: John Enblom, DNR
George Clymer, DNR
U S Fish & Wildlife Service
Att'n: Merryll Bailey
R S McGinnis

bcc: R D Clough
L W Eberley
D L Stephenson

INTERNAL CORRESPONDENCE
FORM 17-3467

FROM	L W EBERLEY - Supervisor, Ecological Studies	DATE	December 30, 1980
		LOCATION	Prairie Island
TO	E H SCHENTZEL - Assistant Administrator, Regulatory Liaison	LOCATION	ERAD

SUBJECT PRAIRIE ISLAND MUSSEL SURVEY

Enclosed is the final report of a Mussel survey conducted by NSP biologist and Minnesota Department of Natural Resources personnel in the vicinity of the Prairie Island Nuclear Generating Plant.

The survey, completed in September 1980, was conducted in response to a request by the U S Army Corps of Engineers. The results indicated that no endangered Mussel species were found in the vicinity of the plant. If there are questions, please advise.

Lee W Eberley

L W Eberley, Supervisor
Ecological Studies
Prairie Island Nuclear Generating Plant

ah

enclosure

cc: R D Clough w/o attach
M N Gregerson w/o attach
J K Poucher w/o attach

RESULTS OF A MUSSEL SURVEY CONDUCTED NEAR NORTHERN STATES POWER COMPANY'S PRAIRIE ISLAND NUCLEAR GENERATING PLANT

DECEMBER, 1980

By

George Clymer - Minnesota Department of Natural Resources

Lee Eberley - Northern States Power Company

ABSTRACT

A mussel survey was conducted in the vicinity of the Prairie Island Nuclear Generating Plant (PINGP) near Red Wing, Minnesota, by biologists from Northern States Power Company and Minnesota Department of Natural Resources. The survey was conducted prior to proposed construction of a new intake and discharge at PINGP to determine whether *Lampsilis higginsii* or any other endangered mussels, as protected under Public Law 93-205 (the Endangered Species Act of 1973) were present in the area.

Brailing with a crowfoot bar, wading, and pollywogging (snorkeling) methods were used in the survey. Sampling was done from September 4-17, 1980.

A total of 248 mussels representing 21 species was collected. Two species were found as relic shells only and one species was collected only from the power plants travelling screen wash. No live specimens of *Lampsilis higginsii* or any other endangered species were collected. Despite the difficulties of adequately sampling mussels in large turbid rivers such as the Mississippi, the survey indicated a viable mussel fauna exists in the vicinity of PINGP.

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

A survey was undertaken in September 1980 by Northern States Power Company (NSP) to determine if *Lampsilis higginsii* or any other endangered mussel species, as protected under Public Law 93-205 (the Endangered Species Act of 1973) were present in the vicinity of the Prairie Island Nuclear Generating Plant (PINGP).

The survey was conducted prior to proposed construction of a new intake and discharge at PINGP designed to minimize impacts on the aquatic environment caused by power plant operation.

PINGP is located on the Mississippi River near Red Wing, Minnesota, 65 km (40 mi.) southeast of Minneapolis and St. Paul, Minnesota. The Mississippi River in the vicinity of PINGP is characterized by a lentic aquatic fauna due to the presence of U.S. Lock and Dam 3 a short distance downstream.

MATERIALS AND METHODS

Description of the Study Area

The mussel survey was conducted in the intake and discharge canals of the Prairie Island Nuclear Generating Plant, main Mississippi River channel, and below Lock and Dam No. 3 (Figure 1).

Collecting Methods

Brailing was used in deep water areas and pollywogging (snorkeling) and wading were used along the shoreline and on shallow sandy and hard bottom areas.

The crowfoot bar (figure 2) used in the survey was manufactured for Northern States Power Company by George Clymer. The crowfoot specifications are as follows:

Beam: Ten feet long, 1½ inches thick and 3½ inches wide (standard 10-foot 2 X 4), pine or fir, some small tight knots may be present but no large knots that might reduce the strength.

Towing bridle: To have three legs fastened to beam with eye-bolts through 3½-inch dimension. To be made of ¼ inch hollow-braided or 3-strand twisted synthetic rope. Legs joined to 2-inch welded ring for attachment of towing line (not included). Galvanized thimbles in all eyes.

Hooks: Rock-hook style, about 6 inches long, made of 14-gauge annealed steel wire. Each hook has 4 points. The 4 points are securely wrapped together with 5 to 10 turn of 22 gauge soft steel

> wire at a point about 1 inch from the end. The ends are spread apart at an approximate 30 to 45 degree angle to the long axis, and fused to form a small ball or bead on each. Hooks are attached to 1-foot chains by means of S-hooks, 5 hooks to each chain. Chains are attached to beam on 3-inch centers by means of screw eyes. Bar has 40 chains and 200 hooks.

A fourteen foot aluminum johnboat with a 25 hp outboard motor was used in brailing. The boat was backed downstream with the current while the brail was being towed from the front.

Mussels are embedded in the riverbed with their incurrent and excurrent siphons showing. While a mussel is siphoning, the shells are open approximately one-quarter of an inch. As the crowfoot bar is towed the points of the hooks contact the fleshy material between the open shells causing the mussel to instinctively close the shells. Balls on the end of the hooks prevent them from slipping between the shells, and the mussel is pulled from the riverbed. The grasp of the mussel is so strong it is sometimes very difficult to pull it off the hook when the brail is brought aboard the boat after each run.

After each run was completed the mussels were identified,[1] counted, and returned to the riverbed. The mussels were positioned in the riverbed in the same way they appear naturally to enhance survival. If the mussels were not replaced carefully, they would land on their sides and not being able to right themselves, would eventually die. Voucher specimens of each

[1] Specimens were identified using Burch (1975), Mathiak (1979) Murray and Leonard (1962), and Parmalee (1967).

species were retained by NSP.

RESULTS AND DISCUSSION

A total of 248 live mussels representing 21 species was collected by all methods. Two species, *Fusconaia ebena* and *Quadrula quadrula* were collected as relic shells only and *Anodonta imbecillis* was collected only from the power plant's travelling screen wash. Table 1 lists the scientific and common names of all species encountered in the survey. Due to problems in making positive identifications, no attempt was made to separate *Amblema peruviana* from *Amblema plicata*. Mathiak (1979) reports that some malacologist consider the two a single species. As indicated in Table 2, *Amblema plicata* (103), *Obliquaria reflexa* (35), and *Fusconaia undata* (30) were the most frequently collected mussels. Nine species were represented by a single specimen. Mathiak (1979) indicated that *Amblema plicata* is "by far the most abundant mussel in the Mississippi River". No specimens of *Lampsilis higginsii* or any other endangered species were collected.

Wading and pollywogging yielded more mussels (133) than brailing (114) (Tables 3 and 4). This is not surprising since the area near PINGP retains many characteristics of a lentic environment because of U.S. Lock and Dam No. 3 located a short distance downstream. The substrate in this area is typically soft and many mussels collected in this area had to be dug or pried out of the riverbed. This factor undoubtedly accounts for the fact that only one adult mussel (*Fusconaia flava*) was collected brailing in the plant area but 25 small unidentified unionids were collected by their byssus thread. The byssus thread is a mucous strand produced by the young mussel which is secured to rocks, sticks or other debris to prevent the mussel from rolling with the current.

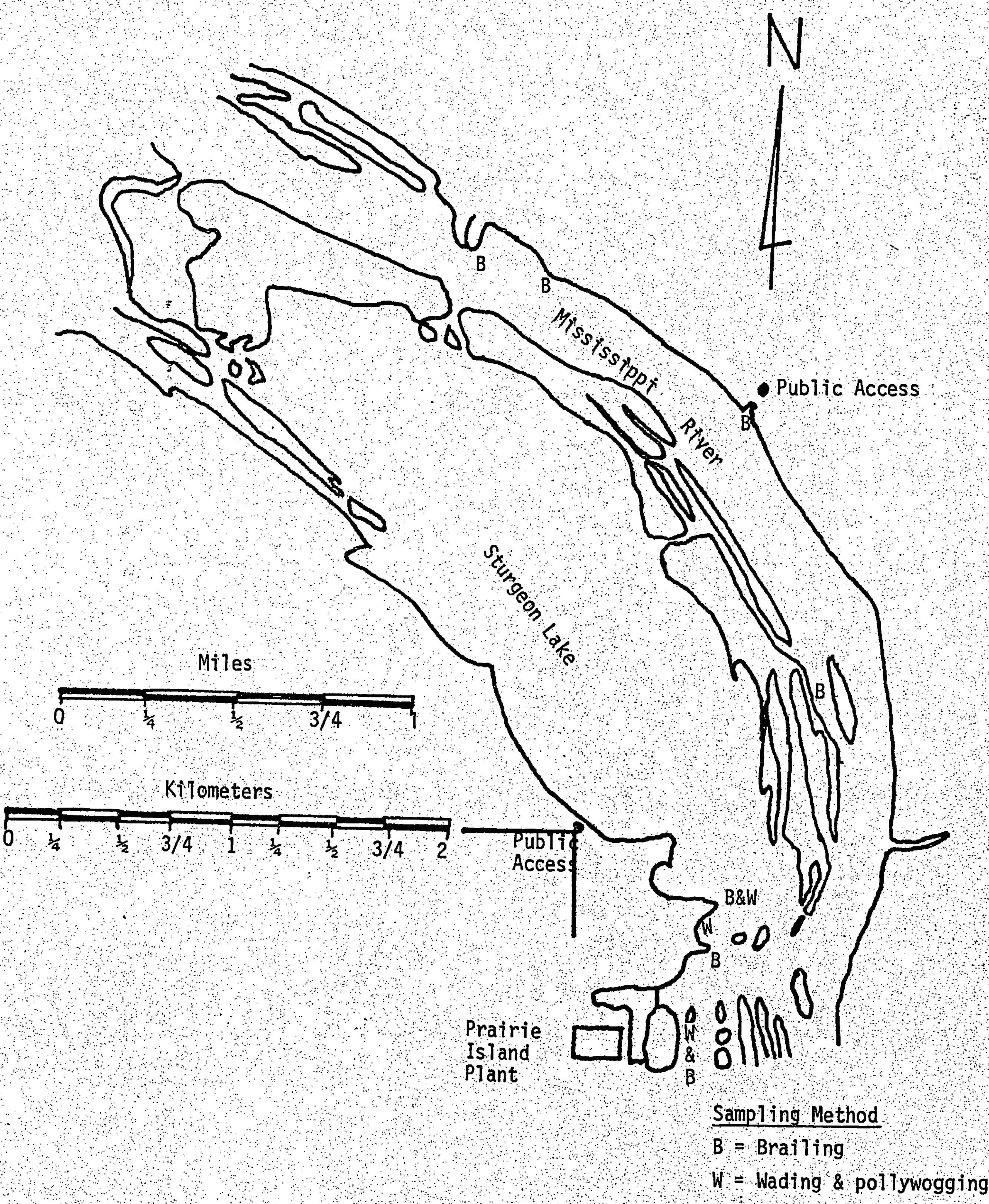
The small unidentified mussels were preserved in formalin and sent to Dr. David H. Stansbery at the Ohio State University for identification. At the time of this report, no results of identification had been received from Dr. Stansbery. Upon receipt, the results of his identification will be incorporated into this survey.

The results from this survey compare well with those reported by National Biocentric (1979) from the Mississippi River near Wabasha, Minnesota. They collected 223 specimens representing 21 taxa. Fifteen species were common to both surveys. Species encountered at Wabasha but not PINGP were *Amblema peruviana*, *Ligumia recta latissima*, *Obovaria olivaria*, *Plethobasus cyphyus*, and *Quadrula metanerva*. Five species collected near PINGP were not reported by National Biocentric (1979): *Anodonta grandis*, *Fusconaia flava*, *Fusconaia ebena* (relic shell only), *Leptodea laevissima* and *Quadrula quadrula* (relic shell only). National Biocentric (1979) also reported finding no specimens of *Lampsilis higginsii*.

Adquately sampling mussels in large turbid rivers presents special problems. At PINGP, turbidity is such that scuba diving is not practical therefore the main channel and deep water areas were sampled only by brailing. In shallow water areas, wading and pollywogging (snorkeling) were most effective. Due to the soft substrate in these areas, brailing was not very effective.

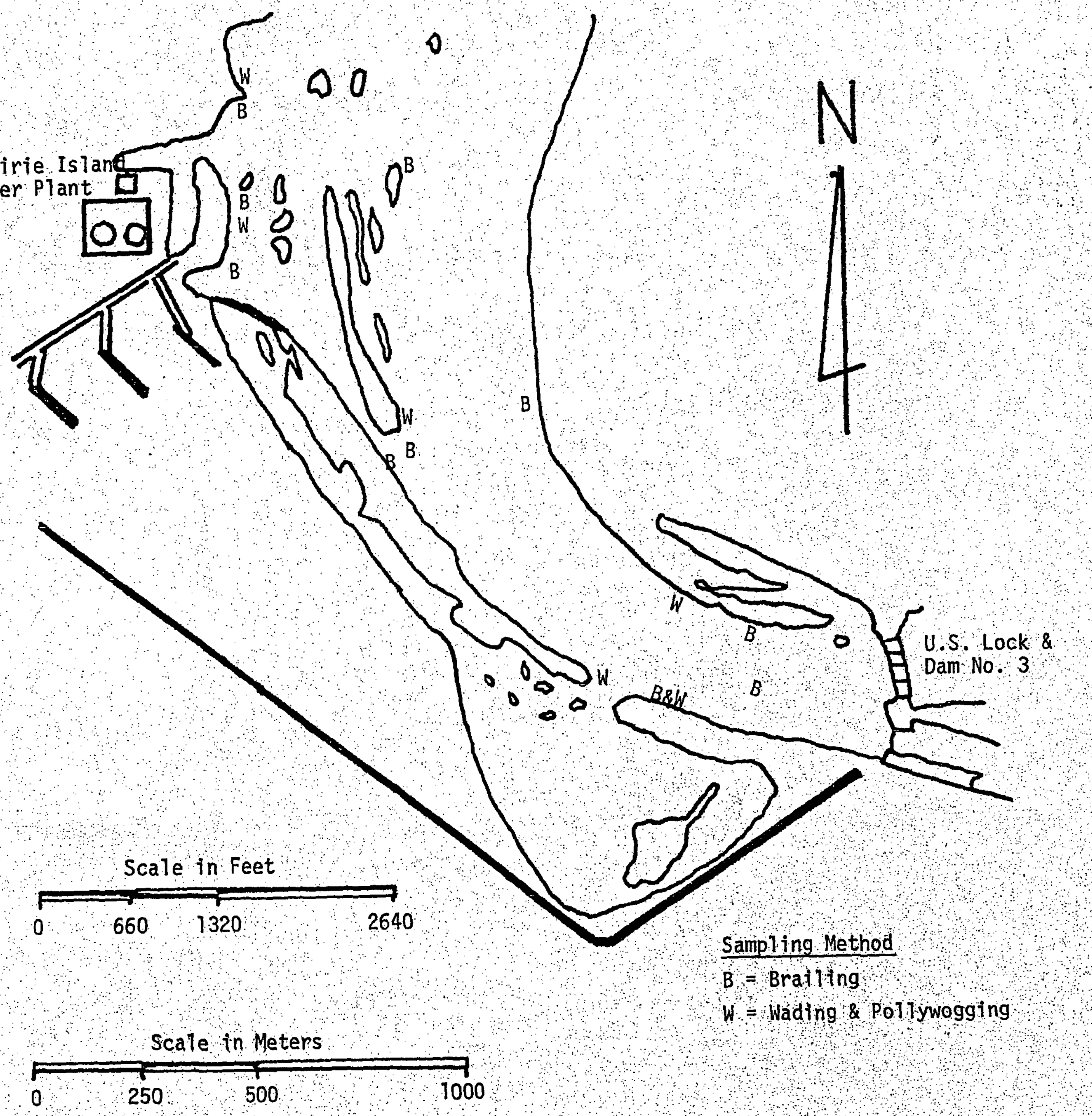
With the exception of one mussel bed located below Lock and Dam #3 near Trenton (Figure 1), sampling revealed no large concentration of mussels in any particular area; specimens were collected in nearly every area sampled, except the dredged portion of the Mississippi River main channel. It would appear that the mussel fauna is actively reproducing near PINGP but at a relatively low density.

Figure 1 PRAIRIE ISLAND SAMPLING SITES[2]



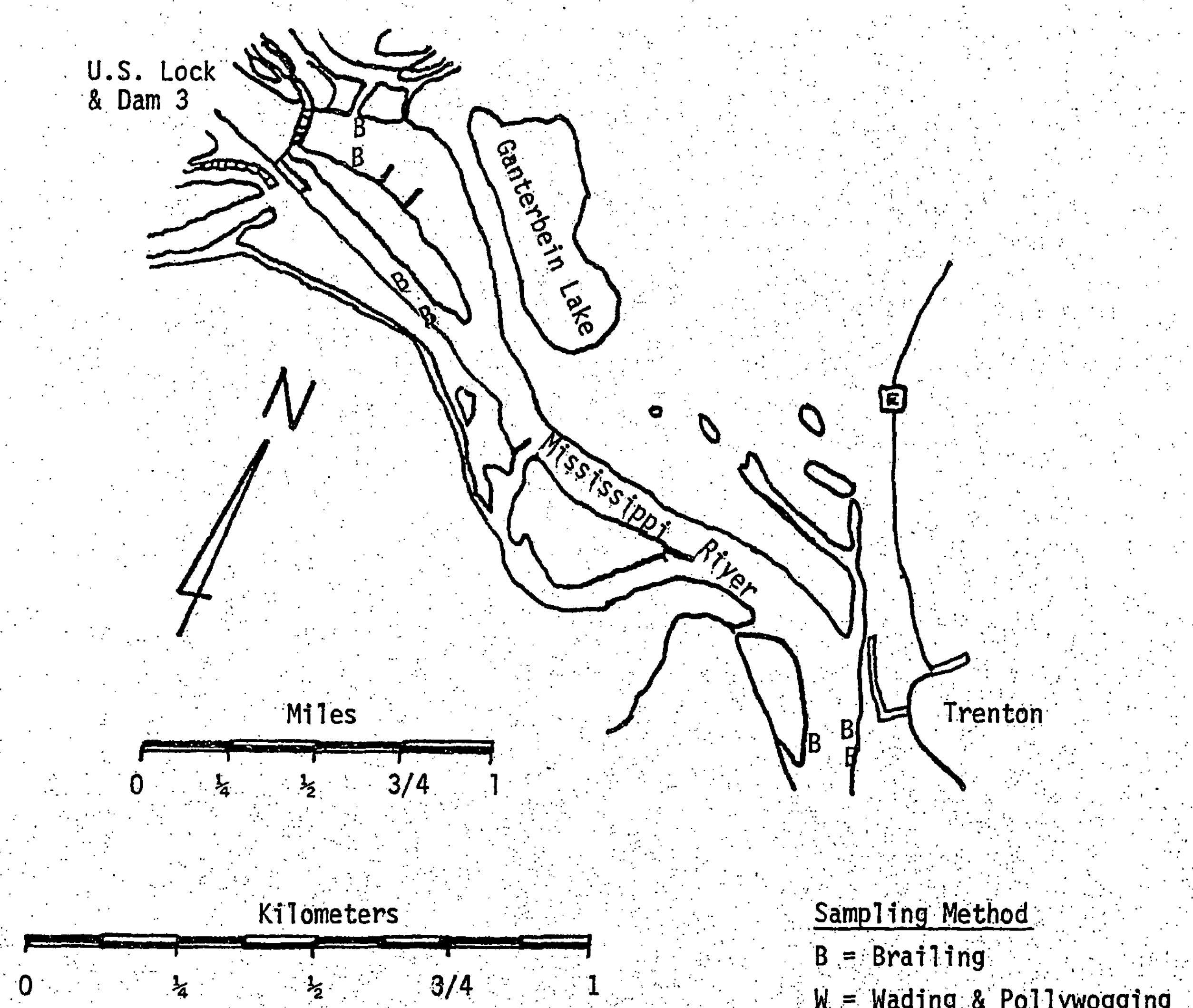
2 Gustafson, Geis, Bublitz 1979

Figure 1 (con't.) PRAIRIE ISLAND SAMPLING SITES[2]



2 Gustafson, Geis, Bublitz 1979

Figure 1 (con't.) PRAIRIE ISLAND SAMPLING SITES[2]



2 Gustafson, Geis, Bublitz 1979

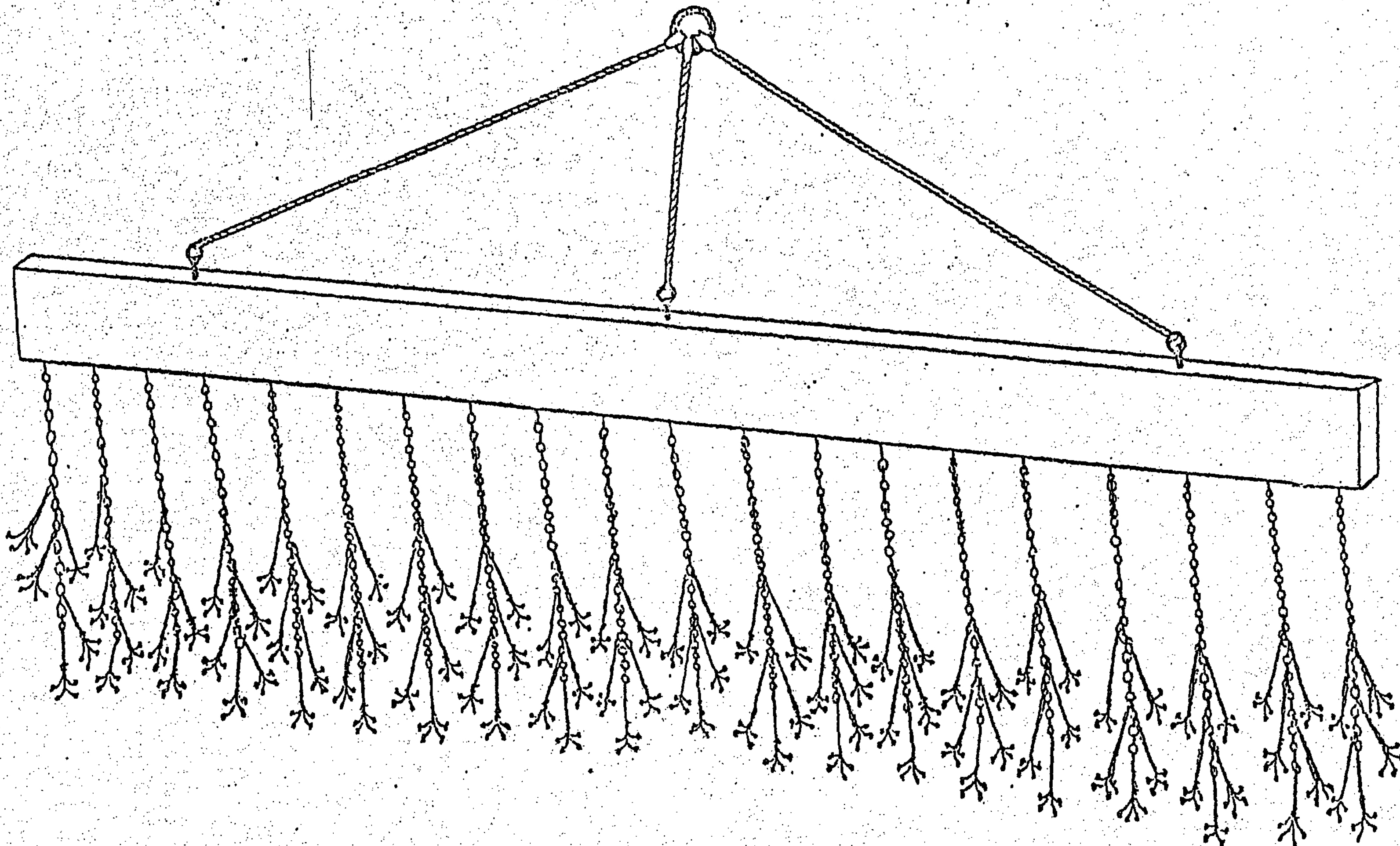


Figure 2.[3] The crowfoot bar used for brailing. (To allow a clearer view, not all chains and hooks actually present are shown here. The materials and dimensions are presented in the text.)

3 National Biocentric 1979

Table 1

Prairie Island Mussel Survey Species List

Scientific Name	Common Name
Actinonaias carinata (Barnes)	Mucket
Amblema plicata (Say)	Three Ridge
Anodonta imbecillis (Say)**	Paper Floater
A. corpulenta (Cooper)	Stout Floater
A. grandis (Say)	Floater
Carunculina parva (Barnes)	Lilliput Shell
Elliptio dilatata (Rafinesque)	Spike
Fusconaia flava (Rafinesque)	Wabash Pigtoe
F. ebena (Lea)*	Ebony Shell
F. undata (Barnes)	Pigtoe
Lampsilis radiata siliquoidea (Barnes)	Fat Mucket
L. ovata ventricosa (Barnes)	Pocketbook
Leptodea laevissima (Lea)	Pink Paper Shell
L. fragilis (Rafinesque)	Fragile Paper Shell
Obliquaria reflexa (Rafinesque)	Three-horned Warty Back
Pleurobema cordatum (Rafinesque)	Ohio River Pigtoe
Proptera alata (Say)	Pink Heelsplitter
Quadrula quadrula (Rafinesque)*	Maple Leaf
Q. pustulosa (Lea)	Pimple Back
Truncilla truncata (Rafinesque)	Deer Toe
T. donaciformis (Lea)	Fawns Foot

*Found as relic shells only

**NSP travelling screen wash

Table 2

Frequency of Occurrence of Mussels in the Vicinity of the Prairie Island Nuclear Generating Plant

Mussel	Frequency of Occurrence
Amblema plicata (Say)	103
Obliquaria reflexa	35
Fusconaia undata	30
Unidentified	25
Quadrula pustulosa	13
Truncilla truncata	8
Anodonta grandis	7
Fusconaia flava	6
Truncilla donaciformis	6
Leptodea fragilis	4
Lampsilis radiata siliquoidea	2
Actinonaias carinata	1
Anodonta imbecillis	1
A. corpulenta	1
Carnunculina parva	1
Elliptio dilatata	1
Leptodea laevissima	1
L. ovata ventricosa	1
Pleurobema cordatum	1
Proptera alata	1
Total	248

Table 3

Species of Mussels and Number Collected By Wading and Pollywogging Near PINGP

Species	Number
Amblema plicata	96
Fusconaia undata	12
Obliquaria reflexa	8
Anodonta grandis	7
Fusconaia flava	4
Anodonta corpulenta	1
Anodonta imbecillis	1
Carunculina parva	1
Leptodea ovata ventricosa	1
Proptera alata	1
Total	134

Table 4

Species of Mussels and Number Collected By Brailing Near PINGP

Species	Number
Obliquaria reflexa	27
Unidentified	25
Fusconaia undata	18
Quadrula pustulosa	13
Truncilla truncata	8
Amblema plicata	7
Truncilla donaciformis	6
Leptodea fragilis	4
Lampsilis radiata siliquoidea	2
Actinonaias carinata	1
Elliptio dilatata	1
Leptodea laevissima	1
Pleurobema cordatum	1
Total	114

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OSU The Ohio State University

Museum of Zoology
1813 North High Street
Columbus, Ohio 43210
Phone 614 422-8560

12 March, 1981

Mr. George Clymer
Aquatic Biologist
Minnesota Department of Natural Resources
Ecological Services Section
Box 25, Centennial Building
658 Cedar Street
St. Paul, MN 55155

Dear Mr. Clymer:

The set of 10 vials of juvenile unionid mollusks arrived here unbroken and I have replaced the formalin solution with our AGW (ethyl alcohol 80%, glycerine 5%, distilled water 15%) solution. Naiad mollusk juveniles are most easily preserved for identification using shell characters by dropping directly into AGW. If the soft parts are to be studied, the specimens are first relaxed, then fixed with a 5% formalin before being run through an alcohol series up to AGW strength for permanent preservation.

I am favorably impressed by how well the shells of these juveniles are preserved. Apparently there were few, if any, breaks in the periostracum which would give the acidic formalin an opportunity to dissolve the shell.

Thank you for your 23 January letter containing the River Mile Location (797.75) of the proposed power plant site. We have expanded this fix into the following locale:

Mississippi River, R.Mi. 797.75,
(2.7 mi. NE of Harliss,
6.0 mi. NW of Red Wing,
T113N, R15W, Burnside Twp.,
Goodhue Co., Minnesota)
September, 1980 George M. Clymer

Please correct us if there are any errors here.

I did take the time to look at the specimens under a binocular microscope before packing them for shipment. I was surprised to find that most of the juveniles were _Truncilla donaciformis_ (Lea, 1827) with _Toxolasma parvus_ (Barnes, 1823) making up most of the remaining specimens. A single _Truncilla truncata_ (Rafinesque, 1820) and one _Elliptio dilatata_ (Rafinesque, 1820) completed the set. These specimens are being catalogued immediately so that you may have the catalogue numbers as vouchers. In the meantime the results are being typed so that they can be sent to you yet today. I had anticipated some days of labor in comparing these specimens with previously identified specimens in the collection here in order to arrive at certain identification. The lack of diversity in these 10 vials plus the presence of easily identifiable species reduced the task to only a few hours. This is a most unusual experience.

The literature on the identification of juvenile unionids is scant and widely dispersed making it almost a must to have extensive sets of identified juveniles at hand in order to do this type of work. Much of the success depends upon a familiarity with the type and extent of variation of umbonal sculpturing in each species. These specimens will help in this regard with the reference collection here.

I am sorry for the several delays including being out sick for several days, but I am pleased to be able to do the determinations after all. I will send a carbon of this letter and the results to Dr. Chelberg. It is good to hear that Dr. Chelberg is continuing his interest in the unionids of the upper Mississippi River. I had the pleasure of visiting him at the time of the concern over dredging of the Minnesota River and was favorably impressed with his interest in and concern about this molluscan fauna.

I hope and trust you will find these determinations of value in your work.

Sincerely,

David H. Stansbery

David H. Stansbery
Director and Professor

DHS/aw

IDENTIFICATION OF JUVENILE UNIONID MOLLUSKS FROM THE MISSISSIPPI RIVER NEAR PRAIRIE ISLAND, MINNESOTA

By
David H. Stansbery
March 1981

DATA		SPECIMENS	SPECIES	OSUM CATALOGUE NO.
Run 1	9-10-80	4	*Truncilla donaciformis* (Lea,1827)	48899
Run 2	9-12-80	1	*Toxolasma parvus* (Barnes, 1823)	48904
		1	*Truncilla donaciformis* (Lea,1827)	48903
Run 2+3	9-4-80	5	*Truncilla donaciformis* (Lea,1827)	48901
Run 3	9-10-80	1	*Toxolasma parvus* (Barnes,1823)	48900
Run 3+4	9-17-80	1	*Truncilla donaciformis* (Lea,1827)	48907
		2	*Toxolasma parvus* (Barnes,1823)	48908
Run 4	9-10-80	1	*Elliptio dilatata* (Rafinesque,1820)	48898
Run 6	9-10-80	1	*Truncilla donaciformis* (Lea,1827)	48899
Run 8+10	9-16-80	2	*Truncilla donaciformis* (Lea,1827)	48905
		1	*Truncilla truncata* (Rafinesque,1820)	48906
Run 9	discharge	1	*Toxolasma parvus* (Barnes,1823)	48909
Run 11	9-5-80 discharge	2	*Truncilla donaciformis* (Lea,1827)	48902

Specific locale: Mississippi River, Prairie Island Generating Plant, R.Mi. 797.75, (2.7 mi. NE of Harliss, 6.0 mi. NW of Red Wing, T113N, R15W, Burnside Twp., Goodhue Co., Minnesota)
4-17 Sept. 1980 Collector: George Clymer

Xcel Energy Prairie Island Nuclear Generating Plant

Design and Construction Technology Plan

Submitted in Accordance with the NPDES Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities

NPDES Permit #MN0004006

October 23, 2006

Prepared by:

Xcel Energy
Environmental Services

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1.0 Introduction

1.1 Purpose

On July 9th, 2004 the EPA published an amendment to rule 316(b) of the Clean Water Act (CWA) in the Federal Register (from hereafter referred to as "the Rule"). The purpose of the amendment is to establish the best technology available for minimizing adverse environmental impact associated with the use of cooling water intake structures. The Design and Construction Technology Plan (DCT Plan) is one component of the Comprehensive Demonstration Study (CDS), which is being submitted by our facility to comply with 40CFR 125.95(b)(4)(i).

1.2 Compliance Alternative 2

The Rule states five alternatives for a facility to choose from in order to be in compliance. Xcel Energy chose compliance alternative 2 (40 CFR 125.94(a)(2)) for Prairie Island Nuclear Generating Plant (PINGP), as discussed in the "Proposal For Information Collection (PIC)." Briefly, compliance alternative 2 requires Xcel Energy to demonstrate that existing design and construction technologies, operational measures, and/or restoration measures at PINGP meet the impingement and entrainment performance standards.

1.3 DCT Plan Description

The DCT Plan is intended to describe the intake technology that is currently used at PINGP. Included in this document are the intake designs, drawings, and specifications currently installed at the facility, as well as the initial intake structure that has been modified over the years. Also included in this Plan are operational measures used that are intended to minimize impingement and entrainment at the facility. Historical impingement and entrainment data, both pre and post intake modification, is also included and confirms that the current intake design and technology is meeting the impingement and entrainment standards of 40CFR 125.94(b).

2.0 Plant Information

2.1 Facility Description

Location

PINGP is located on the Mississippi River in Goodhue County (township 113N, range 15W) near Red Wing, Minnesota (Figure 1). The site is located within the city limits of the City of Red Wing, Minnesota on the west bank of the Mississippi River. The plant site is located about 26 miles SE of the Twin Cities Metropolitan Area. The total area of the site is approximately 578 acres.

Generation

PINGP has two units, identified as units 1 and 2. Each unit employs a 2-loop pressurized water reactor. Full commercial operation began on December 16, 1973 for Unit 1 and on December 21, 1974 for Unit 2. Both units are licensed with the Nuclear Regulatory Commission (NRC) for operation at 1650 MWt per reactor, which is equivalent to a gross electrical output of 575 MWe. Northern States Power (NSP) owns the facility; Nuclear Management Company (NMC) operates the facility.

Cooling System Description

The principal surface waters in the vicinity of the site are the Mississippi River, Sturgeon Lake, the Vermillion River and the Cannon River (Figure 2). Level of the Mississippi River and Sturgeon Lake is regulated by Lock and Dam No.3, which is located approximately one and one-half miles downstream of the plant. Water is withdrawn from the Mississippi River for condenser/circulation water system and cooling water systems. The condenser/circulating water system provides high volume cooling water flow for the turbine-condenser steam cycle whenever a unit is operating. The cooling water system also supplies other plant equipment, such as pumps, motors, and heat exchangers.

River water enters the plant through the intake screenhouse and the plant screenhouse. Circulating water discharge to the river is controlled by sluice gates and recycle gates. When cooling towers are in operation, some of the plant waste heat is transferred to the air and the remainder is transferred to the river. During the period the towers are out of service, the waste heat is transferred to the river or recycled back to the intake canal and mixed with the incoming cold water.

2.1 Capacities and Utilization Rate of Facility

PINGP operating reports are included for the 2001-2005 reporting years and can be found in Appendix A. As documented in the reports, the net generation from each unit is relatively consistent each year, however some slight year-to-year variation does occur. The main factor that drives this yearly variation is the refueling outages. Each unit is on an 18-month refueling schedule, meaning that every 18 months the unit is shutdown for approximately 30 to 40 days for refueling purposes. During this time period, the unit does not generate electricity.

Average Annual Net Generation of Facility Over 5 Year Period

The average annual net generation at PINGP is included in Table 1. Since PINGP has one intake structure that the two units share, the average net generation of the facility is the sum of the average net MWh output for Unit 1 and Unit 2. The five-year average of the annual net generation for the total facility is 8,409,316 MWh.

Table 1. PINGP Annual Net Generation

Year	Net MWh Output		
	Unit 1	Unit 2	Total Facility
2001	3,641,741	4,270,964	7,912,705
2002	4,373,234	4,296,033	8,669,267
2003	4,596,347	4,240,971	8,837,318
2004	3,599,996	4,660,264	8,260,260
2005	4,518,398	3,848,630	8,367,028
Avg:	4,145,943	4,263,372	8,409,316

Total Net Capacity of Facility

PINGP capacities are given in Table 2 below. For calculation of the capacity utilization rate, the sum of the maximum dependable capacities for Unit 1 and Unit 2 is to be used. Thus, the total net capacity of PINGP is 1,044 MWe.

Table 2. PINGP Capacities

	Unit 1	Unit 2
Licensed Thermal Power (MWT)	1650	1650
Nameplate Rating (Gross MWE)	593	593
Design Electrical Rating (Net MWE)	536	536
Maximum Dependable Capacity (Gross MWE)	554	554
Maximum Dependable Capacity (Net MWE)	522	522

Capacity Utilization Rate (CUR)

CUR = Average Annual Net Generation / (Total Net Capacity of Facility * hours/year)
CUR = 8,409, 316 MWh / (1,044 MWe * 8,760 hrs)
CUR = .920

The calculated capacity utilization rate for PINGP is 0.920.

3.0 Intake Design and Technology Narrative Description

In 1977, Xcel Energy examined alternatives to modify their current intake design in order to minimize impingement and entrainment mortality in conjunction with a proposed new mode of plant operation. Design objectives were to develop and evaluate designs which would permit utilizing increased intake flows while maintaining reduced impacts of impingement, entrainment, and cold shock at the plant. Various intake technologies and studies were conducted and are documented in Appendix B. After extensive review of designs and agency input, a new screenhouse was constructed at PINGP. The new screen house, referred to as the "intake" screenhouse, became operational in the fall of 1983 and the final system description can be found in Appendix C. It should be noted that the old screenhouse is still in use and is referred to as the "plant" screenhouse. In order to get a better understanding of the intake technology currently used and the impact it has on minimizing impingement and entrainment mortality, both the pre-modification and post-modification design and technology of PINGP's intake are described below.

3.1 Intake Technologies

Pre-modification Design and Technology

The original circulating water system and intake design was capable of operating as a once-through system, a closed-loop system or a helper system (a portion of the water is recycled to the intake). Cooling water was drawn into the plant through an intake canal, which was about 110 feet wide and 760 feet long. A barrier wall was located near the mouth of the canal to retain heated water in the system. The barrier also excluded floating debris from the screen house. A plot plan of the intake before modification is included in Figure 3 and shows the relative location of the barrier wall, intake canal, plant screen house, and discharge canal.

Water from the Mississippi River was drawn into a common intake screen house structure, which consisted of four vertical shaft, dry-pit circulating water pumps, three electric and two diesel driven cooling water pumps, a trash rack, and vertical traveling screens (Figures 4 and 5). The screenhouse has a common trash rack outside the eight screen bays. Each bay contains a vertical traveling screen. The four circulating and five cooling water pumps are located behind the screens. Each circulating water pump normally drew water from two of the screen bays; however, a plenum downstream from the screen made it possible for a unit operating with one pump to draw water through four screens, thus reducing the approach velocity at the screen faces.

Each traveling screen is 10 feet wide by 36 feet high and utilizes wire mesh with 3/8-inch openings. For cleaning, the eight screens are rotated and washed with approximately 80-psi water pressure (125 psi design) spray nozzles. Debris is washed into a common trough leading to a trash basket for ultimate removal. Normally, the screens are washed intermittently when a pre-set differential head across the screen is exceeded or on a pre-set time cycle. No fish protection technologies or operational measures are used on the coarse mesh screens to minimize impingement mortality.

PINGP used closed-loop operation during the winter months when the ambient river water and air temperatures were low. As these temperatures increased, the condenser inlet temperatures also increased and the helper-cycle mode of operation was initiated when the inlet temperature reached 85° F. This sequence of operation was reverse during the fall as ambient river water temperatures decreased. Under all modes of operation, the circulating water flow was passed through mechanical draft cooling towers in order to reduce the temperature of the discharge water for existing thermal criteria.

Post-modification Design and Technology

From an operational perspective, the modified intake design and technology operate similar to the pre-modified design. This means that the current circulating water and intake system are capable of operating as a once-through system, a closed-loop system, or a helper system. The difference between the two intake systems is the location of the screen house and the traveling screen technology used. A plot plan of the post-modification intake design is shown in Figure 6 and 7, displaying the location of the screenhouse. The location and operation of the four circulating water pumps and five cooling water pumps did not change. Intake screenhouse general arrangement and design drawing is presented in Figure 8.

Plant intake flow from the Mississippi River enters the intake screen house through eight 18.5 foot by 11.2 foot bay openings. The bottom of the inlet skimmer wall is at elevation 667.0 feet. Each bay is equipped with a raked trash rack and a traveling water screen with low-pressure fish wash sprays and high-pressure trash wash sprays. Bypass gates are available to maintain a continuous flow in the event that flow through the screens is reduced due to high debris loading. The bypass gates are a vertical lift gate type with rollers. The gates open automatically when the head differential across the traveling water screens reaches 18 inches or when the head differential across the intake screenhouse reaches 24 inches.

Each screen is 10 foot wide and extends from the operating deck (elevation 685 feet) to the floor (elevation 648.5 feet). Screen panels are replaceable. During the period of April 1 through August 31, fine mesh screens (0.5 mm) are used to minimize the number of fish eggs and larval entrained. For the remainder of the year, coarse mesh screens (3/8-inch or 9.5 mm) are in service. The screens are capable of operation at several different speeds, as necessitated by debris loading.

During fine mesh screen operation, the screens run continuously. When the head differential is 4 inches or less, the screens continuously travel at 3 fpm during fine mesh operation. Coarse screen operation is intermittent, meaning that the spray wash systems (both fish and debris) do not operate when the differential level is less than 4 inches. These screens will, however, automatically rotate, with sprays operating, 1-1/3 revolutions if 8 hours pass without screen operation. For both fine and coarse screen operation, if the differential level exceeds 4 inches, screen speed increases proportionally up to a maximum of 20 fpm at 8 inches differential level.

The post-modification traveling water screens are equipped with fish lift buckets to remove organisms from the intake water (Figure 9). Aquatic organisms impinged on the screens, or carried in the attached buckets, travel with the screen during rinsing and are washed into a fish collection trough. Removal of the fish and organisms is accomplished on the upward travel side with a low-pressure (10 psi) inside spray when fine mesh is used and with a low-pressure (20 psi) outside spray when coarse mesh is used. Debris is removed by a backside interior high-pressure (50 psi for fine mesh and 100 psi for coarse mesh) spray system. The organisms and debris washed off the traveling water screens collect in a fish return trough and a debris trough that combine into a common trough and is returned to the river through a buried pipe approximately 2200 feet long. The pipe discharges into the Mississippi River at a point approximately 1500 feet south of the intake screen house (see Figure 7).

A deicing system is utilized to distribute warm water across the inside face of the intake structure to prevent formation of ice on the exposed surfaces (Figure 10).

3.2 Intake Flows and Velocities

Pre-modification

The flow rates and resulting velocities under the pre-modified intake's barrier wall are given in Table 3 on the right. Pre-modification velocities at the trash racks and traveling screens are included in Table 4.

Table 3. Flow Rates and Velocities, Two Unit Operation (Full Load)

Operating Mode	Flow Rate (cfs)		Velocity Under Barrier Wall (fps)
	From River	Recycle Canal	
Closed-Loop	188	1312	0.3
Helper	750	750	1
Open Cycle	1500	0	2.1

Table 4. Approach Velocity to Trash Rack and Traveling Screens
(based on total plant flow of 1500 cfs)

Water Level	Velocity (fps)	
	At Racks	At Screens
Normal Water Level (674.5 ft)	1.2	1.3
Low Water Level (673.5 ft)	1.2	1.4

Post-modification Intake Flows and Velocities

The design of the post-modified intake screen house structure minimizes the impact of the PINGP on aquatic organisms in the Mississippi River. The approach canal to the intake screen house is 575 feet wide and extends from the main flow of the river (see Figure 8). The canal is designed for a maximum flow of 3360 cfs. Actual flow is limited to a maximum of 1410 cfs resulting in a flow rate of less than 1 fps. The system design requirements change based on various times of the year and screen mesh size.

During 1983 and 1984 velocity profiles were conducted at flow rates specified in the NPDES permit. Design criteria for the fine mesh screen states the average face velocity through the gross area of the screen material should not exceed 0.5 fps based on low water level and a discharge rate of 800 cfs. All flow measurements were less than or equal to 0.2 meters per second (0.6 fps). Most data points recorded were less than 0.1 meters per second (0.3 fps). The average velocity of the water approaching the fine mesh screen was determined to be within the design criteria for all discharge flows measured (150 cfs to 1145 cfs) (NSP, 1984).

Intake velocities were also measured in 2003 and are included in Table 5 (Staley, 2004). One set of measurements was taken at 1006 cfs discharge and the other at 815 cfs. Both sets were taken while the traveling screens were in the coarse-mesh mode of operations. Intake velocities measured during 1006 cfs blowdown averaged 0.388 fps to 0.599 fps across all eight bays. Intake velocities averaged 0.337 fps to 0.427 fps across all eight bays measured during 815 cfs blowdown. The study concluded that intake flows are not outside design requirements and average flows do not differ substantially between intake screen bays.

Table 5. Post-modification Velocity Profiles - Velocities Obtained From The Following Report: Approach Canal Dredging Project (White Paper Report)
April 15, 2004

Blowdown (cfs)	**River Level (ft)**	**Average Velocity At Center of Bays (fps)**								**Average Velocity Across All Bays (fps)**
		128	**127**	**126**	**125**	**124**	**123**	**122**	**121**	
1006	674.6	0.388	0.557	0.599	0.415	0.522	0.420	0.490	0.454	0.481
815	674.6	0.337	0.373	0.349	0.427	0.356	0.346	0.356	0.349	0.362

Blowdown (cfs)	**River Level (ft)**	**Average Calculated Through-Screen Velocity* (Coarse Mesh) (fps)**								**Average Through-Screen Velocity For All Screens (fps)**
		128	**127**	**126**	**125**	**124**	**123**	**122**	**121**	
1006	674.6	0.807	1.159	1.246	0.864	1.086	0.874	1.020	0.945	1.000
815	674.6	0.701	0.776	0.726	0.888	0.741	0.720	0.741	0.726	0.752

Blowdown (cfs)	River Level (ft)	Average Calculated Through-Screen Velocity* (Fine Mesh) (fps)								Average Through-Screen Velocity For All Screens (fps)
		128	127	126	125	124	123	122	121	
1006	674.6	0.899	1.291	1.388	0.962	1.210	0.973	1.135	1.052	1.114
815	674.6	0.781	0.864	0.809	0.989	0.825	0.802	0.825	0.809	0.838

*Equation used for Calculation: TSV = Q/(D*OA*TW*K)

Where:

TSV = Through Screen Velocity

Q = Flow Rate (Calculated from velocities at center of bays, Q = V*A)

D = Water Depth (River Level - Bottom of Bays = 26.1 ft)

OA = Open Area of Screen (Obtained from Table, .610 coarse and .548 fine)

TW = Nominal Tray Width, (10 ft)

K = Through Flow Screen Constant (396)

3.3 PINGP Water Appropriation and NPDES/SDS Permit Allowances

In accordance with the National Pollutant Discharge Elimination System (NPDES)/State Disposal System (SDS) permit, PINGP's intake flows are controlled indirectly by imposing limitations on the circulating water (SD-001) discharge flows. The discharge restrictions are presented in Table 6 and, as shown, are implemented during the spawning season. The goal of these restrictions is to minimize the impingement of fish, larval fish, and eggs on vertical traveling screens.

Table 6. NPDES Discharge Limitations

Date	Discharge Restriction (MGD)	River Flow (cfs)
April 15 - 30	194 (300 cfs)	≥ 15,000
	97 (150 cfs)	< 15,000
May 1 - 31	194 (300 cfs)	NA
June 1 - 15	259 (400 cfs	NA
June 16 - 30	517.5 (800 cfs)	NA
July – April 14	Not restricted	NA

4.0 Fish Protection Technologies and Measures

Table 7 identifies the fish protection technologies and measures used at PINGP to minimize impingement and entrainment and meet the performance standards. A more in-depth review on the operation of the technologies will be submitted in the Technology Installation and Operation Plan. Specifications for the measures and technologies listed below are included in Appendix C.

Table 7. Fish Protection Technologies and Measures Used at PINGP.

Technology/Measure	**Description**
Fine mesh screens (0.5mm)	Fine mesh screens, installed April through August, prevents entrainment of fish eggs and larvae into the cooling system during peak spawning months.
Discharge Restrictions	Discharge restrictions indirectly control intake flows and are implemented during peak spawning months, thus minimizing impingement of eggs, larval fish, and juvenile fish.
Low-Pressure Screen Wash	A low-pressure screen wash is used to gently remove accumulated eggs, larvae, and juveniles from the screens, thus minimizing harm that may occur to them during the removal process.
Fish Buckets	The vertical traveling screens are equipped with fish lift buckets, allowing fish to remain in water during the screen wash process.
Continuous Screen Wash	During fine mesh operation, the traveling screens are continuously washed/rotated at 3 fpm. This decreases the length of time eggs, larvae, and juveniles are impinged on the screens and further minimizes harm that may occur while impinged.

5.0 Impingement and Entrainment

Impingement performance standards are defined as a reduction in impingement mortality for all life stages of fish and shellfish by 80 to 95 percent from the calculation baseline. Entrainment performance standards are defined as the reduction of entrainment of all life stages of fish and shellfish by 60 to 90 percent from the calculation baseline.

Calculation baseline means an estimate of impingement mortality and entrainment that would occur at the site assuming that:

a. The cooling water system has been designed as a once-through system;
b. The opening of the cooling water intake structure is located at, and the face of the standard 3/8-inch mesh traveling screen is oriented parallel to, the shoreline near the surface of the source waterbody;
c. The baseline practices, procedures, and structural configuration are those that your facility would maintain in the absence of any structural or operational controls including flow or velocity reductions, implemented in whole or in part for the purposes of reducing impingement mortality and entrainment.

During the period April 1 through August 31, Prairie Island is required to operate the intake vertical traveling screens in continuous mode and using fine-mesh (0.5 mm) screen material in order to minimize entrainment of larval fish, fish eggs, and other aquatic organisms. In addition, intake flows are limited from April 15 through June 30 in order to minimize the impingement of fish and fish larvae. During the remaining months (September through March) when entrainment of larval fish and eggs is not expected standard 3/8-inch mesh screens are installed. The fish handling and return system is in service during both time periods.

Based on survival studies, sampling induced mortality studies, and operational measures, design and construction technologies at PINGP are already in place to meet the impingement standards set forth by the 316(b) rule. Survival of juvenile and larger fish sampled from fine mesh screens is 71.5 percent. In addition, studies to determine sampling induced mortality determined that nearly 10 percent of mortality to juvenile fish (15 percent mortality for all life stages) is caused by the sampling method. With sampling mortality factored in, over 80 percent survivorship is expected from PINGP fine mesh screens. If operational measures are factored in, it can be assumed that overall fish survivorship of the community is increased since fewer fish overall are being impinged. During the peak larval density period (May and June), PINGP intake flows are limited to 20 to 30 percent of design flow. The assumption can be made that during these months only one-third of the fish that would have been impinged (if operating at design flow) are being impinged resulting in increased overall survivorship.

Due to the use of 0.5 mm (fine) mesh screens at the intake screenhouse from April through August entrainment standards are met at Prairie Island. It has been documented from larval studies conducted at PINGP that 0.5 mesh screens collects eggs and larvae of all fish expected to be encountered in the naturally occurring drift from the Mississippi River community within the vicinity of the plant. In addition to preventing entrainment of eggs and larvae, fine mesh screens limit the establishment of a resident population of fish in the intake and recycle canals and subsequent potential for cold-shock mortality. A more detailed review can be found in the PINGP Impingement Mortality and Entrainment Study.

6.0 References

NSP. 1984. Prairie Island Nuclear Generating Plant Environmental Monitoring Program 1984 Annual Report. Northern States Power Company, Minneapolis, MN.

Staley, M.T. 2004. Approach Canal Dredging Report. White Paper Report

Figures

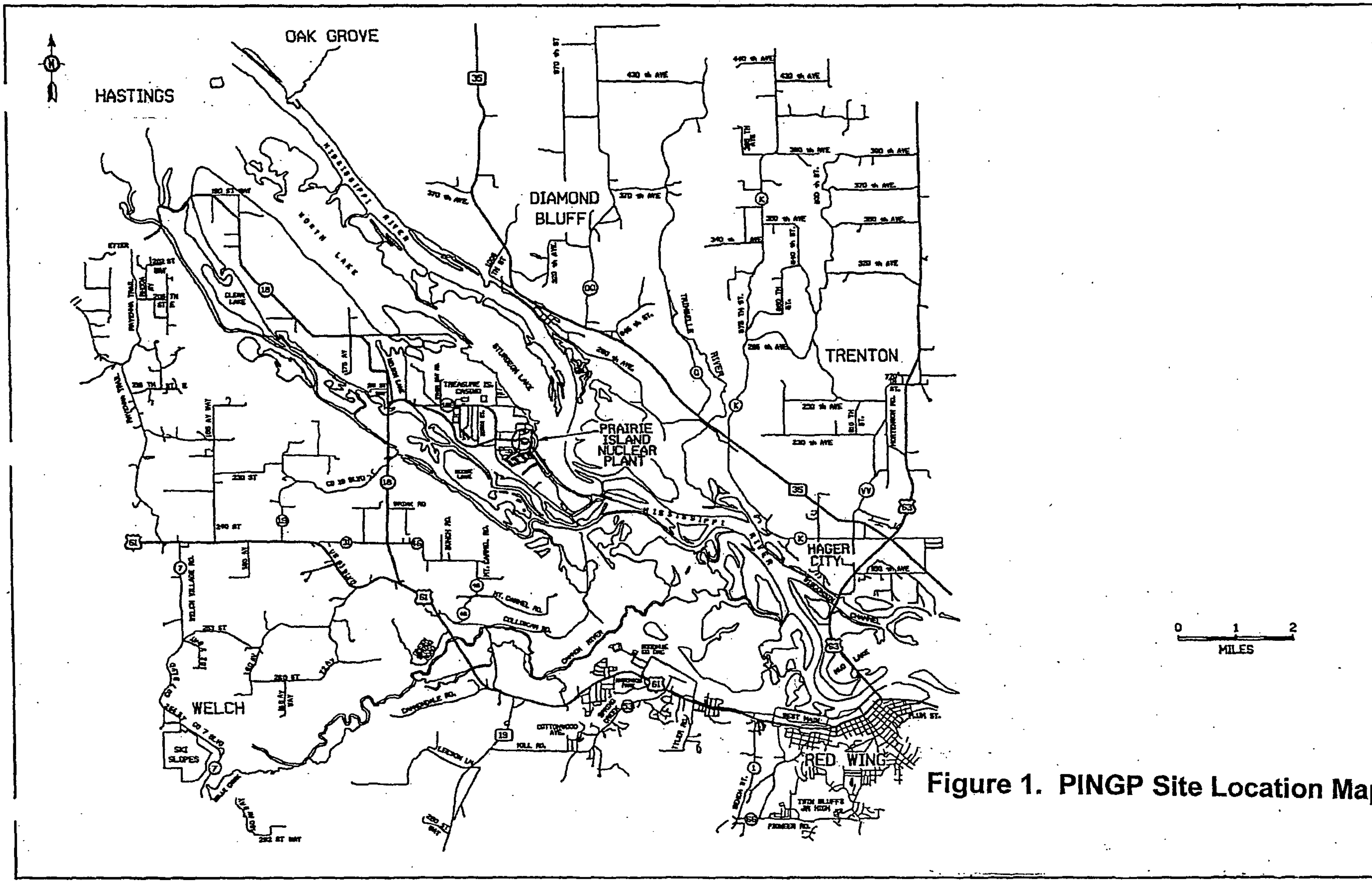


Figure 1. PINGP Site Location Map

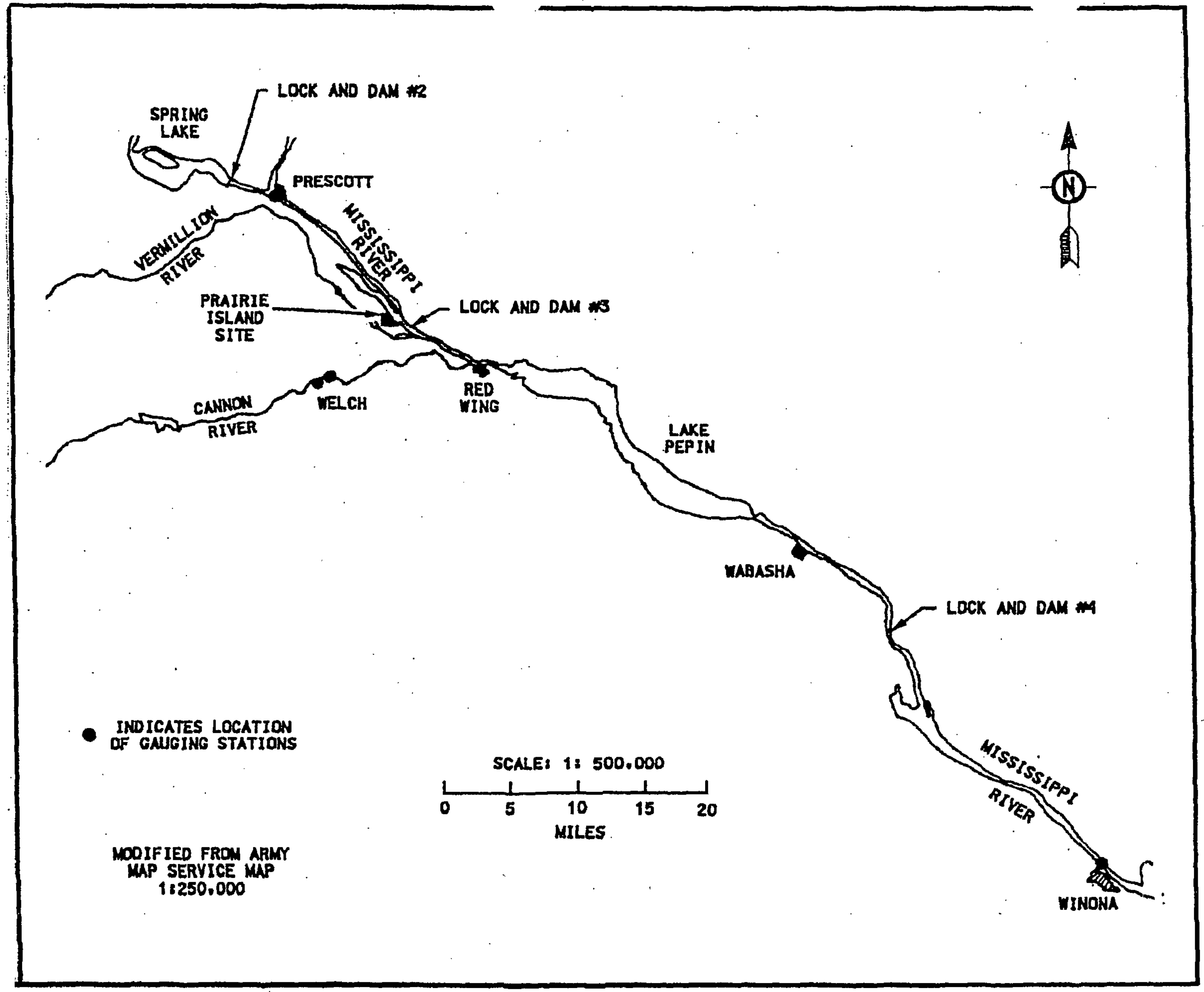


Figure 2. Principal Surface Waters in the Vicinity of PINGP

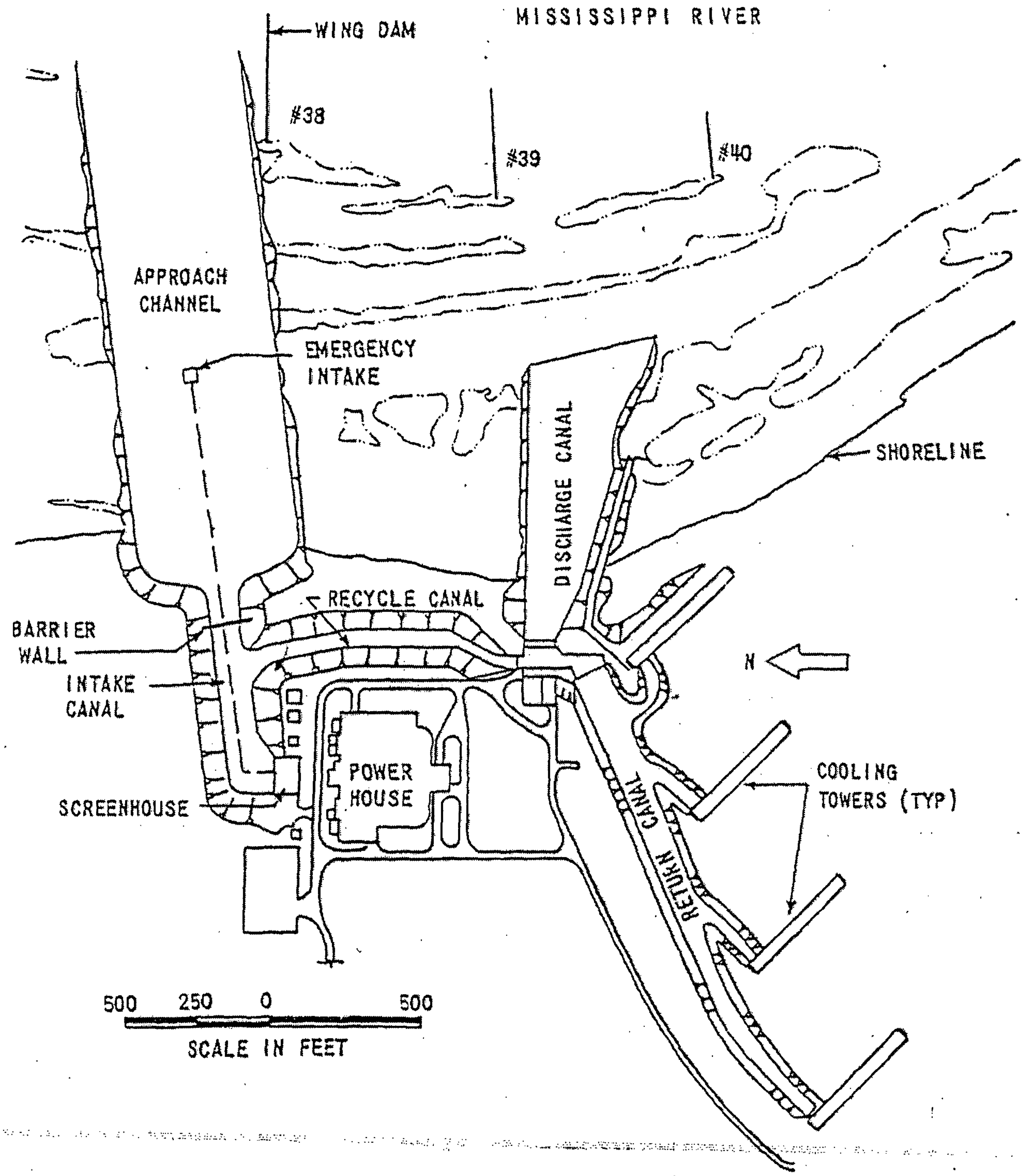


Figure 3. Pre-Modification Intake Screenhouse and Discharge Canal

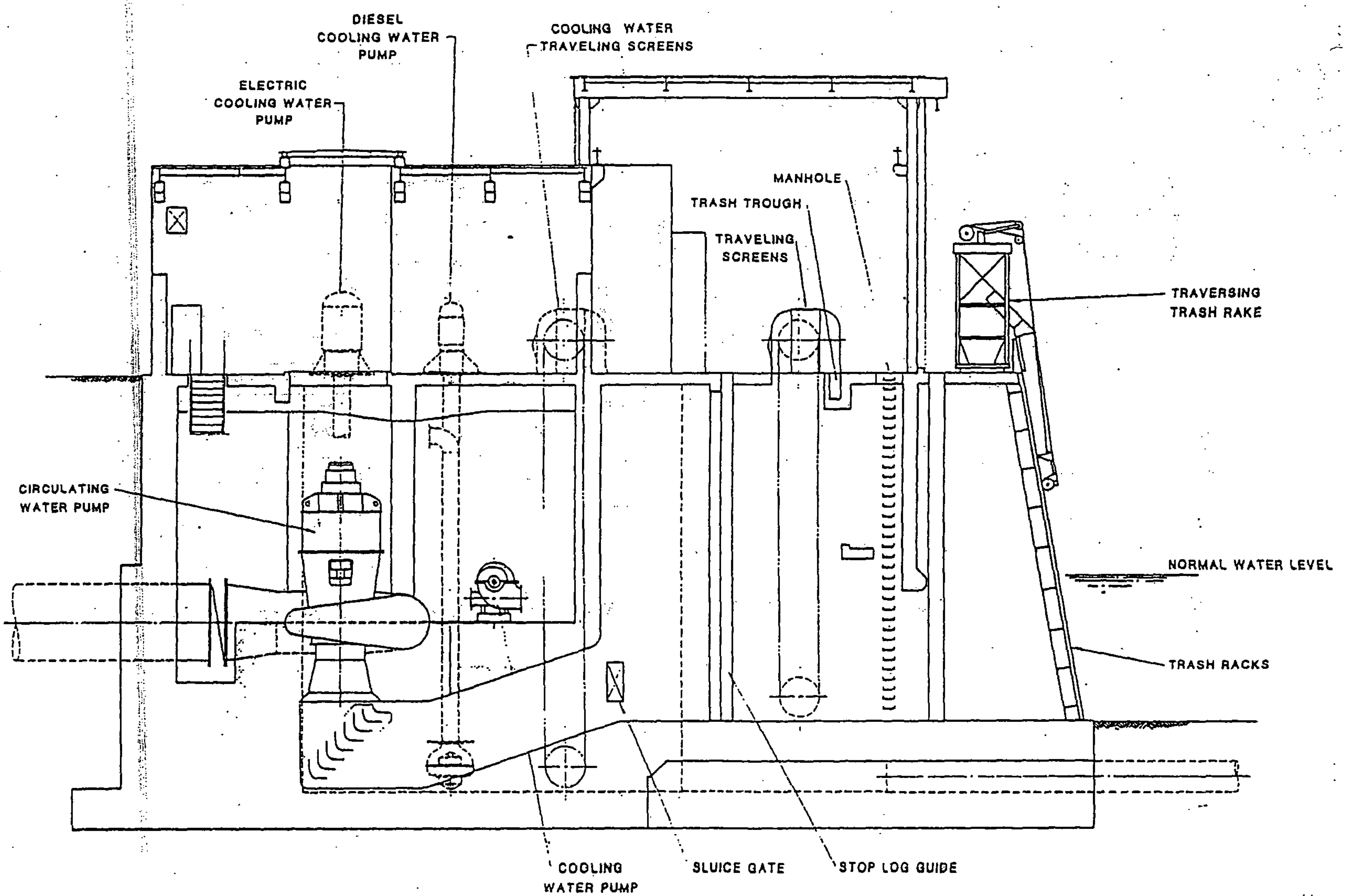


Figure 4. Plant Screenhouse

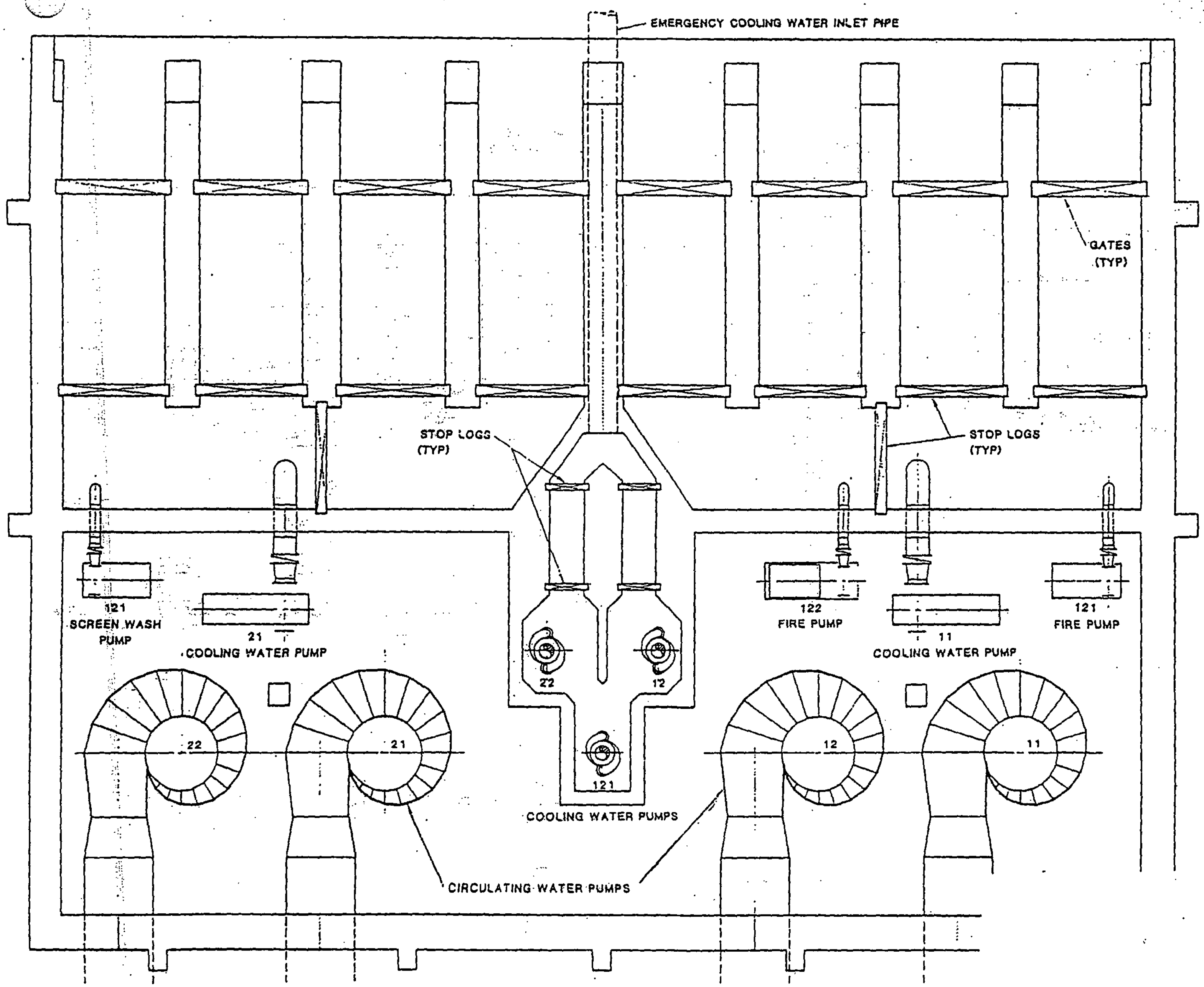
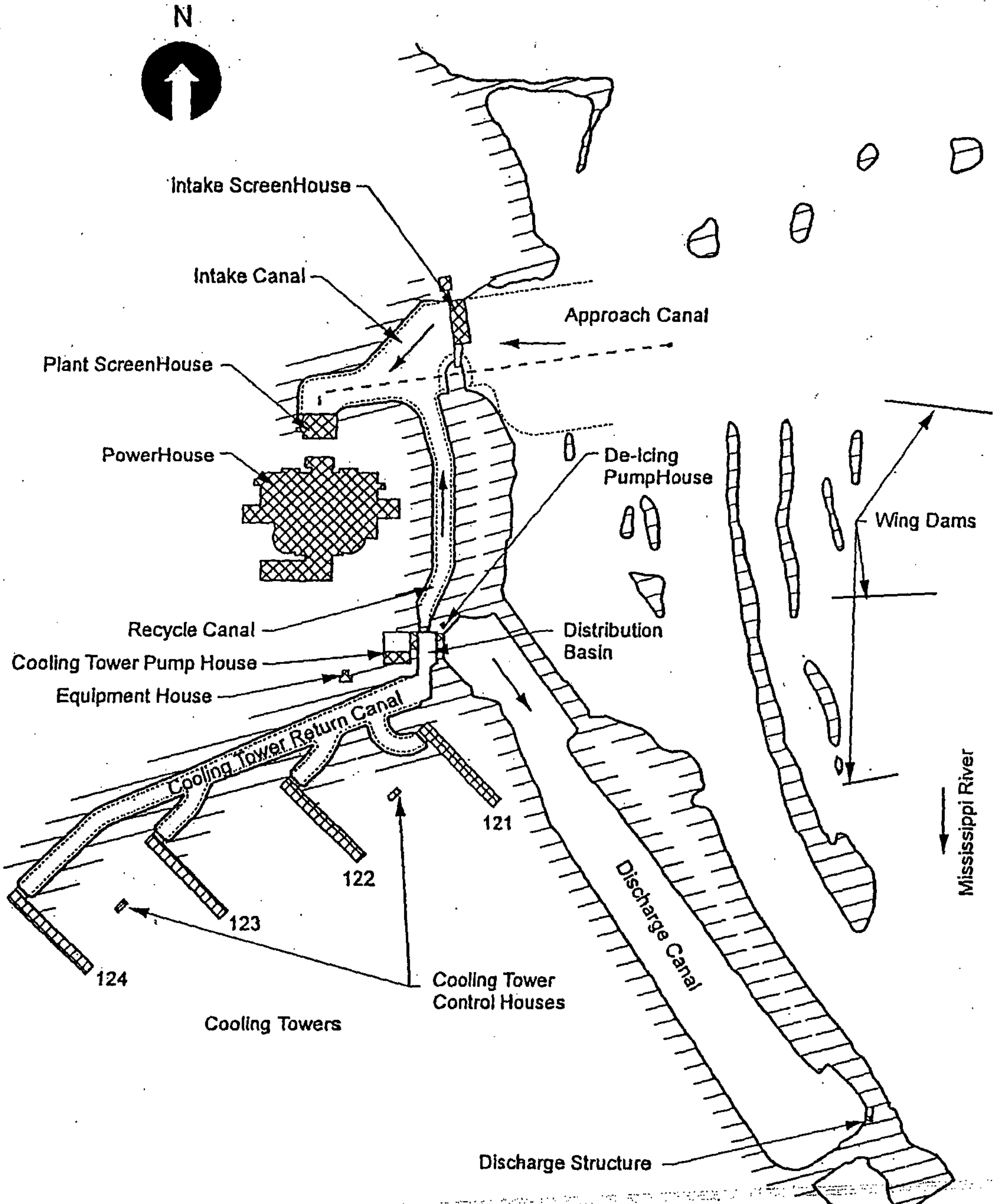


Figure 5. Circulating Water Pumps

Figure 6. Circulating Water System



Appendix A--Operating Reports

2000 PINGP Operating Report

Availability

Month	Period Hours Unit 1	Period Hours Unit 2	Reactor Critical Hrs Unit 1	Reactor Critical Hrs Unit 2	Reactor Reserve Shutdown Hrs Unit 1	Reactor Reserve Shutdown Hrs Unit 2	Generator On-line Hrs Unit 1	Generator On-line Hrs Unit 2	Reserve Shutdown Hrs Unit 1	Reserve Shutdown Hrs Unit 2	Forced Outage Hrs Unit 1	Forced Outage Hrs Unit 2	Service Factor Unit 1	Service Factor Unit 2	Availability Factor Unit 1	Availability Factor Unit 2
January	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100
February	696	696	696	696	0	0	696	696	0	0	0	0	100	100	100	100
March	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100
April	719	719	719	669.7	0	0	719	669.7	0	0	0	0	100	93.1	100	93.1
May	744	744	744	0	0	0	744	0	0	0	0	0	100	0	100	0
June	720	720	720	587.5	0	0	720	550.7	0	0	0	0	100	76.5	100	76.5
July	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100
August	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100
September	720	720	720	720	0	0	720	720	0	0	0	0	100	100	100	100
October	745	745	745	745	0	0	745	745	0	0	0	0	100	100	100	100
November	720	720	720	720	0	0	720	720	0	0	0.	0	100	100	100	100
December	744	744	465.8	744	0	0	459.7	744	0	0	0	0	61.8	100	61.8	100

Outage and Power Reduction Occurrences

Month	Date Unit 1	Date Unit 2	Type Unit 1	Type Unit 2	Hours Unit 1	Hours Unit 2	Reason Unit 1	Reason Unit 2	Method Unit 1	Method Unit 2	LER Number Unit 1	LER Number Unit 2	System Unit 1	System Unit 2	Component Unit 1	Component Unit 2
March	3/11/2000		S		0		B		5		N/A		N/A		N/A	
April		4/28/2000		S		49.3		C		3		20001		N/A		N/A
May	5/28/200	5/31/2000	S	S	0	744	B	C	5	4	N/A	N/A	N/A	N/A	N/A	N/A
June		6/8/2000		S		169.3		C		4		N/A		N/A		N/A
August	9/16/2000	9/23/2000	S	S	0	0	B	B	5	5	N/A	N/A	N/A	N/A	N/A	N/A
December	12/1/2000	12/22/2000	S	S	284.3	0	B	B	1	5	N/A	N/A	N/A	N/A	N/A	N/A
December	36887		S		0		C		5		N/A		N/A		N/A	

Performance

Month	Gross Thermal (MWH) Unit 1	Gross Thermal (MWH) Unit 2	Gross Electrical (MWH) Unit 1	Gross Electrical (MWH) Unit 2	Net Electrical (MWH) Unit 1	Net Electrical (MWH) Unit 2	Capacity Factor (MDC NET) Unit 1	Capacity Factor (MDC NET) Unit 2	Capacity Factor (DER NET) Unit 1	Capacity Factor (DER NET) Unit 2
January	1225051	1224774	427760	426750	407481	407195	104.9	104.8	102.2	102.1
February	1143720	1145494	399880	399020	381040	380726	104.9	104.8	102.1	102.1
March	1205735	1220708	420040	425050	399735	40536	102.9	104.3	100.2	101.6
April	1184386	1103821	404090	376870	380487	355144	101.4	94.6	98.7	92.2
May	1218951	0	416540	0	393584	-3125	101.3	-0.8	98.7	-0.8
June	1184386	848507	401100	286490	378041	266125	100.6	70.8	98	69
July	1224035	1226072	414180	414180	390053	389976	100.4	100.4	97.8	97.8
August	1224035	1226072	414720	414740	390590	390547	100.6	100.6	97.9	97.9
September	1161003	1178369	398360	404990	376813	383356	100.3	102	97.6	99.3
October	1222001	1224042	426680	426120	405382	404977	104.2	104.1	101.5	101.4
November	1184386	1184458	413660	413110	394064	393570	104.8	104.7	102.1	102
December	730964	1222012	254310	425690	239235	405407	61.6	104.4	60	101.7

MDC = Maximum Dependable Capacity

DER = Design Electrical Rating

Outage Occurrence Key

Type	Reason	Method
F - Forced	A - Equip. Failure	1 - Manual
S - Scheduled	B - Maint. Or Test	2 - Man. Trip
	C - Refueling	3 - Auto Trip
	D - Regulatory Restriction	4 - Continued
	E - Operator Training and License Examination	5 - Reduced Load
	F - Administrative	9 - Other
	G - Operational Error	
	H - Other	

2001 PINGP Operating Report

Availability

Month	Period Hours Unit 1	Period Hours Unit 2	Reactor Critical Hrs Unit 1	Reactor Critical Hrs Unit 2	Reactor Reserve Shutdown Hrs Unit 1	Reactor Reserve Shutdown Hrs Unit 2	Generator On-line Hrs Unit 1	Generator On-line Hrs Unit 2	Reserve Shutdown Hrs Unit 1	Reserve Shutdown Hrs Unit 2	Forced Outage Hrs Unit 1	Forced Outage Hrs Unit 2	Service Factor Unit 1	Service Factor Unit 2	Availability Factor Unit 1	Availability Factor Unit 2
January	744	744	454.4	744	0	0	453.6	744	0	0	0	0	61	100	61	100
February	672	672	106.2	672	0	0	73	672	0	0	0	0	10.9	100	10.9	100
March	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100
April	719	719	719	719	0	0	719	719	0	0	0	0	100	100	100	100
May	744	744	744	212.1	0	0	744	212.1	0	0	0	531.9	100	28.5	100	28.5
June	720	720	720	629.6	0	0	720	596.7	0	0	0	123.3	100	82.9	100	82.9
July	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100
August	744	744	16.1	744	0	0	10.2	744	0	0	733.8	0	1.4	100	1.4	100
September	720	720	480.8	720	0	0	474.9	720	0	0	245.1	0	66	100	66	100
October	745	745	745	735.2	0	0	745	735.2	0	0	0	9.8	100	98.7	100	98.7
November	720	720	720	684.1	0	0	720	657.1	0	0	0	62.9	100	91.3	100	91.3
December	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100

Outage and Power Reduction Occurrences

Month	Date Unit 1	Date Unit 2	Type Unit 1	Type Unit 2	Hours Unit 1	Hours Unit 2	Reason Unit 1	Reason Unit 2	Method Unit 1	Method Unit 2	LER Number Unit 1	LER Number Unit 2	System Unit 1	System Unit 2	Component Unit 1	Component Unit 2
January	1/1/2001		S		0		C		5		N/A		N/A		N/A	
January	1/19/2001		S		290.4		C		1		N/A		N/A		N/A	
February	2/25/2001		S		0		C				N/A		N/A		N/A	
February	2/25/2001		S		599		C				N/A		N/A		N/A	
March		3/28/2001		S		0		B		5		N/A		N/A		N/A
April	4/1/2001	4/6/2001	S	S	0	0	B	B	5	5	N/A	N/A	N/A	N/A	N/A	N/A
April	4/4/2001		S		0		.B		5		N/A		N/A		N/A	
May		5/9/2001		F		531.9		A		2		20103		N/A		N/A
June	6/17/2001	6/1/2001	S	F	0	123.3	B	A	5	4	N/A	20103	N/A	N/A	N/A	N/A
July		7/27/2001		S		0		B		5		N/A		N/A		N/A
August	8/1/2001		F		58.5		A		3		10104		N/A		N/A	
August	8/3/2001		F		675.3		A		3		10105		N/A		N/A	
September	9/1/2001		F		245.1		A		4		N/A		N/A		N/A	
October		10/27/2001		S		0		B		5		N/A		N/A		N/A
October		10/31/2001		F		9.8		A		2		20105		N/A		N/A
November		11/1/2001		F		62.9		A		4		N/A		N/A		N/A
December	12/2/2001		S		0		B		5		N/A		N/A		N/A	

Performance

Month	Gross Thermal (MWH) Unit 1	Gross Thermal (MWH) Unit 2	Gross Electrical (MWH) Unit 1	Gross Electrical (MWH) Unit 2	Net Electrical (MWH) Unit 1	Net Electrical (MWH) Unit 2	Capacity Factor (MDC NET) Unit 1	Capacity Factor (MDC NET) Unit 2	Capacity Factor (DER NET) Unit 1	Capacity Factor (DER NET) Unit 2
January	647600	1224042	224960	426980	212043	406394	54.6	104.6	53.2	101.9
February	78244	1105291	27260	385610	22630	366841	6.5	104.6	6.3	101.8
March	1225489	1222012	427400	425540	407267	405184	104.9	104.3	102.1	101.6
April	1167568	1157054	405980	401380	386636	382227	103	101.8	100.3	99.2
May	1226505	348131	419110	118000	395690	105860	101.9	27.3	99.2	26.5
June	1183826	957107	400860	321560	377528	299425	100.4	79.7	97.8	77.6
July	1225489	1191563	413910	399190	389713	375369	100.3	96.7	97.7	94.1
August	14226	1224042	5920	412610	1865	388170	0.5	99.9	0.5	97.3
September	751958	1184458	257080	406780	241264	385371	64.2	102.5	62.5	99.9
October	1225489	1205773	427010	419230	406648	398956	104.6	102.6	101.8	99.9
November	1185859	1061648	413300	369620	394146	351076	104.9	93.4	102.1	91
December	1223457	1224042	426550	425930	406311	406091	104.6	104.6	101.9	101.8

Outage Occurrence Key

Type	Reason	Method
F - Forced	A - Equip. Failure	1 - Manual
S - Scheduled	B - Maint. Or Test	2 - Man. Trip
	C - Refueling	3 - Auto Trip
	D - Regulatory Restriction	4 - Continued
	E - Operator Training and License Examination	5 - Reduced Load
		9 - Other
	F - Administrative	
	G - Operational Error	
	H - Other	

MDC = Maximum Dependable Capacity

DER = Design Electrical Rating

2002 PINGP Operating Report

Availability

Month	Period Hours		Reactor Critical Hrs		Reactor Reserve Shutdown Hrs		Generator On-line Hrs		Reserve Shutdown Hrs		Forced Outage Hrs		Service Factor		Availability Factor	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
January	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100
February	672	672	672	22	0	0	672	21.2	0	0	0	0	100	3.2	100	3.2
March	744	744	744	740.1	0	0	744	717.7	0	0	0	0	100	96.5	100	96.5
April	719	719	719	719	0	0	719	719	0	0	0	0	100	100	100	100
May	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100
June	720	720	720	720	0	0	720	720	0	0	0	0	100	100	100	100
July	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100
August	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100
September	720	720	720	720	0	0	720	720	0	0	0	0	100	100	100	100
October	745	745	745	745	0	0	745	745	0	0	0	0	100	100	100	100
November	720	720	356.3	720	0	0	356.3	720	0	0	0	0	49.5	100	49.5	100
December	744	744	635	744	0	0	616.7	744	0	0	0	0	82.9	100	82.9	100

Outage and Power Reduction Occurrences

Month	Date		Type		Hours		Reason		Method		LER Number		System		Component	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
January	1/19/2002	1/18/2002	S	S	0	0	B	C	5	5	N/A	N/A	N/A	N/A	N/A	N/A
February		2/1/2002		S		650.8		C		1		N/A		N/A		N/A
March		3/1/2002		S				C		4		N/A		N/A		N/A
April	4/20/2002	4/27/2002	S	S	0	0	B	B	5	5	N/A	N/A	N/A	N/A	N/A	N/A
June	6/24/2002		F		0		A		5		N/A		N/A		N/A	
July	7/1/2002	7/13/2002	F	S	0	0	A	B	5	5	N/A	N/A	N/A	N/A	N/A	N/A
July	7/20/2002		S		0		B		5		N/A		N/A		N/A	
October		10/27/2002		S		0		B		5		N/A		N/A		N/A
November	11/15/2002		S		363.7		C		2		202		N/A		N/A	
December	12/1/2002		S		127.3		C		4		N/A		N/A		N/A	
December	12/8/2002		S		0		C		5		N/A		N/A		N/A	

Performance

Month	Gross Thermal (MWH)		Gross Electrical (MWH)		Net Electrical (MWH)		Capacity Factor (MDC NET)		Capacity Factor (DER NET)	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
January	1222440	1195623	426500	416430	406257	396675	104.6	102.1	101.9	99.5
February	1106598	31464	385330	10200	366746	7134	104.6	2	101.8	2
March	1224473	1142075	426850	396640	406784	377034	104.7	97.1	102	94.5
April	1161471	1167545	399310	401040	377603	379314	100.6	101.1	98	98.4
May	1225489	1225616	415710	417510	391759	393180	100.9	101.2	98.2	98.6
June	1185859	1185883	396300	399320	372871	375754	99.2	100	96.6	97.4
July	1222440	1221541	405700	410130	381434	385629	98.2	99.3	95.6	96.7
August	1225489	1225616	410870	415600	387132	391728	99.7	100.9	97.1	98.2
September	1185859	1185883	400590	405240	378538	384044	100.7	102.2	98.1	99.5
October	11224473	1221541	421790	425300	401398	405529	103.2	104.3	100.5	101.6
November	566001	1185883	195070	412780	184789	393411	49.2	104.7	47.9	101.9
December	965930	1225616	335660	426240	317923	406601	81.9	104.7	79.7	102

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Outage Occurrence Key

Type	Reason	Method
F - Forced	A - Equip. Failure	1 - Manual
S - Scheduled	B - Maint. Or Test	2 - Man. Trip
	C - Refueling	3 - Auto Trip
	D - Regulatory Restriction	4 - Continued
	E - Operator Training and License Examination	5 - Reduced Load
	F - Administrative	9 - Other
	G - Operational Error	
	H - Other	

2003 PINGP Operating Report

Availability

Month	Period Hours		Reactor Critical Hrs		Reactor Reserve Shutdown Hrs		Generator On-line Hrs		Reserve Shutdown Hrs		Forced Outage Hrs		Service Factor		Availability Factor	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
January	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100
February	672	672	672	672	0	0	672	672	0	0	0	0	100	100	100	100
March	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100
April	719	719	719	719	0	0	578.6	719	0	0	140.4	0	80.5	100	80.5	100
May	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100
June	720	720	720	720	0	0	720	720	0	0	0	0	100	100	100	100
July	744	744	74	744	0	0	744	744	0	0	0	0	100	100	100	100
August	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100
September	720	720	720	286	0	0	720	284.5	0	0	0	0	100	39.5	100	39.5
October	745	745	745	539.6	0	0	745	479.6	0	0	0	44.7	100	64.4	100	64.4
November	720	720	720	720	0	0	720	720	0	0	0	0	100	100	100	100
December	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100

Outage and Power Reduction Occurrences

Month	Date		Type		Hours		Reason		Method		LER Number		System		Component	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
January		1/11/2003		S		0		B		5		N/A		N/A		N/A
March	3/1/2003	3/24/2003	S	F	0	0	B	A	5	5	N/A	N/A	N/A	N/A	N/A	N/A
April	4/15/2003	4/5/2003	F	S	140.4	0	A	B	1	5	N/A	N/A	N/A	N/A	N/A	N/A
September		9/12/2003		S		0		C		5		N/A		N/A		N/A
September		9/12/2003		S		435.5		C		2		N/A		N/A		N/A
October	10/26/2003	10/1/2003	S	S	0	220.7	B	C	5	4	N/A	N/A	N/A	N/A	N/A	N/A
October		10/10/2003		S		0		C		5		N/A		N/A		N/A
October		10/12/2003		F		44.7		A		1		N/A		N/A		N/A
October		10/14/2003		S		0		C		5		N/A		N/A		N/A
November	11/8/2003		S		0		B		5		N/A		N/A		N/A	

Performance

Month	Gross Thermal (MWH)		Gross Electrical (MWH)		Net Electrical (MWH)		Capacity Factor (MDC NET)		Capacity Factor (DER NET)	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
January	1223444	1206259	426720	419520	406758	399764	104.7	102.9	102	100.2
February	1105374	1106417	385150	383770	366868	366048	104.6	104.4	101.9	101.6
March	1205847	1224598	415140	425040	395246	405369	103.6	104.4	99.1	101.7
April	948627	1164488	325840	400790	305093	379274	82.7	101.1	79.2	98.4
May	1224462	1223579	415640	415720	391840	392061	100.9	101	98.3	98.3
June	1181712	1183846	397700	398810	374330	375711	99.6	100	97	97.4
July	1214283	1223579	411070	412060	386875	388291	99.6	100	97	94.4
August	1217337	1206259	410480	404630	386312	380845	99.5	98.1	96.9	95.5
September	1184766	405482	406030	136160	383913	125415	102.1	33.4	99.5	32.5
October	1221408	712309	424120	246050	403523	230714	103.8	59.3	101.1	57.8
November	1179677	1186163	410310	411500	390258	391654	103.8	104.2	101.1	101.5
December	1221408	1225905	425370	425570	405331	405825	104.4	104.5	101.6	101.8

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Outage Occurrence Key

Type	Reason	Method
F - Forced	A - Equip. Failure	1 - Manual
S - Scheduled	B - Maint. Or Test	2 - Man. Trip
	C - Refueling	3 - Auto Trip
	D - Regulatory Restriction	4 - Continued
	E - Opeartor Training and License Examination	5 - Reduced Load
	F - Administrative	9 - Other
	G - Operational Error	
	H - Other	

2004 PINGP Operating Report

Availability

Month	Period Hours Unit 1	Period Hours Unit 2	Reactor Critical Hrs Unit 1	Reactor Critical Hrs Unit 2	Reactor Reserve Shutdown Hrs Unit 1	Reactor Reserve Shutdown Hrs Unit 2	Generator On-line Hrs Unit 1	Generator On-line Hrs Unit 2	Reserve Shutdown Hrs Unit 1	Reserve Shutdown Hrs Unit 2	Forced Outage Hrs Unit 1	Forced Outage Hrs Unit 2	Service Factor Unit 1	Service Factor Unit 2	Availability Factor Unit 1	Availability Factor Unit 2
January	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100
February	696	696	696	696	0	0	696	696	0	0	0	0	100	100	100	100
March	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100
April	719	719	719	719	0	0	719	719	0	0	0	0	100	100	100	100
May	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100
June	720	720	720	720	0	0	720	720	0	0	0	0	100	100	100	100
July	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100
August	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100
September	720	720	236.7	720	0	0	236.5	720	0	0	0	0	32.8	100	32.8	100
October	745	745	0	745	0	0	0	745	0	0	0	0	0	100	0	100
November	720	720	204	682.8	0	0	182.3	673.6	0	0	0	46.4	25.3	93.6	25.3	93.6
December	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100

Outage and Power Reduction Occurrences

Month	Date Unit 1	Date Unit 2	Type Unit 1	Type Unit 2	Hours Unit 1	Hours Unit 2	Reason Unit 1	Reason Unit 2	Method Unit 1	Method Unit 2	LER Number Unit 1	LER Number Unit 2	System Unit 1	System Unit 2	Component Unit 1	Component Unit 2
February	2/20/2004		S		0		B		5		N/A		N/A		N/A	
April		4/2/2004		S		0		B		5		N/A		N/A		N/A
June	6/25/2004		S		0		B		5		N/A		N/A		N/A	
July		7/8/2004		F		0		A		5		N/A		VC		2VC1538
August	8/12/2004	8/29/2004	S	S	0	0	C	B	5	5	N/A	N/A	N/A	N/A	N/A	N/A
September	9/1/2004	9/20/2004	S	F	0	0	C	B	5	5	N/A	N/A	N/A	LF	N/A	HCV
September	9/9/2004		F		0		A		5		N/A		EE		N/A	
September	9/10/2004		S		483.5		C		2		N/A		N/A		N/A	
October	10/31/2004	10/6/2004	S	S	745	7.8	C	B	4	5	N/A	N/A	N/A	SM	N/A	P
October		10/31/2004		S		11.9		B		5		N/A		AB		P
November	11/23/2004	11/12/2004	S	S	2.6	14.5	B	B	2	5	N/A	N/A	N/A	SM	N/A	P
November	11/23/2004	11/17/2004	S	F	535.1	46.4	C	A	4	2	N/A	N/A	N/A	BK	N/A	FCU
December		12/27/2004		S		48		B		5		N/A		SN		LIT
December		12/28/2004		S		8.5		B		5		N/A		SM		P

Performance

Month	Gross Thermal (MWH) Unit 1	Gross Thermal (MWH) Unit 2	Gross Electrical (MWH) Unit 1	Gross Electrical (MWH) Unit 2	Net Electrical (MWH) Unit 1	Net Electrical (MWH) Unit 2	Capacity Factor (MDC NET) Unit 1	Capacity Factor (MDC NET) Unit 2	Capacity Factor (DER NET) Unit 1	Capacity Factor (DER NET) Unit 2
January	1224462	1225905	425840	426080	405743	406334	104.5	104.6	101.7	101.9
February	1097232	1145401	380440	398720	362018	380254	99.6	104.7	97	101.9
March	1224462	1224886	426680	426600	406472	406615	104.7	104.7	101.9	102
April	1184766	1155591	403310	395400	380569	373524	101.4	99.5	98.8	96.9
May	1224462	1224886	409160	415610	384758	391824	99.1	100.9	96.5	98.3
June	1132856	1186163	378070	400120	354908	377088	94.4	100.3	92	97.7
July	1224462	1223867	413800	412330	389632	388445	100.3	100	97.7	97.4
August	1130820	1221829	386160	414680	362405	390821	93.3	100.6	90.9	98
September	289067	1185143	98200	403110	88869	380792	23.6	101.3	23	98.7
October	0	1218772	0	421270	0	400770	0	103.1	0	100.4
November	213646	1098525	72210	379290	63242	360646	16.8	96	16.4	93.5
December	1206589	1222848	423460	423050	403526	403151	103.9	103.8	101.2	101.1

MDC = Maximum Dependable Capacity

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Outage Occurrence Key

Type	Reason	Method
F - Forced	A - Equip. Failure	1 - Manual
S - Scheduled	B - Maint. Or Test	2 - Man. Trip
	C - Refueling	3 - Auto Trip
	D - Regulatory Restriction	4 - Continued
	E - Opeartor Training and License Examination	5 - Reduced Load
	F - Administrative	9 - Other
	G - Operational Error	
	H - Other	

2005 PINGP Operating Report

Availability

Month	Period Hours		Reactor Critical Hrs		Reactor Reserve Shutdown Hrs		Generator On-line Hrs		Reserve Shutdown Hrs		Forced Outage Hrs		Service Factor		Availability Factor	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
January	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100
February	672	672	490.6	672	0	0	434	672	0	0	0	0	64.6	100	64.6	100
March	744	744	728.3	706.6	0	0	704.8	706.5	0	0	37.3	37.5	94.7	95	94.7	95
April	719	719	719	296.5	0	0	719	290.4	0	0	0	428.6	100	40.4	100	40.4
May	744	744	74	0	0	0	744	0	0	0	0	142	100	0	100	0
June	720	720	720	504.1	0	0	720	478.4	0	0	0	1.1	100	66.4	100	66.4
July	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100
August	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100
September	720	720	720	720	0	0	704.9	720	0	0	0	0	97.9	100	97.9	100
October	745	745	745	745	0	0	745	745	0	0	0	0	100	100	100	100
November	720	720	720	720	0	0	720	720	0	0	0	0	100	100	100	100
December	744	744	744	744	0	0	744	744	0	0	0	0	100	100	100	100

Outage and Power Reduction Occurrences

Month	Date		Type		Hours		Reason		Method		LER Number		System		Component	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
February	2/19/2005	2/10/2005	S	S	238	9	B	B	2	5	N/A	N/A	TK	SM	GEN	P
March	3/1/2005	3/12/2005	S	S	1.9	0	B	B	2	5	N/A	N/A	TK	N/A	GEN	N/A
March	3/2/2005	3/30/2005	F	F	37.3	37.5	A	A	2	2	N/A	N/A	TG	BK	FCV	FCU
March	3/5/2005		S		0		H		5		N/A		TK		GEN	
April		4/1/2005		F		69.05		A		4		N/A		BK		FCU
April		4/15/2005		F		359.55		A		2		N/A		EK		DG
May		5/1/2005		F		30		A		2		N/A		EK		DG
May		5/2/2005		F		112		A		4		N/A		BP		V
May		5/6/2005		S		602		C		2		N/A		N/A		N/A
June		6/10/2005		F		1.1		B		4		N/A		BQ		NZL
June		6/10/2005		S		238		C		4		N/A		N/A		N/A
June		6/11/2005		S		2.5		B		2		N/A		N/A		N/A
September	9/16/2005		S		15.1		B		2		N/A		TK		GEN	
October		10/13/2005		S		10.96		B		5		N/A		SM		P
November		11/19/2005		S		14.72		B		5		N/A		N/A		N/A
December	12/5/2005		S		256.05		B		5		N/A		ID		N/A	
December	12/28/2005		S		18.62		B		5		N/A		SM		P	

Performance

Month	Gross Thermal (MWH)		Gross Electrical (MWH)		Net Electrical (MWH)		Capacity Factor (MDC NET)		Capacity Factor (DER NET)	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
January	1204554	1223867	420780	422330	401091	402606	103.3	103.7	100.6	101
February	700961	1104639	244980	378740	229863	360939	65.5	102.9	63.8	100.2
March	1090610	1118906	380070	382770	361416	363634	93.1	93.6	90.6	91.2
April	1184207	470796	409230	161480	387458	145892	103.2	38.9	100.5	37.9
May	1223884	0	421140	0	399397	0	102.8	0	100.2	0
June	1184207	743515	400430	246190	377852	227477	100.5	60.5	97.9	58.9
July	1221849	1225630	412630	408840	388698	384530	100.1	99	97.5	96.4
August	1222867	1225630	415780	411400	392165	387600	101	99.8	98.3	97.2
September	1147582	1184945	394130	402860	372048	380822	99	101.3	96.4	98.7
October	1222867	1222578	427680	422620	407165	402132	104.7	103.4	102	100.7
November	1183190	1175791	414290	407390	395008	388277	105.1	103.3	102.4	100.6
December	1220832	1223595	426120	424510	406237	404721	104.6	104.2	101.9	101.5

MDC = Maximum Dependable Capacity

DER = Design Electrical Rating

Outage Occurrence Key

Type	Reason	Method
F - Forced	A - Equip. Failure	1 - Manual
S - Scheduled	B - Maint. Or Test	2 - Man. Trip
	C - Refueling	3 - Auto Trip
	D - Regulatory Restriction	4 - Continued
	E - Opeartor Training and License Examination	5 - Reduced Load
	F - Administrative	9 - Other
	G - Operational Error	
	H - Other	

Appendix B--Intake Studies

ALTERNATIVE INTAKE DESIGNS FOR REDUCTION OF IMPINGEMENT AND ENTRAINMENT MORTALITY PRAIRIE ISLAND NUCLEAR GENERATING PLANT UNITS 1 AND 2

NORTHERN STATES POWER COMPANY

JULY, 1977

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the Laws of the State of Minnesota.

Date July 8 1977 Reg. No. 12547

Stone & Webster Engineering Corporation

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A. INTRODUCTION

In December, 1976, Northern States Power Company authorized Stone & Webster Engineering Corporation to develop conceptual designs of various intake alternatives which would have the potential to reduce fish impingement and ichthyoplankton entrainment at the Prairie Island Nuclear Generating Plant. The basic objectives of the program were as follows:

1. Develop and evaluate designs which would permit utilizing intake flows of up to 1500 cfs (open cycle operation) while maintaining fish impingement and ichthyoplankton entrainment at or below baseline levels associated with the present system operating at a 188 cfs withdrawal rate.

2. Estimate the capital costs of construction and annual maintenance costs for those designs which combine the best potential for biological effectiveness and commercial availability.

This report discusses the results of Stone & Webster's efforts. It includes a description of the present Prairie Island intake design, a discussion of existing impingement and entrainment, a general discussion of the various alternatives evaluated, and a detailed description of three alternative intake designs selected for further consideration at Prairie Island. Also included are order-of-magnitude cost estimates for the three selected designs.

B. SUMMARY AND CONCLUSIONS

The objective of this study was to evaluate alternative intake designs or operational modes which might be employed at the Prairie Island Nuclear Generating Plant to control impingement and entrainment mortality. Specifically, it was desired that the alternative systems be capable of maintaining entrainment and impingement impacts at or below the level which would be associated with a continuous 188 cfs cooling water withdrawal rate with the existing intake (baseline level) but which would allow for operation at withdrawal rates of up to 1500 cfs. The potential for reduction of impact through withdrawal rate reduction during periods of high ichthyoplankton density was also evaluated.

A number of intake alternatives were considered in light of their capabilities to meet the study objectives. Based on results of this study, three alternative schemes were selected which appear to offer the potential to satisfy the objectives. These are the modified traveling screen with fish buckets, the angled flush mounted traveling screen, and the center flow traveling screen.

Each of these alternatives has advantages and disadvantages. The mesh size (0.5 mm) chosen for all schemes and the requirement for continous operation at relatively high speed are disadvantages common to all three systems. The fine mesh presents more potential for clogging than the commonly used 3/8 inch mesh. In addition, it requires that special attention be paid to wash systems and screen mesh reinforcement to prevent distortion or tearing of the mesh due to the pressure of the wash water or heavy debris loading. Continous operation at relatively high speeds is required in order to remove impinged organisms rapidly, thus reducing impingement mortality. Continuous operation results in substantial wear and maintenance problems and requires that specially designed bearings, chains, etc., be used in the construction of the screens.

Modified Traveling Screens with Fish Buckets
With respect to being able to judge biological effectiveness, the modified traveling screen with fish buckets offers the advantage of operational data from the Surry Power Station. At this station, immediate mortality data indicate greater than 90 percent survivorship for a variety of species which are also collected on the existing Prairie Island screens (Section 3.2.1). The basic disadvantages which must be assessed in relation to this mode of operation are that fish are stressed, at least to some extent, by the impingement process and subsequent handling, and that there are no long term mortality data available on which to judge the ultimate fate of the impinged fish.

It is estimated that modified traveling screens with fish buckets would cost $14.5 million to construct and that maintenance costs would be about $120,000 per year. The operation of this system would require about 120 KW of auxiliary power and 1050 MWH of energy on an annual basis.

Angled Screens
Angled screens depend on the diversion of fish along the screen face and into a bypass system through the use of natural behavioral responses of the species involved. The major advantages of this scheme are as follows: (1) operational data indicate that these systems work well for several species (Section 3.2.1), (2) laboratory data indicate up to 100 percent guidance efficiency for species with behavioral characteristics expected to be similar to those of species found at Prairie Island, and (3) the fish remain in the water and are subjected to a minimum of handling.

The basic disadvantage with respect to conclusions drawn regarding this scheme is that it is untested for species considered important at Prairie Island. It is therefore necessary to extrapolate from the reactions of other species in order to assess its potential effectiveness for the species of interest. Should it be found that some of the species of Prairie Island do not guide, the fact that this alternative is equipped with lifting buckets and a fish return system provides a backup whereby the potential for survivorship is enhanced through collection and removal of impinged organisms in a fashion equivalent to that of the modified traveling screen with fish buckets.

The design utilizing angled flush mounted traveling screens is the most expensive scheme evaluated. Construction costs are estimated at $17 million with annual maintenance costs of $140,000. The operation of this system would require about 585 KW of auxiliary power and 5140 MWH of energy annually.

Center Flow Screens

Center flow screens offer the advantage that operating experience with the one U.S. installation indicates that there is relatively low mortality to impinged fish. Should impingement be a problem at Prairie Island, the design of the screen is such that it could remove impinged organisms to a fish transport system in essentially the same fashion as the modified traveling screen. The same disadvantages (impingement and handling stresses) apply to this scheme that apply to the modified traveling screen.

Center flow screens are the least expensive of the alternatives evaluated, costing $7 million to construct and $40,000 per year to maintain. The operation of this system would require about 33 KW of auxiliary power and 290 MWH of energy annually.

Impingement

It is not possible to quantify the potential reduction in number of juvenile and adult fish impinged by each of the alternative designs. The modified traveling and center flow screen designs incorporate a low (0.5 fps) screen approach velocity which should reduce the number of fish impinged. Further, available data indicate that immediate survival values are over 90 percent for a system with a similar mode of operation. The angled traveling screen design, which has a 1.0 fps approach velocity (0.5 fps at the screen face), has proven to be effective in operation, and has shown 100 percent guiding effectiveness for selected species in physical model studies with low (less than 4 percent) resultant mortality. Finally, since all three alternative intakes would be located away from the existing warm water attraction area and would be designed to minimize embayments upstream of the screenhouse, it would appear that the selection of any of these schemes for use at Prairie Island would offer the potential for substantial reduction in impingement mortality relative to the existing intake.

Entrainment

With respect to entrainable fish, it is believed that the use of a fine mesh screen offers the potential for significant reduction of entrainment mortality through the use of proper mesh size, low screen approach velocity, and minimal impingement time. These operating characteristics may be achieved with each of the alternatives discussed above, if the screens are upgraded to withstand continuous operation and modified to incorporate adequate wash systems and spray pressures. It may not be possible to operate continuously at a withdrawal rate of 1500 cfs and hold entrainment impacts to the baseline level. However, based on assumptions set forth in the body of this report (Sections 1.0 and 3.2.2) it may be possible to operate at low withdrawal rates during periods of high ichthyoplankton density (May and June), and at withdrawal rates up to 1500 cfs for the balance of the year while maintaining total annual entrainment mortality levels at those associated with the baseline conditions.

As mentioned above, the potential for reduction of entrainment impact through reduction of makeup flow to 188 cfs during times of high ichthyoplankton density was also evaluated. Data presented in the Prairie Island Section 316(b) demonstration (NUS, 1976) indicate that May and June are the months of greatest ichthyoplankton density. Reduction of flow to 188 cfs during May and June would result in a 30 percent reduction in total yearly ichthyoplankton mortality compared to 1976 levels (Section 3.2.2). Maintainence of the 188 cfs flow during July and August as well would result in an additional 9 percnt (total 39 percent) reduction in total yearly ichthyoplankton mortality i.e. approximately 77 percent of the mortality reduction would be obtained in June.

Conclusions

In conclusion, it is believed that any of the alternative designs discussed in this report would reduce impingement and entrainment losses from existing levels. Each has inherent advantages and disadvantages with respect to biological and/or economic considerations. From the point of view of biological effectiveness, it is not possible at this time to compare the merits of the various schemes in terms of numbers of fish saved. There are, however, decided differences in the costs of these schemes. The center flow screens would cost approximately $7 million as compared to $14.5 million for modified traveling screens with fish buckets and $17 million for angled flush mounted traveling screens. Therefore, while all three schemes would require further investigations and more detailed development of design criteria prior to use at Prairie Island, if only one scheme were to be further evaluated it would appear most cost-effective to concentrate this effort on the center flow design.

1.0 ASSUMPTIONS

A number of assumptions were made regarding the effectiveness of various screening systems with respect to impingement and entrainment of aquatic organisms.

Impingement

With respect to reduction of impingement mortality, the two basic assumptions are that all species considered important (Section 2.2) will guide along an angled screen to a bypass and that juveniles and adults of these species (with the possible exception of gizzard shad) are relatively hardy and can survive short term impingement and pumping.

While few data are available regarding ability to guide the specific organisms in question along an angled screen, past studies indicate guidance efficiencies of up to 100 percent (Schuler, 1973; Schuler and Larson, 1974; Taft et al, 1976) over a range of temperatures and screen approach velocities for a diverse assemblage of species. With regard to the assumption of relative hardiness, operational data on immediate mortality from the Surry Power Station indicate greater than 90 percent survivorship (Section 3.2.1) for species found at Prairie Island when impinged on screens modified to incorporate a fish handling and return system.

Other assumptions made with respect to impingement are that all new structures (both intake and fish return) will be unaffected by thermal effluent (thus avoiding adverse effects of cold stress during periods of plant shutdown) and that available impingement data are indicative of long term trends at Prairie Island.

Entrainment

Major assumptions concerning entrainment are that all ichthyoplankton or entrainable fish are passive organisms and cannot be diverted through their own swimming efforts, that 0.5 mm mesh will collect eggs and larvae of all important species, and that the potential exists for relatively high survival of these organisms once they are impinged. While no data are available to support the first of these assumptions, this represents a conservative approach to the problem of assessing entrainment mortality since it implies that these organisms will either be entrained or impinged, depending on the size of screen mesh utilized and that stresses cannot be reduced through guidance of these organisms. The second assumption can be substantiated through examination of egg diameters and larval hatching size of species found at Prairie Island (Table 3.2-1). The assumption concerning survivorship of impinged fish larvae is perhaps most crucial to the problem of reducing entrainment mortality. In support of this assumption, data from a TVA study (Tomljanovich, Heuer, and Voightlander, 1976) indicate that for smallmouth and largemouth bass, survivorship can be high if the proper combination of mesh size, water velocity and impingement time can be achieved. Further, operational data from the Barney Davis Station (which uses 0.5 mm mesh screens) indicates relatively high immediate survivorship of marine fishes in the 10-20 mm size range (S. Murray, personal communication).

Other assumptions made with respect to entrainment are that there is 100 percent mortality of entrained fish in the present system due to stresses suffered in passage through the condenser and cooling towers and that available entrainment data are indicative of long term trends at Prairie Island.

2.0 PRESENT INTAKE DESIGN AND OPERATION

2.1 Physical Facilities

The Prairie Island Nuclear Generating Plant consists of two 560 MWe units utilizing pressurized water reactors. The plant is located on the right (west) bank of the Mississippi River approximately 40 miles southeast of Minneapolis-St. Paul and 6 miles upstream from Red Wing, Minnesota. Units 1 and 2 began operation in December 1973 and December 1974, respectively.

The plant is capable of operating with the circulating water system as a once-through system, a closed-loop system, or a helper system where a portion of the water is recycled to the intake and the remainder discharged to the river. To date, the plant has not operated on a once-through basis.

Cooling water is presently drawn into the plant through an intake canal which is about 110 feet wide and 760 feet long. A barrier wall is located near the mouth of the canal to retain heated water in the system. The barrier also excludes floating debris from the screenhouse. Figure 2.1-1 shows a plot plan of existing facilities at the plant with the relative location of the intake canal, screenhouse, and discharge canal.

Each unit requires approximately 750 cfs of circulating and cooling water. Total plant flow of 1500 cfs is a combination of river water and recycled cooling water. The amount of circulating and cooling water flow withdrawn from the Mississippi River under present operating conditions can vary from approximately 188 cfs to 1500 cfs depending on the time of year and the mode of operation. This flow is drawn into a common intake screenhouse structure incorporating four vertical shaft, dry-pit circulating water pumps, three electric and two diesel driven cooling water pumps, a trash rack and traveling screens (Figures 2.1-2 and 2.1-3).

The screenhouse has a common trash rack outside the eight screen bays. Each bay contains a vertical traveling screen. The four circulating and five cooling water pumps are located behind the screens. Each circulating water pump normally draws water from two of the screen bays; however, a plenum downstream from the screen makes it possible for a unit operating with one pump to draw water through four screens, thus reducing the approach velocity at the screen face.

The flow rates and resulting velocities under the barrier wall, for possible modes of operation, are given in Table 2.1-1. Velocities at the trash rack and traveling screens are given in Table 2.1-2.

Each traveling screen is 10 feet wide by 36 feet high and utilizes wire mesh with 3/8 inch openings. For cleaning, the eight screens are rotated and washed with approximately 80 psi water pressure (125 psi design) spray nozzles. Debris is washed into a common trough leading to a trash basket for ultimate removal. Normally, the screens are washed intermittently when a pre-set differential head across the screen is exceeded or on a pre-set time cycle.

During the winter months when the ambient river water and air temperatures are low, closed loop operation is used. As the river water and air temperatures increase condenser inlet temperatures rise. When an 85 F inlet temperature is reached the helper cycle mode of operation is initiated by increasing the discharge to the river. This sequence of operation is reversed during the fall as ambient river water temperatures decrease. Under all present modes of operation, the circulating water flow is passed through mechanical draft cooling towers. This is done to reduce the temperature of the discharge water in order to meet existing thermal criteria.

Table 2.1-1

FLOW RATES AND VELOCITIES

Two Unit Operation
(Full Load)

Operating Mode	Flow Rate (cfs) From River	Flow Rate (cfs) Recycle Canal	Velocity under Barrier Wall (fps)
Closed-Loop	188	1312	0.3
Helper (50% recycle)	750	750	1.0
Open Cycle	1500	0	2.1

Table 2.1-2

APPROACH VELOCITY TO TRASH RACK
AND TRAVELING SCREENS.
(Based on Total Plant Flow of 1500 cfs)

Water Level	Velocity (fps) At Racks	Velocity (fps) At Screens
Normal Water Level 674.5 ft	1.2	1.3
Low Water Level 673.5 ft	1.2	1.4

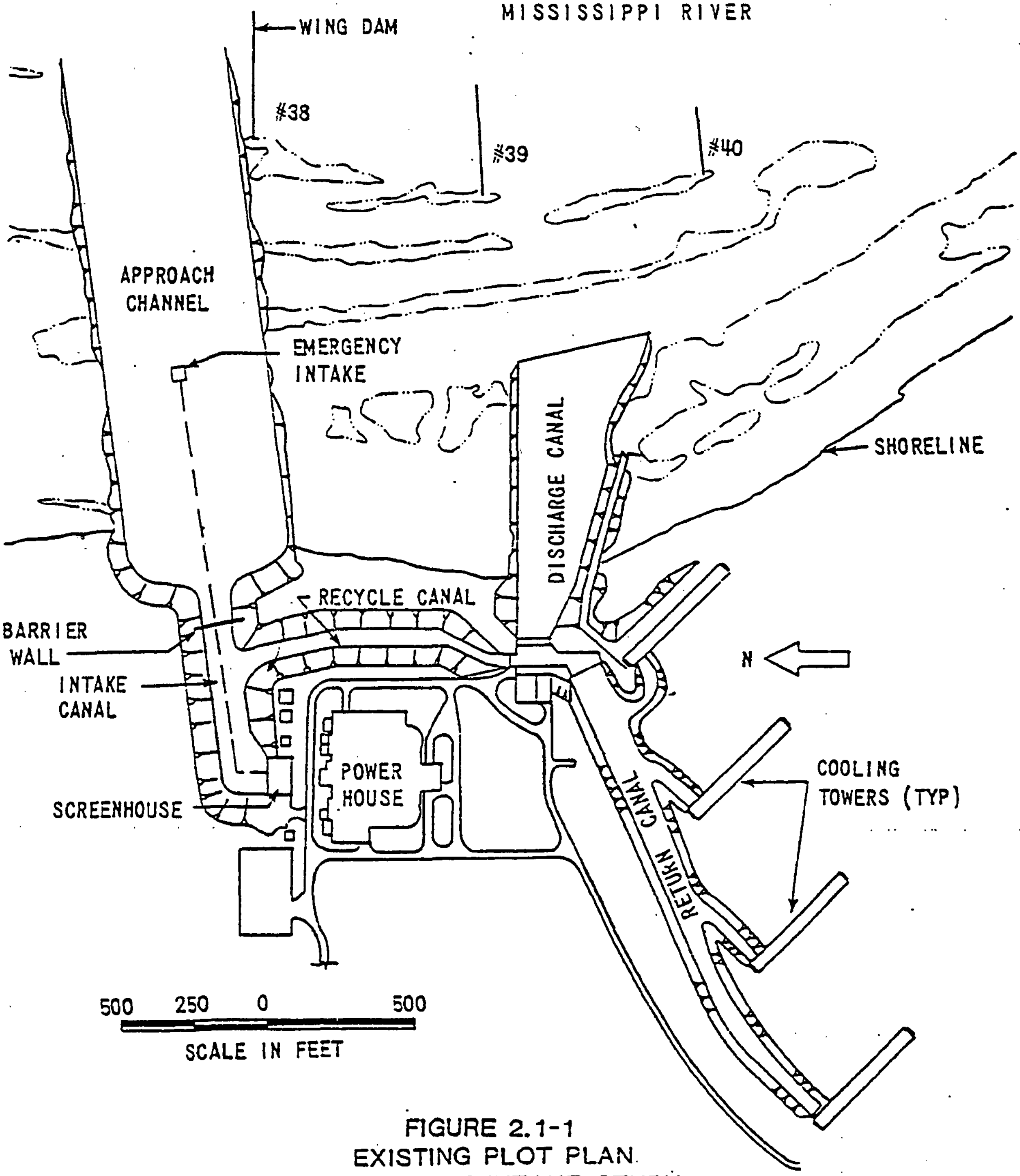


FIGURE 2.1-1
EXISTING PLOT PLAN
ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

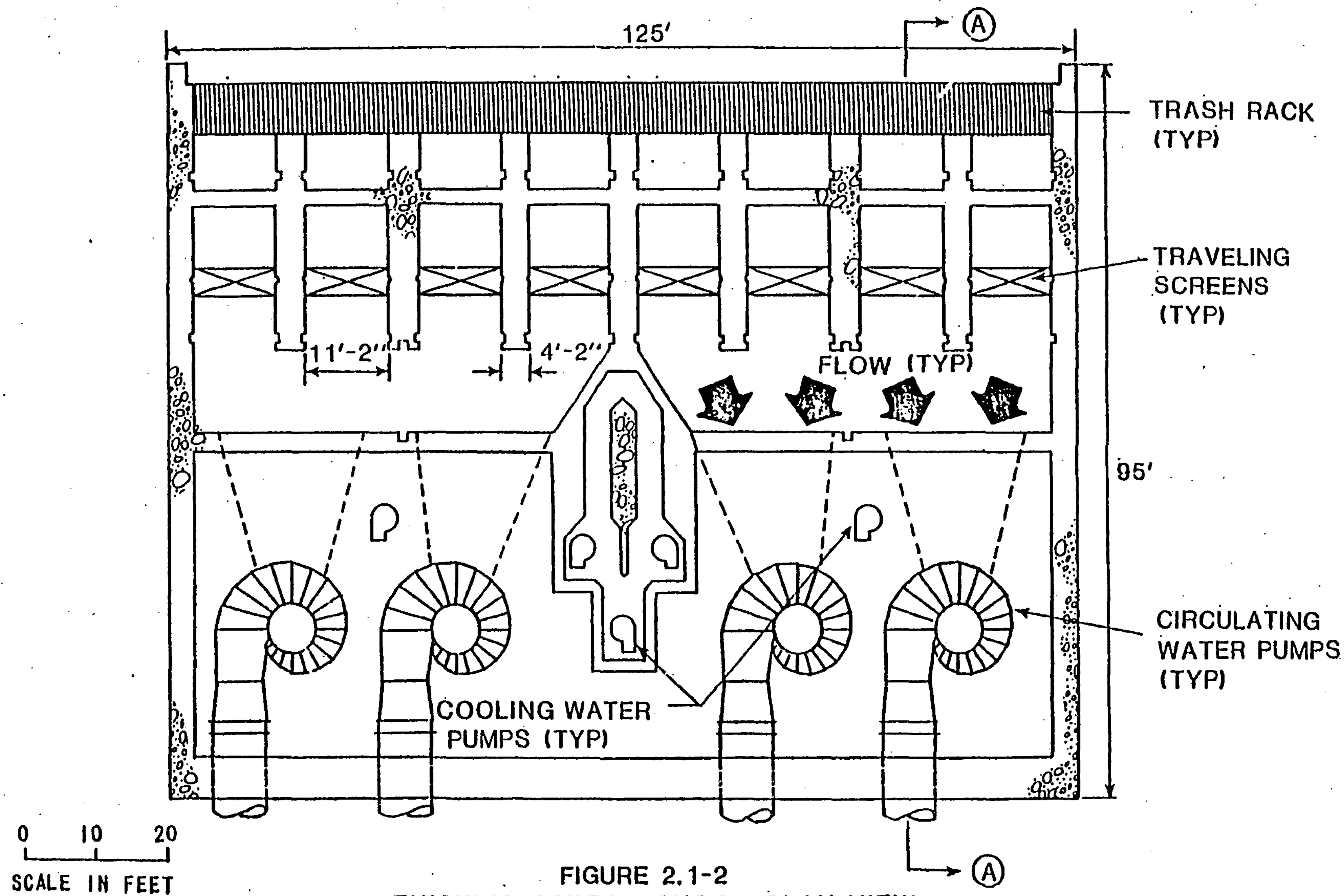


FIGURE 2.1-2
EXISTING SCREENHOUSE - PLAN VIEW
ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

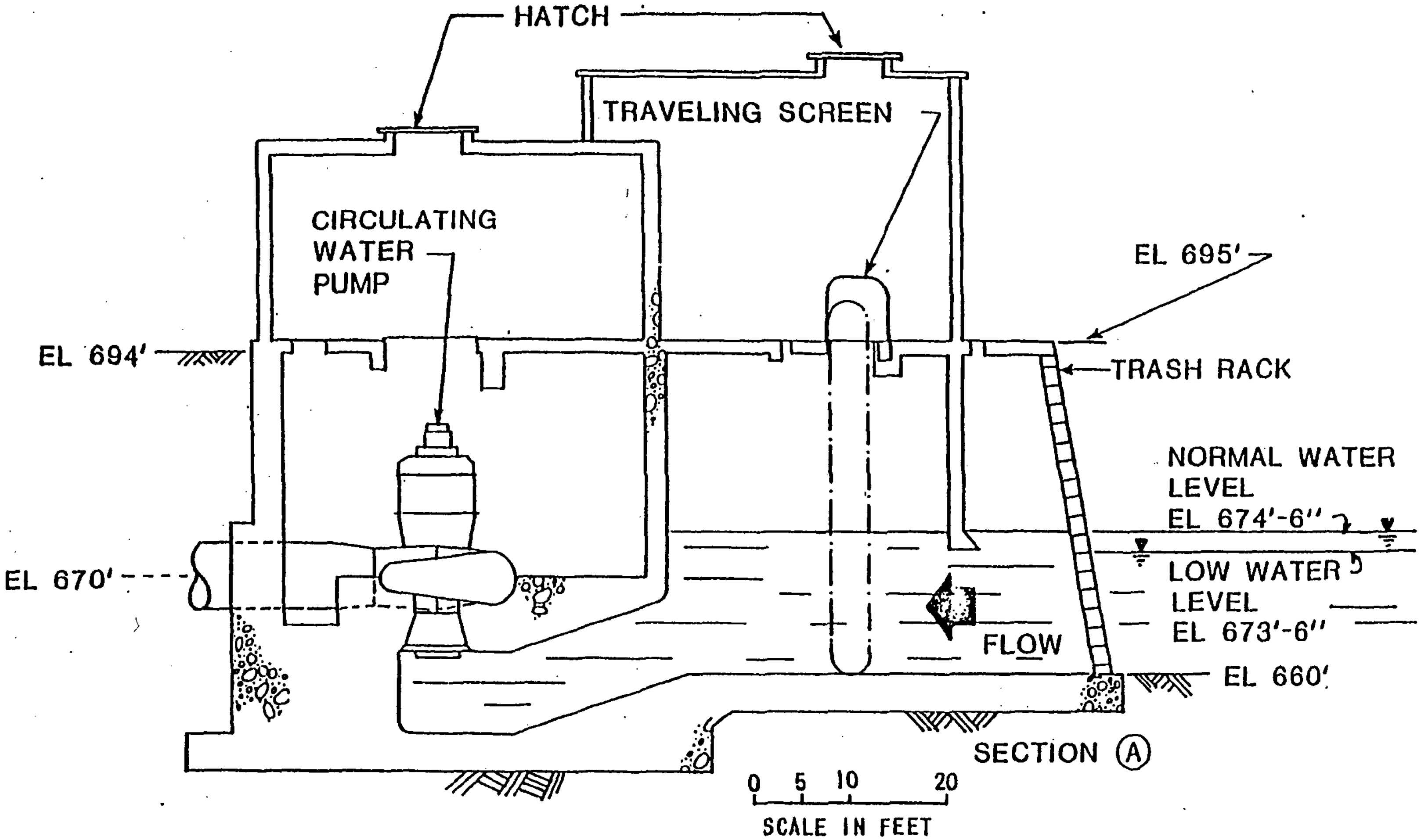


FIGURE 2.1-3
EXISTING SCREENHOUSE - PROFILE VIEW
ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

2.2 Impingement

Impingement and general fisheries data for Prairie Island from 1974 and 1975 have been presented in the Section 316(b) demonstration prepared for NSP by NUS Corporation (1976). This discussion presents a synopsis of that information giving particular attention to species considered important with respect to their impingement at Prairie Island.

Impingement monitoring is accomplished through emptying the trash basket 1-3 times per week and sorting impinged organisms from debris. Fish are identified, counted and total lengths are recorded for up to 100 specimens of each species taken. When feasible, live fish are released.

A total of 44 species (146,063 fish) were impinged in 1974. with 48 species and one hybrid (93,466 fish) impinged in 1975. Gizzard shad was the main species taken and accounted for 94 percent and 75 percent of the 1974 and 1975 totals, respectively. An attempt was made to correlate impingement rate with various physical parameters (such as water temperature and flow appropriation) for black bullhead, white bass, crappies, and freshwater drum. The results suggest that flow is the most important operational characteristic affecting impingement (NUS, 1976). Since data from other power stations indicate a positive correlation between intake velocity (or flow) and impingement, it is possible that the same holds true at Prairie Island. Although no correlation analyses were performed for gizzard shad impingement, a large proportion of the impingement of this species is the result of cold stress on fish resident in the intake and recycle canals during winter-time plant shutdowns as well as periodic dieoffs in the lake and river during cold periods (L. Grotbeck, personal communication).

For the present study, it was necessary to identify important species in order to evaluate the potential biological effectiveness of the various alternative intake designs selected for possible application at Prairie Island. The following criteria were used as a basis for the selection of important species:

1. Sport and commercial value or utilization as a forage species. This led to the exclusion of a number of "rough" species such as carp, carpsucker, and buffalo, and the inclusion of walleye and sauger.

2. Numbers of a species impinged in relation to the estimated population size for that species. If the number impinged was equal to or greater than 0.5% of the total estimated population (NUS, 1976), the species was considered important with respect to impingement.

Table 2.2-1 is a list of species considered important with respect to impingement losses and includes an indication of their seasonal occurrence.

Table 2.2-1 Species Considered Important with Respect to Impingement Losses

Common Name	Scientific Name	Primary Seasonal Occurrence
Gizzard shad winter	Dorosoma cepedianum	October-February
Channel catfish Fall-	Ictaluras punctatus	August-December
Black bullhead Spring	I. melas	April-May
White bass - Fall -Sum	Morone chrysops	July-November
"Crappie" Fall	Pomoxis spp.	July-October
Freshwater drum Fall	Aplodinotus grunniens	September-November
Walleye/Sauger Spring	Stizostedion vitreum/ S. canadense	April

2.3 Entrainment

Entrainment monitoring was conducted at Prairie Island from April 25 to September 5, 1975, (NUS, 1976). Samples were collected from three stations on a weekly basis during one 24-hour period each week. Larvae were identified to species when possible. This information is briefly synopsized below.

A total of 39 taxa and at least 26 species were collected (some were not identifiable). Fresh water drum eggs accounted for 89 percent of the fish eggs collected, attributable to the fact that this species releases pelagic bouyant eggs while most of the other species present either deposit adhesive eggs in nests or broadcast adhesive eggs over weed beds.

Emerald shiners and gizzard shad were the most abundant ichthyoplankters collected, accounting for 22.3 and 20.5 percent of the total, respectively. Catfishes and white bass accounted for another 12.5 and 11.6 percent of the total while 35 other taxa accounted for the remaining 33.1 percent.

Judgements of importance were made with regard to both number entrained, expressed in relation to equivalent loss of adults from the local population, and importance as sport or forage species. It was decided that species whose entrainment led to losses in the adult population of 0.5 percent or more (NUS, 1976) would be considered important. Table 2.3-1 presents the common and scientific names of those species considered important with respect to entrainment losses as well as an indication of their seasonal occurrence. It should be noted that rough fish, such as buffaloes, carpsuckers, and carp were excluded on the basis of undesirability rather than number entrained.

Table 2.3-1 Species Considered Important with Respect to Entrainment Losses

Common Name	Scientific Name	Primary Seasonal Occurrence
Gizzard shad	Dorosoma cepedianum	May-June
Emerald shiner	Notropis atherinoides	May and July
White bass	Morone chrysops	May-June
Walleye	Stizostedion vitreum	May
Sauger	Stizostedion canadense	May
Freshwater drum	Aplodinotus grunniens	May-June
"Darters"	Percidae	May-June

3.0 ALTERNATIVE INTAKE DESIGNS

The three alternative intake designs selected for possible application at Prairie Island would each incorporate at least one of two concepts for fish protection. Schemes 1 and 2 would involve the collection and gentle removal of fish, fish eggs, and larvae. Scheme 3 would combine fish diversion with collection and removal, using angled traveling screens to divert juvenile and adult fish, with eggs and larvae being collected and removed. Each scheme has been designed to exclude organisms from the intake and recycle canals and to return screened fish, eggs, and larvae back to the Mississippi River.

The alternative designs were selected on the basis of their engineering practicality and their potential for biological effectiveness. Engineering considerations included the past operating experience of a device, the practicality of installing such a device at Prairie Island, and the potential for operational and maintenance problems. Biological considerations included the past experience of a device relative to its effectiveness in reducing fish mortality (based on both operating experience at other sites and physical model studies) and its potential for effectiveness with Mississippi River species.

Besides the three schemes discussed in this report, several others were investigated for possible use at Prairie Island. The schemes which were eliminated from detailed consideration included such devices as infiltration galleries, porous dikes, wedgewire screens, louvers, and angled stationary screens. While these devices all have suitable applications, they were eliminated from consideration due to their limited effectiveness or their impracticality relative to the Prairie Island site. Several of the schemes, for example the porous dike and the infiltration gallery, were dropped because the size of the structures required to pass the design flow of 1500 cfs would be prohibitively large. Others, such as stationary screens, had associated engineering problems which made them impractical for this particular application. A louver system for fish diversion was eliminated because it would not divert eggs and larvae, and fish which might pass through the louvers could establish a resident population in the intake and recycle canals.

A description of each scheme developed for possible use at Prairie Island is given below. Each alternative requires the incorporation of a bypass and/or transportation system to return diverted or collected fish, eggs, and larvae to the Mississippi River. Section 4 addresses various possible methods of fulfilling this requirement.

In addition to the intake alternatives discussed below, reduction of withdrawal rates during periods of high ichthyoplankton density was also evaluated as a means to reduce entrainment impacts. This evaluation is presented in Section 3.2.2.

3.1 Engineering Description

The alternatives which were retained for further study have the following common features:

1. All require a new screenhouse structure located upstream of the recycle canal. This removes the possibility of fish being attracted to the warm water in the recycle canal. + establishment of resident canal community

2. All structures would be built at the mouth of the present intake canal on the north shoreline. This location allows the structures to be built on land with minimal interruption to plant operation and provides for easy access and adequate construction lay-down area. larvae which pass through the screens can still establish in recycle.

3. All require the present intake canal to be sealed off, with a new canal constructed to tie the new screenhouse into the existing system. This prevents organisms from by-passing the new structures and establishing a resident population in the recycle canal.

4. All require a transportation system to return organisms back to the Mississippi River.

5. All require provisions for deicing to prevent the formation of frazil ice on the racks and screens to ensure reliable operation during the winter.

6. All screenhouses were sized for a maximum flow of 1500 cfs, with a velocity at the screen face of 0.5 fps based on the gross screen area. This was based upon larval impingement data (Tomljanovich. Heuer, an Voightlander) which indicate velocities in this range yield up to 100 percent survival whereas survival decreases with increasing velocity.

Figure 3.1-1 shows a plot plan of the Prairie Island site with the proposed location of a new screenhouse and possible pipe routings for the deicing water and fish transportation systems.

3.1.1 Scheme 1 - Center Flow Traveling Screen

This scheme would consist of a combined trash rack and screen structure utilizing center flow traveling screens. The screenhouse would be located approximately 600 feet northeast of the existing screenhouse as shown in Figure 3.1-1. Figure 3.1-2 shows the proposed plot plan for the center flow screenhouse.

The screenhouse would be a reinforced concrete structure utilizing four center flow traveling screens. Plan and profile views of the screenhouse are shown in Figures 3.1-3 and 3.1-4 respectively. The upstream end of each screen bay would have a barrier wall extending to elevation 667 to exclude ice and floating debris from the structure. Trash racks would be placed between the barrier wall and the screens to collect large debris. The racks from the existing screenhouse would be removed and used at the new screenhouse, supplemented as necessary with new racks. The racks would have 3/8 inch thick bars with three inch clear spacing and would be inclined at a 10 degree angle to provide traction for the trash rake. The trash rake from the existing screenhouse would also be moved to the new screenhouse. The rake would lift debris from the racks into a rail-mounted trash hopper. The hopper could then be emptied at the end of the rail line for ultimate disposal by truck.

A warm water diffuser would be located at the base of the trash racks and would extend along the walls of each screen bay up to the normal water level. This diffuser would supply sufficient quantities of warm water to raise the ambient water temperature in the screen bays to approximately 39 F in order to prevent the formation of frazil ice on the racks and screens.

The center flow traveling screens would be located behind the trash racks. The screens would be installed so that their longitudinal axes are parallel to the approach flow. Water would enter through the upstream end of each screen and pass through both sides and the bottom. Debris and organisms would be impinged on the 0.5 mm mesh and washed into a combined fish and trash trough for return to the river. Figure 3.1-5 shows a section through a center flow screen. As shown in this figure, the screen baskets are curved, thus allowing for a greater screening area per basket. This, coupled with the fact that water flows out both sides and the bottom, results in a lesser number of screens required to pass a specific flow. Carryover of debris is eliminated with this type of screen by having the trash trough located within the screen itself.

The screened organisms and trash washed from the screens would be carried by gravity flow through a buried pipeline leading to the Mississippi River. The pipeline would be buried approximately 6 feet below ground to protect it from freezing. It would discharge at a point approximately 1200 feet southeast of the proposed screenhouse location. Provisions could be made in the collection trough to route screen washings into a collection basin for ultimate disposal so that trash and organisms could be diverted from the river during periods of heavy debris loading.

Fine screening, utilizing 0.5 mm mesh, presents potential debris removal problems which could have an impact on screen design. A polyester mesh, while having a smooth surface for eggs and larvae removal, could be punctured by sticks or sharp objects or rip if washed with high pressure spray nozzles (80-100 psi). Polyester mesh might have to be braced with coarser mesh to protect it from puncture. Bronze, stainless steel, or copper mesh on the other hand, are stronger but fatigue faster than polyester mesh and form a rougher surface. Studies are presently being conducted at the Barney Davis Plant in Corpus Christi, Texas to determine the structural integrity of various types of light weight mesh material. Preliminary results indicate that the extent of debris loading and the wash pressure are directly related to the useful lifespan of various materials. Therefore, before choosing a type of mesh, the type of debris expected and wash pressure required should be carefully considered.

Continous operation of the screen would be required for removal of eggs and larvae during periods of peak abundance. Also, since the fine mesh would collect more debris than the conventional mesh (3/8 inch), it could clog more rapidly than conventional mesh. The screen should, therefore, be capable of continuous operation at a low speed (1 fpm) for debris removal to prevent the possibility of overloading the motors during sudden clogging. The screen should, furthermore, be capable of operating at about 14 fpm with a 4 inch head differential and up to 28 fpm with an 8 inch differential to keep the screens clean. This continuous operation would require modification of the screen construction to include lighter baskets, heavy duty bearings and bushings, proper slack tensioning, heavy duty chains, and other improved features.

The use of a fine mesh screening media could pose a potential problem with respect to biofouling. Typically a salt water environment has usually resulted in more severe fouling conditions then has a fresh water environment. However, the Mississippi River being rich in nutrients could induce fouling. The fact that the screens will be rotating continuously at a low speed will help to avoid any potential problems since the screens will be continuously washed. If however, biofouling did prove to be a problem, chlorination equipment could be installed in the screenhouse upstream of the screens to control growth on the mesh.

Each screen would be equipped with a two speed motor capable of rotating the screen at either 14 or 28 fpm as stated above. The four motors would each be 5 hp and require about 16.5 KW of auxiliary power with all screen operating. In addition, approximately 16.5 KW of power will be required for the screen wash pump which would have a 20 hp motor. The annual energy requirements for this scheme would be about 290 MWH.

To construct this scheme, the area encompassing the screenhouse and the new intake canal would be graded to an elevation slightly above the groundwater table. Sheetpiling would then be driven around the perimeter of the screenhouse and the interior excavated until an elevation of about 644 was obtained. This elevation was selected in order to increase the available water depth and minimize the number of screens required. A tremie concrete seal mat would then be poured and the area within the sheetpiling dewatered. The sheetpiling would remain in place to be used as the exterior forms for the walls of the screenhouse. After construction of the screenhouse was completed, openings would be made in the sheetpiling to allow for passage of water through the structure.

With the screenhouse completed, dredging of the new intake canal would be undertaken to tie the new structure into the existing system. Bottom slopes of 5:1 would be used, and the slopes rip-rapped to prevent scouring. The majority of the dredging would be performed by land based equipment. As shown in Figure 3.1-2, the shoreline would be excavated flush with the face of the screenhouse in order to reduce potential embayments.

The final phase of construction would be the installation of the fish return pipe and an earthen dam to seal the mouth of the existing intake canal. Excavated material would be used as much as possible for construction purposes. The dam would be scheduled for completion after all work on the screenhouse and canals was done and the system was ready for operation, thus ensuring minimum disruption of plant operation. The fish return pipe would be buried and the portion below water would have the trench covered with rip-rap to prevent erosion.

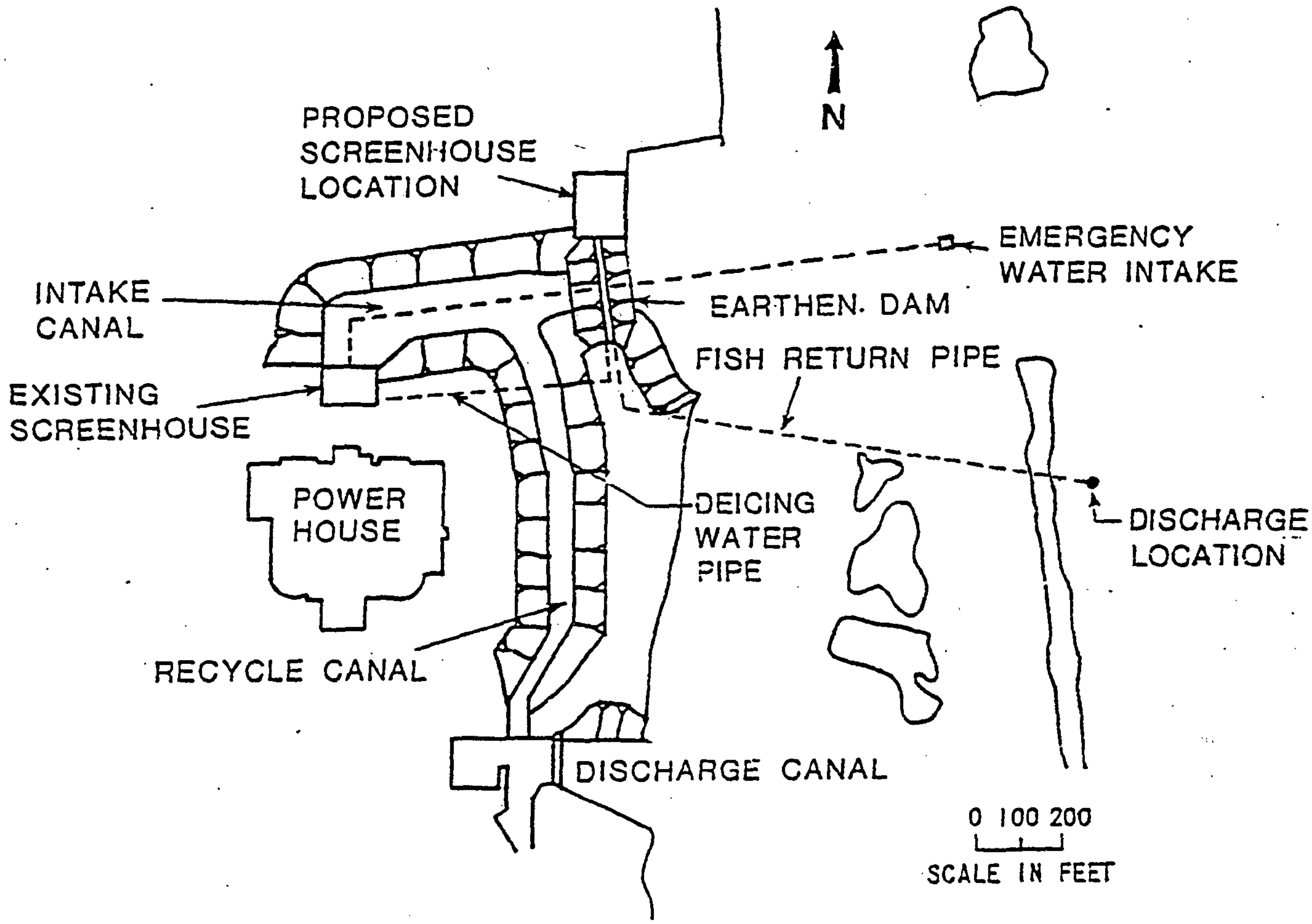


FIGURE 3.1-1
PROPOSED PLOT PLAN
ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

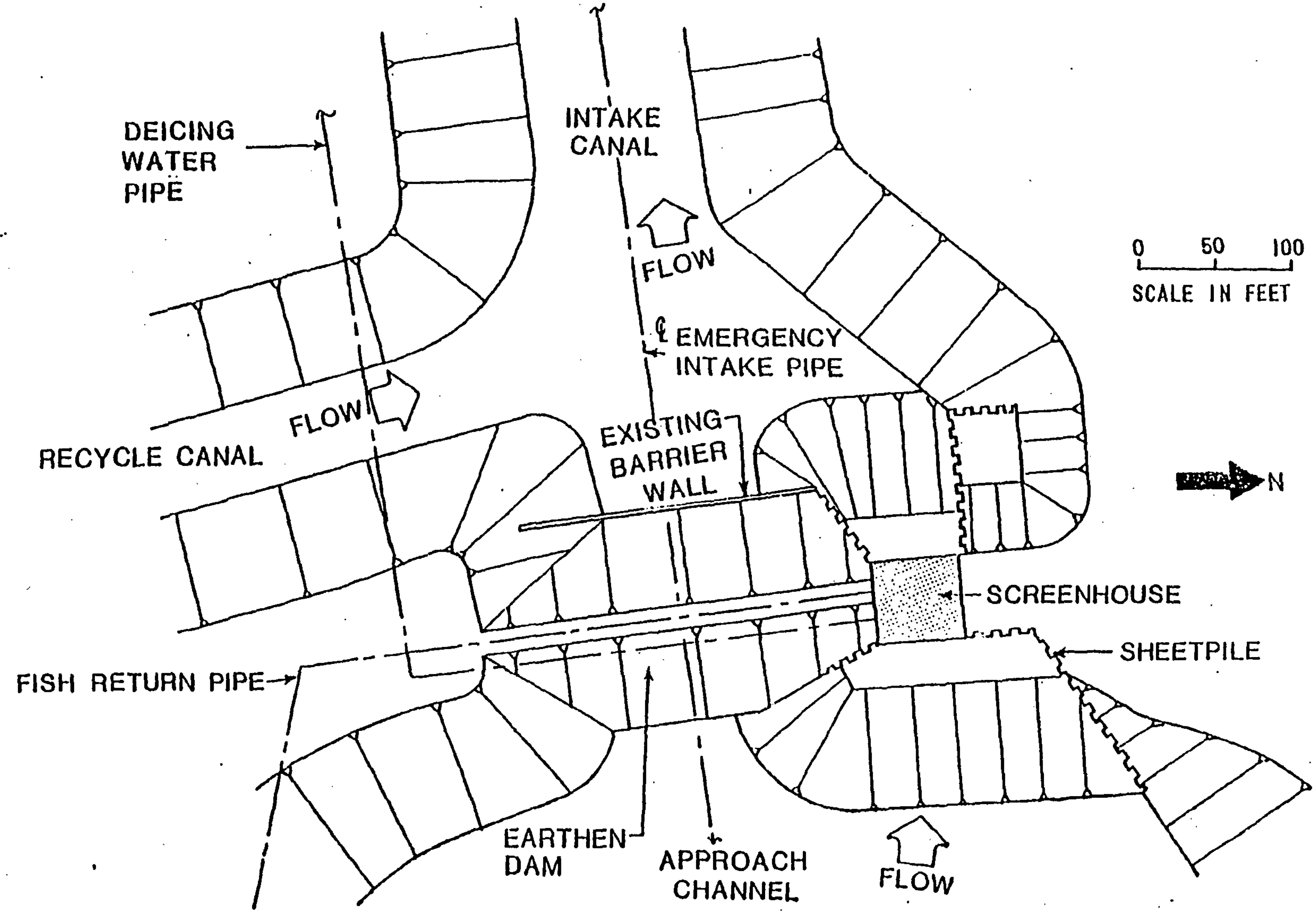


FIGURE 3.1-2
PLOT PLAN - CENTER FLOW TRAVELING SCREENS
ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

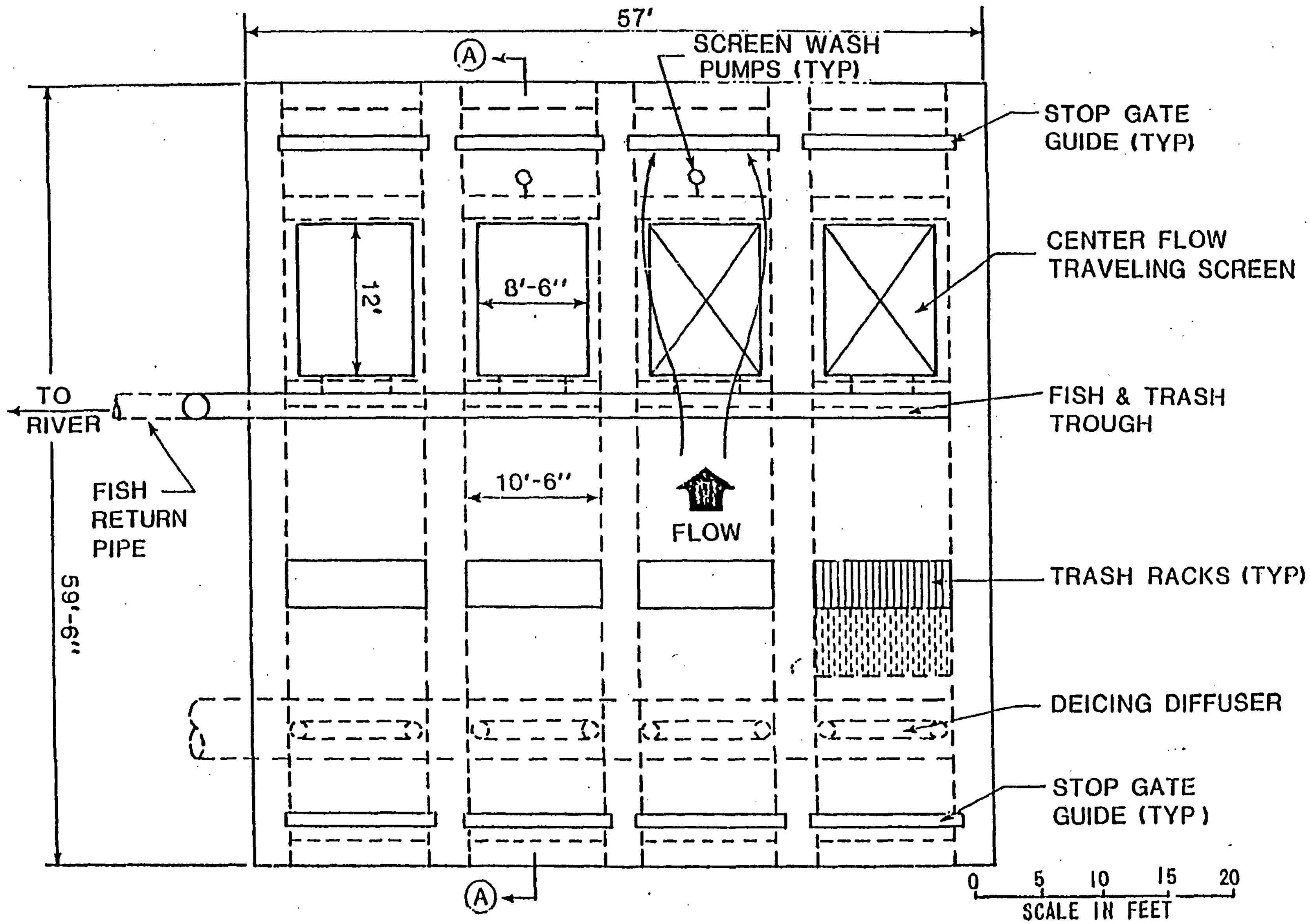


FIGURE 3.1-3
CENTER FLOW TRAVELING SCREEN - PLAN VIEW
ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

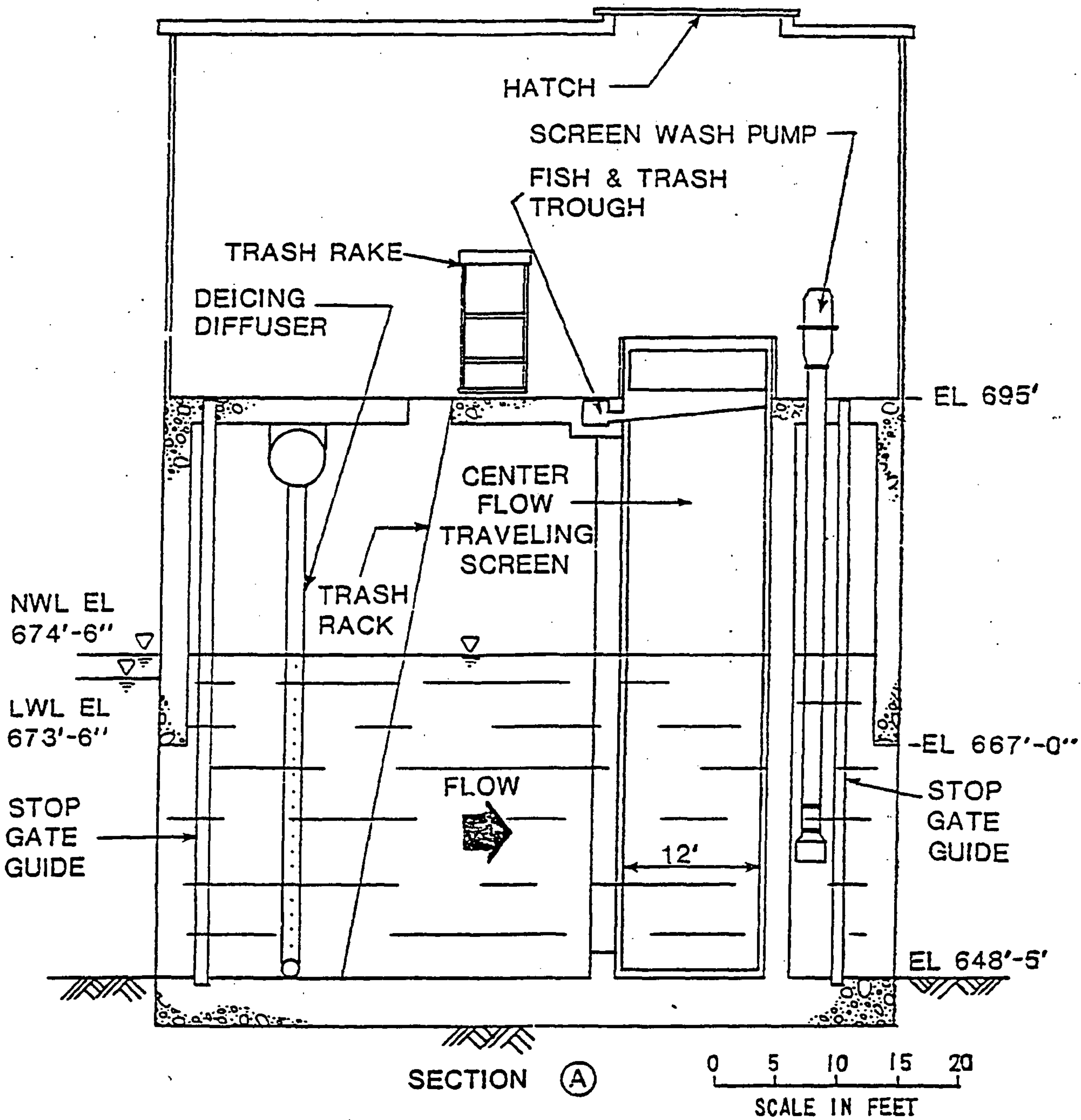


FIGURE 3.1- 4
CENTER FLOW TRAVELING SCREEN - PROFILE VIEW
ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

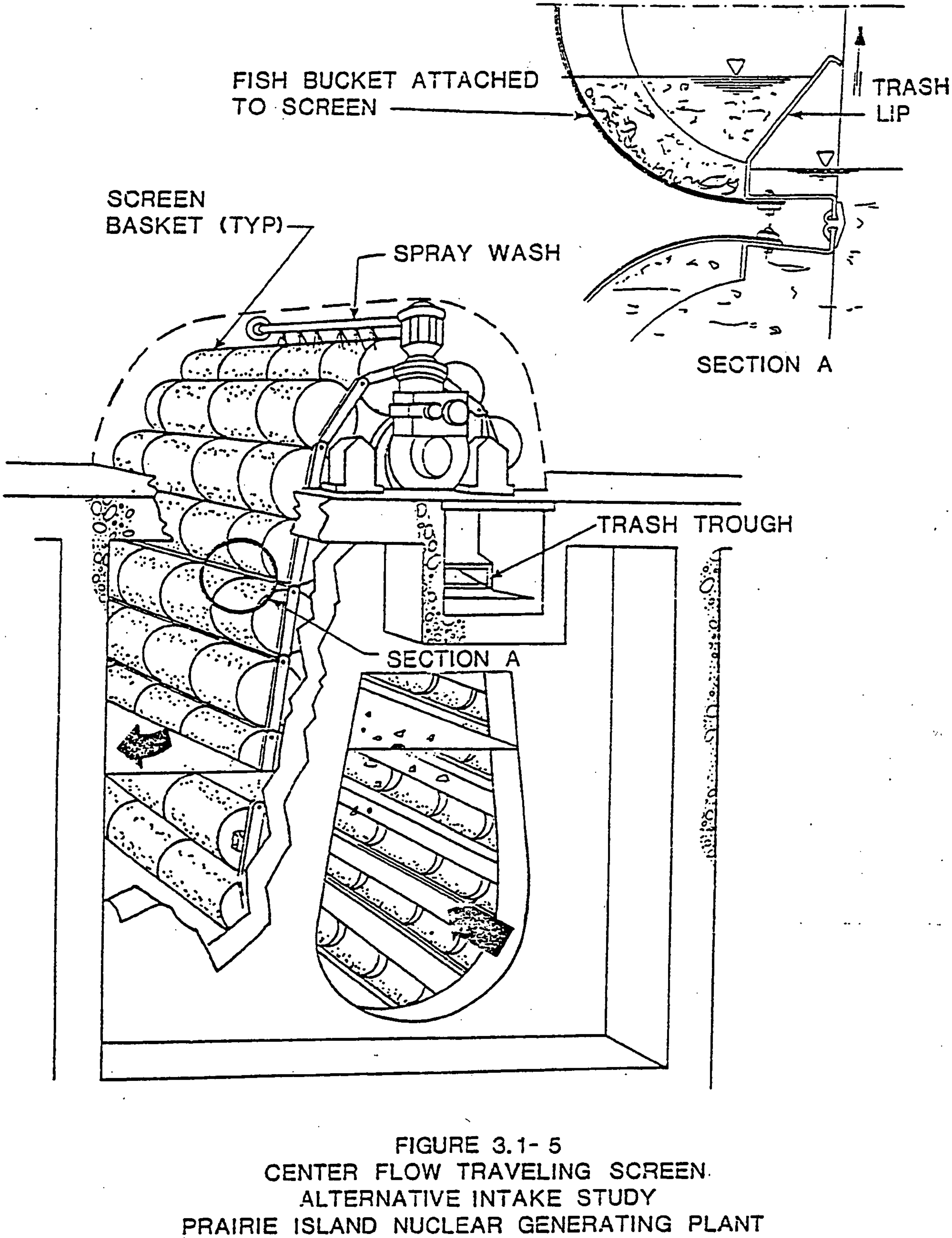


FIGURE 3.1- 5
CENTER FLOW TRAVELING SCREEN
ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

3.1.2 Scheme 2 - Modified Traveling Screens with Fish Buckets

This scheme consists of twelve through-flow traveling screens which would be modified and fitted with fish buckets. The screens would be installed in a reinforced concrete structure constructed in the same location as discussed for Scheme 1. Figure 3.1-6 shows the proposed plot plan for this scheme.

The screenhouse would be similar to that discussed for Scheme 1 with the arrangement and design criteria for the barrier wall, trash racks and rake, and deicing system the same. Plan and profile views of the screenhouse are shown in Figures 3.1-7 and 3.1-8.

The eight screens presently in operation at Prairie Island would be removed from the existing screenhouse, modified and installed in the new screenhouse. Modifications to the screens would include lengthening the screens from 36 to 50 feet, upgrading the screens for continuous operation (including bushings, bearing, chains, baskets, and proper tensioning), replacing the existing 3/8 inch mesh with 0.5 mm mesh, adding a low pressure spray system and fish trough, and installing compartmented fish buckets onto the lifting lips of the screen baskets.

The modified spray system would use a low pressure spray to wash organisms into a fish collection trough for return to the river. The new fish trough would be made of a smooth material, such as fiberglass or polyethylene, and would incorporate long-radius bends to minimize fish abrasion. A high pressure spray would wash debris into a separate trash trough for collection and ultimate removal.

Two types of dual screen wash systems are commercially available; one in which organisms are washed off of the ascending (front) face of the screen and the other in which they are washed from the descending (back) face. For use at Prairie Island, either a back wash or a front wash system could be utilized. Figures 3.1-7 and 3.1-8 show a front wash dual spray system since the existing screens utilize a front wash high pressure spray. In choosing a wash location, the ease of debris removal with minimum spray pressure, and the effect of spray pressure on the integrity of the mesh material should be considered. A back wash system, as shown in Figure 3.1-9, may offer a more effective means for removing organisms and debris since they would tend to fall by gravity towards the collection troughs, especially if a smooth mesh were used. Both the back wash and front wash systems are presently in use on power plant intakes and are being incorporated in the design of a number of further installations. However, before specifying the location of the wash system or the spray wash pressures, investigations should be undertaken since little information is available regarding the biological effectiveness of either system.

As with Scheme 1, this scheme would also require that the screens be capable of continuous operation (10-14 fpm) during periods of high impingement, and would have similar operational problems to those discussed in Section 3.1.1.

To complete the modifications to the existing screens, fish buckets, as shown in Figure 3.1-10, would be bolted onto the lifting lips of the screens in order to maintain impinged organisms in a minimum water depth of 2 inches during the time of travel from the water surface to the head shaft sprocket.

By modifying the existing screens for use in this proposed scheme, only four new screens would have to be purchased. Fixed screens would be installed at the existing screenhouse to replace the traveling screens and to collect leaves or other debris which might fall into the recycle or intake canals.

These screens would utilize two speed motors similar to those on the existing screens. The 12 motors would be 3-3/4 hp each requiring approximately 37 KW of auxiliary power. The screen wash pump for this scheme would have a 100 hp motor requiring about 83 KW of power. The annual energy requirements for this scheme would be about 1050 MWH.

The fish transportation system is the same for Scheme 2 as discussed for Scheme 1 and the construction method for Scheme 2 is also similar.

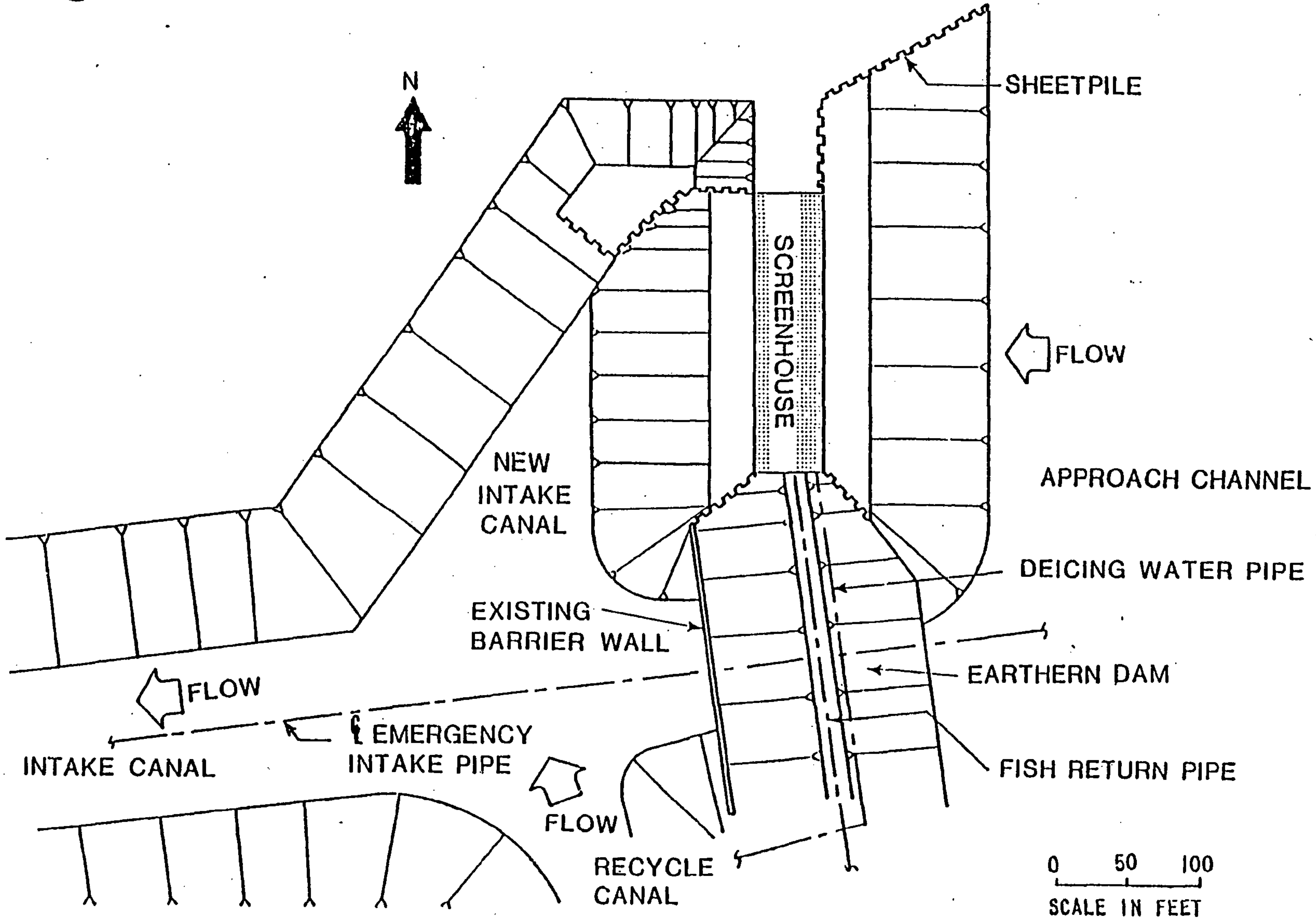


FIGURE 3.1-6
PLOT PLAN - TRAVELING SCREENS WITH FISH BUCKETS
ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND GENERATING PLANT
NORTHERN STATES POWER COMPANY

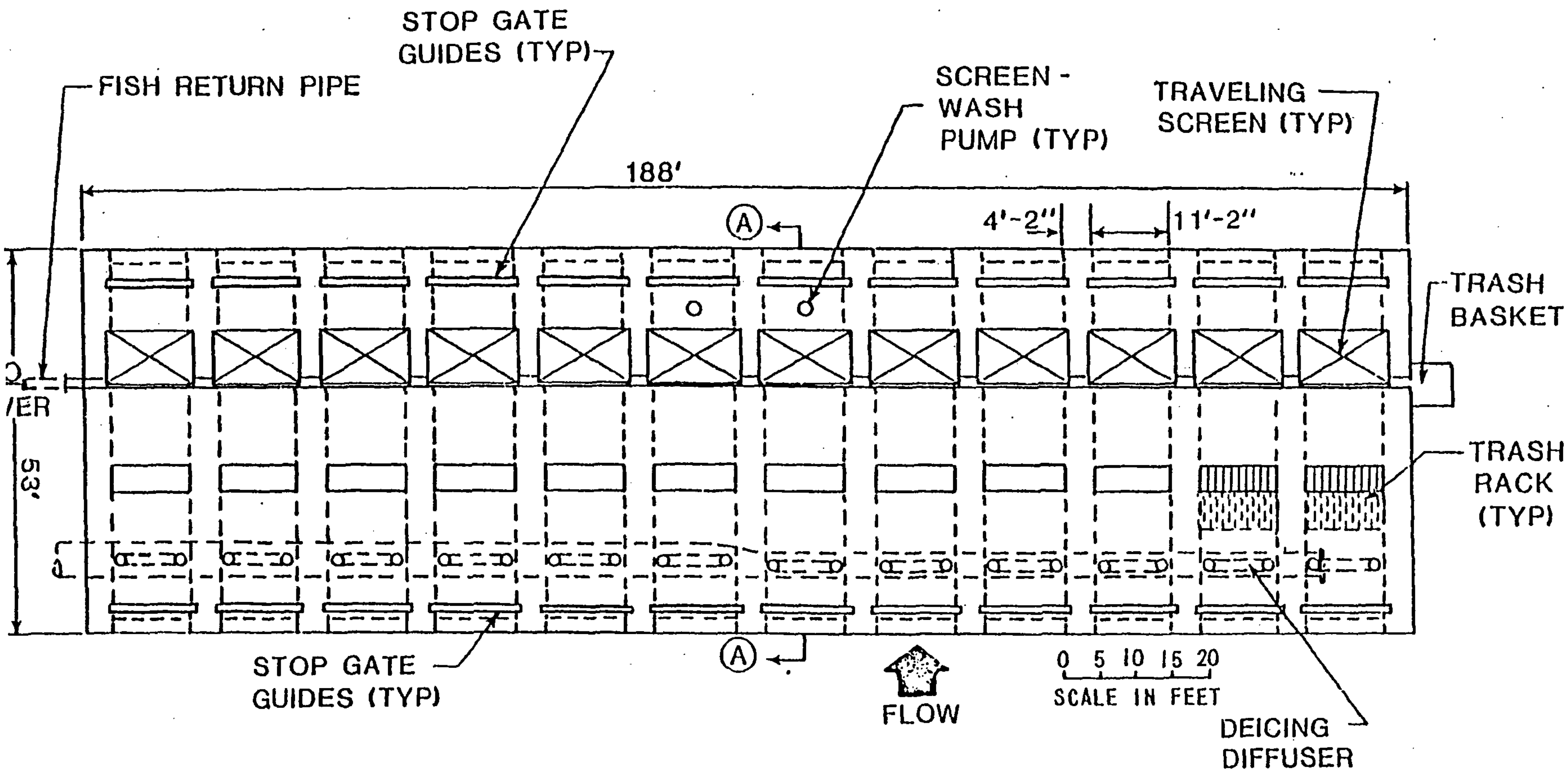


FIGURE 3.1-7
TRAVELING SCREEN WITH FISH BUCKETS - PLAN VIEW
ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

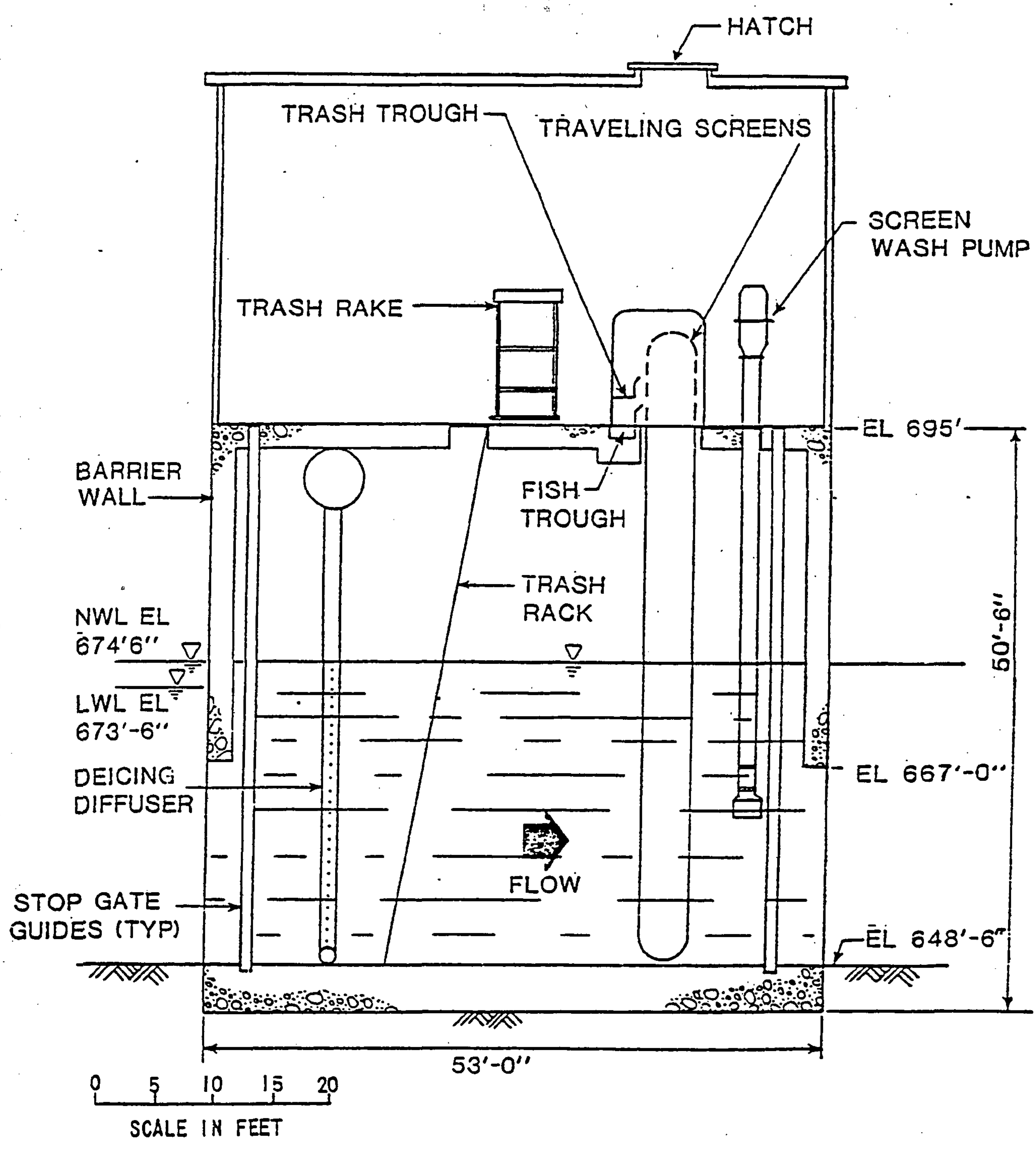
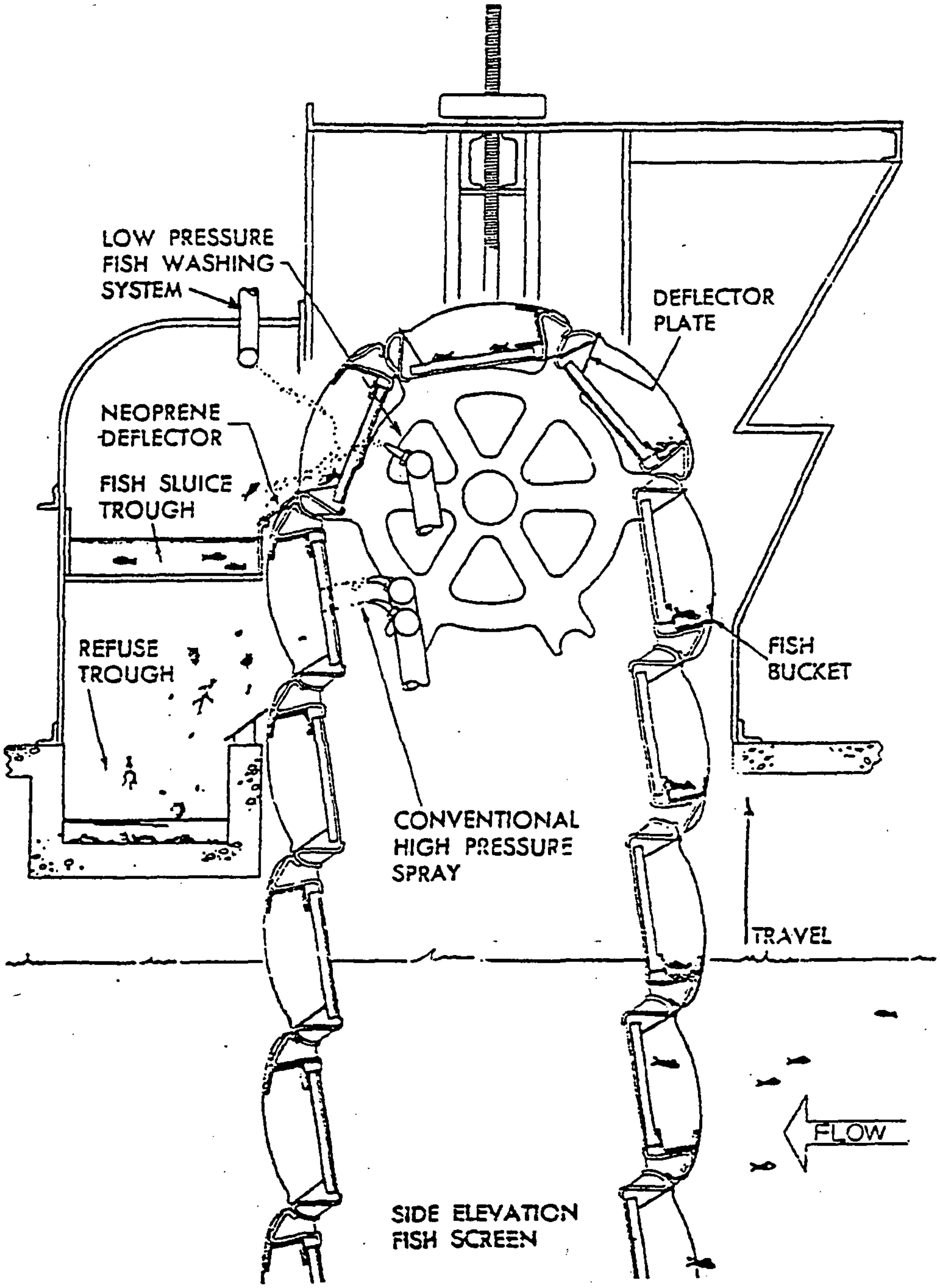


FIGURE 3.1-8
TRAVELING SCREEN WITH FISH BUCKETS - PROFILE VIEW
ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY



COURTESY OF ENVIREX

FIGURE 3.1-9
TRAVELING SCREEN WITH FISH BUCKETS
ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

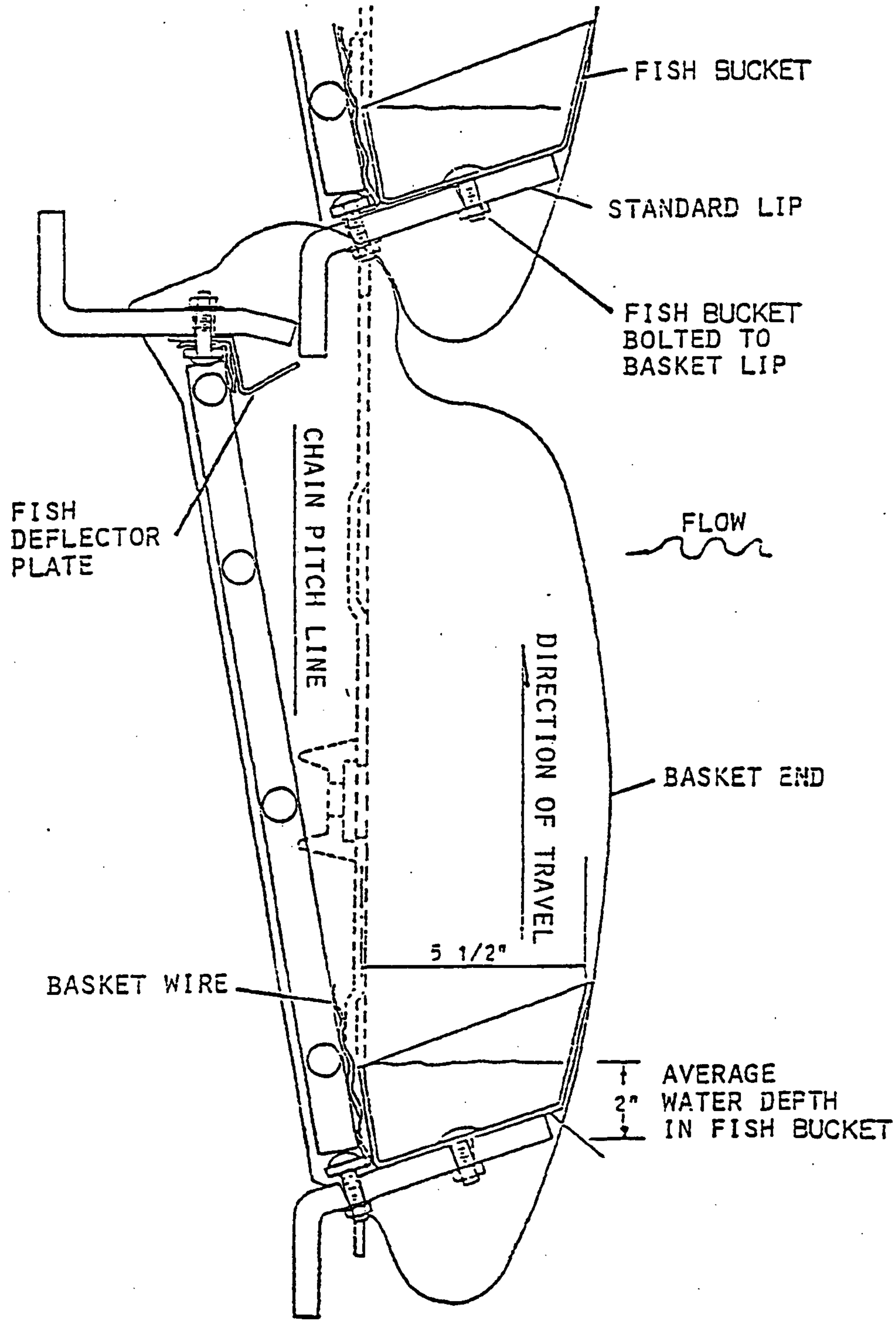


FIGURE 3.1-10
COMBINATION TRASH AND FISH SCREEN
ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

3.1.3 Scheme 3 - Angled Flush Mounted Traveling Screens with Fish Buckets

This scheme would consist of a screen structure utilizing (a) flush-mounted traveling screens with fish buckets and set in a chevron arrangement, (b) 1-foot wide fish bypasses and bypass transition sections, (c) a fish transport pipeline and (d) a pumping unit to return fish safely to the Mississippi River. The location of the structure, the design of the barrier wall, trash rack arrangement and deicing system, and the construction techniques are all similar to those discussed for Scheme 1. The plot plan for this scheme is shown in Figure 3.1-11.

The primary angled screen diversion system would consist of twelve, flush-mounted traveling screens set in chevron arrangements. Since the eight existing screens could be utilized after modification, only six new screens would be required (four for the primary diversion system, two for the secondary diversion system). Four screen bays, each incorporating three angled screens, would be constructed. A concrete pier would separate each set of screens. Details of the chevron arrangement are shown in Figures 3.1-12, 3.1-13 and 3.1-14.

A minimum of 20 feet would be provided between the trash racks and the beginning of the angled screens to ensure that the flow approaches the screens at the proper angle (approximately 25 degrees) for successful fish guidance.

Each bypass would incorporate two transition sections which would direct the water into transport pipes. The transition sections could either be shop fabricated out of steel plate or incorporated into the concrete formwork. Access to each transition would be provided through a manhole located in the bypass entrance to allow for manual cleaning, if necessary.

Each transition section would convey bypassed fish to a pipe. The two pipes in each chevron would then be manifolded into one larger pipe. The pipes from the two chevrons would carry the bypass flow to two jet pumps located in a pit south of, and adjacent to, the screenhouse (Figure 3.1-11). These pumps would induce the suction flow in the bypasses and bypass pipes. The pumps would discharge the bypass flow into a secondary screen bay. The purpose of the secondary bay is to concentrate the fish in a smaller quantity of water in order to reduce pumping costs, and to recover as much of the bypass and driving flow as possible. The secondary screen bay would utilize two angled flush-mounted screens and a secondary bypass. The secondary screens and bypass are of the same design as those used in the primary screenhouse. Flow diverted into the secondary bypass would be conveyed by a pipe to a secondary jet pump. The discharge from this jet pump would convey bypassed fish back to the Mississippi River through a buried pipeline. The discharge point of the pipeline would be the same as discussed for Scheme 1.

The driving flow for the three jet pumps would be supplied by three vertical turbine pumps mounted in a pump bay located behind the secondary angled screens. Since more flow would normally enter the pump bay than the driving pumps require, an overflow weir would be installed, with provisions for stop gates, to regulate the water surface elevation in the pump bay. The excess flow would pass into the intake canal downstream of the screenhouse.

As discussed for Scheme 2, the existing screens at Prairie Island would be modified for use in the new screenhouse and fixed screens installed in their place. Besides the screen modifications which were previously discussed for Scheme 2, the flush mounted screens would be further modified by resetting the individual screen panels so that they are flush in the vertical direction, and removing the seal plates on each side of the screen to form a flush face with the concrete piers and the bypass. In order to prevent debris from passing under and around the foot shaft of the screen, which might result in jamming due to the absence of the seal plates, a special boot plate would be required. This would extend about 2.5 feet above the floor, with the boot loading leg extended to meet the boot plate, and a hinged metal deflector added to the top of the boot loading leg to seal off the boot area.

The screens would also be fitted with fish buckets similar to those discussed for Scheme 2. However, for this scheme the buckets would have to be smaller in size in order to decrease the open space in the lower area of the boot section at the boot plate. The open space in the lower area of the boot section is the result of eliminating the end seal plates in order to form a flush mounted screen. The bucket would extend about 3.5 inches from the screen mesh to the outer edge and would be shaped to be able to retain at least 2 inches of water to remove fish safely.

Organisms and debris which are collected on the screen face would be washed into separate troughs by a dual spray wash system similar to that discussed for Scheme 2. The collected organisms would be discharged into the fish return line downstream of the secondary jet pump. This would allow for the return of all impinged organisms back to the river without having to pass through a pump, thus reducing the potential for injury.

Since this scheme also utilizes a fine mesh screen, it would have similar operational problems as discussed previously in Section 3.1.1.

This scheme would also utilize two speed motors on all the traveling screens. The 14 motors would be 3-3/4 hp, requiring approximately 42 KW of auxiliary power with all screens in operation. The screenwash pump would have a 100 hp motor requiring 83 KW of auxiliary power. The fish return system used in this scheme utilizes two driving pump with 235 hp motors and a secondary driving pump with an 85 hp motor. These three pumps require approximately 460 KW of auxiliary power. The annual energy requirement for this scheme would be about 5140 MWH.

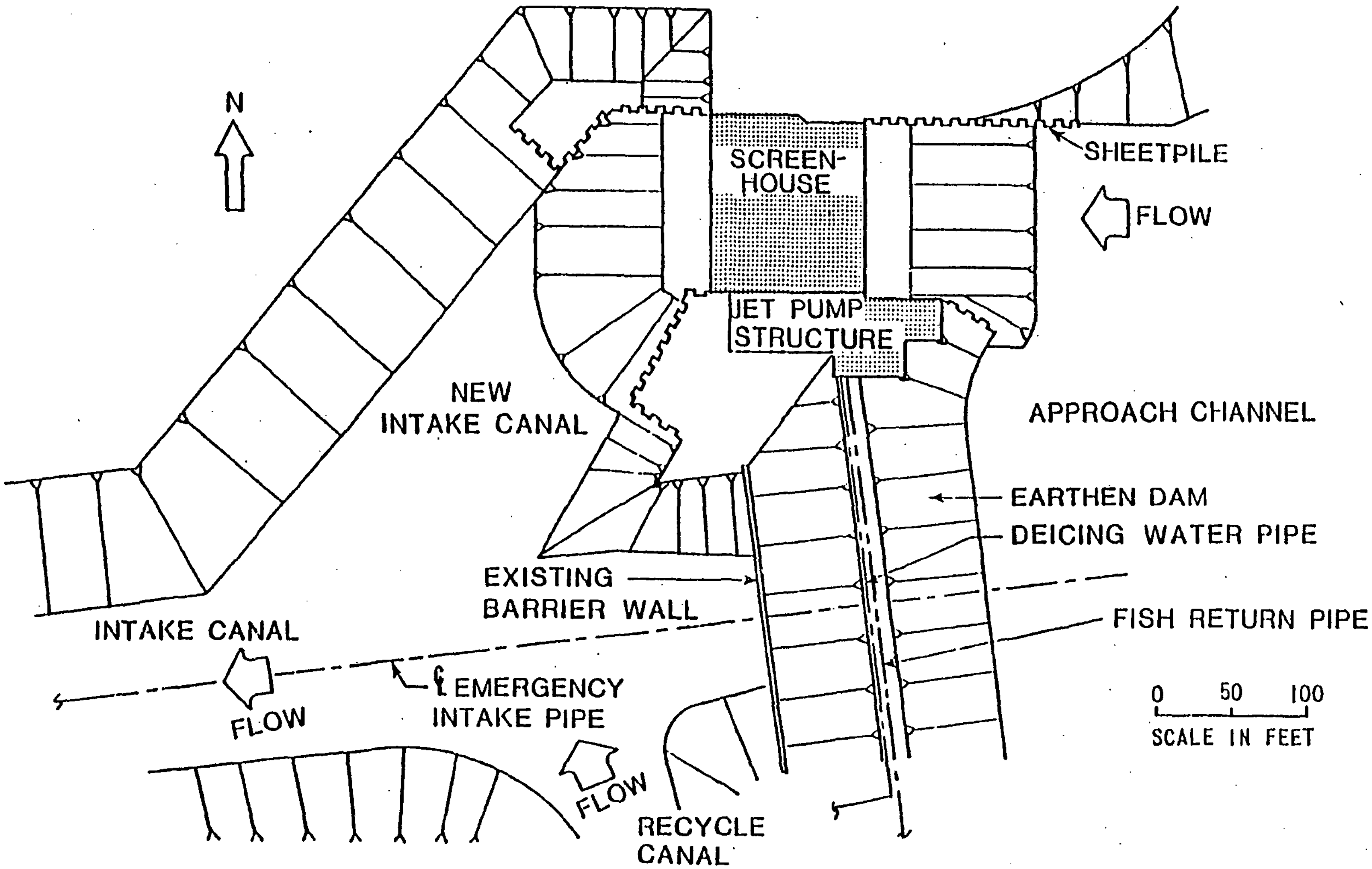


FIGURE 3.1-11
PLOT PLAN - ANGLED TRAVELING SCREENS
ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

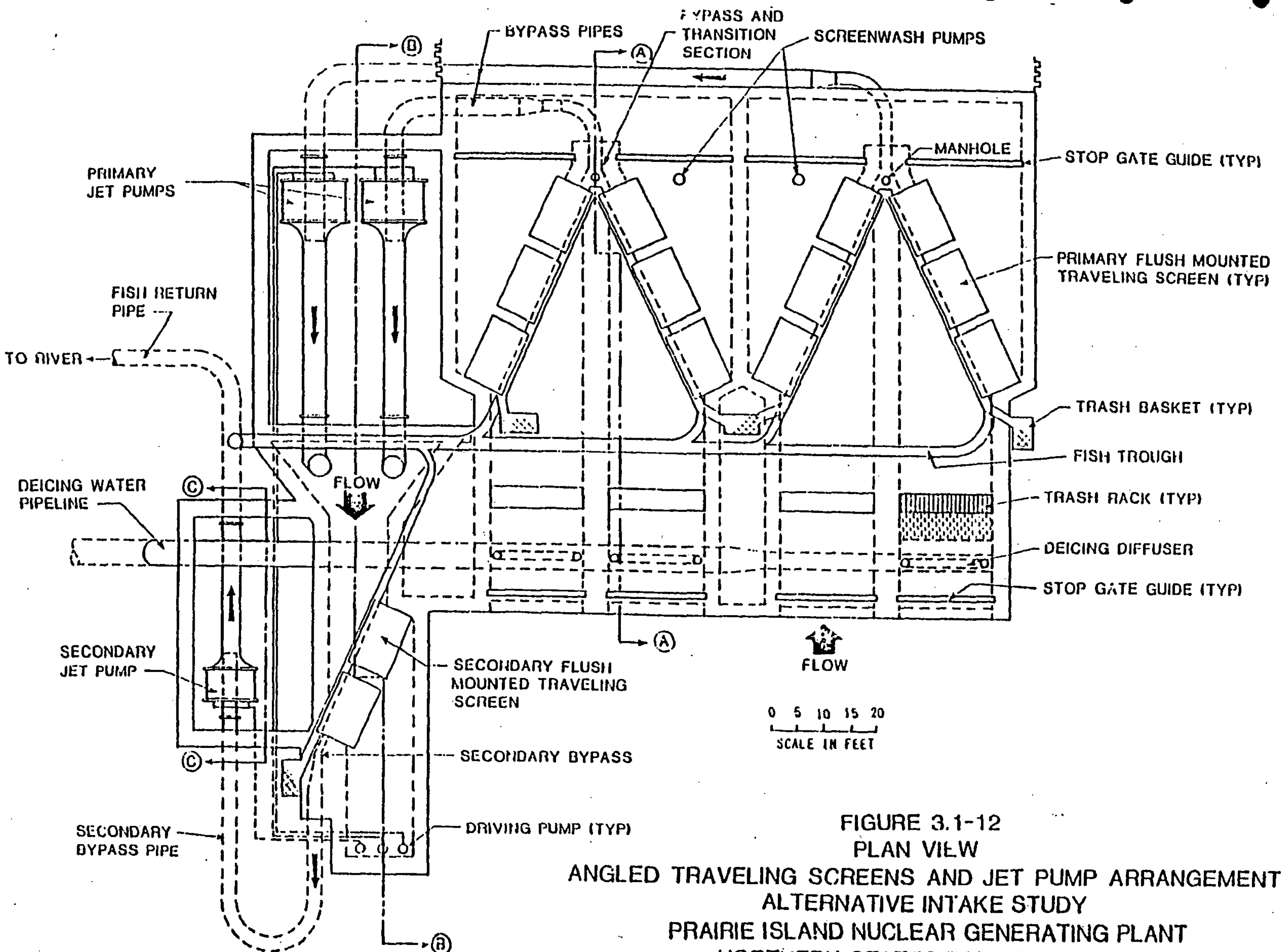


FIGURE 3.1-12
PLAN VIEW
ANGLED TRAVELING SCREENS AND JET PUMP ARRANGEMENT
ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

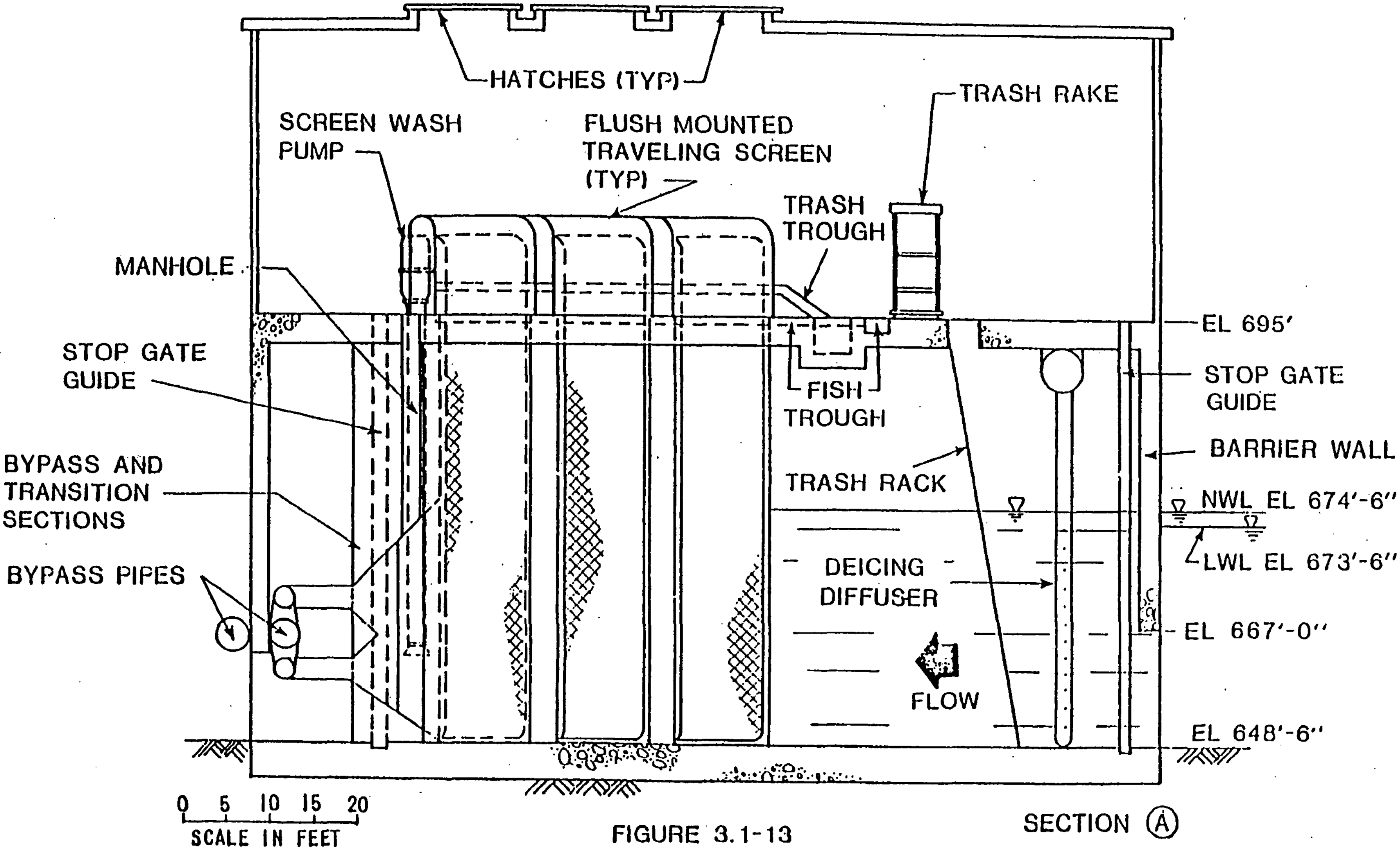


FIGURE 3.1-13
PROFILE VIEW
ANGLED TRAVELING SCREENS AND JET PUMP ARRANGEMENT
ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

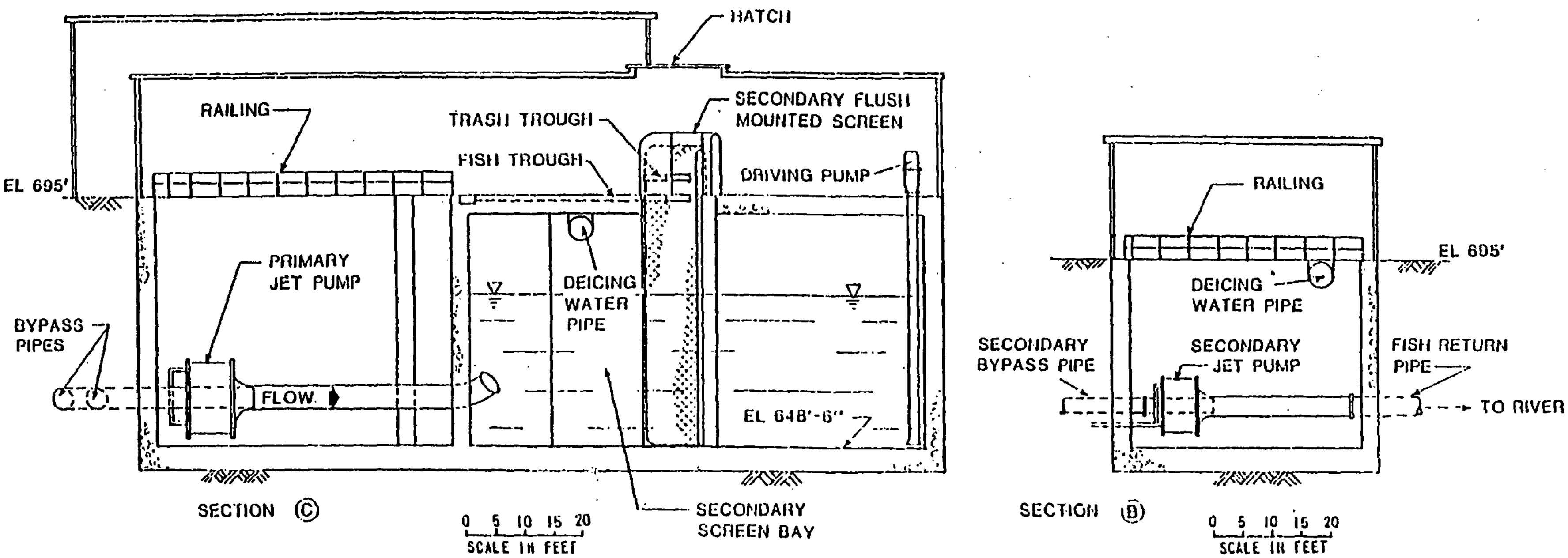


FIGURE 3.1-14
PROFILE VIEW
ANGLED TRAVELING SCREENS AND JET PUMP ARRANGEMENT
ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

3.1.4 Flow Regulation

Each of the schemes previously mentioned have utilized fine mesh screens operating continously. Another option which has been considered is the use of any of these schemes with coarse mesh and reducing the flow rate during potential periods of high entrainment. For example, if the center flow screenhouse was constructed using coarse mesh, the construction costs would be approximately the same. However, the screens would not be operated continuously because of lower clogging potential, thus reducing the annual energy consumption associated with the screenhouse.

During periods of high entrainment (May and June) the flow rate could be reduced to 188 cfs. For the remainder of the year the flow rate could vary up to 1500 cfs. Operating in this manner, the annual energy consumption for the center flow screens would be about 51 MWH.

This example illustrates one possible operating mode which relies on flow regulation to reduce entrainment losses rather than using fine screening. There are an infinite number of variations which could be used; however, the analysis of these variations are beyond the scope of this report. Section 3.2.2 discusses the biological impact associated with this particular operating mode.

3.1.5 Emergency Bypass

As previously mentioned, all of the proposed schemes would utilize a fine mesh (0.5 mm) screen material. With any size screen mesh, the potential for clogging exists; however, as the mesh size decreases the clogging potential can be expected to increase. This potential leads to the possible requirement of an emergency bypass should the screen clog or otherwise become inoperative.

It is difficult to predict how a particular screen will operate under various conditions until it is installed or unless extensive field or laboratory testing is undertaken. Therefore, no judgement on the clogging potential of any of the proposed schemes can be made at this time. However, various methods of bypassing water to the existing screenhouse, should a clogging problem arise, are available.

One solution to this problem would be to install culverts beneath the earthen dam which seals the intake canal. Each culvert would be equipped with a control valve to prohibit flow except when required. The control valve would be motor operated and would be automatically opened when a pre-set differential head was experienced across the screens. All auxiliary equipment would be located in a heated building atop the dam. The area in front of and behind the culverts would be rip-rapped to guard against scouring.

Another scheme would be to construct a flume running alongside the new screenhouse. The flume would connect the approach canal with the intake canal. Again, an automatic control valve, as discussed above, would be used to regulate flow. This scheme would have the advantage that it could be built at a later date if operational data show clogging to be a problem. The flume would be constructed with either concrete or sheetpile walls and would require rip-rap to guard against scouring.

A third scheme would be to incorporate a bypass directly into the screen design. Of the proposed alternative intake schemes, only the center flow traveling screen has this capability. Because of the orientation of the screen, a flap gate can be installed in the downstream end of a center flow screen. This gate could be set to open when a pre-selected differential head across the screen is exceeded, and since the existing traveling screens would not be removed from the existing screenhouse, if the center flow scheme were adopted, trash would still be collected there.

Most of the schemes discussed above would require that they be constructed when a new screenhouse was installed in order to be cost-effective. The necessity for an emergency bypass would require further study.

3.2 Biological Effectiveness

Several important factors bear on biological effectiveness. Among the most important are mode of operation and screen mesh size. These are discussed first with respect to impingement and then with respect to entrainment.

3.2.1 Impingement

The alternative designs discussed in this report rely on either collection and removal (modified traveling screens with fish buckets and center flow screens) or on diversion (angled screens) to reduce mortality to juvenile and adult fish. Modified and center flow screens depend on impingement of organisms followed by careful handling to return fish to the water in good condition.

Modified Traveling Screens with Fish Buckets

This alternative involves modifying and moving the location of the existing traveling screens so that fish could be impinged and removed with minimal stress and mortality. Conventional traveling screens c.. injure fish because of the multiple sources of stress to which the fish are exposed. First, where screen rotation is intermittent (the usual case), fish are subject to suffocation while impinged. Second, as fish are lifted free of the water surface, they are no longer held against the screen cloth and can, therefore, fall back into the water and reimpinge. Third, conventional screen wash systems operate at a high pressure (80 to 100 psi). The high velocity jets which clean the screens of debris can cause injury. Finally, where attempts have been made at power plants to return live fish to their natural environment after impingement and removal, the discharge point is frequently close to the intake structure, a situation which can result in additional reimpingement.

A modified screen and spraywash system has been recently develope which eliminates some of the problems inherent in conventional screen designs. Since this modified system can be backfitted utilizing existing screens, it has obvious advantages over systems that require construction of new structures. However, because the modified screens rely on the impingement of fish, this system can be employed only after it has been determined that the species of concern can withstand such handling. The following briefly describes the operating experience of modified traveling screens relative to biological effectiveness. There is only one presently operating power plant with a modified traveling screen and spraywash system which has been biologically evaluated (White and Brehmer 1975). The Surry Power Station is situated on the James River and withdraws 3740 cfs of water for condenser cooling. Prior to installation of the modified screens, unscreened water was pumped from the river to a canal in which it flowed by gravity to the plant. Early operating experience showed that fish were being pumped into the canal and were ultimately impinged on the traveling screens located at the plant. To remedy this situation, eight modified screens were installed at the river to collect fish upstream from the pumps.

Screen modification involved bolting steel troughs on the trash lips of the conventional screen baskets. The troughs extend approximately 5 inches from the screen face and are capable of maintaining a minimum water depth of 2 inches during screen rotation. This arrangement prevents fish from flipping off the screen and becoming reimpinged and also ensures that the fish are in water as they are lifted to the point of release. Collected fish are carried over the headshaft sprocket and either fall into a collection trough or are gently washed into the trough with a low pressure jet (15-20 psi) on the back side of the screen. The low pressure wash feature of the modified screen prevents the damage caused by conventional spraywash systems.

To ensure maximum survival of impinged fish, the modified screens are operated continuously at a speed of 10 fpm. Consequently, fish are not impinged on the screen mesh for more than 2 minutes. In eighteen months of operation, the modified screens have shown a high degree of success in collecting fish while maintaining low mortality (White and Brehmer 1975). Short-term holding studies (approximately 15 minutes) show that, on the average, survival of 58 fish species was 93.3 percent. Average survival of 19 freshwater species was 98.1 percent. A number of species collected occur at Prairie Island, as listed below:

Common Name	Scientific Name	Percent Survival
Gizzard shad	Dorosoma cepedianum	93.1
Channel catfish	Ictalurus punctatus	98.8
Shiners	Notropis spp.	96.6
Carp	Cyprinus carpio	92.9
Bluegill	Lepomis macrochirus	100.0
Black crappie	Pomoxis nigromaculatus	100.0
Yellow perch	Perca falvescens	100.0

Seven species of the family Clupeidae (which includes gizzard shad), representing 58.1 percent of the 18 month collection total, showed a percent survival range of 82.3 to 94.3 with an average survival of 93.3 percent.

On the basis of these short-term survival data, it appears that the modified traveling screens have provided an effective means for minimizing fish impingement mortality at Virginia Electric Power Company's Surry site. Various utilities (among them Public Service Electric & Gas, Northeast Utilities Service Company, Long Island Lighting Company, and Wisconsin Electric Power Company) are presently modifying existing screens or incorporating modified screens into the design of new power plants. Due to this interest and the apparent potential for effective operation, several screen manufacturers now offer modified screens and spray-wash systems as standard items for new and existing stations. Although modified screens appear to have good potential for alleviating impingement mortality, it should be pointed out that short-term mortality studies alone may not adequately reflect possible longer term mortality which may result from injury incurred during the impingement and removal process. On the basis of impingement survival data collected at a power plant located on the Hudson River, it has been suggested that immediate survival may be a poor indication of impingement mortality, and that some consideration of latent mortality is required for adequate assessment of impingement damage (Ecological Analysts, Inc., 1976). The data offered in support of this statement are given in Table 3.2-1. It can be seen that while initial survival of four species was high, mortality increased rapidly over the 96 hour holding period, particularly for gizzard shad and *Alosa* spp. Similar results have been shown at other power plants, for example Indian Point Units 2 and 3, Nine Mile Point Unit 1, Roseton, and Danskammer (Texas Instruments, 1974; LMS, 1977; EAI, 1976).

These data should not be considered as contradictory to the results obtained at the Surry Power Station for several reasons. First, the Hudson River studies were conducted at plants which do not incorporate modified screens (i.e. lifting buckets). Therefore, there was a good chance that fish could drop off the flat debris lip as it cleared the water surface and be reimpinged one or more times. Those fish which were retained by the lip were out of water for a period of time and, in some cases, were exposed to high pressure sprays. Further, standard shallow, rough concrete sluiceways were generally used to convey fish to a collection area. Also, results of recirculation studies (Ecological Analysts, Inc., 1976) indicate that a relatively large percentage of the fish returned to the river after impingement and sluicing may be reimpinged upon release, thereby increasing the potential for mortality. Finally, the impingement survival study results are based on somewhat limited numbers of test specimens. All of these factors may have biased the results toward higher mortality. Therefore, it is probable that modification of the traveling screens (incorporation of lift... troughs, low pressure sprays, and an appropriate return system ... a more extensive evaluation would result in substanti... higher survival rates.

Table 3.2-1

Impingement Survival at a Hudson River Power Plant[1]

Species	No. of Fish[2]	Percent Survival					
		Initial	6 hr	12 hr	24 hr	48 hr	96 hr
White perch	439	94	--	--	71	63	50
Striped bass	45	93	--	62	44	18	11
Gizzard shad	110	98	58	25	11	0.5	0.5
Alosa spp.	49	70	8	2	0	0	0
Controls							
White perch	38	100	100	100	100	100	100
Gizzard shad	11	100	100	100	100	82	82

1 Based on Ecological Analysts, Inc., 1976
2 Summary of 3 to 6 sampling dates

Although modified screens may be somewhat less effective on a long-term survival basis than the Surry results indicate, it is believed that the excellent short-term survival observed at that site fully warrants consideration of this screening concept for application at Prairie Island. The high survival achieved among the relatively fragile clupeids, including gizzard shad, as well as other species occurring at Prairie Island, indicate that the modified screen system, incorporating a well-designed means of transportation back to the river, would act to greatly reduce the existing level of impingement mortality. Naturally, the effectiveness of the screens in alleviating mortality would vary according to the species present. Therefore, it could be valuable to conduct studies with the species of concern prior to backfitting. In this way, the actual degree of effectiveness could be determined on a small scale and the practicality of installing a complete screening system could be evaluated for cost-effectiveness.

Angled Flush Mounted Traveling Screens

To date, angled traveling screens have not been utilized within an operating power plant. However, a number of studies have recently been conducted which indicate that such a concept is highly effective in diverting fish to bypasses. Most recently, Stone & Webster Engineering Corporation (1976) has completed studies which have led to the development of an angled screen diversion and fish transportation system which is presently being incorporated into the design of two large power plants situated on Lake Ontario. These and other studies are discussed below.

Several major research programs have been conducted to evaluate the potential of an angled screen, leading to a bypass, for effectively diverting fish and thereby minimizing impingement at power plant intakes. The first evaluations were conducted by Ichthyological Associates, Inc. for the Southern California Edison San Onofre Station (Schuler, 1973; Schuler and Larson, 1974). In these studies, 5/8 inch mesh screens were not found to be acceptable due to poor-to-fair guidance (0 to 70 percent) of the northern anchovy (Engraulis mordax), a primary test species. Moderate-to-good guidance (60 to 90 percent) of other test species was obtained with a screen set at 45 degrees to the approach flow, an approach velocity of 2.0 fps, and a bypass velocity of 1.5 to 4.0 fps (higher efficiencies corresponded to higher bypass velocities). This was also the best setting for anchovies, which were guided with 30 to 70 percent efficiency.

The angled screen was not considered further because of the large bypass flow required to yield good guidance efficiencies. However, design limitations at the San Onofre Station permitted only one approach velocity (2 fps) to be tested, this velocity being the minimum possible. Therefore, it should not be concluded from the San Onofre studies that angled screens would not be effective at other sites. It is possible that the same or other species could be effectively guided along angled screens under different conditions, particularly lower velocities and smaller screen mesh sizes.

Later studies by Stone & Webster have shown that angled screens can be effective when properly applied. The S&W studies were conducted for a number of utilities operating large power plants on Lake Ontario and the Hudson River (Taft et al, 1976). In studies with Lake Ontario species, the alewife being the primary species of concern, it was found that an angled screen, set at a 25 degree orientation to the flow at equal approach and bypass velocities ranging from 0.5 to 3.0 fps, was 100 percent effective in diverting 1 to 6 inch long fish to a 6 inch wide bypass under all conditions tested, including low water temperature (Stone & Webster, 1976). As a result of these findings, a complete diversion and transportation system, incorporating pipe and pumping components, has been developed for returning fish safely to the lake. Similar results were obtained by S&W during studies with Hudson River species (striped bass, white perch, and Atlantic tomcod which ranged in length from 2-6 inches). Under the same design and hydraulic conditions given above, the angled screen was found to be 100 percent effective in guiding these species to a 6 inch wide bypass. Results of 1 week mortality studies showed that survival of bypassed fish was greater than 96 percent (Taft et al, 1976).

Although angled screens have not been otherwise evaluated for power plant screenwell application, they have been utilized at several hydroelectric facilities for guiding upstream and downstream migrants. At the North Fork Project on the Clackamas River in Oregon, angled traveling screens are installed at two locations along a 2 mile long fish ladder (Gunsolus and Eicher, 1970). Downstream migrants, primarily chinook (Oncorhynchus tshawytscha) and coho (O. kisutch) salmon and steelhead trout (Salmo gairdneri), enter the fish ladder at the North Fork Dam via a downstream migrant channel. From this point, they can pass either through an open port in a gate system or can travel farther downstream where they are diverted by a set of angled screens and bypassed to the fish ladder. The width of the approach channel is 10 feet. The two traveling screens (0.14 inch mesh, 16 gauge wire cloth) are each 11 feet wide and are set in tandem with a 2 foot center pier between them. The screens are oriented at a 22 degree angle to the flow. The average depth of water in front of the screens is 30 feet. This arrangement has been found to be highly effective in diverting downstream migrants without impingement provided that the total screen flow does not exceed 500 cfs.

The second angled traveling screen installation is located just upstream of the fish ladder entrance (2 miles downstream from the North Fork Dam at the foot of the Cazadero Dam). This single screen is 7 feet wide and is set at a 45 degree angle to the flow. The structure is utilized to separate downstream migrants from the ladder flow for subsequent introduction to a 5 mile long pipeline. This pipeline transports the fish safely to a free-fall discharge just below the last dam in the complex, the River Mill Dam. Both angled traveling screen installations at the North Fork complex have been functioning effectively for nearly 15 years.

Experience at the Mayfield Dam on the Cowlitz River in Washington further substantiates the effectiveness of angled screens in guiding fish (Thompson and Paulik, 1967).

Results of the above studies indicate that angled traveling screens offer a potentially effective method for reducing fish impingement losses at Prairie Island. The size and life stages of the species of concern at Prairie Island (NUS, 1976) are similar to those tested by Stone & Webster and occur at water temperatures similar to those evaluated. Therefore, it is believed that the species at Prairie Island should be capable of guiding along angled screens at the times of year that they commonly inhabit the area. As discussed in Section 3.1, the angled screen design for Prairie Island would incorporate lifting troughs and a dual pressure wash system to aid in the collection of fish eggs and larvae. Therefore, should some juvenile or adult fishes be incapable of guiding along the angled screens, they would be impinged and gently removed for return to the river. The potential effectiveness of this back-up provision relative to fish survival was discussed above under <u>Modified Traveling Screens with Fish Buckets.</u>

<u>Center Flow Screens</u>

Center flow traveling screens have only recently been utilized for power plant application in the U.S. However, they are used extensively in Europe. With attention being turned toward the screening of fish eggs and larvae in the U.S., a small number of utilities and agencies are investigating the possible use of center flow screens with fine mesh. At this time, data are limited, but the results indicate that these screens could offer an effective solution to the problem of excluding eggs and larvae, as well as juvenile and adult fishes, from circulating water systems.

There is only one power plant in the U.S. which presently utilizes center flow screens from which biological data has been collected. Central Power and Light Company's Barney Davis Station is located on Laguna Madre in Corpus Christi, Texas. Due to heavy debris loading in the area caused by marine grasses and ctenophores, four center flow screens were installed to screen the total plant flow of about 800 cfs. Each screen has 53 panels of 0.5 mm polyester mesh. The design velocity through the clean screen is approximately

1.7 fps corresponding to a gross velocity at the screen face of 0.78 fps. The screens are operated continuously at a travel speed of 1 fpm and have an overhead 10 to 20 psi spraywash system. In 1975 and 1976, biological sampling was conducted to determine species composition and mortality (S. Murray, personal communication). The majority of the organisms recovered in sampling nets located in a screenwash debris collection pit consisted of penaeid shrimps which showed high survival. Of approximately 50 fish species collected, the dominant species were the bay anchovy (Anchoa mitchilli) and the gulf menhaden (Brevoortia patronus) ranging in length from 15 to 20 mm. Very few larger fish are taken although this station employs a long intake canal which is generally heavily populated by adult fish. Early studies showed relatively high mortalitites of these small fishes due to extensive clogging of the sampling net during the 5 minute sampling period. Later, a series of 30-second samples were taken which yielded much higher survival. Actual percentages are not available at this time. However, considering the sizes of the fragile species such as menhaden and anchovy which have been successfully collected with good survival, it would appear that the center flow screen deserves consideration for the collection of juvenile and adult fishes. This conclusion is further substantiated by the results of the modified traveling screen evaluations discussed in the previous section since the center flow screen is essentially the same as the modified screen in terms of the manner in which fish are handled.

Screen Mesh Size

Screen mesh size is important with respect to juveniles (and adults of some species) in that use of relatively coarse mesh, such as 3/8 inch openings commonly used for traveling screens, would permit smaller individuals to pass through the screens and into the intake and recycle canal system. This, then, would present the potential for development of a resident population within these canals and such a population would be subject to cold shock and impingement at the existing screenhouse during winter plant shutdowns. As noted in Section 2.2, it is believed that a large proportion of existing impingement losses stem from cold stress effects on fish resident in the canals. It is therefore important that the alternative designs chosen employ a screen mesh sufficiently fine to exclude juveniles and adults from the intake and recycle canals. The subject of screen mesh size is discussed further below with respect to organisms entrainable through the existing 3/8 inch mesh screens.

3.2.2 Entrainment

It is immediately evident from the preceeding discussion that all life stages entrainable through the existing coarse mesh screen must also be screened if the potential for development of resident populations in the intake and recycle canals is to be minimized. In addition, since mortality through the plant is assumed to be 100 percent and it is assumed that these are passive organisms which cannot be guided, reduction of entrainment mortality for a given intake flow rate necessitates use of a design which will collect and remove these organisms from the water prior to their entry to the intake canal. This objective, then, sets the criterion for screen mesh size for all the alternatives discussed, since mesh size must be fine enough to screen a large percentage of the eggs and larval stages of species considered to be important. Further, the design employed should be capable of yielding high survivorship of organisms removed if the objective of reduced entrainment mortality is to be met.

Data on egg diameter and larval hatching size for species entrained at Prairie Island are presented in Table 3.2-2. It may be noted that the first 5 species listed in this table are those considered important with respect to entrainment losses and that egg diameters for these species range from 0.8-2.0 mm, with larval hatching sizes (where known) of from 3.2-8.6 mm. Based on these figures, it was determined that 0.5 mm mesh screen would be required to adequately screen those organisms from the water entering the intake canal.

Examination of Table 3.2-2 also indicates that 0.5 mm mesh should screen a wide range of other species common to the Prairie Island location. Therefore, if it were determined at some later date that a different species assemblage was more important than the one proposed in this report, 0.5 mm mesh screen should work equally as effectively for almost any species selected.

With respect to survival of impinged organisms, limited data are available both from operational traveling screens and from laboratory studies which indicate that, for certain species, impingement mortality of early life stages on fine screens can be kept relatively low if proper design criteria are met. These criteria include mesh size, water velocity, and duration of impingement.

As noted above, the only operational data available are from the Central Power and Light Barney Davis Station in Corpus Christi, Texas. Here, bay anchovy and gulf menhaden are the dominant fish collected from 0.5 mm mesh screens. These fish range in length from 15-20 mm and immediate mortality studies indicate high survivorship of these fragile species (S. Murray, personal communication).

In laboratory studies (Skinner, 1974), it was found that steelhead trout ranging in length from 22-36 mm could be impinged for up to 50 minutes at 1.5 fps and still exhibit greater than 90 percent survivorship. Survival decreased rapidly when impingement time exceeded 10 minutes for both king salmon (Onocorhyncus tshawytscha; 36-56 mm) and steelhead trout when velocity was increased to 2.5 fps. Striped

Table 3.2-2 Egg Diameter and Larval Hatching Size for Species Entrained at Prairie Island

Common Name	Scientific Name	Approximate Egg Diameter (mm)	Approximate Larval Hatching Size (mm)
Gizzard shad	Dorosoma cepedianum	0.8	3.2 (1)
Shiners	Notropis spp.	1.0-1.5	5.0 (1)
White bass	Morone chrysops	0.7-1.2	--- (2)
Darters	Etheostoma spp.	1.1-1.7	4.7-5.0 (1)
Walleye	Stizostedion vitreum	1.5-2.0	6.0-8.6 (4)
Freshwater drum	Aplodinotus grunniens	1.4-1.9	--- (3)
Northern pike	Esox lucius	2.2-3.4	6.0-10.0 (4)
Carp	Cyprinus carpio	1.0-2.0	3.0-6.4 (1,4)
Black bullhead	Ictaluras melas	3.0	--- (4)
Brown bullhead	I. nebulosus	3.0	6.0 (4)
Trout-perch	Percopsis omiscomaycus	1.2-1.8	6.0 (4)
Burbot	Lota lota	1.2-1.7	--- (4)
Largemouth bass	Micropterus salmoides	1.4-1.8	2.7-4.3 (1,4)
Smallmouth bass	M. dolomieu	1.2-2.5	3.6-7.0 (1,4)
Bluegill	Lepomis macrochirus	0.9-1.4	2.0-3.0 (1,4)
White crappie	Pomoxis annularis	0.9	3.0 (1,4)
Black crappie	P. nigromaculatus	1.0	3.0 (1,4)
Yellow perch	Perca flavescens	1.7-4.5	5.0-6.0 (1,4)

(1) Lippson and Moran (1974)
(2) Ruelle (1977)
(3) Grotbeck (personal communication)
(4) NUS (1976)

found to exhibit close to 100 percent survival with impingement times up to 4 minutes at screen approach velocities of less than 0.8 fps. This same study suggests that it may be feasible to impinge striped bass eggs for up to 6 minutes at velocities of up to 0.8 fps with egg survival of over 80 percent.

Prentice and Ossiander (1974) present data which indicate that chinook salmon fry ranging in size from 26-170 mm can be impinged on 0.7 mm mesh screen for up to 15 minutes at water velocities up to 1.5 fps with greater than 94 percent survival (18 hour post-test observation). With a screen approach velocity of 0.5 fps, survival of the smallest fish was virtually 100 percent for impingements up to 60 minutes. At higher velocities, they found greatly decreased survival when impingement time was increased to over 15 minutes; i.e. at 0.5 fps survival was independent of impingement time, but at 1.5 fps survival decreased as impingement time increased from 6 to 60 minutes.

Tomljanovich, Heuer and Voightlander (1976) studied the effects of screen mesh size, water velocity, and impingement time on efficiency of screening and mortality of largemouth bass (Micropterus salmoides), smallmouth bass (M. dolomieui), and striped bass for a range of screen sizes (0.5-2.51 mm mesh). They determined that of the screen sizes tested, 0.5 mm yielded the greatest screening efficiency (90 percent for larval fish with lengths as small as 5.5-7.5 mm). For largemouth and smallmouth bass larvae, 48 hour mortality could be held to approximately 20 percent for 16 minute impingement time with 0.5 fps screen approach velocity and 0.5 mm mesh. Shorter impingement times resulted in survival factors of up to approximately 95 percent for these species. For striped bass, 48 hour mortality studies resulted in mortality of approximately 100 percent, but extremely high control mortalities for this species make it difficult to interpret the data.

If it can be assumed from the data presented above that mortality of fish presently entrained at Prairie Island can be held to approximately 20 percent on fine mesh screens when approach velocities are relatively low and impingement time is kept to 15 minutes or less, then each of the proposed alternative intakes offer the potential for substantial reduction of entrainment mortality as compared to the existing Prairie Island intake system. For example, under present operating conditions, for every 1000 organisms entrained, 1000 die due to 100 percent mortality experienced in passage through the cooling system. With 20 percent mortality assumed for the proposed alternatives, it could be expected that only 200 instead of 1000 organisms would die, equivalent to a 5 times increase in survival. Thus, employment of one of the proposed alternative systems could make it possible to continuously pump 5 times more water than the baseline

Can't we do better than 20% mortality by ↓ imp time (1-2 min)

level (Section B) through the Prairie Island Nuclear Generating Plant while maintaining entrainment mortalities at or below baseline levels. If the baseline intake flow is assumed to be 188 cfs, then the flow could be increased to 940 cfs while maintaining the same level of entrainment impact as would be experienced at the 188 cfs withdrawal rate.

Such a judgement obviously relies heavily on the inference of equivalent mortality (20 percent) between species tested and species found at Prairie Island, and this certainly requires further testing. However, the available data on impingement mortality for early life stages of several species of fish do indicate that the proper combination of screen mesh size, water velocity, and impingement time results in high survivorship and it could be presumed that the same trend would be present for the species of importance at Prairie Island.

Should it be desireable to use coarse mesh screening on any of the intake alternatives discussed, the potential still exists for reduction of entrainment mortality through reduction of makeup flows during periods of high ichthyoplankton density.

Examination of data presented in the Prairie Island Section 316(b) demonstration (NUS, 1976) indicates that May and June have the highest ichthyoplankton densities, accounting for 88 percent of the total yearly entrainment. Reduction of flows during May and June would reduce entrainment mortality. Achievement of a 188 cfs flow rate is assumed to offer no benefit during May, since during May, 1976, flows were somewhat below this figure. In June, however, reduction of makeup flow to 188 cfs from the June, 1976, average makeup flow of approximately 550 cfs, would lead to a 65 percent reduction in the number of fish eggs and larvae entrained. Since June accounts for 46 percent of the total yearly inchthyoplankton entrainment, this flow reduction would result in a 30 percent decrease in yearly ichthyoplankton mortality. Intake flows during July and August, 1976, averaged 1048 and 855 cfs, respectively. Due to relatively low ichthyoplankton densities during these months; however, maintainence of the 188 cfs flow during July and August would have led to additional mortality reductions of only 4 and 5 percent, respectively. A total of 39 percent reduction in yearly mortality could be obtained (compared to 1976 levels) if the makeup flow were held to 188 cfs from June through August. Intake flows and ichthyoplankton densities are sufficiently low for the remainder of the year that continued maintainence of a 188 cfs makeup flow would be of little value. In September, for example, a 188 cfs flow rate would result in a reduction of only 0.05 percent in entrainment mortality.

Based on the assumptions set forth in the body of this report, it may be possible to operate at lower withdrawal rates during periods of high ichthyoplankton density (May and June) and up to 1500 cfs for the balance of the year while maintaining total annual mortality levels at those associated with the baseline conditions.

4.0 FISH TRANSPORT SYSTEM

All three alternative intake schemes proposed for Prairie Island would require a system for returning collected or diverted organisms to the Mississippi River. Since the modified traveling screens and center flow screens would lift the organisms a substantial height above the pool elevations for removal, sufficient head is available for gravity flow return via pipeline. The angled screen alternative, on the other hand, would require a pump to supply the energy needed to transport fish to the release point. Based on extensive studies by Stone & Webster (1975: Taft et al, 1976), a jet pump has been selected for use in this report as an effective means for transporting fish safely.

The jet pump is a unit which performs its pumping action by the transfer of energy from a high velocity jet to one of low velocity. There are two types of jet pumps, as shown in Figure 4.1-1: the core type, in which a concentric nozzle or multiple nozzles are placed centrally, and the peripheral type, in which the nozzle or nozzles are placed around the periphery.

The major elements of either type are the driving nozzle, the suction nozzle, the mixing tube, and the downstream diffuser. The high pressure driving flow enters the mixing tube by means of a nozzle which gives it a high velocity. The nozzle can be of various designs and placed in different configurations and number. In the mixing tube, the momentum exchange from the high velocity flow to the low velocity flow takes place. The suction flow is accelerated at the expense of the energy of the driving flow. The shape of the mixing tube best suited for water jet pumps is one with cylindrical walls. When the combined flow leaves the mixing chamber, it will have attained complete mixing.

Pheripheral jet pumps have been used in the past to transport live fish in hatcheries. Harris Thermal Transfer Products, Tualatin, Oregon, manufactures single-stage and three-stage peripheral jet pumps for use in hatchery truck loading and handling of stock. With a mixing tube of 4 inch diameter, the pump can move 150 pounds of fish per minute with a maximum lift of 5 feet per stage. These pumps have been used to transport 4- to 14- inch long salmonids in the Snake River hatchery at Bulle, Idaho, and in the Gnat Creek hatchery and the Oak Springs hatchery of the Oregon State Game Commission with no initial or delayed mortality (Harris, 1974).

Studies by Stone & Webster (1975; Taft et al, 1976) indicate that the peripheral type jet pump has less potential for causing injury or stress than the core type pump. Therefore, the peripheral pump is now considered to be the most practical method for inducing transport pipe flows.

Information on hydraulic performance characteristics of peripheral jet pumps is mostly proprietary. However, Stone & Webster (1975), in conjuction with the development of a fish transportation system for power plant application, has derived the performance characteristics through a semi-empherical solution verified by model tests. Fish transportation system hydraulics have also been derived analytically, verified by model tests, and have been computerized in order to allow optimization of a system design for a particular application.

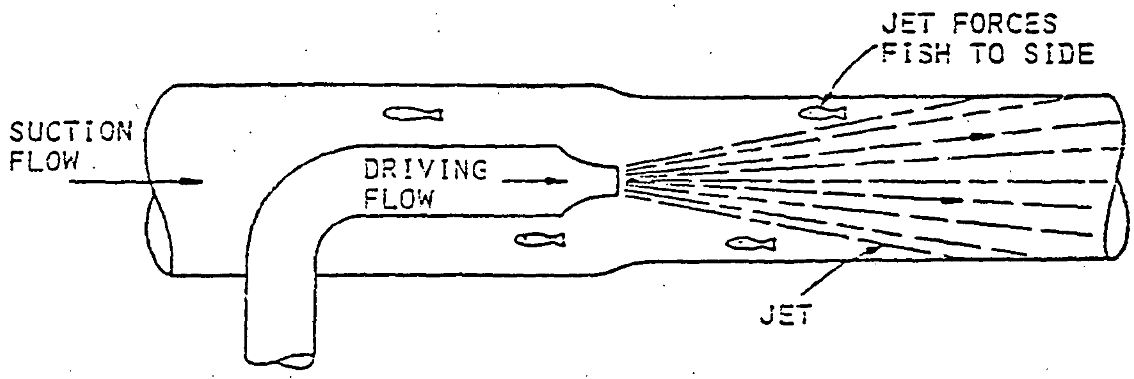
As previously mentioned, Stone & Webster has recently conducted studies to evaluate the effectiveness of a jet pump for inducing bypass and pipe flows and transporting fish safely. In these studies, each element of a complete fish diversion system, including an angled flush-mounted traveling screen, transport piping, and jet pump, was initially evaluated individually. The results of these individual studies were then used to determine the optimum range of operating conditions for each element. Following this evaluation, the components were connected into a complete system model incorporating a large peripheral type jet pump (12 inch mixing tube). Results of testing with alewives in the system model have shown that this relatively fragile species can be diverted and transported effectively over a range of hydraulic and environmental conditions with less than 0.4 percent differential mortality (test mortality minus control mortality), even at jet nozzle velocities as high as 50 fps (Stone & Webster, 1976; Taft et al. 1976). Therefore although the jet pump may contribute to mortality within the system, the fact that the overall mortality was low indicates that the pump is a practical method for transporting fish. It would be reasonable to expect that hardier fish species would experience even lower mortality. Accordingly, a jet pump was selected for possible application at Prairie Island. Should a jet pump fish transport system be chosen for use at Prairie Island; however, tests could be made with the species of concern to verify the suitability of this transport system.

Whether pumped or returned by gravity, all organisms would be returned to the Mississippi via a buried pipe. The discharge point would be 350 feet offshore in 15 feet of water. This location was selected since it is in deep water (below the maximum ice depth) and is downstream of the intake canal, thus minimizing the potential for recirculation of organisms, particularly passive eggs and larvae. To ensure maximum survival potential during transport, the following general design criteria for all piping should be followed:

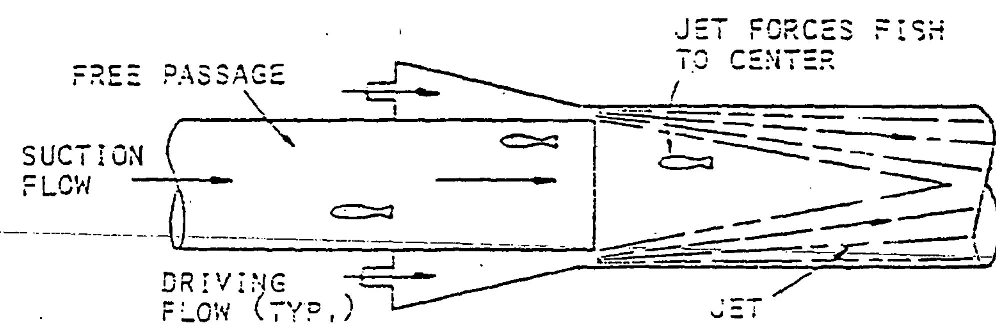
1. The pipe should be constructed of a non-abrasive material, such as fiberglass, polyethylene, or coated steel, to prevent injury due to abrasion.

2. All bends should be of the long-radius type so that fish are not forced toward the sides in these areas.
3. The pipes should be sized so that the velocity at a given flow rate is high enough to transport fish quickly to the release point, but not so high that the fish lose their orientation completely. Past studies by Stone & Webster (1975) indicate that velocities from approximately 5 to 8 fps are acceptable.
4. Pipe joints should be constructed carefully so that they are even and do not create jagged obstructions within the pipe which could injure fish.
5. Valves, flow meters, etc., if required, should be designed to create as little obstruction to, or disruption of, the pipe flow. For example, valves or gates within a pipe represent an obstruction to free fish passage and venturi-type flow meters create undesirable velocity acceleration and deceleration conditions.
6. Transitions from smaller to larger pipes, or vice versa, should be gradual so that rapid velocity changes, which fish might avoid, do not occur.
7. At the point where bypass transition sections enter two or three individual pipes, the pipes should be carefully manifolded so that the bypass flow is equally distributed to each section.
8. The pipe should be located below the frost depth to prevent icing.

All of these criteria have been considered in the design of alternative intake structures proposed for Prairie Island.



CORE-TYPE JET PUMP



PERIPHERAL-TYPE JET PUMP

FIGURE 4.1-1
TYPES OF JET PUMPS
ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

5.0 ESTIMATED COSTS

Based on the designs for the proposed alternative intakes for the Prairie Island Plant, order of magnitude costs were developed for each scheme. The estimated costs are based on the following:

1. Present day prices and fully-contracted labor rates as of May, 1977
2. Forty hour work week, single shift operation
3. Allowance for contingencies to cover material, labor productivity, construction problems, and design changes to satisfy licensing and regulatory requirements
4. All construction performed on a fully-contracted basis
5. Start of construction on June 1, 1978, with construction schedules of 16 months for center flow screens, 21 months for modified screens with fish buckets, and 23 months for angled screens
6. Allowance for overhead to cover distributable construction cost, indirect cost, and general and administrative costs
7. Allowances for escalation and interest during construction

The total evaluated costs for the various schemes are presented in Table 5.1-1. Also included in this table are the power and annual energy requirements and maintenance costs for each scheme.

Table 5.1-1

Economic Comparison

Scheme	Auxiliary Power (KW)	Annual Energy (MWH)	Total Evaluated Cost ($x10^6)	Annual Maintenance Cost ($/yr)
Center Flow Screens	33	290	7.0	40,000
Traveling Screens With Fish Buckets	120	1050	14.5	120,000
Angled Screens With Fine Mesh and Fish Buckets	585	5140	17.0	140,000

The costs listed in this table are for structures designed for an approach velocity of 0.5 fps at the screen face. No attempt was made to optimize any of the schemes. If further investigations indicate that the optimum approach velocity varies significantly from 0.5 fps, the estimated costs would change accordingly.

Annual energy requirements listed in Table 5.1-1 are based on continuous operation of the screens at a low speed of between 1 to 2.5 fpm. During periods of high trash loading or peak density periods of organisms, the screens would operate at higher speeds. The horsepower requirements of all electrical equipment associated with the screens were held constant throughout the year, with variations in screen rotation assumed to be accomplished by gear reduction. Motors were assumed to be 90 percent efficient. Further, it was assumed the screenwash pumps operate whenever the screens are rotating.

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SUPPLEMENT TO REPORT ON ALTERNATIVE INTAKE DESIGNS FOR REDUCTION OF IMPINGEMENT AND ENTRAINMENT MORTALITY

NORTHERN STATES POWER COMPANY
Prairie Island Nuclear Generating Plant
Units 1 and 2

AUGUST 1978

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the Laws of the State of Minnesota.

D. L. Matchett

Date 8-4-78 Reg. No. 12949

Stone & Webster Engineering Corporation

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1.0 INTRODUCTION AND PURPOSE

Northern States Power Company (NSP) previously made a preliminary engineering study of alternative intake systems for the Prairie Island Nuclear Generating Plant. This study was undertaken to evaluate the cost of intake modifications versus the cost of derating the unit to meet permit requirements. The results of this study indicated that substantial overall savings could be achieved by modifying the intake, if the discharge rate to the Mississippi River could be increased and if potential biological problems associated with increased discharge and intake rates could be minimized.

In December 1976 NSP authorized Stone and Webster Engineering Corporation (S&W) to develop conceptual designs of various intake alternatives that could reduce biological impacts while permitting increased intake flows. The three most feasible intake alternatives are presented in the report entitled "Alternative Intake Designs for Reduction of Impingement and Entrainment Mortality, Prairie Island Nuclear Generating Plant, Units 1 and 2, July, 1977."

This report is a supplement to the above-mentioned S&W report. Its purpose is two-fold: first, to provide information in selecting the proposed screenhouse location, including investigation of an offshore submerged intake requested by regulatory agencies in May 1978; and second, to provide supplemental information on the intake alternatives studied by S&W but not considered suitable for use at the Prairie Island Plant.

2.0 SUMMARY AND CONCLUSIONS

2.1 Alternative Intake Locations

Three locations were considered as potential intake siting areas: Sturgeon Lake, the main channel of the Mississippi River and the plant shoreline.

The northern reach of the plant shoreline was chosen as the preferred intake location (Section 4.3). The plant shoreline considered extends from north of the existing intake canal to the discharge canal. The southern reach of the area, near the discharge canal, is shallow and would require extensive construction and maintenance dredging, with associated short-term environmental impacts. This reach was dropped from consideration, since it offered no advantages over the northern reach (Section 4.3). The northern reach, near the intake canal, is deeper and therefore would require less dredging. Good land access is available, and construction impacts would be minimized.

Sturgeon Lake is a shallow backwater area of the Mississippi River and is a highly productive area. Construction of an intake on the shoreline of the lake would require extensive dredging that could result in ecological impacts. An intake located in Sturgeon Lake would also require maintenance dredging, and its reliability during the winter is questionable because of the heavy ice pack in this area. Sturgeon Lake was rejected as a potential intake location (Section 4.1).

The main channel of the Mississippi River is most likely a less productive biological area than Sturgeon Lake. An intake located here would be in deeper water, resulting in less dredging for the intake. However, intake lines extending to the plant would have to cross either Sturgeon Lake or the backwaters in front of the plant. This location would place the intake at the edge of the navigation channel where it would be susceptible to damage from barge traffic. Inspection and maintenance of an intake here would be difficult. This location was rejected as a potential intake site because of engineering impracticality, the construction that would result from installation of the intake pipelines, and the lack of information indicating that this location would substantially reduce fish losses in a cost-effective manner (Section 4.2).

2.2 Offshore Submerged Intake

Even though the main channel location was rejected, as discussed in Section 2.1, an offshore submerged intake near the main channel is discussed here in response to regulatory questions of May 1978.

An offshore submerged intake for the Prairie Island Plant would utilize four velocity cap intakes at the edge of the main channel of the Mississippi River. The intakes would be connected to an onshore pumphouse by buried pipelines. Provisions for backflushing to control ice buildup would be provided. Entrainment losses associated with this intake would probably be less than for other proposed intake schemes, since the larval densities in the river are probably lower than those of Sturgeon Lake. Since the cost of construction of an offshore submerged intake would be approximately $45 million, it is questionable that the potential decrease in entrainment losses justifies the additional capital investment. An additional study, to be issued in the late summer of 1978, is being conducted to answer the cost/benefit question (Section 4.1).

2.3 Alternative Intake Designs

The S&W report of July 1977 presented the three proposed intake alternatives for the Prairie Island Plant. The current report gives additional information on the remaining five alternatives which were studied but rejected for this particular application. These alternatives are discussed in detail in Section 5.

Angled fixed screens were rejected because of their inability to protect fish eggs and larvae, their potential maintenance and reliability problems, and their failure to offer any substantial advantage, except possibly cost, over the proposed intake systems.

Louvers were rejected because they do not protect fish eggs and larvae or eliminate the potential for a resident fish population in the intake and recycle canals, which was one of the prime objectives of the study.

Radial wells were rejected because of the large number required and the impracticality of locating intakes over a 15- to 18-mile stretch of shoreline. Also, radial wells have not been used for once-through cooling systems and thus represent unproven technology for a facility the size of Prairie Island.

Porous dikes were rejected because of the potential maintenance problems associated with the filter media and the large size of the structure required to pass the design flow. Also, porous dikes are still in the development stage and have never been used to protect small organisms at power plant intakes.

Wedgewire screens were rejected because of potential maintenance problems with backflushing the screens to remove debris and for deicing. Also, the ambient current required to flush debris and organisms away from the screens (about 1 fps) is regularly not available at the site.

3.0 ASSUMPTIONS

The assumptions made for this study were used to: 1) estimate the size of structures and associated equipment, 2) evaluate the alternative intake schemes with respect to their relative biological effectiveness, and 3) evaluate the alternatives with respect to their engineering practicality for use at the Prairie Island Plant.

Engineering assumptions used in this report are:

1. The design flow will be 1410 cfs.
2. Approach velocity, based on gross screen or intake area, will not exceed 0.5 fps.
3. No structures will be built within 500 feet of the emergency intake.
4. The velocity in the pipelines will not exceed 9 fps.

With the exception of the design flow rate, which was lowered to 1410 cfs from 1500 cfs, the engineering assumptions are the same as those stated in S&W (1977). Additionally, it is assumed that intake systems or screening equipment would not be acceptable unless they have demonstrated satisfactory engineering reliability.

The biological assumptions used in this report with respect to impingement and entrainment of aquatic organisms are:

Impingement

1. All important species will guide along an angled screen to a bypass.

2. Juveniles and adults of important species, with the possible exception of gizzard shad, are relatively hardy and can survive short-term impingement and pumping.

3. All new structures will be unaffected by thermal effluents, thus avoiding adverse effects of cold stress during periods of plant shutdown.

4. Available impingement data are indicative of long-term trends at Prairie Island.

<u>Entrainment</u>

1. Ichthyoplankton or entrainable fish are passive organisms and cannot be diverted through their own swimming efforts.

2. 0.5 mm mesh will collect eggs and larvae of all important species, thus preventing establishment of a resident population in the intake and recycle canals and subsequent cold-shock mortality.

3. Relatively high survival of these organisms is possible following impingement and removal from fine-mesh screens.

4. 100 percent mortality of entrained organisms now occurs at Prairie Island.

5. Available entrainment data are indicative of long-term trends at Prairie Island.

4.0 ALTERNATIVE INTAKE LOCATIONS

Three areas were originally considered for locating an alternative intake structure. They were Sturgeon Lake, the main channel of the Mississippi River, and the shoreline from north of the existing intake canal to the plant discharge.

4.1 Sturgeon Lake

Sturgeon Lake is a shallow backwater area of the Mississippi River. The southern end of the lake is directly north of the Prairie Island intake canal. This area was originally considered because it would minimize recirculation of waste heat because of its remote location with respect to the discharge canal. Also, there is less boat traffic on the lake than on the Mississippi River.

Sturgeon Lake represents the type of habitat suitable for use as a fish spawning and nursery area. Backwater areas of this nature provide protection from predation, prevent downstream displacement of eggs and larvae by river currents and can contain the rich food supplies critical to early larval development. On the basis of fisheries data collected since 1970, it appears that most species inhabiting the vicinity of Prairie Island prefer such areas for spawning (NUS 1976). Therefore, the eggs, larvae and young of these species are probably more abundant in habitats such as Sturgeon Lake than in other areas of the Mississippi River. While density differences in the vicinity of Prairie Island have not been quantified for these early life stages, it was felt that the spawning and nursing potential of Sturgeon Lake, in conjunction with engineering concerns addressed below, precluded serious consideration of the lake as a site for a new intake structure.

Since the issuance of the July 1977 alternative intake study report, ichthyoplankton distribution and abundance data have been obtained from Sturgeon Lake, the main river channel and the existing Prairie Island intake. These data, which were obtained through sampling in June of 1978, are being analyzed, and a cost/benefit study will be performed. The findings of these analyses will be issued in late summer 1978.

From an engineering viewpoint, there are several aspects which make Sturgeon Lake unattractive for siting an intake structure. The mean depth of the lake is relatively shallow, less than 7 feet, at a flat pool elevation of 674.5 feet (1929 datum), with large areas being less than 4 feet deep, especially near the shoreline. The shallowness of the lake would necessitate a large volume of dredging to provide sufficient water depth at an intake. Periodic maintenance dredging would also be required to ensure reliable intake operation. Ice cover would be a problem for any structure built on Sturgeon Lake. During a severe winter, ice over 3 feet thick could form, which would drastically reduce the effective water depth; in fact, a thick enough ice cover could block the intake from its supply of water.

The Sturgeon Lake intake location was dropped from consideration due to the probable abundance of ichthyoplankton in this area, the potential short-term biological impacts associated with the dredging operation required for intake construction and operation, and because of the reliability problems associated with ice cover and the shallow water depths.

4.2 Mississippi River - Main Channel

The stretch of the Mississippi River main channel originally considered as a possible intake location extends from wing dam number 36 south to wing dam number 40, a distance of approximately 3000 feet (Figure 1).

This area provides relatively deep water, 12.5 feet at a low water elevation of 672.5 feet (1929 datum), and access to currents which are normally of greater magnitude than those of Sturgeon Lake or the backwaters of the river. An intake located here would be built between two adjacent wing dams and as far east as possible without encroaching on the navigation channel. This position would take maximum advantage of the existing water depth and would minimize construction dredging at the intake structure.

Sufficient biological data were not available during the alternative intake study to determine whether fish and ichthyoplankton densities in the main channel are substantially lower than at the proposed screenhouse location (adjacent to the existing intake canal). However, as discussed below, engineering concerns severely limit the practicality of a main channel intake and result in substantial increases in cost over the shoreline schemes. Further, as discussed in S&W (1977), the three shoreline schemes were assumed to be capable of minimizing entrainment and impingement mortality at the proposed location. Therefore, the operational uncertainties and added costs of locating an intake structure in the main channel were considered unwarranted. The potential for further reducing mortality by locating an intake in the channel will be readdressed after the analysis of data from the recently conducted ichthyoplankton studies at Prairie Island.

Locating an intake on the main channel of the river poses several design problems. The intake would have to be as close as possible to the navigation channel in order to obtain water depths sufficient to protect the structure from ice cover and to include an allowance for siltation. Constructing an intake adjacent to the navigation channel could create a potential hazard to navigation and would increase the potential for structural damage due to a collision from commercial or recreational traffic. The intake would also be susceptible to damage from large debris being carried downstream, especially during periods of flooding.

An intake located on the main channel of the river would require large-diameter pipelines to convey the water to the plant. The installation of the pipes would entail a large dredging operation which would traverse shallow backwater areas and possibly some of the small islands fronting the plant shoreline. The construction of an intake and the associated piping would result in heavy short-term construction impacts to the area.

From a biological standpoint it could be desirable to withdraw water from the main channel of the Mississippi River because of the expected lower larval densities; however, the problems associated with constructing an offshore intake on this stretch of river make it impractical from an engineering standpoint. Further, the additional cost associated with an intake on the main channel does not appear to be justified from a cost/benefit standpoint in the absence of any supporting biological data. This cost/benefit study is presently being prepared as mentioned in Section 4.1. Although this location is considered impractical for an intake, a detailed discussion of a typical submerged offshore intake on the main channel of the river is presented in Section 4.4. This discussion, as well as an order-of-magnitude cost estimate, is presented for comparative purposes with respect to the proposed intake schemes discussed in S&W (1977).

4.3 Plant Shoreline

The third area considered as a potential intake location was the shoreline from north of the intake canal south to the discharge canal. This area has two major divisions: the northern area, which has been dredged to create the plant's intake canal and provides relatively deep water, and the southern area, which is shallower and has been left in a relatively undisturbed state. The entire area is subject to some degree of thermal recirculation from the existing plant discharge; however, the extent of recirculation decreases with increasing distance north along the shoreline.

In the southern area, extensive dredging would be required to provide an adequate water depth. Heat recirculation would also be more likely to occur if an intake were located in this area. For these reasons, and because the southern area offered no advantages over the northern area, the southern area was dropped from further consideration.

The northern part of this area appears to be the most acceptable location for a new intake structure. Since the water depth is greater at this location than farther south along the shoreline, less dredging would be required. This location would also provide easy access for construction equipment and has an adequate lay-down area. Recirculation would still occur from the existing discharge canal, but it would be no worse than that experienced with the existing intake. In conjunction with the alternative intake study, S&W has been investigating modification to the discharge system of the Prairie Island Plant. The proposed modifications would significantly reduce recirculation by using a submerged discharge in the main channel of the Mississippi River approximately 700 feet south o. .arney's Point.

The northern area was deemed more acceptable because of the reduced potential for recirculation. Further, the amount of dredging required in the southern area would be more extensive than at the northern area, resulting in a greater impact to established communities. For these reasons, the proposed location north of the existing intake canal was selected rather than other locations along the shoreline and was used for all the alternative intakes discussed in S&W (1977).

4.4 Submerged Offshore Intake

For the purpose of this report, a submerged offshore intake is defined as a velocity-cap intake located at the edge of the navigation channel of the Mississippi River.

The intake system would consist of four reinforced concrete structures located between wing dams number 36 and 37. The structures would be spaced approximately 170 feet on centers and would be as close to the main channel as possible. The U.S. Army Corps of Engineers has recommended that the structures be set back at least 25 feet from the ends of the wing dams. Each intake would be sized for a flow of 360 cfs with a design approach velocity to the trash bars of 0.5 fps (based on gross inlet area). The water withdrawn by the intakes would be primarily from the main channel of the Mississippi River; however, flow from Sturgeon Lake may also be induced into the intake, with the percentage of Sturgeon Lake water increasing during periods of low river flow. Because of the low approach velocities, no significant effects on the flow patterns of the river are expected.

The intakes would be connected to an onshore pumphouse by two 12-foot I.D. pipelines with a design velocity of 6.4 fps. The pipelines would be buried in a common trench and topped with rip-rap to provide adequate protection from erosion during flooding periods. Each pipeline would be approximately 2500 feet long.

The onshore pumphouse used in this evaluation employs center flow traveling screens. Figure 2 shows the plot plan for a submerged offshore intake and the proposed pipeline routes to the onshore screenhouse. Figure 3 shows typical sections of one of the submerged intake structures. A space of 2 feet is allowed from the river bottom to the inlet for sedimentation buildup. Likewise, approximately 5.5 feet submergence from the low water level to the top of the structure is allowed for ice cover during the winter, adequate submergence to minimize vortex formation and entrainment of air and floating debris.

Two-half-capacity pumps would be installed in the pumphouse to provide the necessary head requirements for system operation. An additional pump for backflushing the intakes during winter operation would also be installed in the pumphouse. This flow reversal pump would take warm water from the existing plant discharge structure and use it to backflush the intakes during periods of potential ice blockage of the intakes. The total auxiliary power required for this system would be approximately 2940 kw, with annual energy requirements of about 13,400 mwh.

As discussed previously, data were not available at the time of the alternative intake study to quantify the potential reductions in intake of fish and ichthyoplankton which might be achieved by withdrawing cooling water from the main channel. However, the cost of constructing an offshore intake connected to an onshore center-flow screenhouse is highly unwarranted for two reasons. First, the screenhouse in this scheme (Figure 2) is essentially identical in location and operation as the previously proposed center-flow scheme. Therefore, the added offshore structure and connective piping simply act to move the point of water withdrawal to another location. Second, a velocity cap intake is not designed to reduce entrainment of non-motile forms such as fish eggs and larvae and would therefore act only to reduce juvenile and adult impingement. As mentioned, data on ichthyoplankton distribution and abundance in the plant area are being analyzed. These data will form the basis for a cost/benefit analysis comparing the offshore velocity cap intake with an onshore center-flow screenhouse.

Order-of-magnitude costs associated with constructing a submerged offshore intake were estimated for the scheme shown on Figure 2. These costs are based on present-day prices and fully-contracted labor as of

May 1978 and are directly comparable to the estimates contained in the July 1977 S&W report. Included in the total evaluated costs are allowances for contingencies, distributables, indirect costs, escalation, interest during construction, and general and administrative overhead costs. These allowances are the same as those used to estimate costs in S&W (1977).

The total evaluated cost of constructing a submerged offshore intake, including an onshore pumphouse using center-flow traveling screens, is approximately $45 million. An approximate order-of-magnitude cost for this scheme at another location can be determined by computing the difference in linear feet of common pipe trench required, multiplying that figure by $6140/L.F., and either adding or subtracting the resultant value to or from the total system cost. The cost/L.F. represents an average total evaluated cost, including allowances, for installing two 12-foot I.D. pipes in a common trench.

While this type of intake structure has been used at several installations, the practicality of its use for the Prairie Island Plant is questionable. As previously mentioned, the problems associated with construction and maintenance of an intake close to the navigation channel make this scheme unattractive. Also, the total cost is high compared with that of the proposed intake alternatives.

5.0 ALTERNATIVE INTAKE DESIGNS AT ONSHORE LOCATION

The various alternative intake designs requiring construction of a new screenhouse north of the existing intake canal were discussed and evaluated in Chapter 3 of the July 1977 S&W report. These were the modified traveling screen with fish buckets, the angled flush mounted traveling screen, and the center flow traveling screen.

The July 1977 report also mentioned that several other alternative designs had been investigated for possible use but had been eliminated because of their limited effectiveness or their impracticality relative to the Prairie Island site. These alternatives were: angled fixed screens, radial wells, louvers, a porous dike, and wedgewire screens. These five alternatives were discussed at a meeting with the Minnesota Pollution Control Agency on May 17, 1978. These alternatives and their biological effectiveness, engineering practicality and reasons for rejection are discussed as follows.

5.1 Angled Fixed Screens

Description

Angled fixed screens can be used to divert juvenile and adult fish, by using the natural behavioral response of fish to an object in flowing water. The screens would be set in a chevron arrangement similar to the angled traveling screen alternative shown on Figures 3.1 to 12 of S&W (1977). This system would require a diverting flow of water and a fish bypass system similar to that for either louvers or angled traveling screens.

Biological Effectiveness

As a fish diversion device, angled fixed screens are essentially identical to the angled traveling screens developed as one of the preferred schemes. However, because they can not be rotated and cleaned, they would be ineffective in protecting fish eggs and larvae that would impinge on them. On this basis alone, this system can be rejected. Additional concerns are 1) that clogging of fixed screens would adversely affect juvenile and adult fish diversion, and 2) that removal of fixed screens for cleaning would allow passage of organisms into the existing recycle and intake canals, permitting establishment of a resident population in the system.

Engineering Practicality

An angled fixed screen installation could be constructed at the Prairie Island intake. Large fixed screen installations are now used in sewage treatment plants, but, there are serious questions related to the reliability and maintenance of such a system for the large flows required for a nuclear power plant. In particular, cleaning debris from the fine mesh to avoid plugging would be a problem. Some possible but cumbersome solutions include using screen-washing equipment, rotating screen to remove material lodged in the mesh, removing screens and inserting replacements.

Reasons for Rejection

Although angled fixed screens could satisfy juvenile and adult fish protection requirements, they would be ineffective in protecting ichthyoplankton. Further, the operational problems associated with fixed angled screens have not been resolved. Except for possibly lower construction costs, they offer no significant advantages over the angled traveling screens retained as one of the preferred schemes. Accordingly, angled fixed screens were not considered further.

5.2 Radial Wells

Description

An infiltration scheme using recharge from the Mississippi River was evaluated to determine whether existing conditions are suitable for an installation of this type. The scheme considered was the radial well, typified by the Ranney Water Collector.

Radial wells are constructed by sinking a vertical caisson near a surface water source and then jacking out horizontal screen pipes into the surrounding aquifer, as shown on Figure 4. The major requirements for a successful radial well are (1) a suitable pervious aquifer, (2) an adequate supply of surface water, and (3) the absence of relatively impermeable materials that could limit recharge to the aquifer. To meet the last requirement, hydrologic conditions should be such that impermeable materials can not be deposited over the aquifer being recharged.

Biological Effectiveness

Since the radial well functions essentially the same as a natural aquifer, probably little or no biological impact would occur as a result of operation. In this sense, the radial well concept may be the most environmentally sound alternative intake system (U.S. EPA 1976).

Engineering Practicality

Experience indicates that the maximum capacity of a single radial well installed in an ideal aquifer is about 20,000 gpm. However, based on existing data, the yield from a single well in the vicinity of the Prairie Island Plant would be approximately 10,000 gpm. Assuming this number is representative of the actual yield, a total of 65 radial wells would be required. The wells would have to be spaced from 1200 to 1500 feet apart to prevent unacceptable interference effects between adjacent wells. As a result, the well field would extend along 15 to 18 miles of the shoreline. In addition to the 65 radial wells, an extensive piping network would be required to connect the individual wells to the plant's circulating water system.

The annual energy requirements for this system would be greater than for any of the other alternatives. Additional pumping head would be required to overcome friction losses in the pipelines and for drawdown in the individual wells. Supplying the additional energy required for the pumps would result in increased operating costs and a derating of the plant's net generating capacity.

Reasons for Rejection

Radial wells were rejected for use at the Prairie Island Plant for the following reasons:

1. The heavy sediment loading in the river, especially during spring floods, could eventually settle over the aquifer and reduce the yield from the well. No practical method of backflushing is available to eliminate this problem.

2. The influence of the wells on the existing groundwater table would extend over a 15- to 18-mile stretch of the Mississippi River.
3. The cost of the scheme would be relatively high in comparison with the other schemes investigated. Each radial well would cost about $1 million, not including the costs for the pumps and an extensive piping system.
4. The additional energy requirements and the potential for derating the plant are excessive in comparison to the other alternatives.

5.3 Louvers

Description

Model studies and several operating systems have demonstrated that louver systems can divert fish from water intakes and thus avoid physical impingement on mechanical screens. The louvers are designed to guide fish to a bypass where they can be returned to the receiving waters. Figure 5 shows the velocity vectors in the flow and the resultant path of fish movement toward a bypass for louver arrays set at angles of 11.5 and 45 degrees.

Biological Effectiveness

Louver diversion takes advantage of natural behavioral responses of fish when approaching an object in flowing water. The louver creates a zone of localized turbulence which fish avoid as they move in the direction of flow. This avoidance response, in conjunction with a downstream component of flow, gradually diverts the fish to a bypass connecting to a return pipeline.

Model and prototype studies and applications of louver systems have shown, in many cases, greater than 85 percent guidance efficiency of juvenile and adults under many different experimental conditions with a variety of fish species (Taft and Mussalli 1978). There have been cases, however, where louvers have not functioned effectively in guiding fish to a by-pass (Thompson and Paulik 1967). Further, the guidance capacity of louvers is highly dependent on the length and swimming performance of fish. Since eggs and early larvae are essentially non-motile, louvers would not be expected to guide these life stages. Among later life stages, Skinner (1973) has demonstrated a strong positive relationship between fish length and guidance efficiency for striped bass (Morone saxatilis) for white catfish (Ictalurus catus) in full-scale efficiency evaluations. Figure 6 shows this relationship for striped bass. It can be seen that Skinner (1973) did not generally obtain efficiencies as high as 80 percent with individuals of the species smaller than about 25 mm and 40 mm, respectively.

In general, high guidance efficiencies have been limited primarily to juvenile and adult fish. In addition, louvers have certain engineering features which influence their applicability to Prairie Island. First, the louver principle was initially developed for fish diversion at such facilities as irrigation and hydroelectric projects, which do not require the degree of screening necessary at power plants for condenser protection. Therefore, in past applications, stationary louver systems have been used without great concern for debris clogging problems or the need for further screening for equipment protection purposes. At a power plant, stationary louvers would create serious reliability problems resulting from their clogging potential. Accordingly, traveling louver screens, such as those being installed at the San Onofre Nuclear Generating Station (Downs and Meddock 1974), would be required for debris removal at a great increase in structural cost. In addition, conventional traveling water screens would be required as a backup to the louvers to screen non-diverted organisms and debris to the level necessary to prevent the establishment of a resident fish population in the recycle and intake canals.

Engineering Practicality

A louver system could be constructed for the Prairie Island intake. Special engineering considerations for this type of system include the effect on pumps from eddy formation downstream of the louvers, design of a bypass pumping system which is not harmful to diverted fish, removal of debris from louver face, and handling and disposal of bypassed debris or non-diverted fish.

Reasons for Rejection

Due to their inability to divert fish eggs, their limited effectiveness in diverting larvae, and the engineering problems associated with their design and operation at power plants, louvers do not offer a biologically efficient, reliable and cost-effective means for substantially reducing fish losses at Prairie Island.

5.4 Porous Dike

Description

A porous dike is a physical barrier that uses a filter media on its upstream face to screen organisms while allowing water to pass through the structure. The porous dike design considered for use at Prairie Island consisted of large stones which formed the central core, and sand on the upstream face which serves as the filter medium. Figure 7 shows the plot plan for a porous dike sized for a flow rate of 188 cfs (84,400 gpm), which represents approximately 13 percent of the plant design flow of 1410 cfs.

Biological Effectiveness

The porous dike concept has never been used to protect small organisms at power plant intakes. The primary biological concern with the dike relates to its ability to prevent the passage of fish eggs and larvae. Since these early life stages are essentially non-motile, they drift passively in the current and would, therefore, be subject to entrainment into the dike unless a fine filtering medium is placed on the outer surface and an adequate ambient flushing flow existed to carry the organisms away from the structure. It is believed that non-motile organisms must be screened at the outer surface boundary rather than within the dike, since small organisms which penetrate this boundary will ultimately be lost regardless of the screening capacity of the media located in the interior of the dike. However, locating the fine filter medium at the outer boundary could create engineering problems in protecting the dike from wave forces. Therefore, it may not be possible to design the dike to screen all of the life stages.

Engineering Practicality

Porous dikes are in the developmental stage and as yet have not been used for once-through intakes. A porous dike sized to pass the design flow for the plant would have to be approximately 8500 feet (1.6 miles) long. A dike of this length would extend a considerable distance upstream into Sturgeon Lake and downstream into the backwaters fronting the plant.

Besides the large area required for the dike, there are also several engineering factors which must be considered. The upstream face of the dike, the filter media, would have to be protected from erosion due to prevailing currents and wave action. Also, if the filter performed properly, its hydraulic efficiency would decrease from biofouling and as the medium became clogged with debris and silt. This would require that the sand be replaced periodically, or backflushed, resulting in potential problems of access, maintenance and monitoring of performance to determine the proper replacement interval. To date, there is no reliable method for backflushing this type of filter system since the filter medium is unconfined and could be carried away by any ambient current during backflushing. Further, during backflushing, water quality standards may be exceeded.

Reasons for Rejection

Porous dikes were rejected for use at the Prairie Island Plant for the following reasons:

1. Porous dikes are untested in regard to the screening of fish eggs and larvae.
2. The length of dike required would result in its encroachment on large areas of Sturgeon Lake and the backwaters of the Mississippi River.

3. The filter medium would be difficult to maintain, and the required flow rates could not be sustained because of clogging.

4. No reliable backflushing method is available.

5.5 Wedgewire Screens

Description

Wedgewire screens are commercially available and have been used successfully as a part of make-up water intakes. Figure 8 shows a layout for a wedgewire screen installation sized for the design flow of 1410 cfs. The screens are arranged in four banks, with each bank having 40 screens arranged in pairs, as shown on Figure 9. The screens are sized to have a through slot velocity of 0.5 fps with a slot opening of 1 to 2 mm.

The screens are connected to an onshore pumphouse by two 12-foot I.D. buried pipelines. Each pipeline carries water from two of the screen banks. The screenhouse is equipped with two half-capacity booster pumps to provide the necessary head requirements for system operation. An additional pump, used to backflush the wedgewire screens, would also be installed in the pumphouse. This pump would take water from the plant discharge structure to backflush the screens. Two banks of screens would be cleaned simultaneously, allowing the other two banks to remain operational and provide the required plant flow.

Biological Effectiveness

Biological research on cylindrical, wedge-wire screens indicates that they may be effective in preventing the entrainment of fish eggs and larvae at power plants, provided the screen slot size is small (approximately 1 to 2 mm) and there is a relatively high-velocity cross-flow to carry organisms around and away from the screen (Bason 1978). No such current exists at Prairie Island; however, since the screen would be designed to prevent the passage of all organisms, it is possible that entrainment of fish eggs and larvae would be reduced greatly despite this drawback.

Due to the small slot size and slot velocity (0.5 fps), entrapment or impingement of juvenile and adult fish would not be expected to occur. Therefore, the wedge-wire screen alternative would appear to offer a potentially effective means of reducing fish losses at Prairie Island. Unfortunately, such screens have not been developed to the point where they offer a reliable means of screening once-through cooling water flows, as discussed below.

Engineering Practicality

Wedgewire screens, which use small slot openings, tend to be self-cleaning when installed at a location where the ambient velocity is at least 1 fps (Hanson et al.). This type of screening system also requires provisions for backflushing the screens to ensure the removal of debris should the screens clog and to prevent the accumulation of frazil ice. The location selected for the wedgewire screens (shown on Figure 7) provides the required water depth to allow for sedimentation buildup and for protection from floating debris and pack ice. This location also places the screens outside the navigation channel of the Mississippi River.

However, the ambient velocities in this area are quite low, usually between 0.0 and 0.4 fps, with the velocities tending to decrease as the distance from the main channel increases. With such low ambient velocities the screens would not be self-cleaning.

As previously stated, a pump would be provided to backflush the screens. Although a pump is required, no long-term operational experience on residual cleanliness is available for a once-through cooling system with wedgewire screens. Access would be required for manual cleaning. Extensive research would be required to ensure the adequacy of the backflushing system.

Reasons for Rejection

Wedgewire screens have been used on several smaller installations but never on large once-through cooling systems. Ambient velocities near the plant are such that the screens would not be self-cleaning; therefore, such a system would require reliable methods of backflushing debris from the screens and for preventing the formation of frazil ice. To date, such method has not been developed for once-through cooling systems. Further, the location of the screens and the large number required to pass the design flow would make it very difficult to maintain the screen and to monitor their performance.

The cost of installing a wedgewire screening system is higher than the systems proposed in the original S&W report. Since this system would be close to the proposed screenhouse location and would probably withdraw a combination of Sturgeon Lake and Mississippi River water, the potential for reducing entrainment mortalities beyond that of the proposed screenhouses may not justify the additional expense and construction impact associated with installing the wedgewire screening system offshore in the present intake approach canal. For these reasons, this system was rejected for use at the Prairie Island Plant.

5.6 Comparison of Alternatives

The alternative intake study performed by S&W for NSP considered eight potential schemes. The S&W report of July 1977 discussed the three proposed schemes and this report has discussed the five schemes not considered applicable for use at the Prairie Island Plant. Table 5.6-1 lists the eight original schemes. The intakes are qualitatively compared in four catagories: engineering criteria, biological criteria, construction practicality, and economic ranking.

Schemes considered practicable for use at Prairie Island had to satisfy the first three catagories listed above. To satisfy the engineering criteria a scheme must be able to pass the design flow, use proven technology and equipment, and have good maintenance and dependability records with respect to once-through cooling systems.

To satisfy the biological criteria a system must screen specific species of fish eggs and larvae and must reduce entrainment and impingement mortalities to levels at or below those experienced with the existing intake system at Prairie Island. The system must also prevent a resident population from establishing itself in the recycle and intake canals.

For a system to be considered from a construction standpoint, it must be practical to build it within a reasonable distance of the plant. It also cannot be within 500 feet of the emergency intake or isolate the emergency intake from its water source.

The economic ranking is provided only to indicate the relative position of the various schemes with respect to costs from a qualitative viewpoint. Costs for the proposed schemes are presented in S&W (1977).

6.0 REFERENCES

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TABLE 5.6

Comparison of Alternative Intake Schemes

Alternatives	Satisfies Engineering Criteria	Satisfies Biological Criteria	Construction Practicality	Economic Ranking
Angled Traveling Screen	Yes	Yes	Yes	3
Angled Fixed Stationary Screen	No	No	Yes	**
Centerflow Traveling Screen	Yes	Yes	Yes	1
Modified Conventional Traveling Screen	Yes	Yes	Yes	2
Louvers	Yes	No	Yes	**
Porous Dike	No	No	No	**
Radial Wells	No	Yes	No	5
Wedgewire Screen	No	Yes	Yes	4

* 1 = lowest cost

** not ranked since they do not meet biological criteria

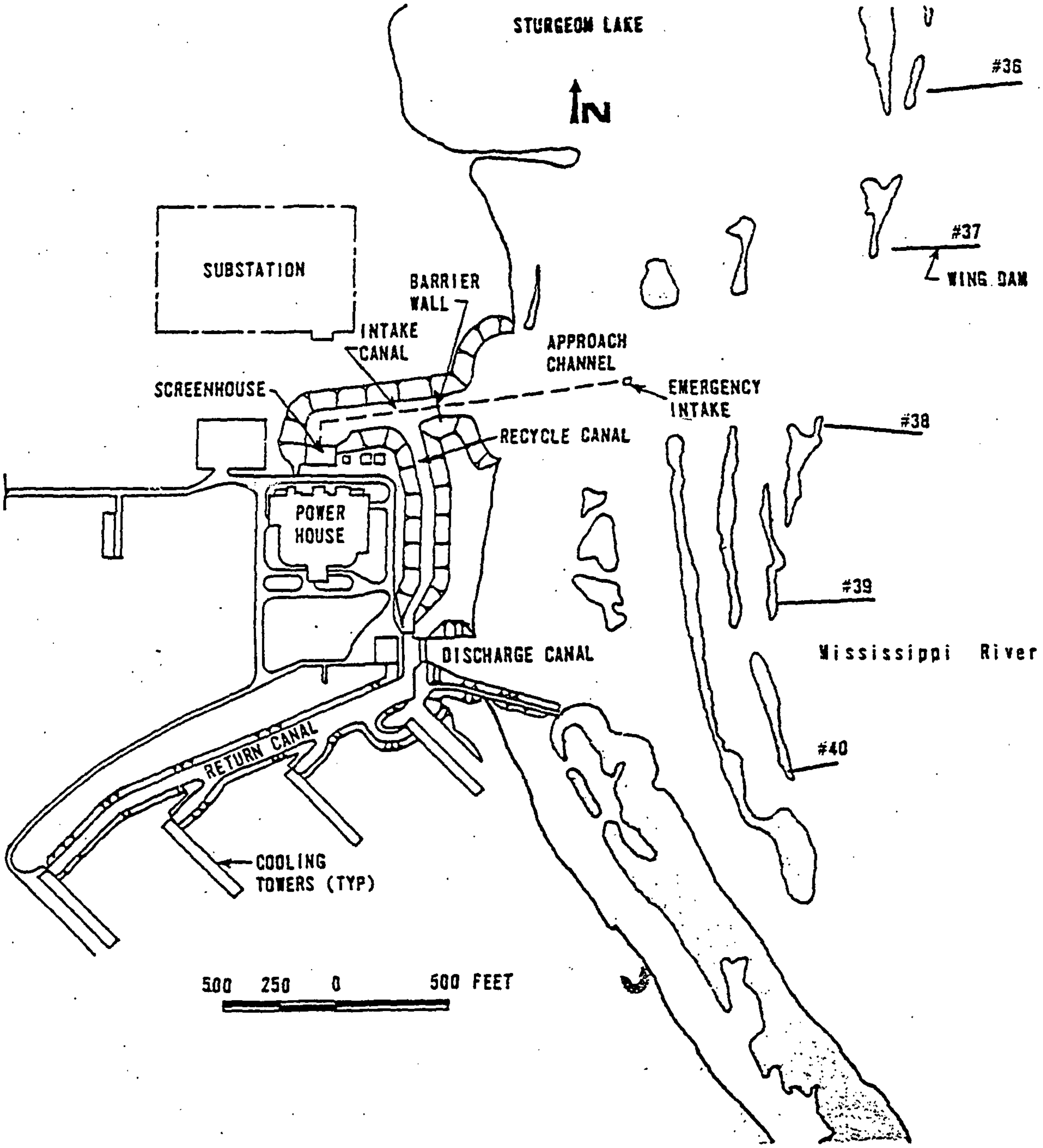


FIGURE 1
EXISTING PLOT PLAN
SUPPLEMENT TO ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

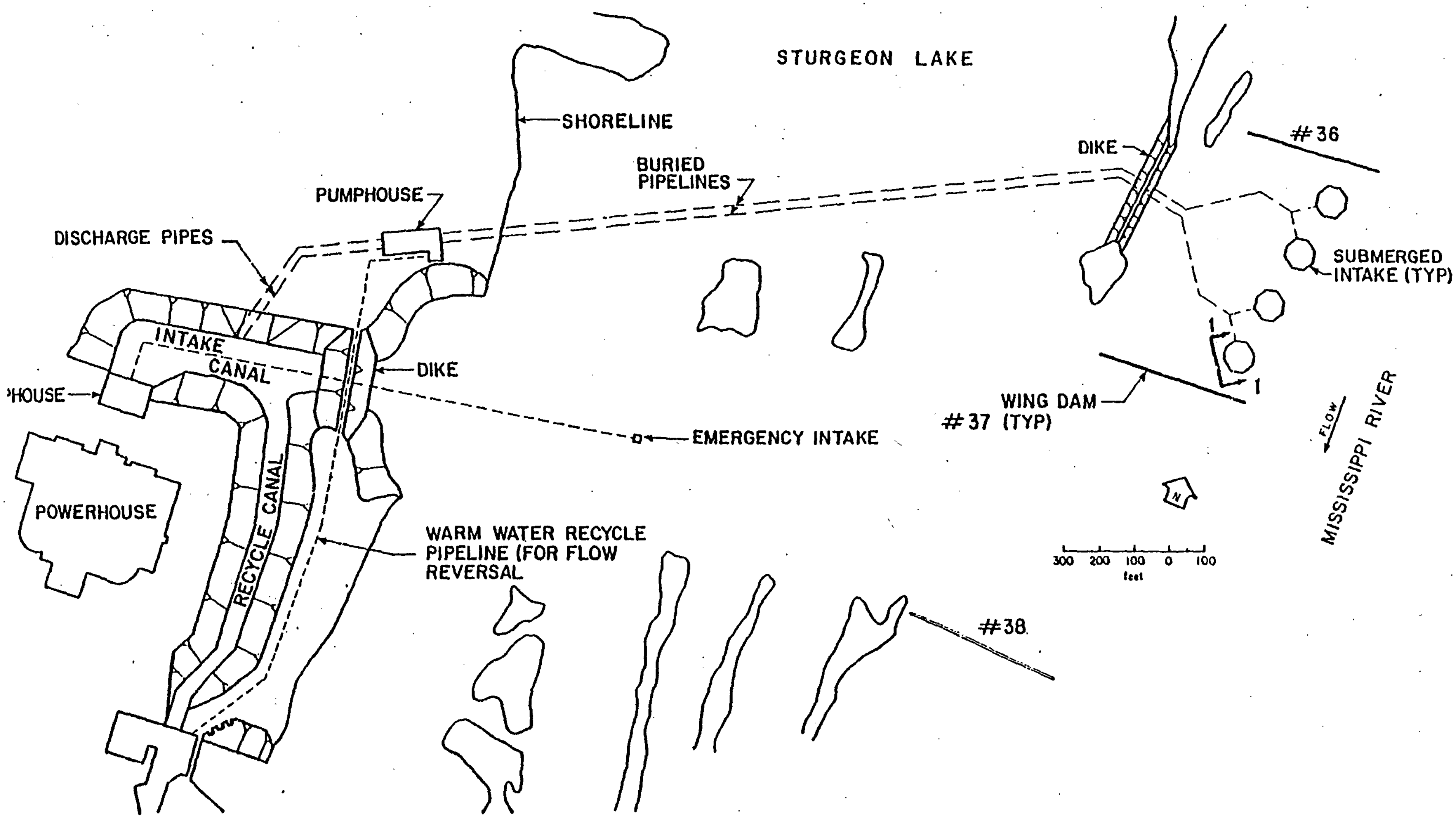


FIGURE 2

SUBMERGED OFFSHORE INTAKE - PLOT PLAN
SUPPLEMENT TO ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

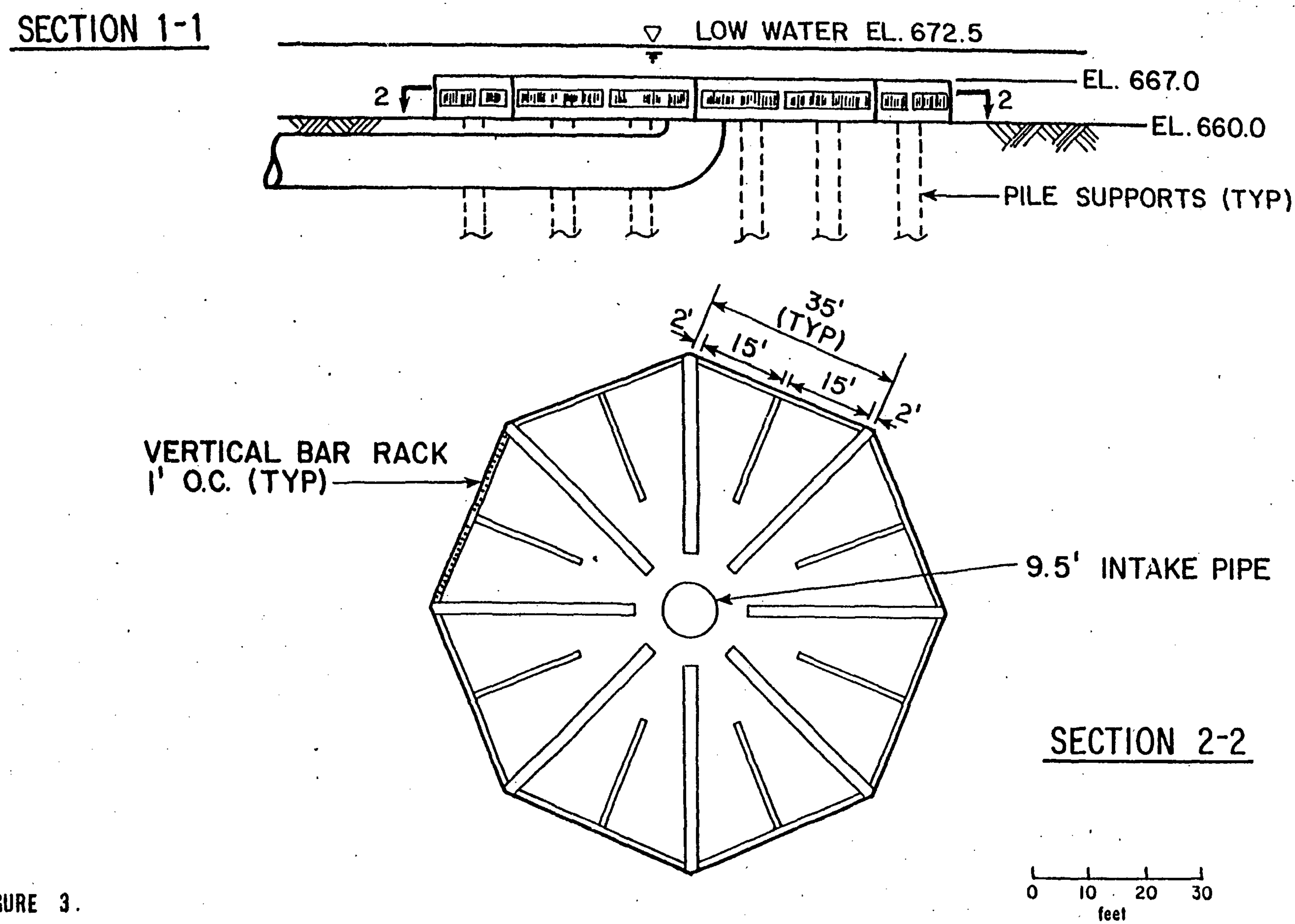
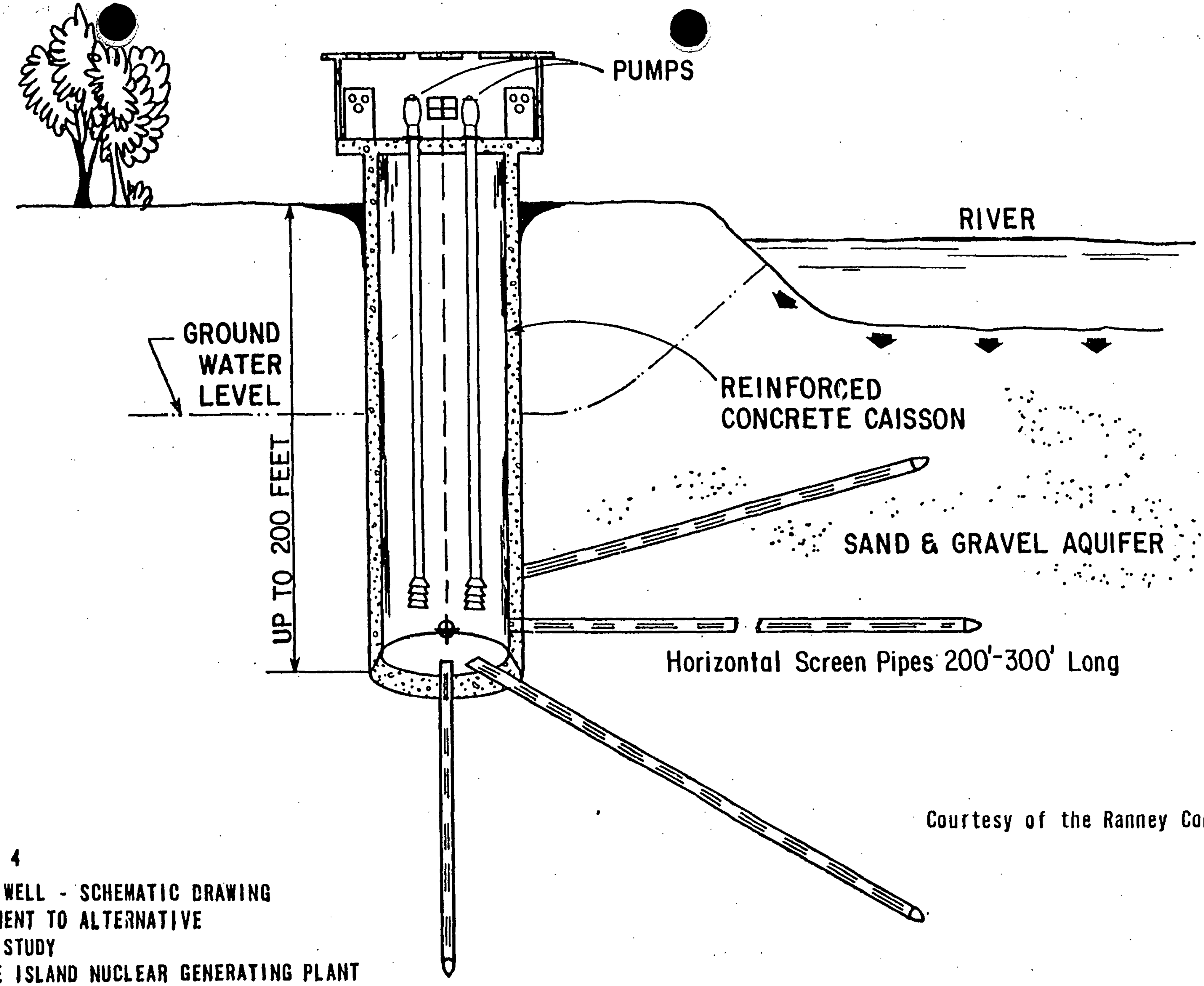


FIGURE 3.

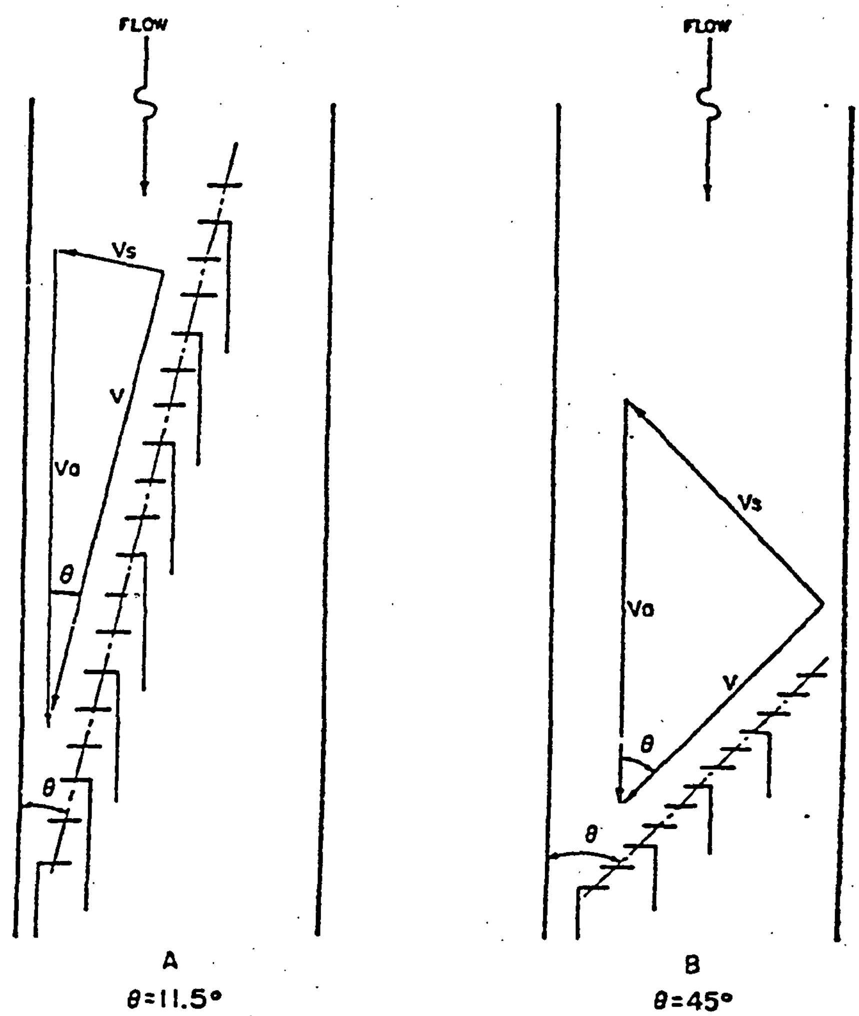
SUBMERGED OFFSHORE INTAKE - SECTIONS
SUPPLEMENT TO ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY



Courtesy of the Ranney Company

ᴉURE 4

ᴉIAL WELL - SCHEMATIC DRAWING
ᴾPLEMENT TO ALTERNATIVE
ᴉAKE STUDY
ᴉIRIE ISLAND NUCLEAR GENERATING PLANT
ᴉTHERN STATES POWER COMPANY



Va = Approach velocity of flow in feet per second
Vs = Swimming speed of fish in feet per second
V = Resultant movement of fish in feet per second
θ = Angle of the line of louvers

(Bates, Logan & Personen 1960)

FIGURE 5

RANGE OF ANGLES IN LINES OF LOUVERS TESTED, AND VECTORS OF FORCE IN FLOW AND FISH MOVEMENT
SUPPLEMENT TO ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

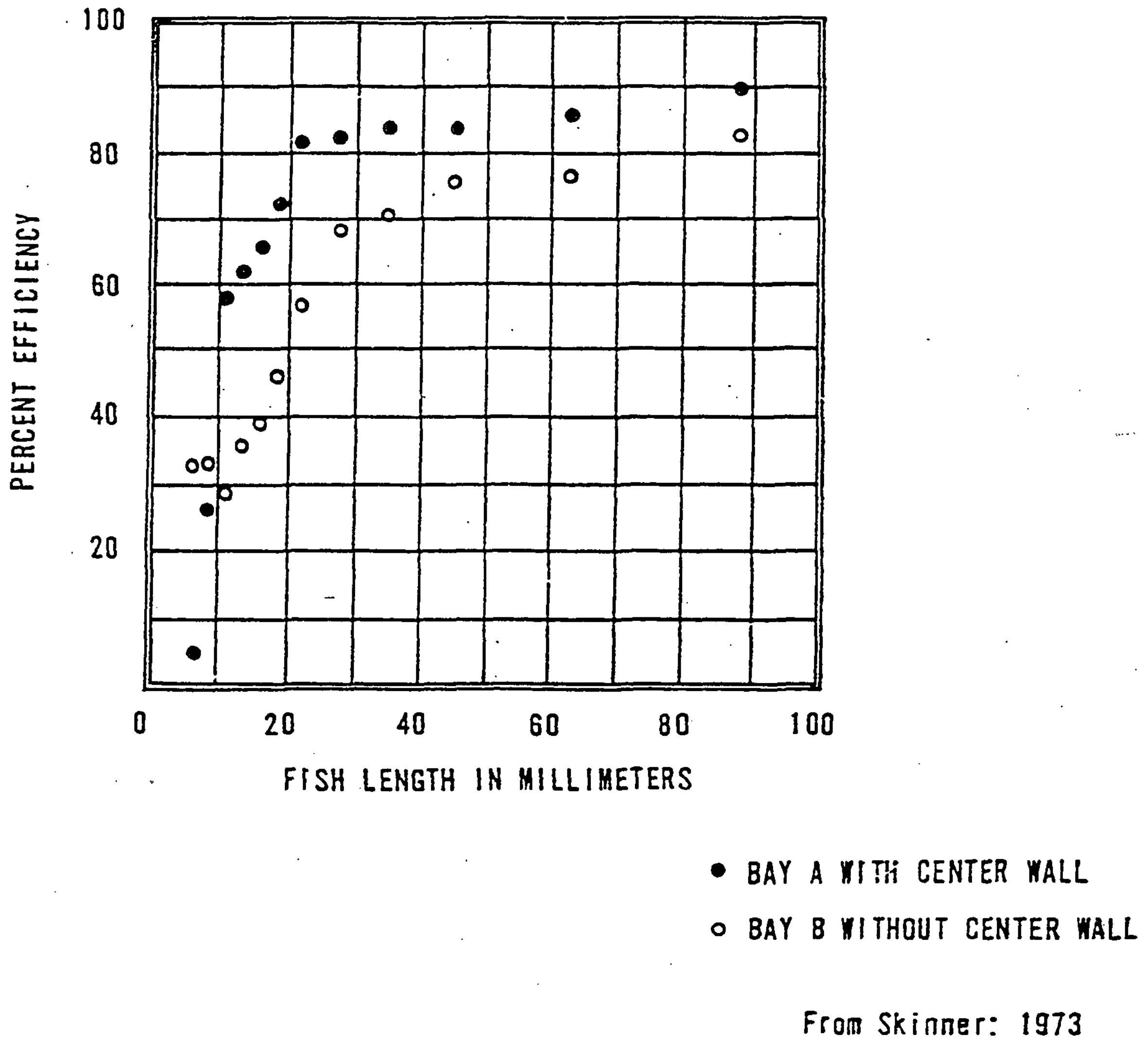


FIGURE 6
EFFICIENCY OF PRIMARY LOUVERS IN RELATION TO THE LENGTH OF THE STRIPED BASS
SUPPLEMENT TO ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORHTERN STATES POWER COMPANY

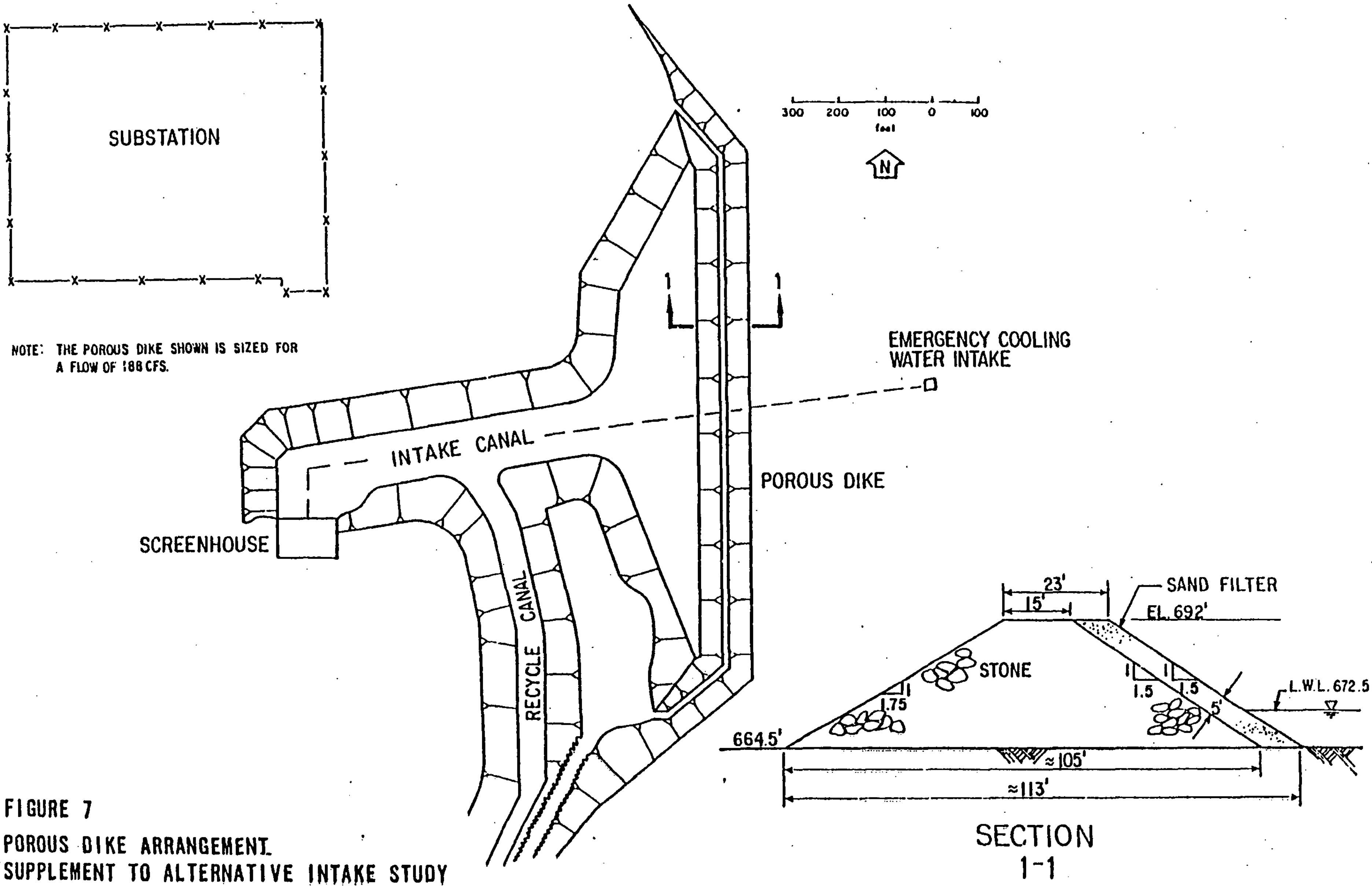


FIGURE 7

POROUS DIKE ARRANGEMENT

SUPPLEMENT TO ALTERNATIVE INTAKE STUDY

PRAIRIE ISLAND NUCLEAR GENERATING PLANT

NORTHERN STATES POWER COMPANY

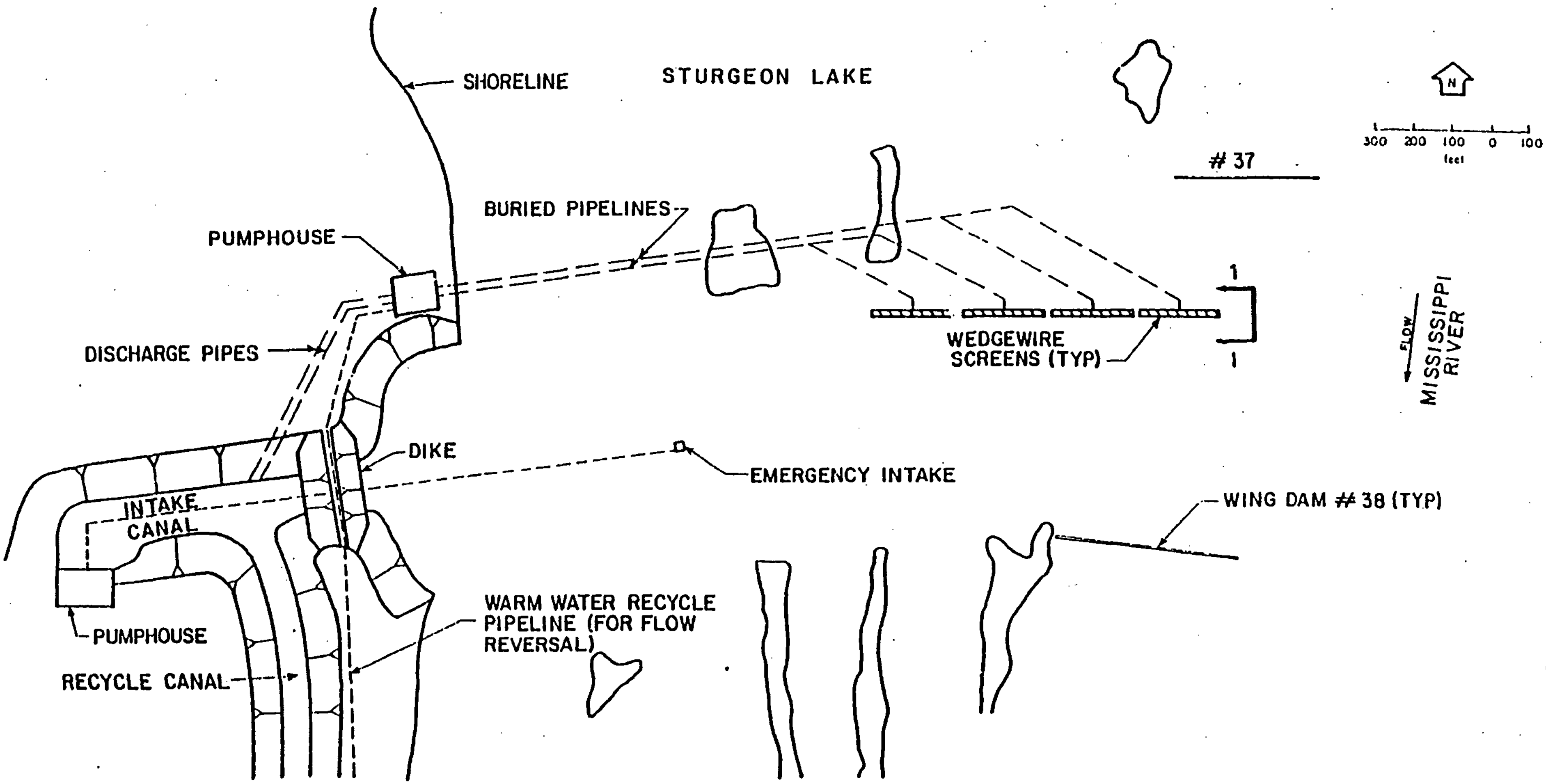
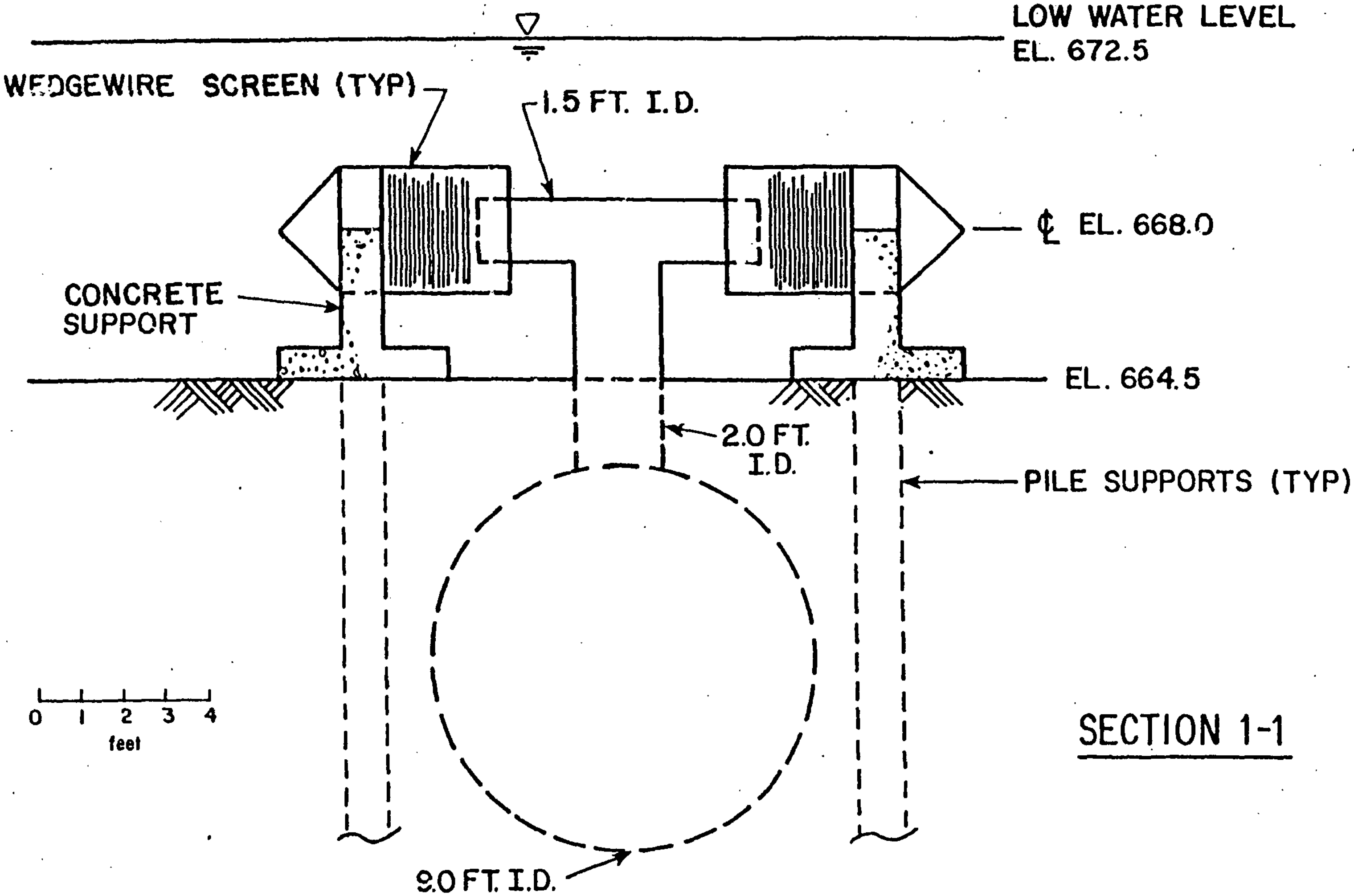


FIGURE 8

WEDGEWIRE SCREENS - PLOT PLAN
SUPPLEMENT TO ALTERNATIVE INTAKE STUDY
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY



SECTION 1-1

FIGURE 9

WEDGEWIRE SCREENS - SECTION

SUPPLEMENT TO ALTERNATIVE INTAKE STUDY

PRAIRIE ISLAND NUCLEAR GENERATING PLANT

NORTHERN STATES POWER COMPANY

A BENEFIT COST ANALYSIS
FOR
INTAKE STRUCTURE LOCATION
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

SEPTEMBER 1978

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the Laws of the State of Minnesota.

Donald L Matchett

Date Sept 19 1978 Reg. No. 12949

Stone & Webster Engineering Corporation

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EXECUTIVE SUMMARY

This report presents a benefit cost analysis for intake structure location at the Prairie Island Nuclear Generating Plant (PINGP). The purpose of the analysis is to quantify the differential benefits and costs related to location of a modified intake system at a new onshore location and at an offshore location at the edge of the main channel of the Mississippi River. Center flow fine mesh screens would be used for each system.

A field sampling program was undertaken from June 6 to June 17, 1978, to study the distribution of fish eggs and larvae at three sampling locations near the alternative intake locations. Hypotheses of spatial and temporal distribution of the ichthyoplankton data collected were statistically analyzed using an Analysis of Variance (ANOVA) technique. The six taxa selected for analysis with respect to entrainment were white bass, freshwater drum, "darters," gizzard shad, emerald shiner, and carp. Statistically highest densities were generally found at the sampling location nearest the proposed onshore intake location.

To conduct the benefit cost analysis, it was first necessary to estimate potential entrainment at PINGP. Two methods were used to estimate the total entrainment of ichthyoplankton during a spawning season:

1. Based on the field study of fish eggs and larvae conducted during the 1978 sampling program, an estimate of the total entrainment for June 6 to June 17 was derived. Proposed PINGP flow conditions

were used. The period of occurrence for most of the eggs and larvae of the taxa of interest is no longer than four months, based on a 1975 study of entrainment at PINGP. The maximal concentrations during the period of occurrence are found to fall within the June 6 to 17 period, based on prior experience. Accordingly, the total entrainment for this period represents a higher than average entrainment based on the concentrations of organisms. Therefore, a conservative estimate was made of the total number of fish eggs and larvae entrained annually by adjusting the number for June 6 to 17 to account for the total proposed plant intake flow for the spawning season, assumed to be May 15 to September 4.

2. The number entrained for the spawning season was also estimated using proposed flow rates and ichthyoplankton densities estimated at the bar racks of the present intake during the 1975 entrainment study. This estimate was then multiplied by the ratio of the maximum concentration in 1978 to the maximum concentration in 1975. This method assumes the temporal pattern of ichthyoplankton is similar in different years and locations, and that there is a proportional relationship in magnitude of abundance among years and locations.

The total number of fish eggs and larvae from the two methods was then used to project the number of adult fish which would have developed had entrainment not occurred. This analysis utilized the equivalent adult model. Based on reimbursement value information published in 1978 by the North

Central Division of the American Fisheries Society, the replacement cost of the fisheries resources lost by entrainment at each of the three locations was calculated.

The benefit cost analysis focuses on the differential benefits to the fisheries resources to be gained from constructing an offshore intake when compared to the additional cost. Costs and benefits were calculated on an annual levelized basis.

Installation of fine mesh screens at the proposed onshore intake location results in a benefit of about $1.5 million annually on the basis of reduced fisheries replacement cost. A further annual benefit to the fishery of $0.36 million could be obtained by locating the intake offshore. However, this additional benefit is estimated to cost $5.8 million per year. Accordingly it is concluded that the increased cost of the offshore location (about 16 times the benefit) is disproportional to the incremental increased benefit to the fisheries resources.

1.0 INTRODUCTION

In December of 1976, Northern States Power Company authorized Stone & Webster Engineering Corporation (S&W) to develop conceptual designs for several alternative intakes which would have the potential for reducing fish impingement and ichthyoplankton entrainment at the Prairie Island Nuclear Generating Plant (PINGP). Three intake designs, utilizing various screening devices, were selected as being practicable to construct and operate in addition to being potentially effective in protecting organisms: center-flow traveling screens, angled traveling screens and modified conventional traveling screens with lifting buckets.

The engineering and biological rationale for selecting these designs is presented in an alternative intake design report prepared by S&W (1977). In May of 1978, the report was submitted to the Minnesota Pollution Control Agency (MPCA) at a meeting on alternative designs. During this presentation, other available intake systems were discussed which had been evaluated but were not considered to be practicable or potentially effective at PINGP. Since the S&W report did not include a discussion of the rationale by which these other designs had been eliminated from consideration, MPCA requested this information be issued as a supplemental report. MPCA further requested that the supplement include the basis for selecting a shoreline location for the three alternative intakes rather than a location in Sturgeon Lake or the main channel of the Mississippi River where organism densities might be lower.

Accordingly, S&W prepared a supplemental report addressing these issues which was submitted to MPCA in August 1978 (S&W 1978). Relative to intake location, the following conclusions were made:

1. As a shallow backwater area, Sturgeon Lake has a high potential as a spawning and nursery area. This potential, in conjunction with serious engineering concerns (S&W, August, 1978, p. 4-2), precluded further consideration of the lake as a site for a new intake structure.
2. Engineering problems associated with offshore intake construction and operation in the river near PINGP made this location impractical. The additional costs of such an installation did not appear justified since the three shoreline design alternatives could mitigate to a large degree entrainment losses to ichthyoplankton.
3. Data on ichthyoplankton distribution and abundance at the offshore intake location were not available during the evaluation of alternative intake locations. Therefore, the preferred, shoreline location (adjacent to the existing intake canal) was selected on the basis of engineering and economic considerations.

Subsequent to submittal of the supplemental report, data from an ichthyoplankton survey conducted at the alternate intake locations in June 1978 were analyzed by S&W. The survey was conducted at the request of MPCA to permit a more quantitative evaluation of ichthyoplankton densities at alternative intake locations.

The ichthyoplankton study was conducted for a two week period during June 1978 which is believed to be the peak portion of the ichthyoplankton season. The ichthyoplankton concentrations at the three locations were used to examine the relative benefits of each location, by first calculating the adult loss equivalent to the entrainment loss. This loss was then converted to a dollar value by considering the replacement cost of the fish as determined by the American Fisheries Society.

This report presents the results and analyses of the 1978 ichthyoplankton study, estimates the environmental benefit associated with each of the alternate locations, and compares these benefits with the costs of intake construction and operation at the three alternate locations.

2.0 DESCRIPTION OF THE 1978 ICHTHYOPLANKTON SURVEY

2.1 SAMPLE COLLECTION

From June 6 to June 17, 1978, an ichthyoplankton survey was conducted at PINGP by NSP. Three sampling stations were chosen to represent potential alternative intake locations for PINGP. The stations are shown in Figure 2.1-1. Station 1 was located in the main channel of the Mississippi River. Station 2 was located at the end of the Sturgeon Lake. From June 6-13, 1978, this station was sampled as represented by 2a in Figure 2.1-1. For the remainder of the study, the Minnesota Pollution Control Agency requested a shift in location of Station 2; this is represented as 2b in the figure. Station 3 was located near the present intake.

Samples were collected on June 6, 8, 10, 13, 15, and 17. Generally sampling was conducted between midnight and 4:00 am. The order in which the stations were sampled on each date was randomly determined. Oblique tows were conducted to sample the entire water column at each station. On each date two consecutive tows were conducted at each station. Each tow consisted of two nets, yielding four observations for each station on a given sample date. The net mouths were square, 41.5 cm per side; the nets were 560 micron mesh and 2.5 meters long. Flow was measured with a General Oceanics (Model 2030 (R-2 rotors) digital flow meter suspended in the mouth of each net. The duration of a tow was set to insure that a minimum of 100 m^3 was filtered by each net. Samples were preserved immediately in the field in a solution of 5 percent buffered formalin and rose bengal dye.

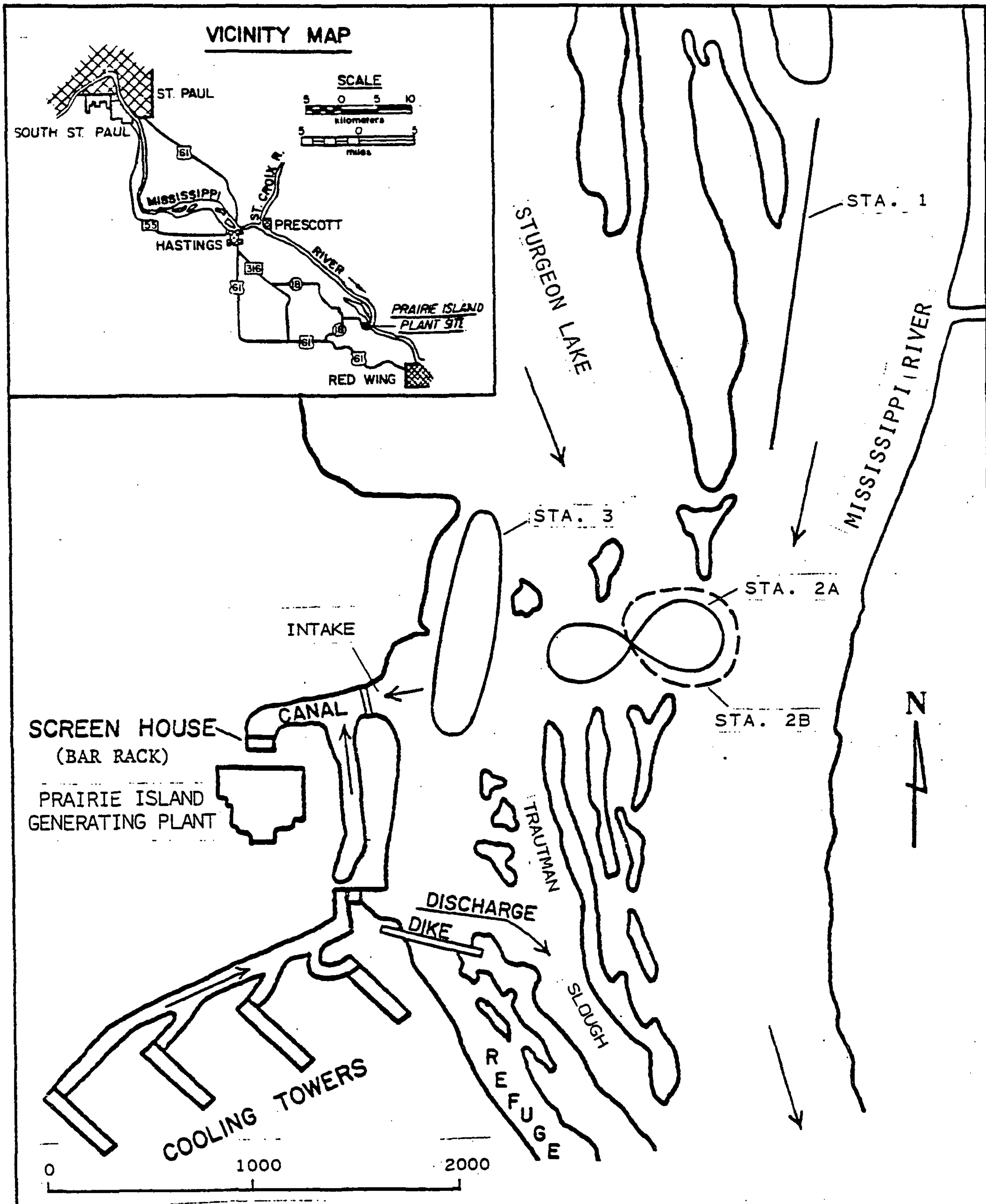

FIGURE 2.1-1

LOCATION OF ICHTHYOPLANKTON SAMPLING STATIONS
JUNE 6 - JUNE 17, 1978

NOTE: ↑ WATER FLOW

REFERENCE: NSP, 1975, VOL I, FIGURE 1 AND
NSP, 1976, VOL II, FIGURE 2.6-1

2.2 SAMPLE ANALYSIS

Light tables and glass sorting trays were used to separate ichthyoplankton from detritus. Specimens were identified to the lowest practical taxonomic level. The phases of larval fish development were taken from Snyder (1976, pages 52-54); the phases enumerated were prolarvae, mesolarvae, and metalarvae. A maximum of 20 specimens of each species and developmental stage was measured to the nearest 0.1 mm. These specimens were indexed and stored in 5 percent buffered formalin.

3.0 RATIONALE FOR SPECIES SELECTION

Studies conducted previously for PINGP (NSP 1975; NUS 1976; S&W 1977) have defined which species are representative of the whole community and critical with respect to the effects of the power station operation. The July 1977 S&W report (Table 2.3-1) identified seven fish taxa considered important with respect to entrainment. This group included white bass, freshwater drum, "darters," gizzard shad, emerald shiner, walleye, and sauger. The criteria for considering a taxon important took into account relative power plant exploitation. Taxa for which entrainment led to losses of 0.5 percent or greater to the adult population (identified in NUS, 1976) were included initially. The taxa considered were further limited as rough fish, such as buffaloes, carpsuckers, and carp were excluded on the basis of minimal exploitation other than the power station and minimal fisheries management concern for the maintenance of these stocks.

The above criteria were utilized as the basis for selection in this study, but some modification was necessary due to species abundance during the 1978 study.

For the purpose of the present study walleye and sauger were excluded from analysis because they were not captured in the 1978 study in sufficient quantities to permit an analysis of spatial pattern. The other taxa considered in the 1977 S&W Report were included in the present study. In addition carp were added to this study because they were abundant during the 1978 sampling period.

4.0 ANALYSES OF ALTERNATIVE INTAKE LOCATIONS

4.1 ICHTHYOPLANKTON DISTRIBUTION

Ichthyoplankton data are presented in Table 4.1-1. Numbers shown represent numbers of individuals per 100 m^3 for each station, sampling trip, and life stage. Since neither meso-larvae nor meta-larvae were found in sufficient numbers for meaningful analysis, these two stages were combined under the one life stage designation of post-larvae. Thus, ichthyoplankton are divided into egg, pro-larvae, and post-larvae life stages.

A two-way nested Analysis of Variance (ANOVA) was used to analyze ichthyoplankton data to test hypotheses of spatial and temporal distribution. The comparison among sampling stations for the taxon/life stage densities was the hypothesis of greatest interest, since this hypothesis would test for consistently higher or lower densities at the alternate locations.

In the ANOVA, the dependent variable was organism density and the discrete variables were trip (random effect), station (fixed effects), tows within trip-station and nets within tows (random effects). The equation for the ANOVA is:

$$Y_{ijklm} = U + T_i + S_j + TS_{ij} + W_{ijk} + N_{ijkl} + E_{ijklm}$$

Table 4.1-1: Number of Organisms Per 100 m^3 by Station, Trip, and Life Stage[1]

A. Gizzard shad

Station	Life Stage[2]	Trip[3] 1	2	3	4	5	6	Total
1	1	0	0	0	0	0	0	0
	2	20.09	35.06	38.40	9.53	8.65	8.41	120.13
	3	5.45	11.07	2.84	2.09	0.55	0.43	22.43
	4	0	0	0	0	0	0	0
		25.54	46.13	41.24	11.61	9.20	8.83	142.55
2	1	0	0	0	0	0	0	0
	2	13.18	16.83	16.69	20.58	13.76	13.04	94.09
	3	4.82	6.87	0.39	0.60	0.95	1.33	14.95
	4	0	0	0	0	0	0	0
		18.00	23.70	17.08	21.97	14.70	14.37	109.82
3	1	0	0	0	0	0	0	0
	2	77.39	110.08	166.30	78.99	137.02	55.35	625.13
	3	57.75	132.18	672.25	84.04	29.52	46.74	1,022.48
	4	0.67	1.24	9.33	2.35	1.72	1.31	16.62
		135.81	243.50	847.88	165.38	168.26	103.40	1,664.23
Total		179.35	313.33	906.20	198.96	192.16	126.60	1,916.60

[1] Average of Four Nets

[2] 1 = Eggs
2 = Pro-larvae
3 = Meso-larvae
4 = Meta-larvae

[3] 1 = June 6
2 = June 8
3 = June 10
4 = June 13
5 = June 15

Table 4.1-1: Continued

B. Freshwater drum

Station	Life Stage	Trip 1	2	3	4	5	6	Total
1	1	34.88	191.35	47.72	34.34	59.78	7.77	375.86
	2	14.32	11.03	23.29	11.61	15.59	55.84	131.69
	3	0.23	0.63	0	0	0.74	2.08	3.69
	4	0	0	0	0	0	0	0
		49.44	203.02	71.01	45.95	76.11	65.70	511.23
2	1	27.34	51.98	3.67	148.28	82.74	22.54	336.53
	2	9.66	9.61	19.46	6.46	11.99	21.34	78.51
	3	0.85	0.63	0.77	0	2.00	0.53	4.77
	4	0	0	0	0.19	0	0	0.19
		37.84	62.21	23.89	154.93	96.72	44.40	420.00
3	1	15.08	46.27	1.73	56.38	172.13	17.28	308.87
	2	23.50	17.33	14.56	8.81	10.57	11.43	86.21
	3	2.28	9.19	13.04	1.25	2.67	1.69	30.12
	4	0	0	0.19	0.44	0	0	0.63
		40.86	72.80	29.52	66.88	185.36	30.41	425.83
Total		128.14	338.03	124.42	267.76	358.19	140.51	1,357.06

Table 4.1-1: Continued

C. White bass

Station	Life Stage	Trip 1	2	3	4	5	6	Total
1	1	0	0	0	6.93	0	0	6.93
	2	0.22	0.63	0	0	0.71	0	1.56
	3	0.43	0.39	0	0.62	0	0	1.44
	4	1.98	3.79	0.20	0.42	0	0	6.57
		2.63	4.99	0.20	7.97	0.71	0	16.49
2	1	0	0	0	0	0	0	0
	2	0.19	0	0	0	0	0	0.19
	3	0.35	0.20	0	0	0	0.18	0.73
	4	7.13	3.55	0.79	0.37	1.24	0.19	13.28
		7.67	3.75	0.79	0.37	1.24	0.37	14.20
3	1	0	0	0	0	0	0	0
	2	0.17	0.39	0.8	3.03	2.91	2.07	9.37
	3	0.17	0.19	2.29	0	0	0.18	2.84
	4	18.96	6.57	59.09	1.27	0.58	1.87	88.33
		19.30	7.15	62.19	4.30	3.49	4.12	100.55
Total		29.26	15.89	63.18	12.46	5.44	4.49	131.24

Table 4.1-1: Continued

D. Emerald shinner

Station	Life Stage	Trip 1	2	3	4	5	6	Total
1	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0
		0	0	0	0	0	0	0
2	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	3	0.15	0	0	0	0	0	0.15
	4	0	0	0	0	0.17	0	0.17
		0.15	0	0	0	0.17	0	0.32
3	1	0	0	0	0.20	0	0	0.20
	2	0	0	0	0.22	0	0.76	0.98
	3	0	0	3.28	9.84	0	0	13.12
	4	0.43	0	10.22	11.27	3.39	3.93	29.24
		0.43	0	13.50	21.34	3.58	4.69	43.54
Total		0.58	0	13.50	21.34	3.76	4.69	44.18

Table 4.1-1: Continued

E. Carp

Station	Life Stage	Trip 1	2	3	4	5	6	Total
1	1	0	0	0	0	0.36	0	0.36
	2	0.21	0.44	2.44	1.47	1.10	15.70	21.36
	3	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0
		0.21	0.44	2.44	1.47	1.47	15.70	21.72
2	1	0	0	0	0	0	0	0
	2	1.85	0.80	3.65	3.73	24.30	42.12	76.44
	3	0	0	0	0	0.17	0.19	0.36
	4	0	0	0	0	0	0	0
		1.85	0.80	3.65	3.73	24.47	42.31	76.80
3	1	0	0	0	1.03	0.59	0	1.62
	2	0.57	0.78	5.02	18.77	22.42	66.74	114.30
	3	0	0	0	0	0.19	0	0.19
	4	0	0	0	0	0	0	0
		0.57	0.78	5.62	19.80	23.19	66.74	116.10
Total		2.63	2.02	11.11	25.00	49.13	124.75	214.62

Table 4.1-1: Continued

F. Darters

Station	Life Stage	Trip 1	2	3	4	5	6	Total
1	1	0	0	0	0	0	0	0
	2	0	0	0.20	0	0.18	0.22	0.60
	3	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0
		0	0	0.20	0	0.18	0.22	0.60
2	1	0	0	0	0	0	0	0
	2	0.15	0	0	0	0	0.19	0.35
	3	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0
		0.15	0	0	0	0	0.19	0.35
3	1	0	0	0	0	0	0	0
	2	0.34	0.39	1.19	0.43	0	0	2.36
	3	0.17	1.02	0	0	0	0	1.20
	4	0	0.20	1.34	0	0	0	1.53
		0.52	1.61	2.53	0.43	0	0	5.09
Total		0.67	1.61	2.73	0.43	0.18	0.41	6.04

Table 4.1-1: Continued

G. Cyprinids

Station	Life Stage	Trip 1	2	3	4	5	6	Total
1	1	0	0	6.09	19.35	2.21	1.66	29.32
	2	1.72	4.76	2.63	3.16	1.48	62.22	75.98
	3	0	0	0.20	0	0	0	0.20
	4	0	0	0	0	0	0	0
		1.72	4.76	8.93	22.51	3.69	63.89	105.50
2	1	0	0	0	0	0.17	0	0.17
	2	0.51	0.39	0.96	2.09	0.43	2.02	6.39
	3	0	0.19	0	0	0.18	0	0.37
	4	0	0	0	0	0	0	0
		0.51	0.58	0.96	2.09	0.78	2.02	6.93
3	1	0	0	0	0	0	0	0
	2	0.39	0.39	0.40	1.71	0.77	3.13	6.80
	3	0	1.57	0.38	0	0	0	1.95
	4	0	0.37	0.21	0	0	0	0.58
		0.39	2.33	1.00	1.71	0.77	3.13	9.33
Total		2.62	7.67	10.89	26.31	5.24	69.04	121.76

where

Y_{ijklm} = m^{th} observation at l^{th} net, k^{th} tow, j^{th} station and i^{th} trip

U = overall mean

T_i = effect of i^{th} trip

S_j = effect of j^{th} station

T_{Sij} = interaction of i^{th} trip and j^{th} station

W_{ijk} = the random effect for the k^{th} tow within the i^{th} trip and j^{th} station

N_{ijkl} = the random effect for the l^{th} net within the k^{th} tow of the i^{th} trip, and j^{th} station

E_{ijklm} = random error, NID $(0,\sigma^2)$

In this analysis, there is no replicate for each level of N, hence N_{ijkl} is considered random error. Prior to examining the ANOVA results, an evaluation was made to determine whether the data sets used in the ANOVA analysis (i.e., four life history stages of seven fish groups, yielding 28 data sets) would meet its assumptions.

Contingency tables of the data were examined for number of zero observations (Table 4.1-1). In addition, the residuals from the ANOVA for untransformed (number per m^3) and transformed density values [$\log_{10}$ (density +1) and square root of density] were analyzed in order to determine for each species-life stage if the assumptions of ANOVA do not appear to be violated and the data appear to provide a meaningful basis for statistical analysis.

Examination of the contingency table (Table 4.1-1) indicated only eight of the 28 data sets had a sufficient number of nonzero observations to yield ANOVA results which could be interpreted. These include shad pro-larvae and post-larvae; freshwater drum eggs, pro-larvae and post-larvae; white bass larvae (all stages combined); carp pro-larvae; and pro-larvae of the group of all other cyprinids. In addition, the larvae (all stages combined) for all species combined were analyzed.

After examining residuals from both transformed and untransformed data, it was determined that the square root of density would best meet ANOVA assumptions for the data sets chosen above. An $\alpha = 0.05$ was chosen as the level of significance. The ANOVA results are summarized in Table 4.1-2.

The existence of differences in density among stations is the hypothesis of prime concern. Station effects for all data groups except freshwater drum eggs and pro-larvae and cyprinid pro-larvae, were found to be significant (Table 4.1-2). In most cases, the highest density was at station 3. Densities at stations 1 and 2 are similar. The mean density of all larvae for all species combined increased from $0.486/m^3$ at station 2 to $0.643/m^3$ at station 1 to the highest density, $3.423/m^3$, at station 3 (Table 4.1-3). The high mean density at station 3 was attributed to shad pro-larval and post-larval densities, $1.042/m^3$ and $1.732/m^3$, respectively, (Table 4.1-3).

Ichthyoplankton were collected in very high densities on June 10, 1978, compared to the other dates. This suggests time may be an important factor related to density. Thus, the interaction of trip and station

Table 4.1-2: F-Ratio Values for the Analysis-of-Variance of the Spatial and Temporal Distributions for the Selected Life Stages and Species, PINGP, June 6-17, 1978

Source	Degrees of Freedom	Gizzard shad		Freshwater drum			White bass	Carp	Cyprinids	All species
		Pro-L	Post-L	Egg	Pro-L	Post-L	All-L	Pro-L	Pro-L	All-L
Trip (T)	5, 18	6.90*	29.893*	155.76*	3.81*	4.59*	21.10*	43.75*	4.28*	11.75*
Station (S)	2, 10	45.40*	9.26*	0.19	1.66	7.21*	5.32*	6.83*	4.01	12.56*
SXT	10, 18	3.05*	29.11*	53.11*	1.98	6.26*	17.68*	3.73*	1.98	10.15*
Tow within	18, 36	2.07	6.1*	0.84	3.11*	1.61	1.80	5.09*	5.38*	7.84*

*Significant at α = 0.05

Table 4.1-3: Station Means and Standard Deviation of Means (In Parenthesis) for the Selected Life Stages and Species, PINGP, June 6-17, 1978

Species/Life Stage	Station 1	Station 2	Station 3
Gizzard shad Pro-larvae	0.200 (0.094)	0.157 (0.094)	1.042 (0.094)
Gizzard shad Post-larvae	0.037 (0.594)	0.026 (0.594)	1.732 (0.594)
Freshwater drum Eggs	0.626 (0.220)	0.561 (0.220)	0.515 (0.220)
Freshwater drum Pro-larvae	0.219 (0.041)	0.131 (0.041)	0.144 (0.041)
Freshwater drum Post-larvae	0.006 (0.012)	0.083 (0.012)	0.051 (0.012)
White bass All-larvae	0.016 (0.055)	0.024 (0.055)	0.168 (0.055)
Carp Pro-larvae	0.036 (0.042)	0.127 (0.042)	0.191 (0.042)
Cyprinids Pro-larvae	0.127 (0.056)	0.011 (0.056)	0.011 (0.056)
All Species All-larvae	0.643 (0.725)	0.486 (0.725)	3.423 (0.725)

effects on the distribution of ichthyoplankton density values was of interest, especially for those groups which did not show a significant station effect; freshwater drum eggs and pro-larvae and cyprinid pro-larvae. Examination of interaction mean values and least significant difference (LSD) tests for shad pro-larvae and post-larvae, freshwater drum post-larvae, and all larval stages of white bass show that density is highest at station 3 and peaked on June 10, 1978. The density of these ichthyoplankton at stations 1 and 2 remained fairly constant during the study. The density of carp pro-larvae tended to increase with trip at all stations but increased fastest at station 3. This may indicate carp began spawning late in the study area. Freshwater drum eggs showed highly inconsistent abundance through time and at the three stations. Freshwater drum pro-larvae and cyprinid pro-larvae did not have significant trip by station interactions (Table 4.1-2).

Density values for all nine groups, varied significantly between sampling trips. Also, the density collected during different tows, which were nested within trip and station, varied significantly for pro-larvae of freshwater drum, carp and other cyprinids and postlarve of freshwater drum. This variation is possibly due to patchy distribution, unknown distributional changes and sampling error.

For the species/life stage group data sets amenable to ANOVA evaluation, the results of these analyses strongly indicate the highest abundance of ichthyoplankton was found at station 3. This is primarily attributable to the high incidence of pro-larvae and post-larvae of shad collected on June 10, 1978.

4.2 PREDICTED LOSS OF FISH AT ALTERNATIVE INTAKE LOCATIONS

4.2.1 Methodology

The methods for estimating impact to the selected species at the alternative intake locations and results of these calculations are presented. Two methods are employed. In the first, the number of ichthyoplankton which potentially could have been entrained without fine mesh screening for the twelve-day sampling period in 1978 is estimated for three life stages (egg, pro-larvae and post-larvae) of each species, assuming the proposed intake flows at each of the three stations. The estimates are used to calculate total adult loss for 1978 resulting from entrainment of ichthyoplankton at each station. The extrapolation from 12 days to the entire spawning season also is based on proposed plant flow. The adult loss is calculated from a simple population dynamics model. In the second method, ichthyoplankton data collected during the entire spawning season in 1975 is analyzed in the same manner as the 1978 data and adjusted to reflect the magnitude of abundance noted in 1978.

4.2.2 Estimated Numbers of Ichthyoplankton Entrained

To estimate total ichthyoplankton entrainment for the sampling period, a mean density was calculated for each of the three stations for each sampling trip. The calculation was repeated for all life stages of the six selected fish taxa.

$$\bar{X}_{s,t} = \frac{\sum_{l=1}^{4} X_{s,t,i}}{4}$$

where

$\bar{X}_{s,t}$ = the mean density at station s on sampling trip t

$X_{s,t,i}$ = density of ichthyoplankton (for a given species and life stage) in i^{th} replicate taken at station s on trip t

The four replicate observations (consisting of two tow, two nets per tow) used to calculate each mean were also used to calculate confidence limits for the means.

$$CL_{\bar{X}_{s,t}} = t_{.05,df=3} \times \sqrt{\frac{s^2_{s,t}}{4}}$$

where

$CL_{\bar{X}_{s,t}}$ = the confidence limit for mean density at station s on trip t

$t_{.05,df=3}$ = the 95 percent student's t-value for three degrees of freedom

$s^2_{s,t}$ = sample variance for observations taken at station s on sampling trip t

The confidence limits may also be calculated in another manner because of the sampling design: two nets are nested within each of two tows.

This provides a sub-sample rather than a replicate. However, analyses of variance for this data show that the density collected at different tows (experimental error) when compared to nets within tows (sampling error) did not vary significantly in five of nine cases. For this reason, confidence limits were calculated by simply using the four samples as replicates.

Multiplying the density of ichthyoplankton by the volume of water withdrawn by PINGP in a given period of time results in the total entrainment for that period of time. Projected daily intake flow rates at PINGP for the study period are shown in Table 4.2-1. To determine the number of ichthyoplankton entrained during the 24-hour period corresponding to each sampling trip, the volume of makeup water which would have been withdrawn under the proposed flow rates during the period was calculated from its daily flow rate (Table 4.2-1). This was then multiplied by the corresponding estimated density (mean and confidence limits expressed as number per m^3). Because flow rates are available for days on which no sampling was done, mean and confidence limit densities were estimated for these days by linear interpolation from the sampling study values. The estimates were then multiplied by the corresponding daily volume of water withdrawn by PINGP.

To determine total number entrained during the 12-day sampling period, the daily entrainment values were added together. The results are shown in Tables 4.2-2 to 4.2-7.

Table 4.2-1 Proposed Intake Flow Rate (CFS) and Corresponding Daily Volume of Water Withdrawn (M^3), Prairie Island Nuclear Generating Plant, May - September

Date	Flow Rate (CFS)	Daily Volume (M^3)
May	330	8.073699×10^5
June 1-15	435	1.064260×10^6
June 16-30	1410	3.449672×10^6
July - September	1410	3.449672×10^6

Table 4.2-2: White Bass Entrainment by Station and Life Stage for June 6-17, 1978 (Lower and Upper Confidence Limits in Parentheses)

Stage	Station 1 Mississippi River Channel	Station 2 Sturgeon Lake	Station 3 Present Intake Location
Eggs	184,310 (0-523,720)	0 (0-0)	0 (0-0)
Prolarvae	40,524 (0-109,290)	2,994 (0-12,521)	316,690 (7,540-739,290)
Postlarvae	164,181 (27,094-399,530)	290,829 (0-754,868)	2,241,709 (1,579,602-2,981,120)

Table 4.2-3: Freshwater Drum Entrainment by Station and Life Stage for June 6-17, 1978 (Lower and Upper Confidence Limits in Parentheses)

Stage	Station 1 Mississippi River Channel	Station 2 Sturgeon Lake	Station 3 Present Intake Location
Eggs	9,201,100 (7,148,800-11,253,000)	9,499,500 (6,642,600-12,356,000)	9,382,800 (4,847,730-13,918,000)
Prolarvae	4,799,300 (933,860-8,664,600)	2,550,600 (784,410- 4,316,800)	2,308,700 (1,103,800- 3,513,400)
Postlarvae	149,580 (0-355,810)	146,222 (6,850-361,051)	805,083 (383,160-1,330,417)

Table 4.2-4: Carp Entrainment by Station and Life Stage for June 6-17, 1978 (Lower and Upper Confidence Limits in Parentheses)

	Station 1	Station 2	Station 3
Stage	Mississippi River Channel	Sturgeon Lake	Present Intake Location
Eggs	848,493 (0-2,147,623)	5,536 (0-23,149)	46,973 (0-161,460)
Prolarvae	4,517,510 (444,551-10,386,700)	3,445,310 (1,914,697-5,080,140)	5,115,060 (1,961,178-8,433,260)
Postlarvae	5,448 (0-22,782)	25,620 (0-107,143)	63,327 (0-195,375)

Table 4.2-5: Darter Entrainment by Station and Life Stage for June 6-17, 1978
(Lower and Upper Confidence Limits in Parentheses)

Stage	Station 1 Mississippi River Channel	Station 2 Sturgeon Lake	Station 3 Present Intake Location
Eggs	0 (0-0)	0 (0-0)	0 (0-0)
Prolarvae	22,580 (0-94,428)	12,490 (0-52,233)	56,963 (0-156,670)
Postlarvae	0 (0-0)	0 (0-0)	64,311 (0-187,286)

Table 4.2-6: Gizzard Shad Entrainment by Station and Life Stage for June 6-17, 1978 (Lower and Upper Confidence Limits in Parentheses)

Stage	Station 1 Mississippi River Channel	Station 2 Sturgeon Lake	Station 3 Present Intake Location
Eggs	0 (0-0)	0 (0-0)	0 (0-0)
Prolarvae	3,064,300 (1,492,500-4,636,700)	2,692,300 (900,070-4,581,100)	17,520,000 (9,533,000-25,507,000)
Postlarvae	494,090 (224,310-800,840)	370,514 (19,121-793,195)	27,728,890 (17,402,099-38,316,600)

Table 4.2-7: Shiner Entrainment by Station and Life Stage for June 6-17, 1978 (Lower and Upper Confidence Limits in Parentheses)

Stage	Station 1 Mississippi River Channel	Station 2 Sturgeon Lake	Station 3 Present Intake Location
Eggs	836,460 (0-2,097,300)	5,536 (0-23,149)	6,482 (0-27,106)
Prolarvae	3,551,900 (85,401-8,724,000)	21,611 (15,197-51,044)	303,660 (3,478-853,210)
Postlarvae	5,448 (0-22,782)	17,890 (0-75,565)	1,300,775 (100,270-2,887,600)

To determine total number entrained during the 1978 spawning season, the number calculated for the sampling period was proportionally increased by a factor based on the proposed intake flow. From data presented in Table 4.2-1, approximately 1/18 of the total flow withdrawn from May 15 to September 4 (the spawning season suggested by data collected in 1975; see NUS, 1976, Table 5.3-6) occurs during the twelve-day period in June when the 1978 study was conducted. Therefore, each mean value in Tables 4.2-2 to 4.2-7 was multiplied by 18 to arrive at total entrainment for 1978. If peak densities of ichthyoplankton occurred from June 6 to June 17, 1978, then this method provides a conservative estimate of total entrainment because the peak densities are assumed to occur throughout the spawning season.

A second method was devised to calculate total entrainment during the 1978 spawning, based on the ichthyoplankton data collected at the PINGP bar rack in 1975 (Figure 2.1-1). The 1975 study was conducted from May 15 to September 4 and appears to encompass the entire spawning season for all species selected for entrainment analysis.

The data are shown in Table 4.2-8. The method used to calculate entrainment for the twelve-day period in 1978 was also applied to the 1975 data, for calculation of mean and confidence limit values.

Once the 1975 total entrainment was calculated, it was used as the basis for calculating total entrainment in 1978. To do this, the ratio of

Table 4.2-8

Mean Density (NO/100 M^3) of Ichthyoplankton of Selected Fish Species Collected During the 1975 Entrainment Study at Prairie Island Nuclear Generating Plant (NSP, 1976, Table 5.3-6)

	Gizzard Shad		Freshwater Drum			White Bass		Emerald Shiner[1]		Carp[2]		Darter[3]	
Date	Prolarvae	Postlarvae	Eggs	Prolarvae	Postlarvae	Prolarvae	Postlarvae	Prolarvae	Postlarvae	Prolarvae	Postlarvae	Prolarvae	Postlarvae
May 15	0.00	0.00	0.00	0.00	0.00	1.05	0.00	0.00	0.00	0.82	0.00	0.25	0.00
21	0.87	0.00	0.32	0.01	0.00	2.38	0.00	0.25	0.00	2.18	0.00	1.79	0.00
29	14.79	1.00	25.52	0.93	0.00	3.45	18.23	48.84	0.04	1.37	0.11	6.68	0.64
June 5	1.04	0.55	2.90	2.02	0.06	0.22	1.62	0.40	0.10	0.40	0.03	0.41	0.29
12	0.44	2.64	0.61	0.44	0.22	0.07	7.42	0.32	0.20	0.52	0.00	0.09	0.00
19	1.28	1.13	3.34	3.30	4.44	0.16	0.88	0.07	0.07	0.07	0.04	0.15	2.28
26	29.98	4.22	0.76	0.99	0.23	0.25	0.23	4.91	0.00	16.75	0.00	0.00	0.00
July 2	1.37	0.60	0.10	0.20	0.00	0.00	0.00	2.29	0.20	1.03	0.20	0.00	0.00
10	0.32	0.87	0.05	0.04	0.02	0.00	0.00	4.86	1.04	1.45	1.80	0.00	0.00
17	0.03	0.48	0.41	0.13	0.02	0.00	0.00	0.43	0.15	0.41	0.06	0.00	0.00
24	0.02	0.01	0.01	1.02	0.02	0.01	0.00	4.57	0.57	0.57	0.04	0.02	0.00
31	0.64	0.05	0.00	0.81	0.02	0.00	0.00	4.16	0.58	0.53	0.00	0.00	0.00
Aug. 7	0.49	0.10	0.00	0.09	0.05	0.00	0.00	0.66	0.10	0.27	0.04	0.00	0.00
14	0.00	0.65	0.00	0.33	0.10	0.00	0.00	0.93	0.78	0.68	0.20	0.00	0.00
21	0.16	0.12	0.00	0.58	0.11	0.00	0.00	0.17	1.05	0.15	0.15	0.00	0.00
Sept. 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[1] Identification was difficult at this level

[2] *Cyprinus Carpino* and cyprinids combined

[3] Percidae, Percina spp., *Percina shumardi* (?), *Percina caprodes*, Etheostoma spp. and *E. nigrum* combined.

maximum density recorded in the 1978 study to the maximum density recorded in the 1975 study was calculated for all life stages of all species. The calculations were conducted for Stations 1, 2, and 3; that is, the ratio of maximum density found at Station 3 in 1978 to maximum density found at the bar rack station in 1975 was calculated, as well as the ratio of maximum density found at Station 1 in 1978 to maximum density found at the bar rack station in 1975, etc. The ratios were then multipled by the appropriate estimates of 1975 entrainment.

The second method assumes that data collected in 1975 provide a reasonable approximation of the temporal pattern of ichthyoplankton abundance in 1978, but differs in magnitude of density. By adjusting for differences in maximum density, the calculated entrainment will be an accurate estimate of total entrainment in 1978.

The results of Method 1 and Method 2 are shown in Table 4.2-9.

Table 4.2-9: Total Entrainment for 1978 Spawning Season, Calculated According to Two Methods

Species	Station 1 (Mississippi River)		Station 2 (Sturgeon Lake)		Station 3 (Present Intake Location)	
	Method 1	Method 2	Method 1	Method 2	Method 1	Method 2
White Bass						
Eggs	3,317,580	0	0	0	0	0
Prolarvae	729,432	103,825	53,892	27,318	5,700,420	441,658
Postlarvae	2,955,258	535,780	5,234,922	919,920	40,350,762	7,542,703
Freshwater Drum						
Eggs	165,619,800	23,305,921	170,991,000	17,287,526	168,890,400	20,061,924
Prolarvae	86,387,400	34,605,571	45,910,800	13,224,980	41,556,600	14,563,591
Postlarvae	2,692,440	541,709	2,631,996	519,256	14,491,494	3,438,310
Carp						
Eggs	15,272,874	0	99,648	0	845,514	0
Prolarvae	81,315,180	24,918,583	62,015,580	14,113,730	92,071,080	22,344,217
Postlarvae	98,064	76,046	461,160	129,325	1,139,886	721,280
Darter						
Prolarvae	406,440	20,047	224,820	17,791	1,025,334	109,629
Postlarvae	0	0	0	0	1,157,598	331,855
Gizzard Shad						
Prolarvae	55,157,400	11,371,685	48,461,400	6,096,470	315,360,000	49,251,537
Postlarvae	8,893,620	5,970,717	6,669,252	3,708,101	499,120,020	367,627,905
Shiner						
Eggs	15,056,280	0	99,648	0	116,676	0
Prolarvae	63,934,200	11,204,960	388,998	375,810	5,465,880	700,479
Postlarvae	98,064	247,358	322,020	420,659	23,413,950	25,502,890

4.2.3 Calculation of Equivalent Adults

The number of adults resulting from the entrained ichthyoplankton can be calculated from a simple population dynamics model, adapted from Horst (1975, 1978). Assuming the fish population is in equilibrium and has a sex ratio of 1:1, the fecundity of a breeding pair results in two breeding adults in one generation.

$$2 = S_{ea} \cdot F \qquad (1)$$

where

S_{ea} = is the survival from egg to adult

F = is the fecundity of a female during her life,

or, rearranging

$$S_{ea} = 2/F \qquad (2)$$

The survivorship from egg to adult equals the product of the survivorship from egg to pro-larvae (S_{el}) and the survivorship from pro-larvae to adult (S_{la})

$$S_{ea} = S_{el} \cdot S_{la} \qquad (3)$$

Therefore, if the entrained life stage is pro-larvae, then F in Equation 2 must be multiplied by the survival from egg to pro-larvae and divided into 2 to give S_{la}

$$S_{la} = \frac{2}{S_{el} \cdot F} \tag{4}$$

Similarly, the survivorship from egg to adult (S_{ea}) is equal to the product of the survivorship from egg to pro-larvae (S_{el}), survivorship from pro-larvae to post-larvae (S_{lp}), and the survivorship from post-larvae to adult (S_{pa}).

$$S_{ea} = S_{el} \cdot S_{lp} \cdot S_{pa} \tag{5}$$

Therefore, if the entrained life stage is post-larvae, then F in Equation 2 must be multiplied by the product of survival from egg to pro-larvae (S_{el}) and survival from larvae to post-larvae (S_{lp}).

$$S_{pa} = \frac{2}{S_{el} \cdot S_{lp} \cdot F} \tag{6}$$

To obtain the number of equivalent adults (N) resulting from the entrained ichthyoplankton, the number of entrained eggs (E) is multiplied by S_{ea}, the number of entrained pro-larvae (L) is multiplied by S_{la}, and the number of post-larvae (P) is multiplied by S_{pa}. Adding these gives the number of adults (N):

$$N = E \cdot S_{ea} + L \cdot S_{la} + P \cdot S_{pa} \tag{7}$$

true because sufficient information existed for each to support the choice of the parameters. A more thorough explanation is provided for each species in Section 4.3.

In all instances, fecundity was estimated for the breeding population. In such cases, the equivalent adults predicted from lifetime fecundity are distributed across reproductive or breeding age classes.

Only the most probable estimates of ichthyoplankton entrainment are used for E, L, and P in Equation 7. Thus, values from Table 4.2-9 were used. The number of equivalent adults corresponding to confidence limits can be easily obtained because EAM predictions are directly proportional to number of ichthyoplankton.

The total estimated cyprinid entrainment was added to the total estimates for carp and emerald shiner, respectively, for equivalent adult analyses of these two species. Similarly, all percid ichthyoplankton were assumed to be Johnny darter; thus, total percid entrainment estimates were used for the darter EAM. The resulting number of equivalent adults calculated for entrainment of these species are conservative (i.e., overestimates) because ichthyoplankton of species other than those selected are present in the estimate of number entrained.

This model assumes the following:

1. The population is in equilibrium. This means that the number of fish in the population is stable (given normal fluctuations)

and the proportion of fish at any age is relatively constant (stable age distribution). If historical information on a fish population shows an increasing or decreasing trend in number of individuals, the numerators of Equations 2 and 4 can be appropriately modified.

2. The reference to a breeding pair (Equation 4) is applicable when the number of males equals the number of females. If a skewed sex ratio exists in the population, Equation 2 can be altered accordingly. A sex ratio dominated by females decreases the numerator in Equation 2, thus decreasing the number of equivalent adults. To derive a conservative impact assessment, modification of the analysis due to unequal sex ratio is made only when the sex ratio is dominated by males.

3. The entrainment of eggs, pro-larvae, and post-larvae is assumed to occur at the time when eggs are laid, pro-larvae hatch, and post-larvae begin exogenous feeding. This assumption results in nonconservative predictions.

4. The number of "equivalent adults" represents the annual loss in an equilibrium, density-independent population with a stable age distribution. This loss is distributed by age in proportion to the stable age distribution. Assuming that

density-dependent factors do not operate in a population results in a conservative estimate of the equivalent adults lost.

Parameters used in the EAM calculations for the selected species are presented in Table 4.3-2; explanation of their derivation can be found in Section 4.3. The results of the EAM model are shown in Table 4.2-10.

Table 4.2-10: Equivalent Adults Lost From Entrainment at Alternative Intake Locations

Species	Station 1 (Mississippi River) Method 1	Station 1 (Mississippi River) Method 2	Station 2 (Sturgeon Lake) Method 1	Station 2 (Sturgeon Lake) Method 2	Station 3 (Present Intake) Method 1	Station 3 (Present Intake) Method 2
White Bass	2,124	376	3,618	636	28,242	5,231
Freshwater Drum	42,984	13,992	29,538	6,670	67,356	16,871
Carp	7,524	2,301	5,958	1,381	9,288	2,650
Darters	19,602	968	10,890	859	608,508	165,612
Gizzard Shad	7,578	3,750	6,066	2,279	279,990	196,598
Emerald Shiner	2,754,973	569,939	150,715	190,934	9,983,946	10,655,391

Table 4.3-1: Weighted Mean Fecundity of White Bass

Age	Estimated Length[a] (mm)	Effective Fecundity[b] At Age (From Length)	Percent By Age[c] of ♀ Spawners	Weighed Mean Fecundity
III	298.1	124,900	23.4	
IV	331.6	218,850	48.1	225,752
V	354.7	312,700	26.0	
VI	371.2	398,250	2.5	

[a]NSP 1975 Annual Report, Volume II, Table 2.5.2-25
[b]Ruelle 1977. Figure 4 (Average of 1970 and 1971)
[c]Ruelle 1977. Page 68

Table 4.3-2: Summary of Life History Information

Species	Mean Generation Time	Fecundity	S_{ea}	S_{la}	S_{pa}
White Bass	4+	290,091	$6.8944x10^{-6}$	$6.8944x10^{-5}$	$6.8944x10^{-4}$
Freshwater Drum	4+	60,400	$3.3112x10^{-5}$	$3.3112x10^{-4}$	$3.3112x10^{-3}$
Carp	5	223,150	$8.9626x10^{-6}$	$8.9626x10^{-5}$	$8.9626x10^{-4}$
Darters	1	45	$4.4444x10^{-2}$	$4.8309x10^{-2}$	$4.8309x10^{-1}$
Gizzard Shad	2	379,000	$5.2770x10^{-6}$	$5.2770x10^{-5}$	$5.2770x10^{-4}$
Emerald Shiner	1	600	$3.3333x10^{-3}$	$4.1667x10^{-2}$	$4.1667x10^{-1}$

older fish were mature at age IV, it is assumed at least 28.5 percent of the white bass were repeat spawners. Increasing the annual fecundity by a factor of 28.5 percent yields an estimate of 290,091 as the lifetime fecundity of a female white bass (Table 4.3-2).

Because information on early life stage survivorship is not available from the literature, it was assumed egg to pro-larvae and pro-larvae to post-larvae survivorship is 10 percent.

4.3.2 Freshwater Drum

The fecundity of freshwater drum has been examined by Daiber (1952) for Western Lake Erie and by Swedberg and Walburg (1970) for Lewis and Clark Lake populations.

Daiber (1952, Table 2, page 162) found from 43,000 to 508,000 ova in the seven female drum examined. He also found that just prior to spawning there are three distinct egg sizes in the ovaries and that after spawning two egg size groups remained in the ovaries to serve as the supply for the next and later years of spawning.

Swedberg and Walburg (1970, page 562) also found three sizes of ova in the ovaries. These authors estimated fecundity only from counts of the fully yolked ova that would be spawned in the current year. Swedberg and Walburg (1970, page 562) estimated an average fecundity of 49,300 eggs for the 17 mature females examined.

Butler and Smith (1950, Table 6, page 52) reported the maturity at age for female drum in the Mississippi River taken from navigation pools 4A, (just below PINGP 8, 10, and 17). They report 46.1, 48.3, 96.6, and 100 percent mature at ages IV, V, VI, and VII, respectively.

Butler (1962, Table 3, page 345) estimates the annual survival of adult drum in navigation pools 3 (at PINGP) and 6 to be 56.6 percent for the years 1944 to 1948.

From Swedberg and Walburg's (1970) estimate of fecundity, Butler and Smith's (1950) estimate of percent maturity at age and Butler's (1962) estimate of adult survivorship, an estimate of lifetime fecundity for an age IV to VII female drum can be made. The estimated lifetime fecundity is 60,400 ova (Table 4.3-2).

Because information on early life stage survivorship is not available from the literature, it was assumed egg to pro-larvae and pro-larvae to post-larvae survivorship is 10 percent.

4.3.3 <u>Carp</u>

Swee and McCrimmon (1966, page 374) describe the fecundity of carp. They report a direct relationship between fecundity at age, length, and weight (Swee and McCrimmon 1966, page 372). They also report age V carp were the most common in the spawning populations they studied for both years of study. (Swee and McCrimmon 1966, page 374 and Figure 3).

Most of the carp collected from the Prairie Island site, based on length-frequency observation (NSP, 1975 Annual Report Volume II, Tables 2.5.2-5, 2.5.2-7, 2.5.2-11, 2.5.2-14, 2.5.2-16, and 2.5.2-19) are of a size range comparable to the age V carp studied by Swee and McCrimmon (1966, Table 3, page 377). Because of this, the average fecundity of age V carp (Swee and McCrimmon, 1966, Table 3) of 223,150 was used (Table 4.3-2).

Swee and McCrimmon report the sex ratio of male to female carp on the spawning grounds to be 1.8 to 1. They explain, however, that this may be partially due to an extended spawning season for male carp. Therefore, a sex ratio of 1:1 was used in the model.

Because information on early life stage survivorship is not available from the literature, it was assumed egg to pro-larvae and pro-larvae to post-larvae survivorship is 10 percent.

4.3.4 Darters

Of the Percidae ichthyoplankton identified to species level for the samples collected in the first two weeks of June, Johnny darter (*Etheostoma nigrum*) was the most abundant. Since fecundity and egg survival of Johnny darter is available from the literature, the fecundity estimate for Johnny Darter will be used to calculate equivalent adult darters.

Winn (1958, Table 4, page 182) compared the fecundity of 14 species of darters from Michigan, Kentucky, and Tennessee. Winn claimed the fecundity of age I and II Johnny darters to be 610 and 1043 ova, respectively.

Speare (1965, pages 309-310) found three size classes of eggs in ovaries of Johnny darters collected in southern Michigan. Speare (1965, page 309) found only the largest of the size classes of eggs is spawned each year and that the smallest size classes are resorbed. Speare's (1965, page 310) estimates of fecundity of age I, II, and III Johnny darters is 45, 82, and 112 eggs, respectively. Since age I is the first age of reproduction the fecundity used for the model is 45 eggs per female (Table 4.3-2).

Speare (1965, page 313) determined the hatching success (egg to pro-larvae survivorship) of Johnny darter eggs to be 92 percent. Since pro-larvae to post-larvae survivorship is not available from the literature, it is assumed to be 10 percent.

4.3.5 Gizzard Shad

Bodola (1966, page 423) found that age I female gizzard shad are rarely mature. Most gizzard shad spawn for the first time at age II (Bodola, 1966, page 423) and since most of the spawners in the population are age II, the fecundity of age II will be used for the model Bodola (1966, page 424) reported that the fecundity of age II shad is 379,000 eggs.

Because information of early life stage survivorship is not available from the literature, it was assumed egg to pro-larvae and pro-larvae to post-larvae survivorship is 10 percent.

4.3.6 Emerald Shiner

Fuchs (1967) reviewed the life history of emerald shiner in Lewis and Clark Lake. Fuchs (1967, page 252) found emerald shiners reach maturity at age I and post spawning mortality is high (page 256). Most of the emerald shiners in the population studied by Fuchs (1967, page 255) were composed of age I fish.

Fecundity information for emerald shiner are not readily available from literature. However, a few authors have investigated fecundity of other Notropis species, such as spottail, spotfin, redfin, and rosyface shiner, which are also found in the vicinity of the Prairie Island plant. McCann (1959, page 341) reports the fecundity of age I spottail shiner in Clear Lake, Iowa, to be 100-1,400 eggs. Wells and House (1974, pages 9 and 10) report 915-3,709 eggs from Lake Michigan spottails, 955-1,768 eggs from Kalamazoo River spottails, and 1,769-8,898 eggs from Western Lake Erie spottails. Scott and Crossman (1973, page 467) report the fecundity of spotfin shiner taken by another author in New York State to be 225-1,580 ova. Black (1945, Table 3, page 460) reports an average fecundity of mimic shiner to be 367 ova. Finally, Pfeiffer (1955, Table 1, page 99) reports an average fecundity of 600 ova for age I rosyface shiner. It is assumed for the equivalent adult model that the fecundity of age I emerald shiners is 600 eggs per female (Table 4.3-2).

Reed (1958; pages 325 and 326) estimated about 20 percent of rosyface shiner and stoneroller minnow eggs were not successfully fertilized using artificial techniques. An average of 10 percent of the successfully fertilized eggs survived to hatch 57 to 59 hr later. (Reed, 1958, page 326). The overall result is that 8 percent of the spawned eggs become newly hatched pro-larvae. Since pro-larvae to post-larvae survivorship is not available from literature sources, it is assumed to be 10 percent.

4.4 MONETARY VALUE OF EQUIVALENT ADULTS

In order to compare the benefits of alternate intake locations with their incremental costs, the monetary values of adults resulting from entrained ichthyoplankton were estimated. The Monetary Values of Fish Committee, North Central Division of the American Fisheries Society, published a list of reimbursement values for fish found in the North Central United States (Monetary Values of Fish Committee, 1978). The reimbursement values are a composite of hatchery production costs, commercial values and angler expenditures for each species of fish. The Committee recommended these values be used for assessing potential damages to fish populations. Therefore, the value of the fish lost due to entrainment can be calculated by determining the cost of equivalent adults lost at each of the three alternate locations.

Since the value of most of the fish species is expressed in pounds of fish some estimate of the weight of an equivalent adult of each of the species was made. The weight of an equivalent adult should represent the average weight of the breeding population.

The reported value of an adult white bass over 13 inches in length is $3.00/lb. Using length at age and weight at length information for white bass in the PINGP area (NSP, 1975, Vol. II, Table 2.5.2-25 and 2.5.2-24, respectively), the weights of age IV and age V white bass are approximately 1.1 and 1.4 lb/fish; the latter is used as the weight of an equivalent adult fish.

The reported value of an adult freshwater drum over 12 inches in length is $0.40/lb. Butler and Smith (1950, page 51) report the length of age IV and age V drum to be 13.4 and 14.8 in., respectively. Scott and Crossman (1973, page 815) report drum of that length to weigh about one pound. One pound is used as the weight of an equivalent adult freshwater drum.

The reported value of an adult gizzard shad over 12 inches in length is $0.39/lb. Bodola (1966, figure 9) reports age II shad to be about one pound in weight. One pound is used as the weight of an equivalent adult gizzard shad.

The reported value of an adult carp over 12 inches in length is $0.20/lb. Swee and McCrimmon (1966, Table 3) report the mean weight of an age V female carp to be 3.4 lb (1561 grams); this is used as the weight of an equivalent adult carp.

The reported value for darters is $0.15/fish. The value for shiners, assuming they can be categorized as cyprinidae bait fishes, is assumed to be $0.06/fish.

The values of equivalent adult fish lost due to entrainment of ichthyoplankton during the 1978 spawning season are shown in Table 4.4-1. Two sets of values are given, corresponding to the two methods used to estimate total entrainment in the 1978 spawning season; see Section 4.2.2 for further explanation.

Table 4.4-1: Annual Reimbursement Value of Equivalent Adults Lost Due to Entrainment of Ichthyoplankton Assuming Total Mortality

	Station 1 (Mississippi River)		Station 2 (Sturgeon Lake)		Station 3 (Present Intake)	
Species	Method 1	Method 2	Method 1	Method 2	Method 1	Method 2
White Bass	$ 8,928	$ 1,579	$ 15,192	$ 2,671	$ 118,620	$ 21,970
Freshwater Drum	$ 17,190	$ 5,597	$ 11,808	$ 2,668	$ 26,946	$ 6,748
Carp	$ 5,112	$ 1,565	$ 4,050	$ 939	$ 6,318	$ 1,802
Darters	$ 2,934	$ 145	$ 1,658	$ 129	$ 91,278	$ 24,841
Gizzard Shad	$ 2,952	$ 1,463	$ 2,358	$ 889	$ 109,206	$ 76,673
Emerald Shiner	$165,298	$ 34,196	$ 9,043	$ 11,456	$ 599,037	$ 639,323
TOTAL ANNUAL COST (1978 Dollars)	$202,414	$ 44,545	$ 44,109	$ 18,752	$ 951,405	$ 771,357
LEVELIZED COST	$489,842	$107,799	$106,744	$ 45,380	$2,302,400	$1,866,684

5.0 BENEFIT-COST ANALYSIS

This benefit cost analysis considers the relative environmental benefits of locating the intake of the PINGP at each of three alternate locations. A statistical analysis, utilizing least squares analysis of variance for a nested design, led to the conclusion that for most species and life stages the present onshore location (sampling station 3) had higher densities of eggs and larvae than either of the other two locations (Table 4.1-3). Thus, there is some benefit to the fisheries resources to be gained from moving the intake from its present location to an offshore location.

To provide a quantitative basis for evaluating these environmental benefits, the cost of replacing the fisheries resources at each station was estimated. This analysis relied on certain conservative assumptions which tend to over-estimate of the cost for replacement. Benefits are calculated on the basis of annual levelized costs in 1978 dollars.

In the first part of the analysis, estimates were made of the loss in terms of adult fish associated with the loss of eggs and larvae by entrainment utilizing the equivalent adult model (Horst 1975, 1978). The results of this portion of the analysis are presented in Table 4.2-10. These equivalent adults were then translated into dollar values by using the replacement costs for fishery resources published by the North Central Division of the American Fisheries Society (Monetary Values of Fish Committee, 1978). The replacement costs were then estimated (Table 4.4-1) for the proposed onshore intake location and the offshore locations under the assumption that all the fish eggs and larvae entrained will suffer mortality. Replacement costs are stated in Table 4.4-1 as annual costs in 1978 dollars and as levelized costs.

The proposed use of the center flow fine mesh screens represents a significant and substantial step toward minimization beyond that which might result from alternate intake locations. In the S&W Report (1977, page 53) on alternate intake designs for the onshore location, data on survival of fish with a fine mesh screen modification were reviewed. It was stated, assuming literature values are appropriate for PINGP, that survival would be approximately 80 percent with low approach velocities and short impingement times. Thus the replacement costs for the fisheries' loss should be reduced to 20 percent of the amounts in Table 4.4-1, since only 20 percent of the organisms would suffer mortality. The benefit associated with 80% mortality reduction is about $1.5 million (Method 1) and $1.84 million (Method 2). These values are 80% of the levelized costs shown on Table 4.4-1 for station 3.

The cost for the intake at the onshore and offshore location with the center flow fine mesh screen technology is presented in Table 5.0-1. These costs were developed by NSP based on capital costs developed by S&W (1977, Table 5.1-1 and 1978, Table 4-9). The cost information is presented for an offshore location nearer the 1978 ichthyoplankton sampling station 1 (S&W, 1978, Figure 2). The environmental benefits as indicated by the analysis of the 1978 ichthyoplankton would be similar at stations 1 and 2, and in fact the analysis of variance did not declare the concentrations at these locations statistically different at $\alpha = 0.05$. However, engineering considerations (S&W, 1978, page 17) indicate that a location near sampling station 1 would be more suitable.

Differential benefits and costs are the important consideration in choosing between possible intake locations. The differential benefit of locating the intake offshore is estimated as the difference in levelized costs for replacing the fisheries resources at the onshore and offshore locations. On an annual levelized basis the differential benefit for the offshore location is about $0.36 million. Referring to Table 5.0-1, the cost for this differential benefit is $5.8 million per year.

To summarize, installation of fine mesh screens at the proposed onshore intake location results in a benefit of about $1.5 to $1.84 million annually on the basis of reduced fisheries replacement cost. A further annual benefit to the fishery of $0.36 million could be obtained by locating the intake offshore. However, this additional benefit is estimated to cost $5.8 million per year. Accordingly it is concluded that the increased cost of the offshore location (about 16 times the benefit) is disproportional to the incremental increased benefit to the fisheries resources.

Table 5.0-1: Benefits and Costs of Alternate Intake Locations For Prairie Island Nuclear Generating Plant

Cost (Millions of Dollars)	Alternative	
	Center Flow, Onshore Location	Center Flow Submerged Offshore
Demand Charge	0.02	1.89
Energy Charge	0.05	2.54
Maintenance	0.66	0.82
Capital	8.87	57.04
Total Cost[1]	9.60	62.29
Levelized Cost (Millions of dollars per year)	1.07	6.93
Benefit		
Method 1		
Total Cost	0.19	0.04
Levelized Cost	0.46	0.10
Method 2		
Total Cost	0.15	0.01
Levelized Cost	0.37	0.02

[1] 1978 Costs

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ALTERNATE DISCHARGE STUDY FOR THE PRAIRIE ISLAND NUCLEAR GENERATING PLANT

Prepared for

NORTHERN STATES POWER COMPANY

MINNEAPOLIS, MINNESOTA

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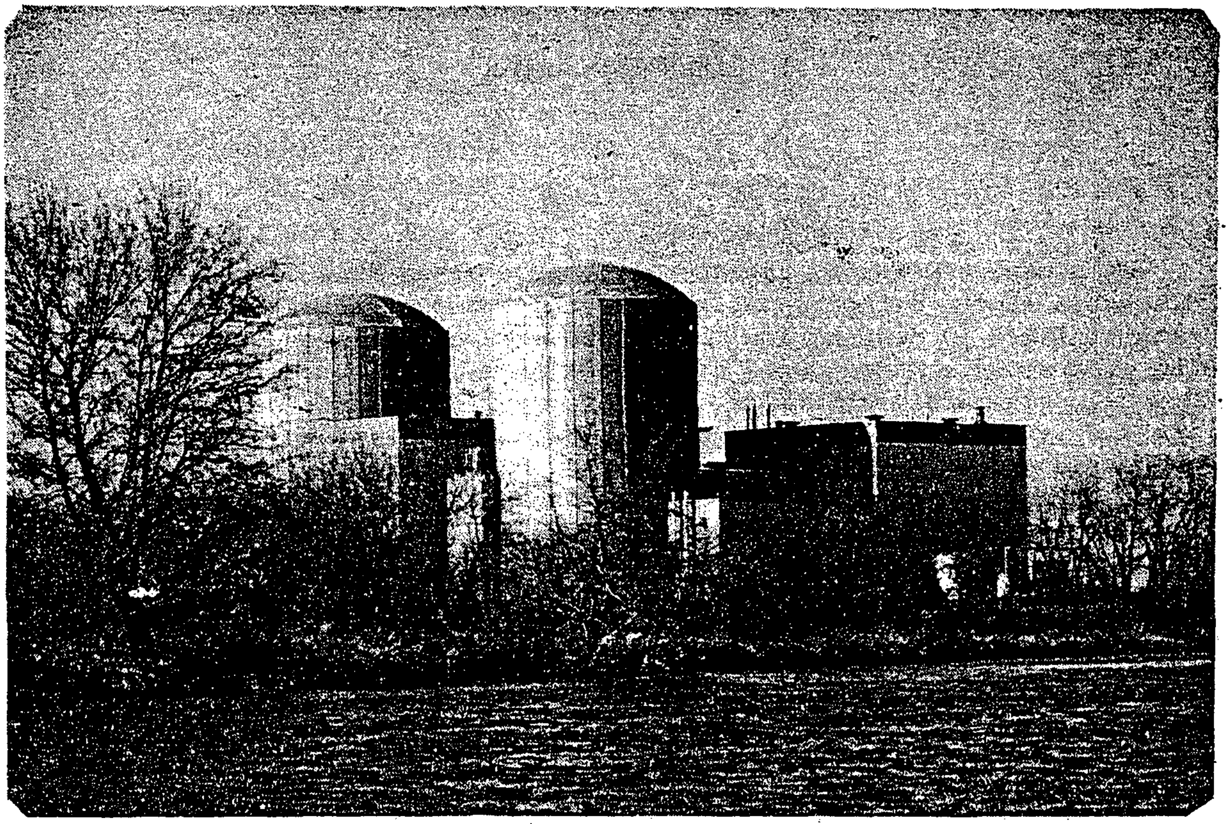
I EXECUTIVE SUMMARY

This report presents the thermal impact assessment of an alternate discharge scheme being considered for the Prairie Island Nuclear Generating Plant (PINGP) in conjunction with a proposed new mode of plant operation. The proposed discharge would be located on the west bank of the Mississippi River approximately 150 m (500 ft) downriver from Barney's Point so that the thermal discharge would enter the main channel of the river. Discharge velocities would be maintained at approximately 2.3 m/sec (7.5 fps). [redacted] Cooling towers would not be used from November through March to eliminate mechanical damage that has occurred in past winters. The closed and partial recycle modes of operation are employed to minimize potential impacts to fish and their progeny during the spawning period. The proposed discharge modification would eliminate heat recirculation to the intake and increase mixing of the thermal plume with the receiving water, both of which would reduce biological impacts.

The environmental characteristics in the vicinity of the plant have been described in the PINGP 316 (a) Demonstration (HDR, 1978) and are summarized in this report. The plant is located on the west bank of the Mississippi River approximately 64 km (40 mi) south of the Minneapolis-St. Paul metropolitan area and 2.4 km (1.5 mi) upriver from Lock and Dam No. 3. The existing intake and discharge are located at the southern end of Sturgeon Lake. The river is 300 to 370 m (1,000 to 1,200 ft) wide in the vicinity of the plant. River flows are regulated for flood control throughout the year and for navigation during ice-free months. The weekly average discharge rates for the period 1928 to 1976 ranged from 7,000 cfs in December to 44,000 in April, with velocities generally less than 0.6 m/sec (2 fps) most of the year. Ambient river temperatures range from 0° to 29° C (32° to 85° F) annually with daily fluctuations of about 1° C (2° F). Sewage discharges upriver have enriched the water in nutrients and toxicants but conditions do not appear limiting for any biota.

Fisheries studies conducted near PINGP have indicated that gizzard shad, white bass, freshwater drum, and carp dominate the adult and juvenile fish populations from late May through October. Seasonal and



PINGP is located on the west bank of the Mississippi River approximately 64 km (40 mi) south of the Minneapolis-St. Paul metropolitan area. The proposed discharge would be located about 150 m (500 ft) downriver from Barney's Point [approximately 300 m (1,000 ft) to the left of this scene].

annual variations in abundance occur for the dominant species. Peak ichthyoplankton densities are in June or early July, and densities are greater in Sturgeon Lake than in the main channel of the river. A high diversity of benthic macroinvertebrates, zooplankton, and primary producers exists near PINGP, and all groups show marked seasonal variations in abundance. Many of the macroinvertebrates are larval stages of terrestrial and aquatic insects that emerge as adults. Aquatic macrophytes occur in many shallow water areas, but few occur in the main channel of the river. Bald eagles (threatened status in Minnesota) and various waterfowl migrate through the area in spring and fall, but the present discharge does not appear to be an important overwintering area for the eagles. Peregrine falcons (endangered status) are being reintroduced about 48 to 80 km (30 to 50 mi) downriver from PINGP.

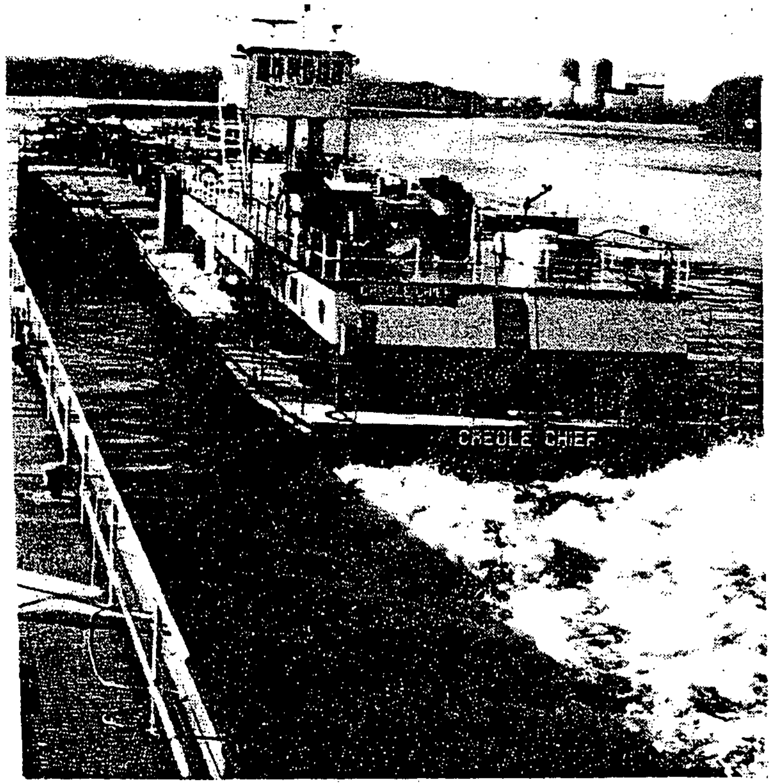
To assess the potential impacts of operating the PINGP alternate discharge, the [redacted]) selected to represent biological communities and ecological interactions for assessing impacts in the PINGP 316 (a) Demonstration were also used in this report. The fish selected were [redacted], and [redacted] The macroinvertebrates were [redacted], and [redacted] Thermal tolerances of these RIS, determined from an extensive literature review, were compared to the thermal plume modeling results for a range of plausible environmental and operating conditions. The predicted impacts are generally expressed in terms of physical areas within the thermal plume where conditions limiting various life functions (e.g., survival or reproduction) could occur for each RIS during typical and extreme environmental conditions.

The thermal plume from the alternate discharge was modeled for both typical and extreme environmental conditions. Forty-one cases were run, using both near- and far-field models, and isotherm plots were drawn for each. [redacted]. The indigenous biota, however, would be protected from cold shock as discussed below.

To predict the potential biological impacts of constructing and operating the alternate discharge, both literature and field data for the RIS were used along with the thermal plume model results. Construction of the new discharge would be most likely to impact aquatic biota during dredging for and laying of the outfall pipes across the backwater commonly called the refuge. Potential impacts to fish in the refuge would result from temporary habitat disturbances that could affect feeding and spawning. The area affected would be very small compared to other similar habitat available nearby, and thus, impacts to fish populations in the vicinity of PINGP are expected to be minimal. Potential impacts to invertebrates, primary producers, and birds are likewise predicted to be small.

An [redacted] for preferred temperatures indicates that during operation of the proposed discharge all of the fish RIS should be attracted to some portion of the thermal plume when ambient temperatures are low and some should avoid at least the warmer areas within the plume during summer. Similar predictions were made for the existing discharge, and [redacted]. Differences in habitat between the existing and proposed discharge locations, however, preclude extrapolation of the field data from the existing discharge to the proposed discharge, and thus, only predictions based on literature data were used. Upper lethal temperatures were used to estimate the area potentially excluded from long-term use by adult fish during typical summer conditions. Under these conditions, only one species, [redacted], should be excluded from the thermal plume, and the exclusion area for this species would be less than 0.01 ha (0.03 A) from June through August. High discharge velocities in this small area would also exclude fish.

The thermal plume from the proposed discharge is predicted to have negligible effects on spawning and reproductive success. Induction of premature spawning is not likely since the main river channel does not provide suitable habitat for most of the RIS, and turbulence from the frequent passage of barges would tend to reduce residence times in the plume. Loss of spawning habitat should be negligible, and mortality from thermal and shear stresses to larvae drifting through the plume should be minimal.



The main channel does not provide suitable spawning habitat for most of the representative important species of fish. Frequent passage of barges disturbs the area of the proposed discharge reducing residence by fish and mixing the thermal plume.

The potential for cold shock occurs at PINGP during winter since temperatures in the plume exceed the recommended maximum weekly average temperature (MWAT) for cold shock protection and a significant probability (0.55) of a forced trip (shutdown) occurring at one unit while the other unit is refueling exists. Fish residing in areas with temperatures above the MWAT could acclimate to these temperatures and thus be susceptible to cold shock impacts. The area in which fish could acclimate to temperatures above the MWAT would be approximately 0.3 ha (0.7 A) during typical one-unit operation. If only the minimum volume for deicing were recycled, the area would be reduced to 0.04 ha (0.1 A) since initial discharge temperatures would be reduced. The available area would be further reduced to 0.02 ha (0.05 A) because discharge velocities exceeding the maximum sustained swimming ability of most of the RIS [0.9 m/sec (3 fps)] would occur in an area of 0.02 ha adjacent to the discharge.

Operation of the alternate discharge would not be expected to affect any endangered species of fish nor to inhibit any migrations. Effects of the thermal discharge on growth rates, predator-prey interactions, and the incidence of parasites and diseases are also predicted to be negligible. Neither recreational nor commercial fishing should be influenced by the proposed discharge.

Potential impacts to macroinvertebrates are expected to be negligible. The preferred temperatures of *Hydropsyche* and *Macronemum* are exceeded in an area of less than 0.02 ha (0.05 A) along the river bank in June through August, and *Stenonema* may be excluded from less than 0.007 ha (0.02 A) of shoreline in November. Early emergence of adult macroinvertebrates could theoretically occur in a small area [less than 0.4 ha (0.9 A)] throughout the year, although this has not been observed in the present discharge. Potential impacts to other invertebrates, primary producers, and birds are predicted to be negligible.

Table I-1 compares potential impacts predicted for the existing and proposed alternate discharges for each organism group. In all cases, impact potential would be reduced at least one or two orders of magnitude if the proposed discharge were used.

In conclusion, construction and operation of the proposed discharge is predicted to cause neither appreciable harm nor adverse levels of impact to aquatic biota. Operation of the proposed alternate discharge would reduce the potential for impacts from the PINGP thermal discharge below the level predicted for continued use of the existing discharge which was likewise shown to cause no appreciable harm.

Table I-1. Comparison of predicted biological impacts during operation of the existing and proposed discharges under typical environmental conditions.

ORGANISM GROUP AND PARAMETER AFFECTED	EXISTING DISCHARGE[1]	ALTERNATE DISCHARGE
Fish (RIS)		
Summer Survival	Maximum area of exclusion is 4.4 ha in July and August (velocity not calculated but very low).	Maximum area of exclusion is 0.01 ha in June through August. Velocities within this area exceed 0.9 m/sec.
Spawning and Reproductive Success	Premature spawning could occur in walleye, carp, gizzard shad, and emerald shiner but effects on populations expected to be minimal.	Premature spawning not predicted for any species.
	Exclusion area for spawning is less than 2.6 ha.	Exclusion area for spawning is less than 0.01 ha.
	Exclusion area for embryo development is less than 17 ha.	Exclusion area for embryo development is less than 0.1 ha.
	No thermal stress to larvae drifting through the plume predicted. No shear effect due to discharge configuration.	No thermal stress to larvae drifting through the plume predicted. Shear stress may occur to a few larvae but should not alter recruitment to adult populations.
Winter Survival	Area in which plume temperature exceeds MWAT for winter survival is 4.4 ha (2 unit operation). For 1 unit operation, when cold shock potential is greatest, area would be less than 2.2 ha.	Area in which plume temperature exceeds MWAT for winter survival is 0.2 to 0.9 ha depending on amount of recycle (2 unit operation). The area would be reduced to 0.02 ha for 1 unit operation with minimum recycle when area of high velocity (> 0.9 m/sec) is subtracted.
Growth Rates, Predator-Prey Interactions, and Incidence of Parasites and Diseases	Minimal effects predicted.	Negligible effects predicted.
Macroinvertebrates (RIS)		
Survival	Preferred temperature exceeded in ≤ 6.6 ha of plume during June through August.	Preferred temperature exceeded in ≤ 0.02 ha of bank during June through August (remainder of plume is unsuitable habitat).
	Maximum area of exclusion is less than 0.5 ha in May.	Maximum area of exclusion is less than 0.007 ha in November.
Emergence	Emergence may be accelerated up to 2 weeks in an area of 18.5 ha and up to 5 months in an area of 1.5 ha.	Emergence may be accelerated up to 2 weeks in an area of 0.4 ha and up to 5 months in an area of 0.01 ha.
Phytoplankton, Zooplankton, and Periphyton	Negligible impacts predicted.	Negligible impacts predicted.
Aquatic Macrophytes	No impacts predicted.	No impacts predicted.
Birds	Negligible impacts predicted.	Negligible impacts predicted.

[1]From the PINGP 316(a) Demonstration (HDR, 1978).

II INTRODUCTION

This report presents the thermal impact assessment of an alternate discharge scheme being considered for Prairie Island Nuclear Generating Plant (PINGP) in conjunction with a proposed new mode of plant operation. Although this is only a proposed scheme, this report has been written to satisfy the legal requirements governing thermal discharges as described in the introduction to the PINGP 316(a) Demonstration (HDR, 1978). The new scheme, which is proposed to minimize the extent of the thermal plume, involves relocation of the discharge so that heated effluent would enter the main channel of the Mississippi River rather than a backwater area as it presently does. Plant operation would also be changed to minimize impacts to the aquatic ecosystem at both the intake and discharge.

In this report, potential impacts of the proposed discharge are predicted using the thermal plumes modeled by Stone & Webster Engineering Corporation. The input conditions and isotherm plots from their report are included as an appendix. Various environmental conditions, including typical and extreme cases, were modeled, and the results are combined with biological and physical data derived primarily from the PINGP 316(a) Demonstration for impact analysis.

The report is organized as follows: Section III briefly summarizes the general environmental characteristics of the area and presents some new ichthyoplankton data. Details of the location, design, and operation of the proposed discharge are presented in Section IV, while the thermal plume is discussed in Section V. Both construction and operational impacts of the proposed discharge are considered in Section VI, utilizing a predictive (Type 2) approach, and the operational impacts are compared to those predicted for the existing discharge in the PINGP 316(a) Demonstration. A Conclusions section and a list of literature cited are also included. Appendix A contains tabular data utilized in the report, Appendix B contains selected portions of the Stone & Webster Engineering Corporation report (Stone & Webster, 1978a) on the thermal plume analysis, and Appendix C contains unpublished information used in this report.

Many of the individuals who contributed to the PINGP 316(a) Demonstration also were instrumental in the development of this report. In particular, Mr. Lee Eberley and Mr. Richard McGinnis of NSP provided primary guidance, and initial assistance was given by Mr. Larry Grotbeck. Dr. Y. Y. Shen and Mr. Donald Matchett of Stone & Webster Engineering Corporation were instrumental in providing the information included in Appendix B.

III ENVIRONMENTAL CHARACTERISTICS

Environmental characteristics in the vicinity of PINGP have been described in detail in the 316(a) Demonstration (HDR, 1978) and are briefly summarized in this section.

A. HYDROLOGY

PINGP is located on the west bank of the Mississippi River approximately 64 km (40 mi) south of the Minneapolis-St Paul metropolitan area and 2.4 km (1.5 mi) upriver from Lock and Dam No. 3 (Figure III-1). The existing intake and discharge are located at the southern end of Sturgeon Lake, a backwater lake connected to the main channel of the river by numerous coulees and reaches. The river is 300 to 370 m (1,000 to 1,200 ft) wide near PINGP with steeply sloping banks along the main channel. River flows are regulated for flood control throughout the year and for navigation during ice-free months. Weekly average discharge rates for the period 1928 to 1976 ranged from 7,000 cfs in December to 44,000 cfs in April. Maximum and minimum daily rates recorded during this period were 228,000 cfs and 2,100 cfs. Velocities are generally low, less than 0.6 m/sec (2 fps), most of the year.

B. WATER QUALITY

Ambient water temperatures range from 0° to 29° C (32° to 85° F). Daily temperature fluctuations are low in the river [1.1° C (2° F)] but can be higher in backwater areas. The average fluctuation was 2° to 3° C (3.5° to 5.4° F) with a maximum of 9.7° C (17.5° F) in Sturgeon Lake during ice-free months of 1974 through 1977.

Dissolved oxygen levels low enough to be limiting to aquatic biota have not been measured near PINGP even though domestic sewage is discharged from the Minneapolis-St Paul Metropolitan Sewage Treatment Plant located 61 km (38 mi) upriver. Elevated nutrient and toxicant levels, however, have been observed at PINGP, possibly reflecting upriver contributions from domestic/industrial and agricultural sources. Near Lock and Dam No. 3, some toxicants, such as cyanide, have been periodically measured at levels that could stress many types of aquatic biota, including fish and plankton. Generally, however, water quality conditions near PINGP promote a diverse and productive assemblage of river and backwater organisms.

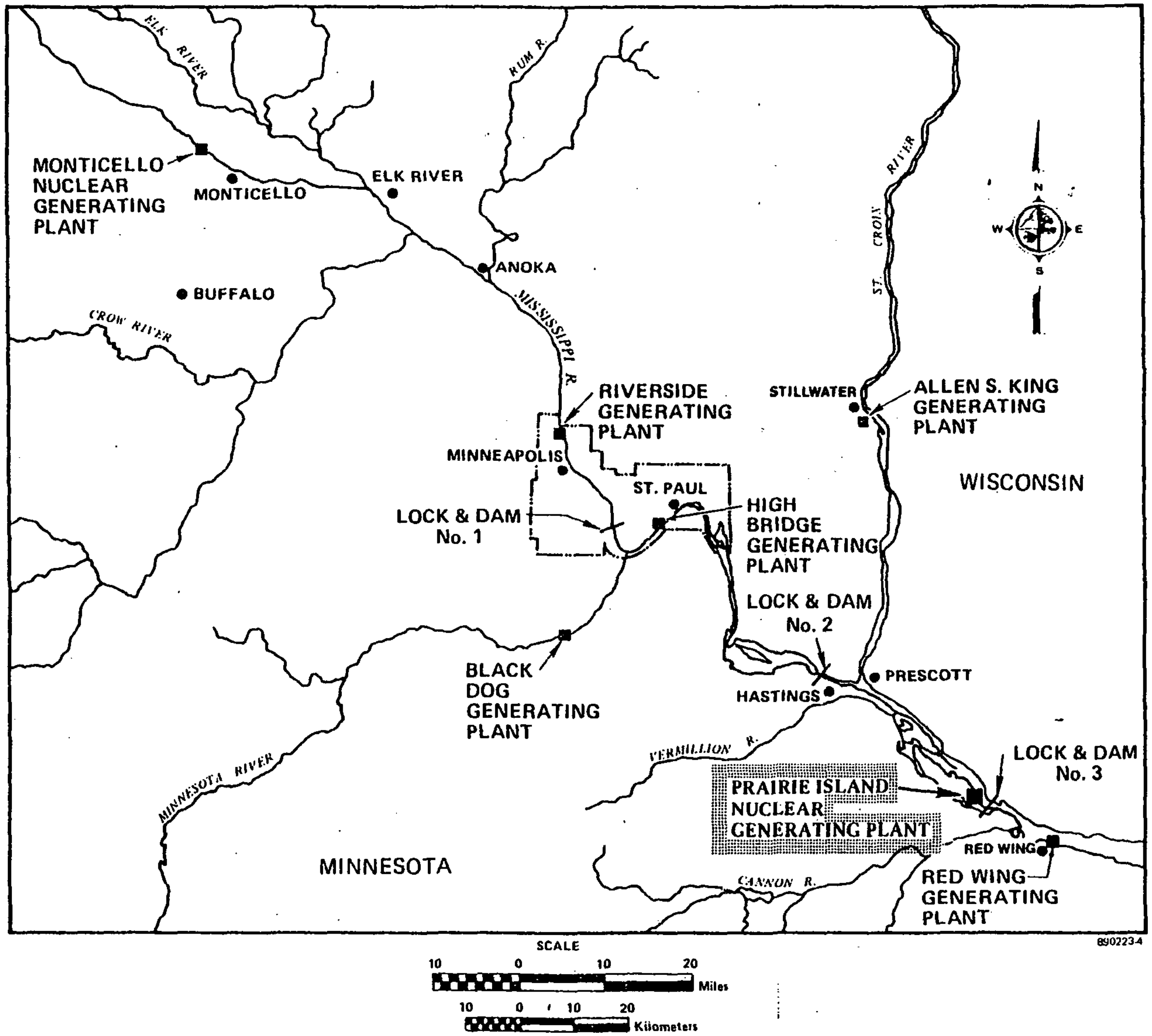


Figure III-1. Location of PINGP on the Mississippi River in relation to other NSP power plants.

C. BIOLOGICAL ENVIRONMENT

The variety of aquatic habitats and the eutrophic conditions near PINGP have led to a density and diversity of biota at all trophic levels that are nearly maximal for this particular climatic and geographic location. Both lake and river biota flourish, primarily because of a broad food base accompanied by few and infrequent limiting environmental conditions other than normal seasonal fluctuations.

The list of representative important species (RIS) selected for assessing impacts in the 316(a) Demonstration are used in this report to assess potential impacts of the alternate discharge. The fish selected were walleye, white bass, channel catfish, northern pike, black crappie, gizzard shad, carp, emerald shiner, white sucker, and shorthead redhorse. The macroinvertebrates chosen were *Hydropsyche, Stenonema, Pseudocloeon,* and *Macronemum*. Life histories, thermal tolerances, migrations and spawning areas, predator-prey interactions, and diseases and parasites were included in the 316(a) Demonstration for the RIS.

Fisheries studies conducted for NSP have indicated that gizzard shad, white bass, freshwater drum, and carp dominate the adult and juvenile fish populations near PINGP from late May through October. Abundance varies both seasonally and annually for the dominant species. Ichthyoplankton densities determined in 1974 and 1975 for the PINGP 316(b) Demonstration indicated that peak densities occurred in July 1974 and June 1975, and the most abundant species were white bass, emerald shiner, carp, and gizzard shad. An additional ichthyoplankton study was conducted in June of 1978 (see Figure III-2 for locations sampled). Total densities were about 5 times higher in Sturgeon Lake (Station III) than in the main channel of the river (Station I), and the relative species abundance differed also (see Figure III-3 and Table A-1). Gizzard shad, carp, white bass, and emerald shiner were the dominant RIS in Sturgeon Lake while gizzard shad carp, catostomids (suckers), and white bass were dominant in the river.

Both commerical and recreational fishing occur in Pool No. 3 of the Mississippi River navigation system, which is located between Lock and Dam No. 2 and No. 3 (see Figure III-1). Catfish, carp, drum, and buffalo are the most valuable commerical species. The harvest and catch per unit effort in Pool No. 3 increased from 1970 through 1974 while declining in Pool Nos. 4 and 4a, which are located between Lock and Dam No. 3 and No. 4 downriver from PINGP. Creel census information from 1973 through 1976 indicates that recreational fishing pressure has remained lower in the vicinity of PINGP than in the tailwaters of Dam No. 3 with fishing success greater above the dam. Walleye and white bass were the RIS most frequently caught near PINGP, while white bass dominated the catch in the existing PINGP discharge area during spring.

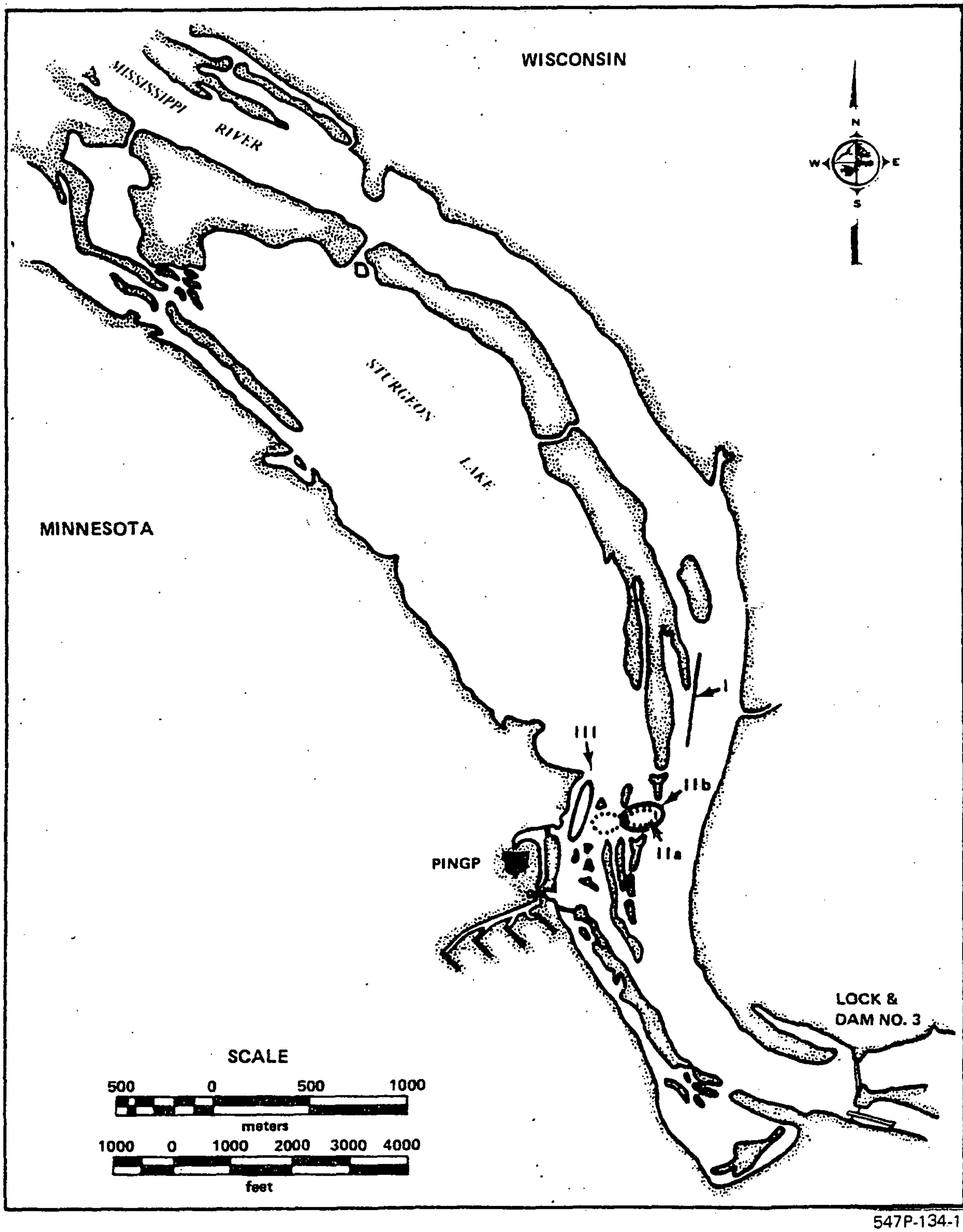


Figure III-2. Locations sampled for larval fish in June, 1978. Station II-a was sampled on 6, 8, 10, and 13 June while Station II-b was sampled on 15 and 17 June (Stone & Webster, 1978b).

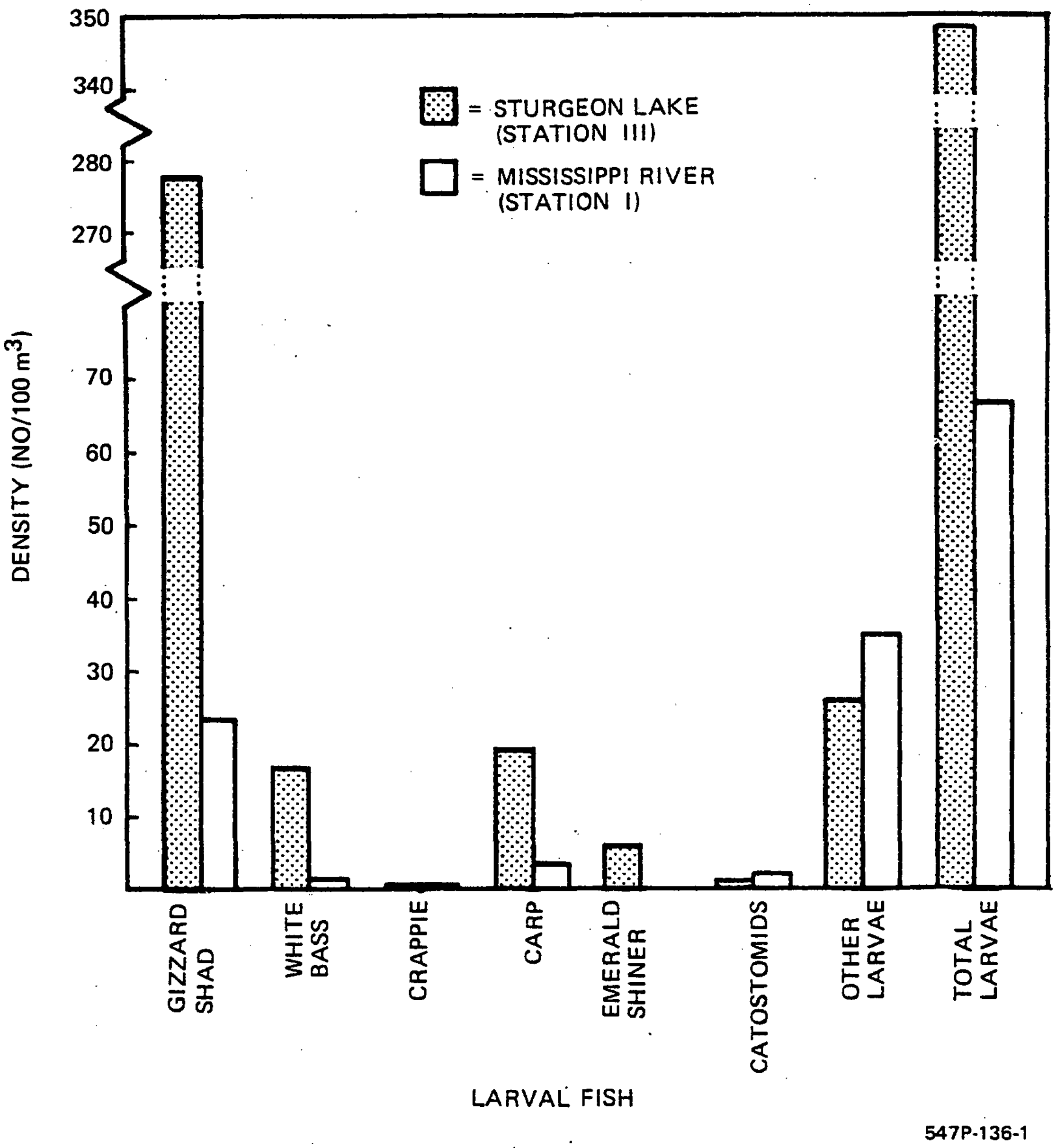


Figure III-3. Densities of larval fish in the main channel of the river (Station I) and Sturgeon Lake (Station III) in June 1978 (Stone & Webster, 1978b).

A high diversity of benthic macroinvertebrate, zooplankton, and primary producer populations exists near PINGP. Marked seasonal variations in organism abundance are common in all groups. Many of the macroinvertebrates are larval stages of terrestrial and aquatic insects that emerge from the water during summer. Various taxa of phytoplankton and zooplankton bloom at intervals in response to changing levels of nutrients or food organisms and temperature. Aquatic macrophytes are present in many shallow backwater areas, but few occur in the present PINGP discharge canal or the main channel of the river. Life histories and thermal tolerance information for all biotic categories except macrophytes were also discussed in the 316(a) Demonstration.

The bald eagle, classified as a threatened species in Minnesota (Federal Register, 14 February 1978), and various waterfowl migrate through the Mississippi River Valley in spring and fall with some overwintering in areas of open water. The existing PINGP discharge does not appear to be an important eagle overwintering area. Ducks and other waterfowl utilize open water areas during their migrations, and open water created by the existing discharge may enhance the number of mallards overwintering. The peregrine falcon, an endangered species, is being reintroduced in former nesting areas along Lake Pepin approximately 48 to 80 km (30 to 50 mi) downriver from PINGP.

IV PLANT DESCRIPTION AND OPERATING PROCEDURES

A. CIRCULATING WATER SYSTEM

1. Alternate Discharge Description. The general layout of the proposed alternate discharge system is shown in Figure IV-1 and in Figures 3-2 and 3-3 in Stone & Webster (1978a). In this system, discharged water would be routed from the existing discharge structure through a canal to a new discharge control structure located approximately 244 m (800 ft) south of the present discharge gates. From there, the heated water would be pumped through 1 to 4 pipes, depending on the flow rate, to the main channel of the river about 150 m (500 ft) downriver from Barney's Point. The pipeline would cross an existing backwater area (commonly known as the refuge) and the island separating this backwater from the river. The pipeline would consist of one 1.7 m (5.5 ft) diameter pipe and four 2.4 m (8 ft) diameter pipes. The small pipe would be used during closed cycle operation (150 cfs blowdown = plant discharge to river), and various combinations of the pipes would be used when blowdown exceeds 300 cfs to maintain a discharge velocity of about 2.3 m/sec (7.5 fps) (Stone & Webster, 1978a).

2. Modes of Operation. The circulating water system at PINGP may be operated in four basic modes: closed, partial recycle, helper, and open cycle. Detailed discussions of each mode of operation can be found in Section IV A of the PINGP 316(a) Demonstration. For the alternate discharge system, the proposed operating procedure is open cycle with partial recycle (600 to 1,300 cfs blowdown) from November through March; closed cycle (150 cfs blowdown) in April; partial recycle (300 cfs blowdown) in May; partial recycle (400 cfs blowdown) the first half of June; and helper cycle (up to 1,410 cfs blowdown) from 16 June through October. These projected discharge rates and schedules are shown in Figure IV-2 and discussed in more detail below.

From November through March when river temperatures are low, the plant would operate in an open cycle mode (no cooling towers). To maintain the turbine-generator at peak efficiency, the condenser inlet temperature should be approximately 15.6° C (60° F). To accomplish this, a portion of the total circulating water would be returned to the intake canal via the recirculation canal to mix with the cold makeup water before entering the screenhouse. Discharge rates would be varied between 600 and 900 cfs to maintain the 15.6° C inlet temperature. This mode of operation is

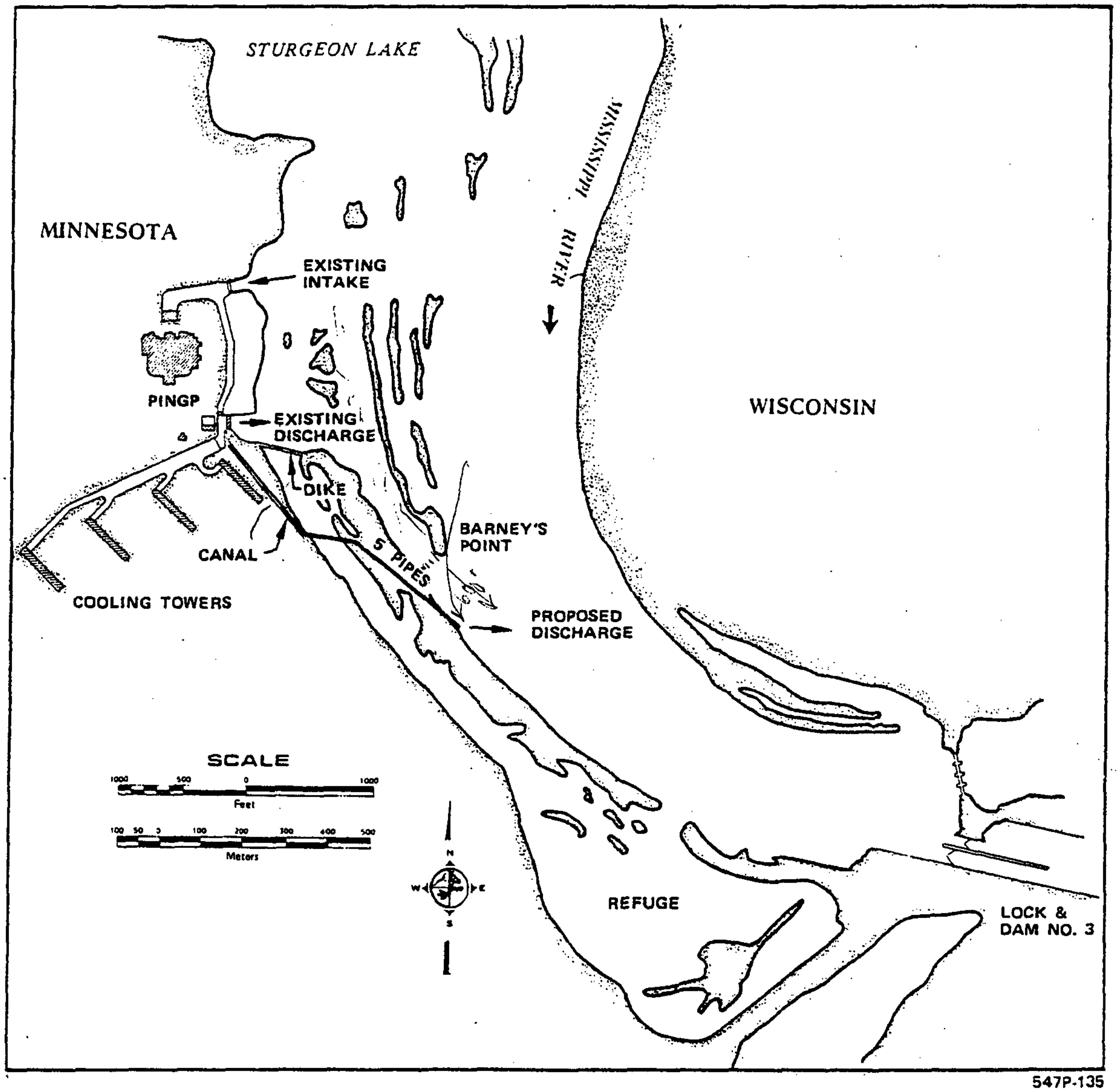


Figure IV-1. Location of the proposed discharge structure.

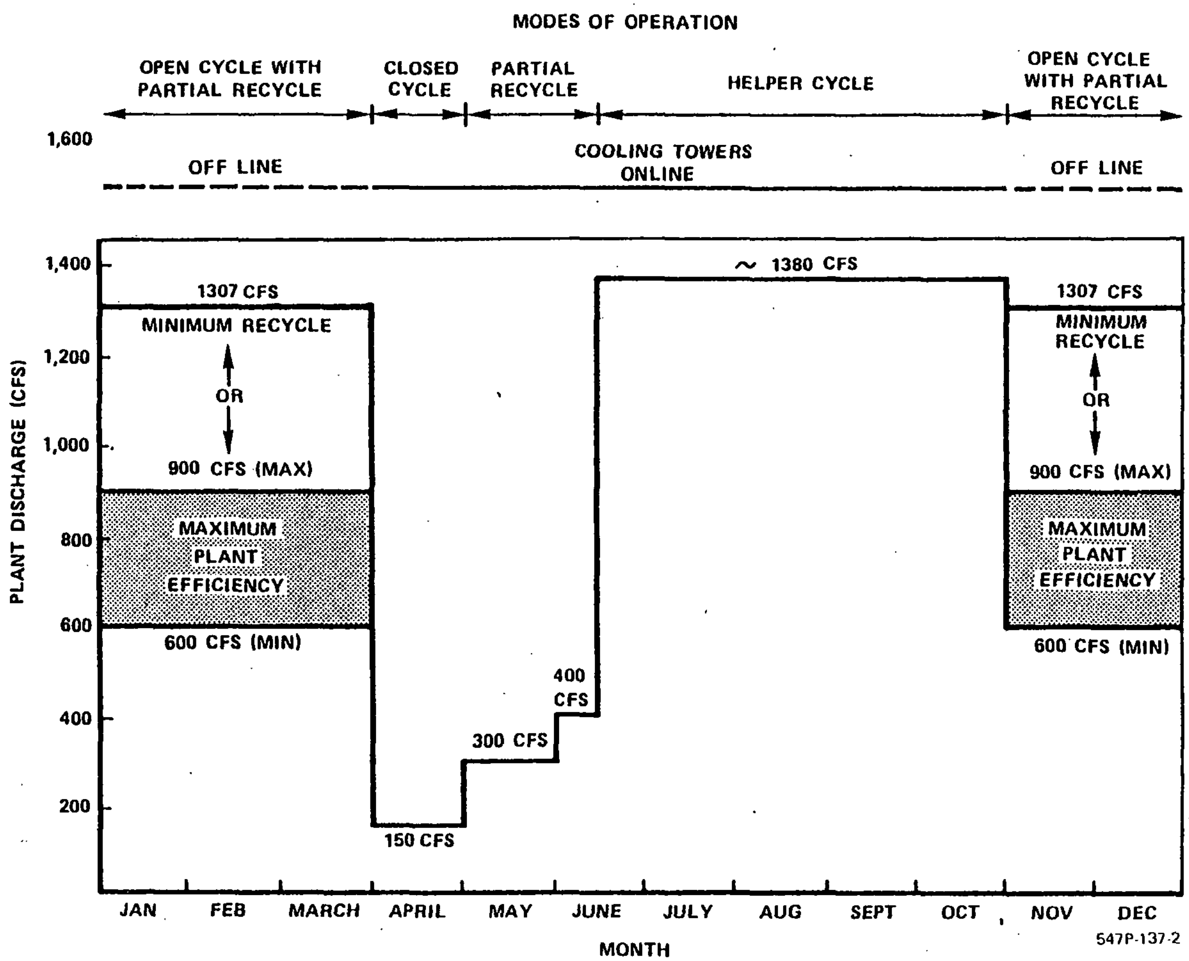


Figure IV-2. Annual time course of projected plant discharge rates and modes of operation. During winter, two variations of open cycle operation may be used: one for maximum plant efficiency and one with minimum recycle for intake deicing (see text).

essentially the same as the partial recycle mode except that warm water does not pass through the cooling towers before being discharged to the river or recycled to the intake. Cooling towers would be bypassed in winter to eliminate the icing-associated mechanical damage that has occurred in the past and caused shutdown of cooling towers during the critical warm water months.

In order to lower temperatures in the discharge plume for protection of fish from potential cold shock, the amount of recycle could be reduced to the minimum necessary for intake deicing (up to 84 cfs for 2 unit operation and 42 cfs for 1 unit operation) with an associated loss in plant efficiency. Both maximum and minimum recycle operation during winter have been modeled for impact analysis.

During April, the plant would be operated in a closed cycle mode to minimize potential impacts to fish and their progeny at the intake and discharge. In this mode, circulating water would be cooled in the cooling towers before being recirculated to the intake, and approximately 150 cfs would be discharged to the river.

As ambient river temperatures increase in spring, the partial recycle mode would be utilized to maintain condenser inlet temperatures below the design maximum of 29.4° C (85° F). Blowdown rates would increase to 300 cfs for May and 400 cfs from 1 through 15 June. During the partial recycle mode, circulating water is also cooled through the cooling towers.

As wet-bulb and river temperatures increase and ichthyoplankton densities decrease, helper cycle would be utilized. In this mode of operation, circulating water passes through the cooling towers and is discharged to the river with no recirculation.

In addition to the benefits of eliminating icing-associated cooling tower damage in winter and increased plant efficiency*, the proposed alternate discharge system would also offer the following advantages: elimination of heat recirculation to the intake and increased mixing of the thermal effluent with the receiving river water. Increased mixing would reduce the extent of the thermal plume, and thus, reduce the potential for impact to the indigenous biota (Section VI).

3. Use of Chlorine and Other Chemicals. Chemical use within the plant will not change as a result of operating the alternate discharge. Present procedures are described in Section IV A.3 and IV A.4 of the PINGP 316(a) Demonstration (HDR, 1978).

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*Plant efficiency is a function of turbine back pressure, which is a function of condenser inlet temperature.

B. PLANT PERFORMANCE

Plant availability and outages as discussed in detail in the PINGP 316(a) Demonstration are not expected to change as a result of the alternate discharge and new mode of plant operation. Thus, the probability of simultaneous forced trips (unscheduled unit outages) would remain 0.0004 and the probability of a forced trip occurring at one unit when the other one is refueling would remain 0.55.

V THERMAL PLUME

A. MODEL DESCRIPTION

The thermal plume modeling performed by Stone & Webster Engineering Corporation is divided into two parts: near-field analysis and far-field analysis. The near-field model assumes a surface jet for simplicity (Stone & Webster, 1978a). The PDS model developed by Shirazi and Davis (1974) was used to compute thermal plume profiles and incorporates adjustments for river bottom geometry suggested by Jirka et al. (1975) was also incorporated. Similar profiles were assumed for both velocity and temperature in the discharge jet.

The far-field model was developed by Yeh and Tsai (1976). In the far-field model, the initial jet-induced turbulence no longer affects the diffusion process, and the only dispersion mechanisms are buoyancy-driven currents and the existing turbulence in the river flow. Thermal profiles are computed by integrating the time-dependent Green's function solution. The eddy diffusivities used in the thermal diffusion equation are the same as those used in the far-field model (3-D zone) in the PINGP 316(a) Demonstration (HDR, 1978).

The distance from the source at which the near-field model ends and the far-field model starts is called the transition point. The selection of the transition point is based on the "best fit" which utilizes a ~~trial-and-error method to match three outputs: surface isotherms,~~ vertical temperature profiles, and lateral temperature profiles. Typical transition points for various input conditions range from 90 to 213 m (300 to 700 ft) measured from the point of discharge. Detailed model descriptions and the selection of the transition point can be found in Section 4 of the model study report (Stone & Webster, 1978a).

B. CASES STUDIED

A total of 41 cases were modeled for the alternate discharge impact analysis. Of these, 32 cases are presented in Appendix B: 13 cases of proposed monthly extreme conditions and 19 cases of variations of the proposed monthly extreme conditions. The input conditions are presented in Tables 5-1 and 5-2 in Appendix B. The remaining 9 cases provided additional information necessary for impact assessment. These cases are:

April typical and April proposed extreme with 90° angle of discharge and 7 cases combining 1 and 2 unit operation in January with optimum and minimum recycle for typical and proposed extreme conditions.

The proposed monthly extreme conditions are based on the combination of ambient environmental and discharge conditions which would result in maximum absolute temperature readings downstream from the discharge during each month. The combination used was:

- expected maximum blowdown rate
- a condenser rise of 13.8° C (24.8° F)
- maximum river temperature (based on records from Red Wing Generating Plant)
- 7-day 10-year low river flow
- the 95 percentile wet-bulb temperature plus 1.1° C (2° F) (to account for possible cooling tower plume recirculation).

Variations of the proposed extreme conditions consisted of maximum blowdown [except for the winter months when the blowdown would be controlled by maintaining an optimum condenser inlet temperature of 15.6° C (60° F)]; a 13.8° C (24.8° F) condenser temperature rise; maximum or median river temperature; 7-day 10-year low or median river flow; and the 95 or 50 percentile plus 1.1° C (2° F) wet-bulb temperature.

C. COMPARISON OF PREDICTED THERMAL PLUME WITH TEMPERATURE STANDARDS

The models presented earlier in this section were used to describe the thermal plume from the proposed discharge. In order to compare predicted plume temperatures to Minnesota temperature criteria (WPC 15), the absolute temperature and temperature differential (ΔT) at various distances downriver from the discharge were calculated as described by Stone & Webster (1979). These computations were based on environmental conditions used in the various model runs and measured environmental conditions for the period 1960 through 1976. Plant discharge flows and temperatures were calculated utilizing the proposed discharge rates shown in Figure IV-2, and then plume temperatures or ΔTs were calculated. The results are tabulated in Tables C-23 through C-28.

The Minnesota temperature criteria for the Mississippi River below Dam No. 2 require that:

1. The river temperature should not be raised more than 2.8° C (5° F) above natural based on the monthly average of the maximum daily temperature.

2. A daily average of 30° C (86° F) should not be exceeded at any time.

3. The weekly average temperature in any month shall not exceed:

January	4.4° C (40° F)	July	28.9° C (84° F)
February	4.4° C (40° F)	August	28.9° C (84° F)
March	12.2° C (54° F)	September	27.8° C (82° F)
April	18.3° C (65° F)	October	22.8° C (73° F)
May	23.9° C (75° F)	November	14.4° C (58° F)
June	28.9° C (84° F)	December	8.9° C (48° F)

For thermal discharges such as power plants, the Minnesota Pollution Control Agency (MPCA) generally specifies a mixing zone outside of which these criteria apply. This zone is determined on a site-specific basis and is defined in the National Pollutant Discharge Elimination System (NPDES) permit. The size and shape of the mixing zone varies but is usually on the order of 305 m (1,000 ft) long in rivers. For the purpose of this report, distances of 305, 610, and 915 m (1,000, 2,000, and 3,000 ft) will be used in comparing the predicted plume with the criteria.

The calculated temperatures at the above distance (Tables C-23, C-25, and C-27) indicate that the proposed discharge would meet the 30° C (86° F) criterion throughout the year. The maximum temperature at 305 m (1,000 ft) is estimated to be 30° C, and this should occur only 0.1 percent of the time in July. The weekly average temperature criteria for each month would also be met except possibly in November, December, January, and February.

The 2.8° C (5° F) ΔT criterion, however, would typically be exceeded at 305 m (1,000 ft) during November through March (Table C-24) and would be exceeded about 50 percent of the time in October. Even at 610 and 915 m (2,000 and 3,000 ft) downstream, the 2.8° C ΔT criterion would not be met from November through March (Tables C-26 and C-28). Consequently, a variance to state water quality standards would be necessary for this discharge. The potential biological impacts of the thermal plume during these months are predicted to be minimal as discussed in Section VI.

VI BIOLOGICAL IMPACTS OF THERMAL DISCHARGE

Potential impacts of constructing and operating the proposed PINGP alternate discharge are discussed in this section. A predictive Type 2 approach based on literature data for thermal tolerances, the thermal plume model results (presented in Section V and Appendix B), and calculated occurrence of various temperatures and ΔTs in the plume is used for all trophic levels. Potential impacts of operating the alternate discharge are predicted for both typical and extreme environmental conditions. These conditions are defined in Tables 5-1 and 5-2 of Appendix B for the model results. For the calculated temperatures (Appendix C), plume temperatures occurring 50 percent or more of the time are considered typical and those occurring 5 percent or less of the time are considered indicative of extreme conditions. Intermediate conditions were also modeled and the results are presented in Appendices A and B. Site-specific data were utilized where possible.

Present plant operation would be altered to the proposed modes of operation described in detail in Section IV. Closed cycle (150 cfs blowdown) would be used in April and partial recycle used from May to mid-June (300 to 400 cfs blowdown). Helper cycle would be used from mid-June through October, and once-through cooling (no cooling towers in operation) with partial recycle would be used from November through March. Once-through cooling with partial recycle may recirculate as much as 50 percent of the circulating water (for maximum plant efficiency) or as little as 6 percent (for intake deicing).

The predicted impacts of the proposed discharge and those of the existing discharge [described in the PINGP 316(a) Demonstration (HDR, 1978)] are compared for fish, macroinvertebrates, zooplankton, phytoplankton, periphyton, aquatic macrophytes, and birds in the following sections.

A. CONSTRUCTION IMPACTS

1. Fish. Construction of the alternate discharge would affect several aquatic habitats in the immediate vicinity of the plant. Effects would be most pronounced in the upper reaches of the refuge (a backwater area just south of PINGP) and a small area along the west bank of the main river channel in the immediate vicinity of the proposed discharge outlets (see Figure IV-1). Construction activities

could be scheduled for April 1980 through August 1981 with the majority of the work occurring during warm weather months. Fish utilizing the refuge could be affected by various construction activities throughout this period, but dredging and laying of pipes across this backwater (which would occur during the spring of 1981) would be the activities most likely to cause adverse environmental effects through habitat disturbance (e.g., substrate removal, increased turbidity, and noise or vibration).

The refuge is a shallow backwater with a soft, sedimentary substrate and a few aquatic macrophyte beds. Such habitats associated with large rivers are often utilized by many fish species for resting, feeding, and spawning. Sampling during 1973 through 1977 indicated that all of the RIS utilize the refuge to some extent but gizzard shad, carp, and white bass were the most abundant throughout the ice-free months. The literature for preferred spawning habitat and seasonal sampling data indicate that gizzard shad, carp, white bass, and shorthead redhorse probably spawn in the refuge and that northern pike, black crappie, and emerald shiner may also.

Potential impacts to fish in the refuge will involve a temporary and intermittent disturbance of feeding and resting patterns, particularly in the northern portion of the refuge. In addition, some of the potential spawning area at the northern end of the refuge will be eliminated during dredging and pipe-laying activities. The increased turbidity associated with these activities may also effect spawning by causing adults to avoid the area when seeking a place to spawn or by causing increased mortality of eggs attached to the bottom (demersal) through suffocation by settling sediments (all RIS except emerald shiners). The area in the refuge affected by construction activities (including turbidity) will be relatively small in comparison to total refuge area and to similar habitats available for use by fish in the vicinity of PINGP (e.g., North and Sturgeon Lakes). Consequently, both short- and long-term construction-related effects to fish populations in the vicinity of PINGP are expected to be minimal.

The potential construction impacts to fish in the main channel of the river are also expected to be minimal since only a small area of river bank just south of Barney's Point would be disturbed when the pipes and sheet pile are emplaced. This area is situated along the main channel where barges frequently pass and is thus suboptimal habitat for most fish species.

Limiting the disturbance of aquatic habitats to the shortest time period possible and utilizing dredging techniques that minimize turbidity are recommended in order to minimize impact potential.

2. Macroinvertebrates. Construction activities are expected to disturb less than 0.15 ha (0.4 A) of benthic habitat when the discharge pipes are laid across the upper end of the backwater commonly called the refuge (see Figure IV-1). Since the pipes will be buried, this area would be recolonized after construction is completed. Increased turbidity and sedimentation are expected to have only temporary and minimal effects. Removal of the dike constructed to separate the existing discharge from the refuge would permanently remove approximately 0.05 ha (0.12 A) of riprap habitat [assuming a length of 100 m (328 ft) and depth of 3 m (10 ft) on the north side and 1.5 m (5 ft) on the south side of the dike]. Flow through the refuge would be returned to near natural (prior to PINGP) conditions, which could cause scouring of the bottom during floods. If the tops of the pipes are exposed, habitat for aufwuchs would replace that for burrowing organisms. Furthermore, flowing water could change the species composition of macroinvertebrates inhabiting the refuge area. These changes are difficult to quantify but would tend to return the backwater area to more natural conditions.

3. Zooplankton. Construction of the proposed alternate discharge should have minimal and temporary effects on zooplankton populations in the refuge. Removal of the dike would allow zooplankton from Sturgeon Lake to enter the refuge since the discharge pipes should not restrict water flow.

4. Phytoplankton. Construction activities could affect phytoplankton temporarily in the refuge area as a result of increased turbidity. These effects, however, are not expected to alter overall productivity or species composition in the vicinity of PINGP. Removal of the dike separating the existing discharge from the refuge would tend to equalize phytoplankton populations in the refuge and in Sturgeon Lake and allow return of the refuge to more natural (pre-PINGP) conditions.

5. Periphyton. Construction of the proposed discharge would disturb a negligible amount of periphyton habitat while increased turbidity, and sedimentation would temporarily reduce photosynthesis in the refuge. Removal of the dike separating the existing discharge canal from the refuge would eliminate approximately 0.01 ha (0.03 A) of riprap substrate suitable for periphytic growth since light penetrates approximately 50 cm (20 in.) [see Section III of the PINGP 316(a) Demonstration (HDR, 1978)]. This loss of habitat should not affect river populations or overall periphyton production.

6. Aquatic Macrophytes. Since occurrence of macrophytes is extremely limited in the upper end of the refuge (Eberley, 25 August 1978), impact upon these plants is expected to be almost non-existent. As mentioned previously, less than 0.15 ha (0.4 A) of bottom habitat in the refuge will be disturbed during construction, and this area will be restored to normal

conditions before alternate discharge operation begins. Removal of the dike separating the refuge from the present discharge canal will restore flow through Sturgeon Lake to the pre-PINGP regime. Scouring during floods may expose some upper surfaces of alternate discharge pipes and thus eliminate a slight amount of potential macrophyte habitat, but the impact of this is expected to be negligible.

7. Birds. Construction activities should have negligible effects on waterfowl and other birds, including bald eagles, in the vicinity of PINGP. Construction could be scheduled to begin in April of 1980 and continue through August of 1981 with most of the activities conducted during warm weather months. Since bald eagles and waterfowl are most abundant in the PINGP area during late fall and winter and since only limited construction activities would occur during that time, construction-related impacts to these organisms are predicted to be small.

B. OPERATIONAL IMPACTS

In order to quantify the predicted impacts of the proposed thermal discharge, two approaches were taken. First, the thermal plume model results (Stone & Webster, 1978a) for typical and extreme environmental conditions were utilized to illustrate configuration of the plume under such conditions. The frequency of occurrence for the combined proposed extreme environmental conditions used in the model can not be readily calculated. Therefore, a second study was undertaken to estimate the frequency with which plume temperatures could exceed the thermal criteria for various life functions of the RIS. The methodology and results of this approach are described in Appendix C. For predictive purposes, typical environmental conditions were considered to exist whenever the plume temperature of concern occurred at least 50 percent of the time in a given area. A frequency of less than 5 percent was considered indicative of extreme environmental conditions.

1. Fish. In this section, potential operational impacts for typical and extreme environmental conditions are discussed. In predicting the potential operational impacts to fish, effects of attraction to and avoidance of the thermal plume are considered in terms of spawning and reproductive success; thermal stress (avoidance area exceeding upper thermal tolerance levels and cold shock potential); general fish population stability; and the incidence of diseases and parasites. Literature data, such as thermal tolerances, and thermal plume model results with some use of site-specific field data are the basis for the predictions. All predictions are quantified to the maximum extent possible by estimating area and time period within which conditions exist that would prohibit completion of various life functions of the RIS chosen for this study.

a. THERMAL CRITERIA. The EPA recommended thermal criteria presented in the PINGP 316(a) Demonstration (HDR, 1978) were utilized for impact prediction. Table VI-1 summarizes these criteria for each of the RIS.

b. ATTRACTION TO AND AVOIDANCE OF THE THERMAL DISCHARGE. Literature data on preferred temperatures presented in the PINGP 316(a) Demonstration indicate that all of the RIS should be attracted to some portion of the thermal plume when ambient temperatures are low while some species should avoid at least the warmer portions of the plume during summer. Table VI-2 summarizes the literature data and shows that walleye, white sucker, emerald shiner, and northern pike would probably not frequent the mixing zone when ambient temperatures exceed 25° C (77° F). Under such ambient temperatures, plume temperatures 8° C (14° F) or more above ambient would not be preferred by the other species, except possibly carp.

Field surveys conducted in the existing discharge support these predictions. Shorthead redhorse, white bass, carp, and gizzard shad avoided the warmest parts of the discharge during summer while these species plus walleye and emerald shiner were attracted to the plume during one or more of the other seasons. Differences in predicted plume temperatures and location (habitat type) of the discharge, however, preclude direct extrapolation of these results to the proposed discharge.

Although preferred temperatures of many of the RIS may be exceeded in the predicted plume during summer, these species may not necessarily be excluded from the discharge area. Fish may avoid areas with temperatures above their preferred levels but may enter occasionally for feeding or to escape predators. Based on the thermal plume model results (Stone & Webster, 1978a), the maximum temperature in the discharge in August would range from 28.6° C (83.4° F) during typical conditions to 33.2° C (91.7° F) ~~for proposed extreme conditions. The temperature differential between~~ plume and ambient disappears rapidly in August as a result of mixing (see figures in Appendix B), and the area within the mixing zone [2.8° C (5° F) ΔT] ranges from 0.3 ha (0.8 A) for typical conditions (plume temperatures $\geq$ 26.4° C) to 0.08 ha (0.2 A) for proposed extreme conditions (plume temperatures $\geq$ 32.2° C). Thus, the areas in which the preferred temperatures of some of the RIS may be exceeded are small, especially when compared to the amount of similar habitat available [e.g., 320 ha (800 A) in Sturgeon Lake].

Upper lethal temperatures for the RIS more accurately define the areas in the plume that may be excluded from long-term use by the RIS. Based on literature data presented in the PINGP 316(a) Demonstration, it appears that exclusion of some species would begin when plume temperatures reach 31° C (88° F) (Table VI-2). Maximum discharge temperatures are predicted to exceed 31° C only during extreme environmental conditions of high ambient river temperature or low river flow (7-day 10-year low) or both from

Table VI-1. Temperature criteria for the RIS in Centigrade (Farenheit in parenthesis).

SPECIES	MAXIMUM WEEKLY AVERAGE TEMPERATURE FOR GROWTH[2]	MAXIMUM TEMPERATURE FOR SHORT-TERM SURVIVAL IN SUMMER[3]	MAXIMUM WEEKLY AVERAGE TEMPERATURE FOR SPAWNING[4]	MAXIMUM TEMPERATURE FOR SHORT-TERM SURVIVAL DURING SPAWNING		MAXIMUM WEEKLY AVERAGE TEMPERATURE FOR WINTER SURVIVAL[7]
				EMBRYO[5]	ADULT[6]	
Walleye	24.5 (76)	29.5 (85)[8]	7.5 (46)	19 (66)	25 (77)[9]	10 (51)
White Bass	N.D.	N.D.	16.5 (62)	26 (79)	N.D.	10 (51)
Channel Catfish	31.9 (89)	35.2 (95)	27 (81)	29 (84)	33.6 (93)	10 (51)
Northern Pike	28.4 (83)	30.1 (86)	8.4 (47)	18 (64)	24 (75)[10]	10 (51)
Gizzard Shad	N.D.	34 (93)[11]	19.5 (67)	29 (84)	31 (88)	10 (51)
Carp	30.2 (86)[12]	38 (100)[8]	21 (70)	33 (91)	30.5 (87)[9]	10 (51)
Black Crappie	26.7 (80)	31 (88)[8]	17 (63)	20 (68)	N.D.	10 (51)
Emerald Shiner	29.6 (85)	30 (86)[13]	23.5 (74)	27 (81)	29.5 (85)	10 (51)
White Sucker	27.7 (82)[12]	28.4 (83)	7.2 (45)	21 (70)	23.3 (74)	10 (51)
Shorthead Redhorse	N.D.	N.D.	11 (52)	N.D.	N.D.	10 (51)

[1]Data used for the calculations are from Tables A-11 through A-20 and A-45 in the PINGP 316(a) Demonstration. References are listed with the data.

[2]MWAT = Optimum for growth + $\frac{\text{Ultimate incipient lethal-Optimum}}{3}$

[3]24-hour survival calculated from log time = a + b(T) at an acclimation temperature of the MWAT for growth and with the 2° C safety factor subtracted.

[4]Optimum or mid-range for spawning.

[5]Maximum of incubation and spawning temperatures.

[6]24-hour survival calculated from log time = a + b(T) at an acclimation temperature of the MWAT for spawning and with the 2° C safety factor subtracted.

[7]From Figure VI-5 in the PINGP 316(a) Demonstration when ambient is ≤ 2.5° C (December to mid-March at PINGP).

[8]Ultimate lethal -2° C since no regression equation available.

[9]Upper lethal of juvenile -2° C since no regression equation available.

[10]Upper lethal of larvae -2° C since no regression equation constants for 18° C acclimation.

[11]At an acclimation temperature of 30° C.

[12]Based on data for larvae.

[13]At an acclimation temperature of 25° C.

Table VI-2. Estimated potential effects of increased temperature in the thermal plume on the RIS in the vicinity of PINGP.

TEMPERATURE C (F)	SPECIES POTENTIALLY SUBJECTED TO TEMPERATURES ABOVE PREFERRED TEMPERATURE[1]	SPECIES POTENTIALLY EXCLUDED[2]
20 (68)		
21 (70)		
22 (72)		
23 (73)	white sucker	
24 (75)		
25 (77)		
26 (79)	walleye, emerald shiner	
27 (81)	northern pike	
28 (82)	shorthead redhorse	
29 (84)		
30 (86)		
31 (88)	white bass, black crappie	emerald shiner, white sucker
32 (90)	gizzard shad	walleye, shorthead redhorse,[3] white bass[3]
33 (91)	channel catfish	northern pike, black crappie
34 (93)		
35 (95)		
36 (97)	carp	
37 (99)		gizzard shad
38 (100)		channel catfish
39 (102)		
40 (104)		
41 (106)		carp

[1]Based on maximum preferred temperature in Appendix A of the PINGP 316(a) Demonstration (HDR, 1978).

[2]Maximum upper lethal temperature (LT_{50}) at highest reported acclimation temperature for juvenile fish. Adults generally have a slightly lower upper lethal temperature.

[3]From Bush et al., 1974.

May through August, and the area with temperatures in excess of 31° C is small — less than 1.5 ha (3.7 A). The estimates of exclusion presented in Table VI-2, however, must be interpreted carefully since they were derived from the highest reported lethal temperature for each species, and many other factors are involved (as discussed in Bush et al., 1974). For example, the data are based on laboratory experiments that undoubtedly did not simulate all of the conditions near PINGP that influence thermal tolerance. In addition, the data are based on a 50 percent survival rate at a specified time and acclimation temperature. Small changes in temperature near the upper tolerance limit can cause large increases in mortality (Bush et al., 1974), and exposure time is also an important factor.

The extent and duration of plume temperatures which could exceed the short-term summer survival criterion for each RIS (Table VI-1) were estimated as described in Appendix C. The results of these calculations are summarized in Tables VI-3 through VI-12. White sucker is the only species for which exclusion is predicted during typical environmental conditions in July and to a lesser extent in June and August. The estimated area of exclusion is less than 0.01 ha (0.03 A) in all three months and occurs within about 15 m (50 ft) of the discharge. During more extreme environmental conditions, the exlusion areas are predicted to be 0.005 ha (0.012 A) or less in May, 0.05 ha (0.12 A) or less in June, 1.0 ha (2.5 A) or less in July, and 0.1 ha (0.3 A) or less in August and September for northern pike, black crappie, and emerald shiner. For walleye and white sucker, the exclusion areas are predicted to be less than 0.005 ha (0.012 A) in May, 0.5 ha (1.2 A) or less in June and September, and 0.5 ha or greater in July and August. No exclusion is predicted for channel catfish, gizzard shad, and carp, and no data are available for white bass and shorthead redhorse.

These calculated areas of exclusion represent the maximum in which thermal mortality could occur since the 2° C (3.6° F) safety factor was subtracted from the median tolerance temperature when the criteria were calculated. The calculated areas are also conservative since exclusion from the immediate vicinity of the discharge as a result of velocity was not considered. The following paragraphs discuss the effect of discharge velocities on the exclusion of fish from portions of the thermal plume.

To determine velocity exclusion, swimming abilities of fish must be related to velocities in the plume. Swimming speed in fish depends on both environmental and physiological factors including temperature, dissolved oxygen, species, size, and condition. Figure VI-1 shows the relationship of swimming speed to water temperature for three species and indicates that swimming speed increases as water temperature increases until an optimum temperature is reached after which swimming speed decreases. Swimming ability also increases with increasing size for a given species (Bainbridge, 1958) as can be seen in Figure VI-1. The speeds presented in the figure are maxima which can be maintained for

Table VI-3. Estimated areas in the thermal plume where temperatures may exceed the criteria for various life functions of walleye and the frequency with which they may occur.

Species: Walleye

PARAMETER	TEMPERATURE CRITERION[1] (C)	AREA IN WHICH PLUME TEMPERATURE EXCEEDS CRITERION[2] (HA)	FREQUENCY CRITERION EXCEEDED IN AREA[3] (%)	REMARKS
Maximum for short-term survival in summer	29.5	≤0.001; 0.005 ≤0.01; 0.05 to 0.1 ≤0.01; ≥0.5 ≤0.01; 0.1 to 0.5 ≤0.1	May: ≤7.6; 0.1 June: 7 to 23.6; ≤0.7 July: ≤34.7; ≤1.3 Aug: ≤21; ≤1.7 Sept: ≤2.3	
Maximum for short-term survival of adult during spawning	25.0	≤0.001; 0.05	May: ≥65.7; 0.2	Spawn April to mid-May. Little or no suitable spawning habitat in plume.
Maximum for incubation and larval development	19.0	≤0.01; ≥2.5	May: ≥74; ≤3.7	Ambient river temperature exceeds criterion 12 percent of time.
Maximum weekly average for growth[4]	24.5	>2.5 >2.5	July: <82 Aug: <72	

[1]From Table VI-1.

[2]From Tables C-1 through C-21. Areas that occur ≥ 50% of time are considered typical and those that occur ≤ 5% of time are considered extreme. See Appendix C for description of how these numbers were derived.

[3]~~From Tables C-1 through C-21. Does not include time when ambient temperature exceeds~~ criterion.

[4]Estimated from Tables C-23 through C-28. Frequencies of < 40% were not considered to have any measurable effect on growth.

Table VI-4. Estimated areas in the thermal plume where temperatures may exceed the criteria for various life functions of white bass and the frequency with which they may occur.

Species: White Bass

PARAMETER	TEMPERATURE CRITERION[1] (C)	AREA IN WHICH PLUME TEMPERATURE EXCEEDS CRITERION[2] (HA)	FREQUENCY CRITERION EXCEEDED IN AREA[3] (%)	REMARKS
Maximum for short-term survival in summer	N.D.	—	—	
Maximum for short-term survival of adult during spawning	N.D.	—	—	Spawn late May and June. Little or no suitable spawning habitat in plume.
Maximum for incubation and larval development	26.0	≤0.001; 0.01 ≤0.01; ≥2.5	May: ≥49.3; 2.9 June*: ≥57.2; ≤4.3	*Ambient river temperature exceeds criterion 1% of time
Maximum weekly average for growth[4]	N.D.	—	—	

[1]From Table VI-1. N.D.= no data.

[2]From Tables C-1 through C-21. Areas that occur ≥ 50% of time are considered typical and those that occur ≤ 5% of time are considered extreme. See Appendix C for description of how these numbers were derived.

[3]From Tables C-1 through C-21. Does not include time when ambient temperature exceeds criterion.

[4]Estimated from Tables C-23 through C-28. Frequencies of < 40% were not considered to have any measurable effect on growth.

Table VI-5. Estimated areas in the thermal plume where temperatures may exceed the criteria for various life functions of channel catfish and the frequency with which they may occur.

Species: Channel Catfish

PARAMETER	TEMPERATURE CRITERION[1] (C)	AREA IN WHICH PLUME TEMPERATURE EXCEEDS CRITERION[2] (HA)	FREQUENCY CRITERION EXCEEDED IN AREA[3] (%)	REMARKS
Maximum for short-term survival in summer	35.2	0	0	
Maximum for short-term survival of adult during spawning	33.6	0	0	Spawn May through July. Suitable spawning habitat in plume along bank only.
Maximum for incubation and larval development	29.0	≤0.001; 0.005 ≤0.001; 0.05 to 0.1 ≤0.01; ≥0.5	May: ≤11.3; 0.4 June: 31.7; ≤1.8 July: ≤47.1; ≤3.9	
Maximum weekly average for growth[4]	31.9	0	0	

[1]From Table VI-1.

[2]From Tables C-1 through C-21. Areas that occur ≥ 50% of time are considered typical and those that occur ≤ 5% of time are considered extreme. See Appendix C for description of how these numbers were derived.

[3]~~From Tables C-1 through C-21. Does not include time when ambient temperature exceeds~~ criterion.

[4]Estimated from Tables C-23 through C-28. Frequencies of < 40% were not considered to have any measurable effect on growth.

Table VI-6. Estimated areas in the thermal plume where temperatures may exceed the criteria for various life functions of northern pike and the frequency with which they may occur.

Species: Northern Pike

PARAMETER	TEMPERATURE CRITERION[1] (C)	AREA IN WHICH PLUME TEMPERATURE EXCEEDS CRITERION[2] (HA)	FREQUENCY CRITERION EXCEEDED IN AREA[3] (%)	REMARKS
Maximum for short-term survival in summer	30.1	≤0.001 ≤0.001; 0.01 to 0.5 ≤0.01; 0.1 to 1.0 ≤0.01; 0.05 to 0.1 ≤0.1	May: ≤4.1 June: 16.3; ≤3.9 July: ≈20; ≤2.2 Aug: ≈10; ≤1.8 Sept: ≤1.5	
Maximum for short-term survival of adult during spawning	24.0	≤0.001; 0.05 to 0.1	May: ≥81.2; ≤1.9	Spawn April to early May. No suitable spawning areas in plume.
Maximum for incubation and larval development	18.0	≤0.01; ≥2.5	May: ≥74.5; ≤3.9	Ambient river temperature exceeds criterion ∿18% of time.
Maximum weekly average for growth[4]	28.4	0	0	

[1]From Table VI-1.

[2]From Tables C-1 through C-21. Areas that occur ≥ 50% of time are considered typical and those that occur ≤ 5% of time are considered extreme. See Appendix C for description of how these numbers were derived.

[3]From Tables C-1 through C-21. Does not include time when ambient temperature exceeds criterion.

[4]Estimated from Tables C-23 through C-28. Frequencies of < 40% were not considered to have any measurable effect on growth.

Table VI-7. Estimated areas in the thermal plume where temperatures may exceed the criteria for various life functions of gizzard shad and the frequency with which they may occur.

Species: Gizzard Shad

PARAMETER	TEMPERATURE CRITERION[1] (C)	AREA IN WHICH PLUME TEMPERATURE EXCEEDS CRITERION[2] (HA)	FREQUENCY CRITERION EXCEEDED IN AREA[3] (%)	REMARKS
Maximum for short-term survival in summer	34.0	0	0	
Maximum for short-term survival of adult during spawning	31.0	≤0.001 ≤0.01	May: ≤1.6 June: ≤7.7	Spawn April through June.
Maximum for incubation and larval development	29.0	≤0.001; 0.005 ≤0.001; 0.05 to 0.1	May: ≤11.3; 0.4 June: 31.7; ≤1.8	
Maximum weekly average for growth[4]	N.D.	—	—	

[1]From Table VI-1. N.D.= no data.

[2]From Tables C-1 through C-21. Areas that occur ≥ 50% of time are considered typical and those that occur ≤ 5% of time are considered extreme. See Appendix C for description of how these numbers were derived.

[3]From Tables C-1 through C-21. Does not include time when ambient temperature exceeds criterion.

[4]Estimated from Tables C-23 through C-28. Frequencies of < 40% were not considered to have any measurable effect on growth.

Table VI-8. Estimated areas in the thermal plume where temperatures may exceed the criteria for various life functions of carp and the frequency with which they may occur.

Species: Carp

PARAMETER	TEMPERATURE CRITERION[1] (C)	AREA IN WHICH PLUME TEMPERATURE EXCEEDS CRITERION[2] (HA)	FREQUENCY CRITERION EXCEEDED IN AREA[3] (%)	REMARKS
Maximum for short-term survival in summer	38.0	0	0	
Maximum for short-term survival of adult during spawning	30.5	≤ 0.001 ≤ 0.001; 0.01 ≤ 0.01; 0.03-0.5	May: ≤ 2.7 June: ≤ 12.4; 2.5 July: ≤ 14.4; ≤ 3.1	Spawn May through July. Suitable spawning area in plume along river bank only.
Maximum for incubation and larval development	33.0	0	0	
Maximum weekly average for growth[4]	30.2	0	0	

[1]From Table VI-1.

[2]From Tables C-1 through C-21. Areas that occur ≥ 50% of time are considered typical and those that occur ≤ 5% of time are considered extreme. See Appendix C for description of how these numbers were derived.

[3]From Tables C-1 through C-21. Does not include time when ambient temperature exceeds criterion.

[4]Estimated from Tables C-23 through C-28. Frequencies of < 40% were not considered to have any measurable effect on growth.

Table VI-9. Estimated areas in the thermal plume where temperatures may exceed the criteria for various life functions of emerald shiner and the frequency with which they may occur.

Species: Emerald Shiner

PARAMETER	TEMPERATURE CRITERION[1] (C)	AREA IN WHICH PLUME TEMPERATURE EXCEEDS CRITERION[2] (HA)	FREQUENCY CRITERION EXCEEDED IN AREA[3] (%)	REMARKS
Maximum for short-term survival in summer	30.0	≤0.001 ≤0.001; 0.01 to 0.05 ≤0.01; 0.1 to 1.0 ≤0.01; 0.05 to 0.1 ≤0.1	May: ≤4.6 June: 18.1; ≤4.4 July: ≤24.3; ≤2.8 Aug: ≤13.7; ≤2.3 Sept: ≤1.7	
Maximum for short-term survival of adult during spawning	29.5	≤0.005 ≤0.005; 0.05 to 0.1 ≤0.01; >0.5 ≤0.01; 0.1 to 0.5	May: ≤7.6 June: ≤23.6; ≤0.7 July: ≤34.7; ≤1.3 Aug: ≤21.1; ≤1.7	Spawn May through August.
Maximum for incubation and larval development	27.0	≤0.001; 0.005 to 0.01 ≤0.005; >0.5 ≤0.1; ≥2.5 ≤0.05; ≥2.5	May: ≤35.3; ≤5.0 June: ≥53.0; ≤2.7 July: ≥58.1; ≤23.9 Aug: ≥57.4; ≤11.2	
Maximum weekly average for growth[4]	29.6	0	0	

[1]From Table VI-1.

[2]From Tables C-1 through C-21. Areas that occur ≥ 50% of time are considered typical and those that occur ≤ 5% of time are considered extreme. See Appendix C for description of how these numbers were derived.

[3]From Tables C-1 through C-21. Does not include time when ambient temperature exceeds criterion.

[4]Estimated from Tables C-23 through C-28. Frequencies of < 40% were not considered to have any measurable effect on growth.

Table VI-10. Estimated areas in the thermal plume where temperatures may exceed the criteria for various life functions of black crappie and the frequency with which they may occur.

Species: Black Crappie

PARAMETER	TEMPERATURE CRITERION[1] (C)	AREA IN WHICH PLUME TEMPERATURE EXCEEDS CRITERION[2] (HA)	FREQUENCY CRITERION EXCEEDED IN AREA[3] (%)	REMARKS
Maximum for short-term survival in summer	31.0	≤0.001 ≤0.001; 0.005 to 0.01 ≤0.01; 0.05 to 0.1 ≤0.05 ≤0.05	May: ≤1.6 June: 7.7; ≤2.7 July: ≤8.2; ≤1.0 Aug: ≤2.8 Sept; ≤0.6	
Maximum for short-term survival of adult during spawning	N.D.	—	—	Spawn May and June. No suitable spawning area in plume.
Maximum for incubation and larval development	20.0	≤0.01; ≥0.5 ≤0.1; 2.5	May: ≥65.8; ≤4.9 June: ≤27.7; 6.7	
Maximum weekly average for growth[4]	26.7	>2.5	July: <45	Immediate discharge area unsuitable habitat.

[1]From Table VI-1. N.D. = no data.

[2]From Tables C-1 through C-21. Areas that occur ≥ 50% of time are considered typical and those that occur ≤ 5% of time are considered extreme. See Appendix C for description of how these numbers were derived.

[3]From Tables C-1 through C-21. Does not include time when ambient temperature exceeds criterion.

[4]Estimated from Tables C-23 through C-28. Frequencies of < 40% were not considered to have any measurable effect on growth.

Table VI-11. Estimated areas in the thermal plume where temperatures may exceed the criteria for various life functions of white sucker and the frequency with which they may occur.

Species: White Sucker

PARAMETER	TEMPERATURE CRITERION[1] (C)	AREA IN WHICH PLUME TEMPERATURE EXCEEDS CRITERION[2] (HA)	FREQUENCY CRITERION EXCEEDED IN AREA[3] (%)	REMARKS
Maximum for short-term survival in summer	28.4	≤0.001; 0.005 ≤0.001; 0.05 to 0.5 ≤0.01; ≥2.5 ≤0.01; ≥0.5 ≤0.5	May: ≤16.2; 0.9 June: 42.2; ≤4.0 July: ≤63.9; ≤4.4 Aug: ≤45.1; ≤2.3 Sept: ≤4.8	
Maximum for short-term survival of adult during spawning	23.3	≤0.001; 0.5 to 1.0	May: ≥89.3; ≤4.2	Spawn late April to mid-May. No suitable spawning area in plume.
Maximum for incubation and larval development	21.0	≤0.01; 0.5 to 1.0	May: ≥53.7; ≤3.1	Ambient river temperature exceeds criterion 36% of time.
Maximum weekly average for growth[4]	28.4	0	0	

[1]From Table VI-1.

[2]From Tables C-1 through C-21. Areas that occur ≥ 50% of time are considered typical and those that occur ≤ 5% of time are considered extreme. See Appendix C for description of how these numbers were derived.

[3]From Tables C-1 through C-21. Does not include time when ambient temperature exceeds criterion.

[4]Estimated from Tables C-23 through C-28. Frequencies of < 40% were not considered to have any measurable effect on growth.

Table VI-12. Estimated areas in the thermal plume where temperatures may exceed the criteria for various life functions of shorthead redhorse and the frequency with which they may occur.

Species: Shorthead Redhorse

PARAMETER	TEMPERATURE CRITERION[1] (C)	AREA IN WHICH PLUME TEMPERATURE EXCEEDS CRITERION (HA)	FREQUENCY CRITERION EXCEEDED IN AREA (%)	REMARKS
Maximum for short-term survival in summer	N.D.	—	—	
Maximum for short-term survival of adult during spawning	N.D.	—	—	Spawn late April to early June.
Maximum for incubation and larval development	N.D.	—	—	
Maximum weekly average for growth	N.D.	—	—	

[1]From Table VI-1. N.D.= no data.

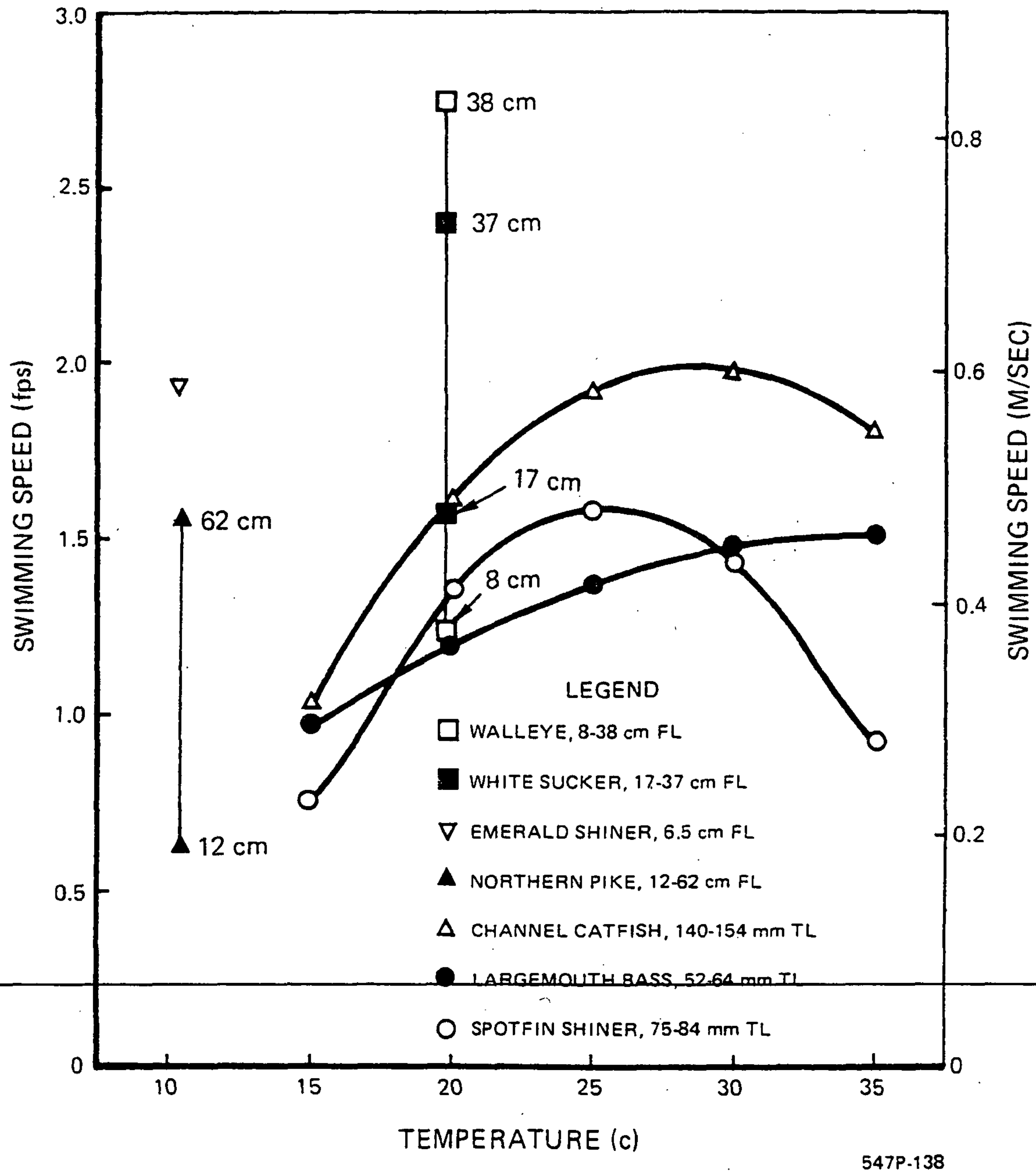

Figure VI-1. Swimming speeds of fish of different size at various temperatures. Data for walleye, white sucker, emerald shiner, and northern pike are critical velocities (maximum maintained for 10 minutes) as reported in Jones et al. (1974) while data for the other three species are critical swimming speeds calculated from regression equations (Hocutt, 1973). All swimming speeds are less than 0.9 m/s (3 fps). The relationship of swimming speed to plume velocities is discussed in the text.

a specified period of time and are generally less than 0.6 m/sec (2 fps). Darting speeds, however, are considerably higher but can be maintained for only a few seconds. For example, darting speeds of 2.1 m/sec (6.9 fps) have been recorded for northern pike 16.5 cm (6.5 in.) in length while carp 13.5 cm (5.3 in.) in length have been recorded to dart at 1.7 m/sec (5.6 fps) (Bainbridge, 1958.)

Discharge velocities are expected to be approximately 2.3 m/sec (7.5 fps) as the heated effluent enters the river. This initial velocity decreases rapidly as the plume mixes with the river, particularly during April through mid-June when river flows are high. For typical environmental conditions, velocities exceeding 0.9 and 0.6 m/sec (3 and 2 fps) are predicted to extend approximately 31 and 61 m (100 and 200 ft) down the plume centerline, except during spring. Discharge velocities exceeding 0.9 m/sec should extend about 61 m downstream in April and 18 to 23 m (60 to 75 ft) downstream in May and early June. River flow typically exceeds 0.6 m/sec in April, and velocities greater than 0.6 m/sec should extend approximately 52 m (170 ft) downstream in May and early June.

Since most of the RIS probably cannot maintain swimming speeds in excess of 0.9 m/sec (3 fps), the area in which discharge velocities exceed 0.9 m/sec would be excluded from use by the RIS. This area would be approximately 0.02 ha (0.05 A) in May and early June and 0.05 ha (0.12 A) the remainder of the year. Thus, fish could not reside in the highest temperature waters in the immediate vicinity of the discharge even if they would prefer to (as in winter).

A comparison of the exclusion areas predicted for the present and the proposed discharge locations (based on thermal plume modeling) indicates a reduced influence of the thermal plume for the alternate discharge. The areas within which equal temperatures are predicted are considerably smaller for the proposed discharge than for the existing discharge. Furthermore, the navigation channel is unsuitable for prolonged residence or spawning by many of the RIS whereas the existing discharge is in a backwater area more suitable for these activities. In addition, the higher proposed discharge velocities would exclude fish from the area of highest water temperatures thus further reducing the potential for effects to fish.

c. EFFECTS ON SPAWNING AND REPRODUCTIVE SUCCESS. The PINGP thermal plume could influence spawning and reproductive success primarily by inducing premature spawning, eliminating spawning habitat, and causing thermal stress to embryos and larvae residing in or drifting through the plume.

Premature spawning as a result of thermal discharge from the PINGP alternate discharge is not likely since the navigation channel is not a suitable habitat for most of the RIS and frequent passage of barges would tend to reduce residence times for those species which inhabit the main channel.

Elimination of spawning habitat through thermal or velocity exclusion of adults should also be negligible. Temperatures within the thermal plume are calculated to exceed the maximum for short-term (24-hour) survival of adult RIS during the spawning period at least 50 percent of the time for walleye, northern pike, and white sucker (Tables VI-3, VI-6, and VI-11). The predicted exclusion area is less than 0.005 ha (0.012 A) which is very small compared to available spawning areas in the vicinity of PINGP. Furthermore, the immediate discharge area is not a very suitable spawning area for these species. For the more extreme environmental conditions, exclusion from some larger area may occur for these three species as well as gizzard shad, carp, and emerald shiner during at least part of their spawning period (see Tables VI-3 through VI-12). The area of exclusion should exceed 0.5 ha (1.2 A) less than 4.2 percent of the time. Since these conditions are expected to occur very infrequently, they should not appreciably influence spawning.

The temperature limits for embryo development are lower than those for adult survival indicating that adults could lay eggs in areas not suitable for embryo development. The areas within the plume in which temperatures are calculated to exceed the criteria for embryo development are summarized in Tables VI-3 through VI-12 and are presented in detail for each RIS in Appendix C. At least 50 percent of the time, these areas are less than 0.01 ha (0.03 A) for all of the RIS, except emerald shiner in July and August where the area would be less than 0.1 ha (0.3 A). For extreme environmental conditions, the areas are generally less than 0.1 ha (0.3 A), although they may exceed 0.5 ha (1.2 A) for most species during the latter part of the spawning period. The calculated exclusion areas are very conservative estimates of the maximum area in which reproduction and embryo development could be affected by the thermal discharge. In other words, the 2° C safety factor has been included for adult survival, and the most conservative upper limits for development have been used. Furthermore, the areas include little or no suitable spawning habitat for some species, such as white bass, northern pike, carp, black crappie, white sucker, and shorthead redhorse, thus further reducing the potential for impact to these species.

Larval fish produced upriver may also be affected by drifting through the PINGP thermal discharge. Larvae in the immediate vicinity of the proposed discharge come from both Sturgeon Lake and the main channel of the river. The total density of larvae and the relative abundance of each species varies over time as a result of changes in river flow, wind speed and direction, and other factors which influence the hydrodynamics of the area. Drift times through the plume are difficult to calculate since velocity is not constant. Velocities in the river average about 0.3 m/sec (1 fps) from April through August and were used as a conservative estimate for calculating drift time.

The ichthyoplankton study conducted in June 1978 (Stone & Webster, 1978b) indicated that ichthyoplankton densities are higher in Sturgeon Lake than in the river and relative species abundance differs as well (Section III C). The dominant species of larvae drifting in Sturgeon Lake during May through August of 1975 was calculated to be gizzard shad followed by white bass, emerald shiner, and carp [PINGP 316(a) Demonsration (HDR, 1978), Figure III-26]. Few larvae of the other RIS were found in the drift. Comparing short-term lethal temperatures (minus 2° C for 100 percent survival) for each RIS (Table VI-13) with the thermal plume model results for typical environmental conditions (Appendix B) indicates that only northern pike and walleye larvae would be likely to experience thermal stress in the PINGP alternate discharge thermal plume. Northern pike larvae drifting near the shoreline in April could encounter temperatures exceeding 20.2° C (68.4° F) for less than 1.25 minutes while walleye larvae could drift through temperatures above 19° C (66° F) for less than 1.4 minutes in April and 5 minutes in May. These estimates are conservative for these species since velocities near the shoreline would exceed 0.3 m/sec in the plume and the thermal tolerance data were for exposure times exceeding those estimated here. Thus, thermal stress to drifting larvae is expected to be negligible.

Shear stress may occur to larval fish entering the discharge jet. Assuming a round jet as described in Hinze (1959, pp. 420-426), the maximum shear force is calculated to be 900 dynes/cm^2. This force would occur approximately 6 m (20 ft) from the point of discharge and would attenuate rapidly since shear is inversely proportional to distance. Consequently, only a small submerged area [center of discharge is 4.4 m (14.5 ft) below normal pool elevation] would contain high shear force. Laboratory experiments have indicated that 50 percent mortality would occur after a one minute exposure to 415 dynes/cm^2 for white perch larvae and 785 dynes/cm^2 for striped bass larvae (Morgan et al., 1976.) Thus, even though each species differs in its susceptibility to shear stress, mortality to some RIS larvae could be expected. Exposure times would generally be less than one minute since discharge velocities would be high in the areas of high shear force, and the area of high shear force would be small; therefore, impacts to drifting larvae are expected to be minimal. Based on ichthyoplankton studies at PINGP gizzard shad are the dominant species in the drift and, thus, the most likely to be affected.

d. COLD SHOCK POTENTIAL. Cold shock may occur during winter when fish that have become acclimated to warm temperatures in the thermal discharge are suddenly exposed to the colder ambient temperatures either from sudden removal of the heat source (both units shut down) or from swimming out of the plume to escape predators, etc.). Effects may be sublethal (e.g., loss of equilibrium) or lethal depending on temperature differential, species of fish, ambient temperature, and physiological state of the organism. Although not directly lethal, loss of equilibrium may result in death through increased susceptibility to predation.

Table VI-13. Short-term thermal tolerances of larval fish.

SPECIES	LARVAL STAGE	ACCLIMATION TEMPERATURE (C)	LT_{50} (C)	TEST TIME	REFERENCE
Northern Pike	1 day old	6.1	22.2	24 hrs.	Hokanson et al., 1973
		11.8	28.2	24 hrs.	
		17.6	28.0	24 hrs.	
	free swimming	7.2	23.5	24 hrs.	
		12.6	26.3	24 hrs.	
		17.7	28.4	24 hrs.	
White Sucker	new hatch	8.9	29.0	24 hrs.	McCormick et al., 1977
		15.2	31.0	24 hrs.	
		21.1	31.5	24 hrs.	
	swim-up	10.0	28.5	24 hrs.	
		15.8	30.7	24 hrs.	
		21.1	32.0	24 hrs.	
Walleye	2-5 days old	6	21[1]	72 min.	Smith and Koenst, 1975
		11	21[2]	72 min.	
Channel Catfish	—	29	31	—	West, 1966
White Bass	pre-feeding	21.5	32	17 min.	Coutant, 1974
		21.5	34	7 min.	
Carp	3 days old	25	37	24 hrs.[3]	Coutant, 1974
	9 days old	25	36	24 hrs.	
	19 days old	25	38	24 hrs.	

[1] LT_{44}
[2] LT_{22}
[3] After a 10 minute exposure to test temperature

To ensure protection of all warm water fish species a maximum weekly average temperature (MWAT) of 10° C (50° F) when the ambient temperature is 2.5° C (37° F) or 15° C (59° F) when the ambient temperature is 5° C (41° F) should not be exceeded in the plume. At PINGP, maximum weekly ambient temperatures are less than 5° C (41° F) from mid November to early April and less than 2.5° C (37° F) from December to mid March. Thermal plume model results (Stone & Webster, 1978a) show that temperatures in the plume would routinely exceed the recommended MWAT. During typical winter conditions (January) when both units are operating in a partial recycle mode (no cooling towers) to maximize plant efficiency and when ambient temperatures are near 0° C (32° F), plume temperatures are predicted to exceed 10° C in an area of approximately 0.9 ha (2.2 A). For 1 unit operation, the area would be 0.3 ha (0.7 A). This area is sufficient for fish to congregate and acclimate to the elevated temperatures; thus, under these conditions, the potential for cold shock at PINGP exists. For proposed extreme conditions, the area with temperatures greater than 10° C is predicted to be 1.4 ha (3.5 A) for 2 unit operation and 0.7 ha (1.7 A) for 1 unit operation. The plant can also be operated with only enough recycle for deicing which would reduce the temperature differential at the discharge by increasing the volume discharged. In this mode of operation, the plume area in which temperatures exceed 10° C would be reduced to 0.2 ha (0.5 A) with 2 units and 0.04 ha (0.1 A) with 1 unit for typical conditions and 0.6 ha (1.5 A) with 2 units and 0.06 ha (0.2 A) with 1 unit for proposed extreme conditions.

Both units may shut down simultaneously during winter and the probability of this has been calculated to be 0.0004. During refueling of one unit, the probability of a trip at the other unit is 0.55 (55 percent).

Temperatures as high as 29.3° C (84.8° F) may occur in the plume for typical and extreme conditions during maximum efficiency operation. High velocities near the discharge, however, would limit the residence of fish in the highest temperatures. During 2 unit operation, for example, velocities exceeding 0.9 m/sec (3 fps) would extend about 31 m (100 ft) downstream for typical and extreme conditions. For 1 unit opreration, the distance would be about 24 m (80 ft). Assuming the areas containing these velocities follow the isotherm contours, fish would be excluded from approximately 0.04 ha (0.1 A) and 0.03 ha (0.08 A) because of velocity. The areas with temperatures greater than 10° C would be reduced by 10 percent or less. The maximum temperatures available for fish to acclimate to would then be 22° C (71.6° F) for 2 unit operation and 18° C (64.4° F) for 1 unit operation.

Based on thermal tolerance data for the RIS presented in Appendix A of the PINGP 316(a) Demonstration, cold shock (direct lethal effects) to fish acclimated to about 20° C (68° F) is predicted to be minimal for channel catfish, northern pike, and white sucker. Cold shock may occur in walleye and emerald shiner acclimated to 20° C or higher, while gizzard shad would be very likely to suffer cold shock. The area within the plume (1 unit operation) where temperatures are predicted to exceed 18° C (64.4° F) also has velocities greater than 0.9 m/sec (3 fps). Thus, channel catfish, northern pike, and white sucker should not become acclimated to temperatures sufficiently high for cold shock to occur if the other unit tripped. Cold shock would probably occur to any of the other RIS that had become acclimated to the warmest plume temperatures available. Data collected in the existing discharge area during winter indicate that the species most likely to reside in the plume during winter are gizzard shad, carp, white bass, and black crappie. Gizzard shad are expected to be fairly abundant and carp should be moderately abundant while only a few white bass and black crappie would be expected. Of these, all but carp would probably suffer cold shock if one unit trips while the other is refueling.

During once-through operation with minimum recycle, the discharge temperature could be as low as 13.8° C (56.8° F). For 1 unit operation, velocities exceeding 0.9 m/sec (3 fps) would extend 23 m (75 ft) downstream in an area of 0.02 ha (0.05 A) for both typical and extreme conditions. Thus, the areas in which predicted temperatures would exceed 10° C (50° F) and where velocities are less than 0.9 m/sec are 0.02 ha for typical conditions and 0.04 ha (0.1 A) for proposed extreme conditions. These areas are about 15 times less than those for maximum efficiency operation; consequently, once-through cooling with minimum recycle during winter operation when one unit is refueling would provide better protection of fish from potential cold shock. An unscheduled trip of one unit during 2 unit operation would reduce the area within the various isotherms, but warm water would still be available so that no cold shock would be expected.

A comparison of the existing plume (150 cfs blowdown and use of cooling towers) and proposed alternate discharge plume (2 unit operation with no use of cooling towers) shows that the area where temperatures exceed 10° C (50° F) would be reduced by a factor of 5 using the alternate discharge and operating at maximum efficiency. The area would be reduced by more than 12 times when operating with minimum recycle. Thus, the potential for cold shock would be greatly reduced with use of the alternate discharge.

e. OVERALL EFFECTS ON FISH (RIS) POPULATIONS. In general, the effects of environmental perturbations on fish populations are difficult to assess, particularly in a large river such as the Mississippi. An inordinate amount of sampling would be necessary to determine anything except large changes, and such long-term data are not available for most water bodies, including the upper Mississippi River. Furthermore, the evaluation of a single perturbation such as a power plant discharge is often complicated by the effects of other activities of man (e.g., sewage disposal, dredging, building dams, etc.).

The PINGP alternate discharge could affect fish populations primarily through altered spawning, exclusion of spawning areas, thermal stress to drifting larvae, cold shock, blockage of migrations, species shifts, and altered growth rates. Most of these have been discussed for the discharge area in previous sections with quantitative information where possible.

Thermal effects on spawning and reproductive success are expected to have negligible effects on river populations. Premature spawning is not expected to occur as a result of thermal discharges from the proposed alternate discharge, and exclusion of suitable spawning area is predicted to be negligible for typical environmental conditions. The low frequency of occurrence (less than 5 percent of the time) for the more extreme environmental conditions precludes any significant influence on reproduction. Thermal stress to developing embryos in the plume is predicted to be negligible since little if any spawning is expected in the warmer areas of the plume and the areas where thermal criteria may be exceeded are less than 0.1 ha (0.3 A) 50 percent or more of the time. Furthermore, no lethal thermal stress to larvae drifting through the plume is expected during typical conditions, and shear stress mortalities to larvae are not expected to reduce recruitment to adult populations.

Thermal discharge from the proposed location should not inhibit any fish migrations in the area. The discharge would be located on the west (Minnesota) bank of the main river channel which is also the navigation channel, and the plume is predicted to remain near the bank and on the surface. Thus, the remainder of the river channel and the area below the plume would be available for migration routes. Walleye and white sucker are the only species that normally migrate to spawn, and these species could easily avoid the plume.

No impacts to threatened or endangered species are predicted since no species protected by state or federal endangered species provisions have been reported in the area.

Potential effects of the alternate discharge on recreational and commercial fishing are expected to be negligible. The present discharge appears to have had no adverse effects and has even provided an increased white bass fishery in the discharge area during spring (see PINGP 316(a) Demonstration). The new discharge location would probably eliminate the enhanced white bass recreational fishing in the discharge but otherwise would have the same effects as the present discharge.

The PINGP alternate discharge thermal effluent is expected to have negligible effects on RIS predator-prey interactions in the aquatic ecosystem near the plant since the area of potential influence is very small. Forage species (e.g., emerald shiners and gizzard shad) may be subject to somewhat higher predation rates when they are attracted to the discharge in large numbers during the cooler months of the year. Walleye and white bass are the only piscivorous (fish-eating) RIS that show an increased abundance in the existing discharge concurrent with the congregation of forage species, and it is unlikely that increased predation by these fish would deplete the forage stocks in the general area. In fact, the predators, which are important sport species, could benefit from such prey concentration. Lower trophic level interactions among fish and invertebrates should be relatively unaffected by the discharge.

Growth rates of fish may also be influenced by the proposed thermal discharge and subsequently affect populations through physiological changes such as altered age at maturity. Temperatures outside the mixing zone are not expected to exceed the MWAT for growth for channel catfish, northern pike, carp, emerald shiner, or white sucker (Tables VI-3 through 12) at least 60 percent of the time. A portion of the plume beyond the mixing zone, however, is expected to exceed the MWAT for growth for walleye during July and August and black crappie in July. Since the plume beyond the mixing zone is located along the west bank of the river main channel which is also the navigation channel, this area is probably suboptimal for residence by most species, particularly quietwater species such as black crappie. Condition factors (relation of length to weight) for fish collected inside and outside the plume in the existing discharge area were not found to differ significantly (Krosch, 25 October 1977). During extreme environmental conditions, the areas where temperatures exceed the MWAT for growth may be fairly large, but the infrequent occurrence and short duration of these conditions preclude any measureable effect on fish growth. Consequently, thermal plume effects on growth are expected to be negligible.

Small changes in fish population structure are difficult to measure and nearly impossible to predict. Many factors are involved in determining population structure including natural density-dependent compensatory mechanisms and influences of man such as fishing, navigation, and pollution. The potential for alternation of fish population structure as a result of the PINGP thermal discharge is sufficiently small that it would likely be masked by pre-existing variability. The effects of the proposed discharge on river populations is predicted to be even less than the small effect predicted for the existing discharge.

f. EFFECTS ON PARASITES AND DISEASES. As with the present discharge, no effect on parasites or diseases of fish is expected as a result of discharging heated water from the proposed location. Specific parasites possibly influenced are considered in the PINGP 316(a) Demonstration.

2. Macroinvertebrates. Based on literature for thermal tolerances and the thermal plume results (Stone & Webster, 1978a), impacts to macroinvertebrate populations are predicted to be negligible. Temperatures in the plume are not expected to exceed thermal tolerances of the RIS

long enough to cause any damage to drifting macroinvertebrates (Tables VI-14 through VI-17). Since the thermal plume is essentially a surface plume less than 3 m (10 ft) deep (Figure 4-6 in Stone & Webster, 1978a), the only potential for impact to benthic (bottom-dwelling) macroinvertebrates would be along the submerged shoreline to a depth of 3 m (10 ft). *Hydropsyche* could be excluded from 0.007 ha (0.02 A) of shoreline downriver from the discharge point during typical environmental conditions in February and from 0.014 ha (0.04 A) in June through August (Table VI-14). For *Macronemum,* the calculated exclusion area would be less than 0.01 ha (0.025 A) during typical conditions in August (Table VI-15), and *Stenonema* may be excluded from up to 0.007 ha (0.02 A) in November (Table VI-16). In addition, the warmer plume temperatures could cause emergence of *Hydropsyche* to be advanced as much as 5 months within an area of approximately 0.01 ha (0.03 A) of shoreline habitat during typical winter conditions. For the remainder of the year, emergence could be advanced by 2 weeks along almost the entire length of the west (Minnesota) shoreline extending to Lock and Dam No. 3, or about 0.04 ha (0.9 A). *Macronemum* could also experience accelerated emergence schedules downriver from the proposed discharge to Lock and Dam No. 3 for the entire year. Significant early emergence is not expected, however, since this phenomenon has not been observed in the existing discharge canal. For the proposed extreme environmental conditons, the exclusion areas for *Hydropsyche* and *Macronemum* would be larger, but the low frequency of occurrence precludes any measurable influence on survival or emergence. No comparable data are available for the other two RIS.

In comparing the proposed alternate discharge with the existing discharge, the predicted area of habitat exclusion for macroinvertebrate RIS would be greatly reduced by the proposed discharge. The area within which accelerated emergence could occur is also much smaller. The primary reasons for the lower impact potential are better mixing and less suitable habitat in the main channel of the river where critically high plume temperatures can occur. Thermally influenced habitat would be limited to a narrow band of shoreline downriver from the proposed discharge. This area also has a steep bank and is periodically scoured by turbulence from passing barges. Thus, potential impacts of the proposed discharge to macroinvertebrate populations are expected to be negligible.

3. Zooplankton. As with macroinvertebrates, no mortalities to any taxa of zooplankton drifting through the plume are expected since none were observed or predicted to result from operation of the existing discharge where conditions more stressful than those predicted for the proposed discharge occur. Rapid mixing and smaller areas of high temperatures account for this prediction.

Table VI-14. Estimated areas in the thermal plume where temperatures may exceed the critical temperature for various life functions of *Hydropsyche* and the frequency with which this could occur.

BIOLOGICAL ACTIVITY	CRITICAL TEMPERATURE[1] (C)	AREA IN WHICH PLUME TEMPERATURE EXCEEDS CRITICAL TEMPERATURE[2] (HA)		FREQUENCY CRITICAL TEMPERATURE EXCEEDED IN AREA[3]		REMARKS
		TYPICAL	EXTREME	TYPICAL	EXTREME	
Maximum temperature where live specimens have been observed.	35-38	0	0	–	–	
Mean lethal temperature (48 or 96 hr TL_m or LT_{50}) of mature larval or adult stage.	32-38 (Spring, Fall) 38 Summer	0	0	–	–	
Most common temperature taxon recorded at, based on frequency of occurrence at different temperature levels.	27-29	0.007 0.014	0.006- >0.186	Feb. June - Aug.	May - Sept.	Ambient river temperature naturally exceeds 29° C during August proposed extreme condition.
Temperature increases which have been shown to affect emergence period.	1 = 2 week advance	0.382	0.382	All year	All year	Coutant (1968)
	14 (±2) = 5 mo. advance in winter	0.010	0.008-0.010	Nov. - Mar.	Dec. - Mar.	Nebeker (1971)

[1]From Table A-29 in the PINGP 316(a) Demonstration (HDR, 1978).

[2]From Tables A-3 through A-43 for typical (median) and proposed extreme environmental conditions (see Tables 5-1 and 5-2 in Appendix B for conditions).

[3]Frequencies of occurrence are given as month for typical environmental conditions since these are assumed to occur at least 50 percent of the time throughout the month. Month of occurrence is also given for the proposed extreme conditions since the frequency cannot be readily calculated.

Table VI-15. Estimated areas in the thermal plume where temperatures may exceed the critical temperature for various life functions of *Macronemum* and the frequency with which this could occur.

BIOLOGICAL ACTIVITY	CRITICAL TEMPERATURE[1] (C)	AREA IN WHICH PLUME TEMPERATURE EXCEEDS CRITICAL TEMPERATURE[2] (HA)		FREQUENCY CRITICAL TEMPERATURE EXCEEDED IN AREA[3]		REMARKS
		TYPICAL	EXTREME	TYPICAL	EXTREME	
Maximum temperature where live specimens have been observed.	35	0	0	–	–	
Mean lethal temperature (48 or 96 hr TL_m or LT_{50}) of mature larval or adult stage.	N.D.	–	–	–	–	
Most common temperature taxon recorded at, based at frequency of occurrence of different temperature levels.	28	0.008	0.005->0.186	Aug.	May - Sept.	Ambient river temperature naturally exceeds 28° C during August proposed extreme condition.
Temperature increases which have been shown to affect emergence period.	> 0 = 2 week advance	0.382	0.382	All year	All year	Hopwood (1975)

[1]From Table A-29 in the PINGP 316(a) Demonstration (HDR, 1978). N.D. = no data.

[2]From Tables A-3 through A-43 for typical (median) and proposed extreme environmental conditions (see Tables 5-1 and 5-2 in Appendix B for conditions).

[3]Frequencies of occurrence are given as month for typical environmental conditions since these are assumed to occur at least 50 percent of the time throughout the month. Month of occurrence is also given for the proposed extreme conditions since the frequency cannot be readily calculated.

Table VI-16. Estimated areas in the thermal plume where temperatures may exceed the critical temperature for various life functions of *Stenonema* and the frequency with which this could occur.

BIOLOGICAL ACTIVITY	CRITICAL TEMPERATURE[1] (C)	AREA IN WHICH PLUME TEMPERATURE EXCEEDS CRITICAL TEMPERATURE[2] (HA)		FREQUENCY CRITICAL TEMPERATURE EXCEEDED IN AREA[3]		REMARKS
		TYPICAL	EXTREME	TYPICAL	EXTREME	
Maximum temperature where live specimens have been observed.	32.0	0	0	–	–	
Mean lethal temperature (48 or 96 hr TL_m or LT_{50}) of mature larval or adult stage.	25.5	0.007	≤ 0.007	Nov.	Mar. & Nov.	10° C acclimation temperature
Most common temperature taxon recorded at, based on frequency of occurrence at different temperature levels.	N.D.	–	–	–	–	
Temperature increases which have been shown to affect emergence period.	N.D.	–	–	–	–	

[1]From Table A-29 in the PINGP 316(a) Demonstration (HDR, 1978). N.D. = no data.

[2]From Tables A-3 through A-43 for typical (median) and proposed extreme environmental conditions (see Tables 5-1 and 5-2 in Appendix B for conditions).

[3]Frequencies of occurrence are given as month for typical environmental conditions since these are assumed to occur at least 50 percent of the time throughout the month. Month of occurrence is also given for the proposed extreme conditions since the frequency cannot be readily calculated.

Table VI-17. Estimated areas in the thermal plume where temperatures may exceed the critical temperature for various life functions of *Pseudocloeon* and the frequency with which this could occur.

BIOLOGICAL ACTIVITY	CRITICAL TEMPERATURE[1] (C)	AREA IN WHICH PLUME TEMPERATURE EXCEEDS CRITICAL TEMPERATURE[2] (HA)		FREQUENCY CRITICAL TEMPERATURE EXCEEDED IN AREA[3]		REMARKS
		TYPICAL	EXTREME	TYPICAL	EXTREME	
Maximum temperature where live specimens have been observed.	40.7	0	0	–	–	
Mean lethal temperature (48 or 96 hr TL_m or LT_{50}) of mature larval or adult stage.	N.D.	–	–	–	–	
Most common temperature taxon recorded at, based on frequency of occurrence at different temperature levels.	N.D.	–	–	–	–	
Temperature increases which have been shown to affect emergence period.	N.D.	–	–	–	–	

[1]From Table A-29 in the PINGP 316(a) Demonstration (HDR, 1978). N.D. = no data.

[2]From Tables A-3 through A-43 for typical (median) and proposed extreme environmental conditions (see Tables 5-1 and 5-2 in Appendix B for conditions).

[3]Frequencies of occurrence are given as month for typical environmental conditions since these are assumed to occur at least 50 percent of the time throughout the month. Month of occurrence is also given for the proposed extreme conditions since the frequency cannot be readily calculated.

Of the zooplankton taxa likely to encounter the plume and for which thermal bioassay data exist, *Diaptomus* (a copepod) is probably the most thermally sensitive. Thermal stress would occur in this organism only if it remained in the highest predicted plume temperatures [greater than 31° C (88° F)] for more than 24 hours. This would not be a likely situation, however, since discharge velocities would approximate 2.3 m/sec (7.5 fps) precluding long residence times of zooplankton in the plume. Stress resulting from elevated temperatures combined with limiting water quality conditions resulting from upriver sewage discharges could occur in the plume, but any effects would be very localized and consequently should have negligible impacts on general zooplankton populations in the river. Thermal stress to zooplankton is thus expected to be negligible.

4. Phytoplankton. As stated in the PINGP 316(a) Demonstration, phytoplankton are among the most thermally tolerant planktonic organisms. Densities and species composition of phytoplankton are not expected to change as a result of the proposed discharge since drift times through the plume are relatively short. Furthermore, delayed response to plume passage should be minimal, a prediction supported by the fact that no statistical evidence for decreases in chlorophyll pigments was found in the existing discharge compared to intake waters. Local reductions in productivity, however, may be observed in the vicinity of the alternate discharge during summer operation as a result of plant entrainment of phytoplankton. Thus, impacts of the proposed discharge on phytoplankton populations in the river are predicted to be negligible.

5. Periphyton. Periphyton colonize most exposed submerged surfaces where light intensities are sufficient for photosynthesis. Nutrients are not limiting in this section of the Mississippi River but light penetration is, and consequently, the most dense growth can be expected to occur within 50 cm (20 in.) of the surface. Periphtyon, especially diatoms, have high thermal tolerances similar to those of phytoplankton. A limited amount of habitat suitable for periphytic growth would be influenced by the thermal plume from the proposed discharge. Where the highest temperatures impinge upon the shoreline, diatom species composition may gradually change as less tolerant species are excluded. Observations in the existing discharge canal suggest that no reduction in biomass or productivity or unsightly or nuisance growth should occur.

6. Aquatic Macrophytes. No impacts to aquatic macrophytes are expected to occur as a result of operating the proposed alternate discharge since no macrophyte beds exist along the western shoreline of the main channel in the area of predicted thermal influence. A small macrophyte bed (No. 2) occurs at the mouth of the refuge about 750 m (2,500 ft) downriver from the proposed location of the pipes [see Figure III-29 in the PINGP 316(a) Demonstration (HDR, 1978)]. Thermal influence, however,

is predicted to be minimal since temperatures will be elevated less than 2° C (3.6° F) at this distance downriver. No deterimental effects of elevated temperatures have been observed in the present discharge canal, and thus, neither density nor composition of aquatic plants occurring in bed No. 2 would be influenced as a result of operation of the proposed discharge.

7. Birds. Effects of thermal effluent from the proposed alternate discharge on the bald eagle (a threatened species) and waterfowl should be similar to those predicted for the existing discharge in the PINGP 316(a) Demonstration. The open water area created by the thermal effluent in winter would be smaller than that in the present discharge canal, and velocities would be higher near the discharge (bank). Thus, the small impacts predicted for the existing discharge would be even smaller. No effects on migrations of ducks and other waterfowl are expected, and the peregrine falcon (an endangered species) should not be affected if they become reestablished in the area.

VII CONCLUSIONS

The impact analysis performed in Section VI indicates that construction of the proposed alternate discharge should not adversely affect aquatic biota in the vicinity of PINGP. Its operation, moreover, should reduce potential impacts to indigenous populations of fish, invertebrates, and primary producers to a level below that of the existing discharge. Attraction to and avoidance of the thermal plume by at least some species of fish will continue during various times of the year, but the subsequent effects on spawning, growth, migrations, predator-prey interactions, parasites and diseases, and winter survival are predicted to be lower than if use of the present discharge is continued. Thermal effects on primary producers and invertebrates are expected to be negligible as are potential impacts to waterfowl and raptors which frequent the vicinity of PINGP.

Table VII-1 compares the predicted operational impacts of the existing and proposed discharges. For fish, the area in which plume temperatures would exceed the criterion for summer survival would be decreased by more than two orders of magnitude with use of the alternate discharge. The areas in which plume temperatures could exceed the criteria for adult and embryo survival during the spawning period would be much smaller for the proposed discharge, and its location on the bank of the main river channel would also reduce potential impacts to spawning and reproductive success since the habitat there is less suitable for spawning. Higher discharge velocities at the alternate discharge could cause some shear stress to larval fish drifting through the immediate discharge area, but this potential mortality is not expected to alter recruitment to adult populations.

The potential for cold shock would be greatly reduced in the alternate discharge plume since the areas in which temperatures could exceed the maximum weekly average temperature (MWAT) for winter survival would be much smaller. Other impacts to river populations such as effects on growth, migrations, predator-prey interactions, and the incidence of parasites and diseases are expected to be minimal for both discharge schemes.

For macroinvertebrates, the potential effects on survival and emergence would be substantially reduced if the alternate discharge were used. Impacts to other invertebrates, primary producers, and birds are expected to be negligible for both discharges.

Therefore, it is concluded that construction and operation of the proposed alternate discharge would not cause appreciable harm or adverse levels of impact to aquatic biota in the vicinity of PINGP. Furthermore, the predicted impacts would be substantially reduced relative to those predicted for continued use of the existing discharge.

Table VII-1. Comparison of predicted biological impacts during operation of the existing and proposed discharges under typical environmental conditions.

ORGANISM GROUP AND PARAMETER AFFECTED	EXISTING DISCHARGE[1]	ALTERNATE DISCHARGE
Fish (RIS)		
Summer Survival	Maximum area of exclusion is 4.4 ha in July and August (velocity not calculated but very low).	Maximum area of exclusion is 0.01 ha in June through August. Velocities within this area exceed 0.9 m/sec.
Spawning and Reproductive Success	Premature spawning could occur in walleye, carp, gizzard shad, and emerald shiner but effects on populations expected to be minimal.	Premature spawning not predicted for any species.
	Exclusion area for spawning is less than 2.6 ha.	Exclusion area for spawning is less than 0.01 ha.
	Exclusion area for embryo development is less than 17 ha.	Exclusion area for embryo development is less than 0.1 ha.
	No thermal stress to larvae drifting through the plume predicted. No shear effect due to discharge configuration.	No thermal stress to larvae drifting through the plume predicted. Shear stress may occur to a few larvae but should not alter recruitment to adult populations.
Winter Survival	Area in which plume temperature exceeds MWAT for winter survival is 4.4 ha (2 unit operation). For 1 unit operation, when cold shock potential is greatest, area would be less than 2.2 ha.	Area in which plume temperature exceeds MWAT for winter survival is 0.2 to 0.9 ha depending on amount of recycle (2 unit operation). The area would be reduced to 0.02 ha for 1 unit operation with minimum recycle when area of high velocity (> 0.9 m/sec) is subtracted.
Growth Rates, Predator-Prey Interactions, and Incidence of Parasites and Diseases	Minimal effects predicted.	Negligible effects predicted.
Macroinvertebrates (RIS)		
Survival	Preferred temperature exceeded in ≤ 6.6 ha of plume during June through August.	Preferred temperature exceeded in ≤ 0.02 ha of bank during June through August (remainder of plume is unsuitable habitat).
	Maximum area of exclusion is less than 0.5 ha in May.	Maximum area of exclusion is less than 0.007 ha in November.
Emergence	Emergence may be accelerated up to 2 weeks in an area of 18.5 ha and up to 5 months in an area of 1.5 ha.	Emergence may be accelerated up to 2 weeks in an area of 0.4 ha and up to 5 months in an area of 0.01 ha.
Phytoplankton, Zooplankton, and Periphyton	Negligible impacts predicted.	Negligible impacts predicted.
Aquatic Macrophytes	No impacts predicted.	No impacts predicted.
Birds	Negligible impacts predicted.	Negligible impacts predicted.

[1]From the PINGP 316(a) Demonstration (HDR, 1978).

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APPENDIX A

DATA CATALOG

Tables

Table A-1. Numbers and density of larval fish collected near PINGP in June 1978 (NSP, Unpublished data).

DATE	STATION[1]	VOLUME SAMPLED (m^3)	*Dorosoma cepedianum*	*Morone chrysops*	*Pomoxis* spp.	*Cyprinus carpio*	*Notropis atherinoides*	Catostomidae	*Stizostedion* spp.	Other larvae[2]	Eggs[2]	Total larvae
6- 6	I	461.0	119	12	2	4	0	1	0	75	189	213
	II	580.6	106	47	1	11	1	2	0	73	166	241
	III	527.0	734	105	3	4	0	1	0	167	82	1,014
6- 8	I	478.5	223	24	1	2	0	2	0	78	932	330
	II	498.1	119	19	0	4	0	0	1	57	258	200
	III	509.2	1,236	36	0	3	0	3	0	180	235	1,458
6-10	I	494.8	204	1	5	12	0	5	0	132	279	359
	II	520.1	75	4	1	19	0	2	0	129	21	230
	III	517.7	4,390	323	5	26	46	7	0	221	9	5,018
6-13	I	475.9	55	5	3	7	0	9	0	70	288	149
	II	510.4	114	2	0	22	0	8	0	46	766	192
	III	468.6	774	20	4	88	101	2	0	60	269	1,049
6-15	I	550.1	51	4	3	6	0	9	0	103	348	176
	II	523.6	76	7	2	130	1	9	0	76	430	301
	III	523.0	880	18	6	118	18	23	0	76	898	1,139
6-17	I	490.8	43	0	2	76	0	39	0	578	73	738
	II	544.5	77	2	1	232	0	6	0	133	124	451
	III	534.0	556	22	1	359	21	2	0	92	92	1,053
Total	I	2,951.1	695	46	16	107	0	65	0	1,036	2,109	1,965
	II	3,177.3	567	81	5	418	2	27	1	514	1,765	1,615
	III	3,079.5	8,570	524	19	598	186	38	0	796	1,585	10,731
NO/100 m^3	I		23.6	1.6	0.5	3.6	0	2.2	0	35.1	71.5	66.6
	II		17.8	2.6	0.2	13.2	0.1	0.9	0.03	16.2	55.6	50.8
	III		278.3	17.0	0.6	19.4	6.0	1.2	0	25.9	51.5	348.5

[1] I = main channel, II = intake approach channel, and III = lower Sturgeon Lake (see Figure III-2 for location).

[2] Primarily *Aplodinotus grunniens* (drum).

Table A-2. Monthly and annual cumulative distributions of daily maximum river temperatures at RWGP (1950-1976 plant logs).

TEMPERATURE	PERCENT OF TIME TEMPERATURE EQUALED OR EXCEEDED											
	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	ANNUAL
85								0.1					.01
84							0.0	0.1					.01
83							0.7	0.1					.16
82							2.1	1.3					.28
81							5.4	1.9					.61
80						0.0	15.1	5.5					1.72
79						0.5	23.9	9.9	0.0				2.86
78						1.4	34.0	20.8	1.0				4.76
77						4.4	44.2	30.5	2.2				6.76
76						7.6	56.0	39.3	3.0				8.80
75						12.5	67.0	48.5	4.1				11.0
74					0.0	18.6	75.6	62.2	5.6				13.4
73					0.1	27.1	84.0	72.1	7.1				15.8
72					0.2	36.6	89.6	80.6	10.7				18.0
71					1.1	46.3	93.8	86.7	15.6	0.0			20.0
70					2.5	56.6	97.1	91.5	21.5	0.1			22.2
69					3.5	63.3	98.2	94.4	27.1	0.1			23.6
68					5.6	72.6	99.6	97.3	34.9	0.1			25.5
67					7.9	81.4	99.9	99.4	43.1	0.1			27.4
66				0.0	11.1	87.7	99.9	99.6	49.9	0.4			28.7
65				0.1	16.1	92.2	99.9	100.0	58.3	0.6			30.2
64				0.1	20.4	93.9	100.0		67.4	2.3			31.6
63				0.3	26.9	96.5			73.4	5.8			33.1
62				0.3	34.9	98.1			79.9	8.6			34.7
61				0.5	42.1	99.1			86.5	10.7			35.0
60				0.6	50.1	99.5			92.1	16.4			37.8
59				1.0	56.6	100.0			94.8	22.1			39.0
58				2.5	63.1				96.5	29.7			40.5
57				3.9	70.0				98.0	36.3			41.9

Table A-3. Areas within various isotherms from the thermal plume model (Appendix B) for January proposed extreme conditions (determined by computer planimetry). River temperature = 1.1° C (34° F) and river flow = 3,699 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
45	26.1	79	1,972	183	0.018
40	23.3	74	3,769	350	0.035
35	20.6	69	6,602	613	0.061
30	17.8	64	14,212	1,320	0.132
25	15.0	59	34,844	3,237	0.324
20	12.2	54	84,528	7,853	0.785
15	9.4	49	171,633	15,945	1.595
10	6.7	44	401,635	37,312	3.731
5	3.9	39	>681,008	>63,266	>6.327

Table A-4. Areas within various isotherms from the thermal plume model (Appendix B) for February proposed extreme conditions (determined by computer planimetry). River temperature = 3.3° C (38° F) and river flow = 3,780 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
40	25.6	78	1,580	147	0.015
30	20.0	68	8,142	756	0.076
25	17.2	63	19,997	1,858	0.186
22.5	15.8	60.5	40,647	3,776	0.378
20	14.4	58	65,336	6,070	0.607
15	11.7	53	150,403	13,972	1.397
10	8.9	48	341,840	31,757	3.176
5	6.1	43	>591,246	>54,927	>5.493

Table A-5. Areas within various isotherms from the thermal plume model (Appendix B) for March proposed extreme conditions (determined by computer planimetry). River temperature = 7.2° C (45° F) and river flow = 4,279 cfs.

ΔT (F)	ABSOLUTE TEMPERATURE (C)	(F)	AREA (ft^2)	(m^2)	(ha)
35	26.7	80	3,067	285	0.029
30	23.9	75	6,847	636	0.064
25	21.1	70	18,743	1,741	0.174
20	18.3	65	70,333	6,534	0.653
15	15.6	60	153,271	14,239	1.424
10	12.8	55	346,581	32,197	3.220
5	10.0	50	>622,388	>57,820	>5.782

Table A-6. Areas within various isotherms from the thermal plume model (Appendix B) for April proposed extreme conditions (determined by computer planimetry). River temperature = 18.3° C (65° F) and river flow = 7,623 cfs.

ΔT (F)	ABSOLUTE TEMPERATURE (C)	(F)	AREA (ft^2)	(m^2)	(ha)
15	26.7	80	874	81	0.008
10	23.9	75	3,832	356	0.036
5	21.1	70	22,269	2,069	0.207
2.5	19.7	67.5	79,455	7,381	0.738
1	18.9	66	357,124	33,177	3.318

Table A-7. Areas within various isotherms from the thermal plume model (Appendix B) for April proposed extreme (90° discharge) conditions (determined by computer planimetry). River temperature = 18.3° C (65° F) and river flow = 7,623 cfs.

ΔT (F)	ABSOLUTE TEMPERATURE (C)	(F)	AREA (ft²)	(m²)	(ha)
15	26.7	80	1,011	94	0.009
10	23.9	75	5,351	497	0.050
5	21.1	70	35,651	3,312	0.331
2.5	19.7	67.5	118,131	10,974	1.097
1	18.9	66	>415,789	>38,627	>3.863

Table A-8. Areas within various isotherms from the thermal plume model (Appendix B) for May proposed extreme conditions (determined by computer planimetry). River temperature = 22.8° C (73° F) and river flow = 8,475 cfs.

ΔT (F)	ABSOLUTE TEMPERATURE (C)	(F)	AREA (ft²)	(m²)	(ha)
15	31.1	88	334	31	0.003
10	28.3	83	1,866	173	0.017
7.5	26.9	80.5	5,602	520	0.052
5	25.6	78	21,471	1,995	0.200
2.5	24.2	75.5	118,102	10,972	1.097
1	23.3	74	476,371	44,255	4.426

Table A-9. Areas within various isotherms from the thermal plume model (Appendix B) for June #1 (1-15 June) proposed extreme conditions (determined by computer planimetry). River temperature = 26.1° C (79° F) and river flow = 6,431 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
10	31.7	89	1,310	122	0.012
5	28.9	84	9,697	901	0.090
2.5	27.5	81.5	102,387	9,512	0.951
1	26.7	80	>413,389	>38,404	>3.840

Table A-10. Areas within various isotherms from the thermal plume model (Appendix B) for June #2 (16-30 June) proposed extreme conditions (determined by computer planimetry). River temperature = 26.1° C (79° F) and river flow = 6,431 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
9	31.1	88	2,396	223	0.022
8	30.5	87	4,808	447	0.045
7	30.0	86	9,465	879	0.088
6	29.4	85	18,744	1,741	0.174
5	28.9	84	42,069	3,908	0.391
4	28.3	83	113,375	10,533	1.053
3	27.8	82	403,288	37,466	3.747
2	27.2	81	>694,179	>64,489	>6.449

Table A-11. Areas within various isotherms from the thermal plume model (Appendix B) for July proposed extreme conditions (determined by computer planimetry). River temperature = 28.3° C (83° F) and river flow = 4,299 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
8	32.8	91	3,235	301	0.030
7	32.2	90	6,710	623	0.062
6	31.7	89	12,386	1,151	0.115
5	31.1	88	27,122	2,520	0.252
4	30.6	87	87,269	8,117	0.812
3	30.0	86	350,845	32,594	3.259
2	29.4	85	>658,933	>61,215	>6.122

Table A-12. Areas within various isotherms from the thermal plume model (Appendix B) for August proposed extreme conditions (determined by computer planimetry). River temperature = 29.4° C (85° F) and river flow = 3,390 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
6	32.8	91	3,147	292	0.029
5	32.2	90	8,408	781	0.078
4	31.7	89	26,610	2,472	0.247
3	31.1	88	127,059	11,804	1.180
2	30.6	87	>550,340	>51,127	>5.113

Table A-13. Areas within various isotherms from the thermal plume model (Appendix B) for September proposed extreme conditions (determined by computer planimetry). River temperature = 25.6° C (78° F) and river flow = 3,680 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
8	30.0	86	3,252	302	0.030
7	29.4	85	7,951	739	0.074
6	28.9	84	16,475	1,531	0.153
5	28.3	83	39,671	3,685	0.369
4	27.8	82	133,232	12,377	1.238
3	27.2	81	421,269	39,136	3.914
2	26.7	80	>654,134	>60,769	>6.077

Table A-14. Areas within various isotherms from the thermal plume model (Appendix B) for October proposed extreme conditions (determined by computer planimetry). River temperature = 21.1° C (70° F) and river flow = 4,010 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
10	26.7	80	2,827	263	0.026
9	26.1	79	5,719	531	0.053
8	25.6	78	9,666	898	0.090
7	25	77	19,913	1,850	0.185
6	24.4	76	38,517	3,578	0.358
5	23.9	75	108,253	10,057	1.006
4	23.3	74	300,675	27,933	2.793
3	22.8	73	>573,672	53,294	5.329
2	22.2	72	>766,211	>71,181	>7.118

Table A-15. Areas within various isotherms from the thermal plume model (Appendix B) for November proposed extreme conditions (determined by computer planimetry). River temperature = 12.8° C (55° F) and river flow = 4,243 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
20	23.9	75	9,443	877	0.088
15	21.1	70	34,696	3,223	0.322
10.5	18.6	65.5	90,194	8,379	0.840
10	18.3	65	228,632	21,240	2.124
5	15.6	60	>629,074	>58,441	>5.844

Table A-16. Areas within various isotherms from the thermal plume model (Appendix B) for December proposed extreme conditions (determined by computer planimetry). River temperature = 6.7° C (44° F) and river flow = 3,787 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
35	26.1	79	3,640	338	0.034
30	23.3	74	8,292	770	0.077
25	20.6	69	22,352	2,077	0.208
20	17.8	64	69,908	6,494	0.649
15	15.0	59	155,718	14,466	1.447
10	12.2	54	356,587	33,127	3.313
5	9.4	49	>583,038	>54,164	>5.416

Table A-17. Areas within various isotherms from the thermal plume model (Appendix B) for February typical conditions (determined by computer planimetry). River temperature = 0° C (32° F) and river flow = 7,088 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
50	27.8	82	1,743	162	0.016
40	22.2	72	5,510	512	0.051
30	16.7	62	15,255	1,417	0.142
25	13.9	57	31,950	2,968	0.297
20	11.1	52	69,786	6,483	0.648
15	8.3	47	152,936	14,208	1.421
10	5.6	42	369,957	34,369	3.437
5	2.8	37	>659,948	>61,309	>6.131

Table A-18. Areas within various isotherms from the thermal plume model (Appendix B) for March variation #1 conditions (determined by computer planimetry). River temperature = 7.2° C (45° F) and river flow = 10,614 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
35	26.7	80	3,886	361	0.036
30	23.9	75	7,986	742	0.074
25	21.1	70	14,327	1,331	0.133
20	18.3	65	30,082	2,795	0.280
17.5	16.9	62.5	50,215	4,665	0.467
15	15.6	60	79,010	7,340	0.734
10	12.8	55	180,437	16,763	1.676
5	10.0	50	>462,472	>42,964	>4.296

Table A-19. Areas within various isotherms from the thermal plume model (Appendix B) for March variation #2 conditions (determined by computer planimetry). River temperature = 1.1° C (34° F) and river flow = 4,279 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft²)	(m²)	(ha)
45	26.1	79	1,937	180	0.018
30	17.8	64	12,917	1,200	0.120
25	15.0	59	33,607	3,122	0.312
20	12.2	54	75,770	7,039	0.704
15	9.4	49	163,407	15,181	1.518
10	6.7	44	383,978	35,672	3.567
5	3.9	39	>640,803	>59,531	>5.953

Table A-20. Areas within various isotherms from the thermal plume model (Appendix B) for March typical conditions (determined by computer planimetry). River temperature = 1.1° C (34° F) and river flow = 10,614 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft²)	(m²)	(ha)
45	26.1	79	2,093	194	0.019
40	23.3	74	4,181	388	0.039
30	17.8	64	7,204	669	0.067
25	15.0	59	17,992	1,672	0.167
20	12.2	54	40,743	3,785	0.379
15	9.4	49	95,386	8,861	0.886
10	6.7	44	221,050	20,536	2.054
5	3.9	39	>479,084	>44,507	>4.451

Table A-21. Areas within various isotherms from the thermal plume model (Appendix B) for April typical (90° discharge) conditions (determined by computer planimetry). River temperature = 5.1° C (44.7° F) and river flow = 32,170 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
25	20.9	69.7	897	83	0.008
10	12.6	54.7	3,321	309	0.031
5	9.8	49.7	11,316	1,051	0.105
2.5	8.4	47.2	32,386	3,009	0.301
1	7.6	45.7	75,294	6,995	0.700

Table A-22. Areas within various isotherms from the thermal plume model (Appendix B) for May variation #1 conditions (determined by computer planimetry). River temperature = 22.8° C (75° F) and river flow = 25,586 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
10	29.4	85	1,991	185	0.019
7.5	28.1	82.5	4,386	408	0.041
5	26.7	80	10,990	1,021	0.102
2.5	25.3	77.5	36,226	3,365	0.337
1.75	24.9	76.75	68,343	6,349	0.635
1	24.4	76	>157,741	>14,654	>1.465

Table A-23. Areas within various isotherms from the thermal plume model (Appendix B) for May variation #2 conditions (determined by computer planimetry). River temperature = 15.6° C (60° F) and river flow = 8,475 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft²)	(m²)	(ha)
25	29.4	85	772	72	0.007
20	26.7	80	1,762	164	0.016
15	23.9	75	4,421	411	0.041
10	21.1	70	16,982	4,365	0.437
5	18.3	65	101,807	9,458	0.946
3.2	17.3	63.2	129,967	12,074	1.207
2.5	16.9	62.5	403,003	37,439	3.744

Table A-24. Areas within various isotherms from the thermal plume model (Appendix B) for May variation #3 conditions (determined by computer planimetry). River temperature = 22.8° C (73° F) and river flow = 8,475 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft²)	(m²)	(ha)
7.5	26.9	80.5	778	72	0.007
5	25.6	78	3,151	293	0.029
2.5	24.2	75.5	20,946	1,946	0.195
1.5	23.6	74.5	109,799	10,200	1,020
1	23.3	74	301,003	27,963	2.796

Table A-25. Areas within various isotherms from the thermal plume model (Appendix B) for May typical conditions (determined by computer planimetry). River temperature = 15.6° C (60° F) and river flow = 25,586 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
15	23.9	75	879	82	0.008
10	21.1	70	2,866	266	0.027
5	18.3	65	11,877	1,103	0.110
2.5	16.9	62.5	38,264	3,555	0.356
1.75	16.5	61.75	63,340	5,884	0.588
1	16.1	61	129,587	12,039	1.204

Table A-26. Areas within various isotherms from the thermal plume model (Appendix B) for June variation #1 conditions (determined by computer planimetry). River temperature = 26.1° C (79° F) and river flow = 1,986 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
10	31.7	89	702	65	0.006
7.5	30.3	86.5	4,608	428	0.043
5	28.9	84	14,139	1,314	0.131
2.5	27.5	81.5	48,969	4,549	0.455
1.75	27.1	80.75	83,119	7,722	0.772
1	26.7	80	225,777	20,975	2.098

Table A-27. Areas within various isotherms from the thermal plume model (Appendix B) for June variation #2 conditions (determined by computer planimetry). River temperature = 21.5° C (70.7° F) and river flow = 6,431 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
15	29.8	85.7	2,207	205	0.021
10	27.1	80.7	6,879	639	0.064
5	24.3	75.7	69,153	6,424	0.642
2.5	22.9	73.2	>684,786	>63,617	>6.362

Table A-28. Areas within various isotherms from the thermal plume model (Appendix B) for June variation #3 conditions (determined by computer planimetry). River temperature = 26.1° C (79° F) and river flow = 6,431 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
5	28.9	84	1,215	113	0.011
2.5	27.5	81.5	11,698	1,087	0.109
1.75	27.1	80.75	42,481	3,947	0.395
1	26.7	80	468,152	43,491	4.349

Table A-29. Areas within various isotherms from the thermal plume model (Appendix B) for June typical conditions (determined by computer planimetry). River temperature = 21.5° C (70.7° F) and river flow = 19,462 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
10	27.1	80.7	2,020	188	0.019
5	24.3	75.7	13,836	1,285	0.129
2.5	22.9	73.2	46,166	4,289	0.429
1.75	22.5	72.45	114,647	10,651	1.065
1	22.1	71.7	242,439	22,523	2.252

Table A-30. Areas within various isotherms from the thermal plume model (Appendix B) for August variation #1 conditions (determined by computer planimetry). River temperature = 29.4° C (85° F) and river flow = 9,209 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
6	32.8	91	4,245	394	0.039
5	32.2	90	9,281	862	0.086
4	31.7	89	23,032	2,140	0.214
3	31.1	88	70,357	6,536	0.654
2	30.6	87	285,489	26,522	2.652
1	30.0	86	>658,037	>61,132	>6.113

Table A-31. Areas within various isotherms from the thermal plume model (Appendix B) for August variation #2 conditions (determined by computer planimetry). River temperature = 23.7° C (74.6° F) and river flow = 3,390 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
10	29.2	84.6	10,179	946	0.095
8	28.1	82.6	23,844	2,215	0.222
7	27.6	81.6	50,202	4,664	0.466
6	27.0	80.6	116,392	10,813	1.081
5	26.4	79.6	264,632	24,584	2.458
2.5	25.1	77.1	>766,221	>71,182	>7.118

Table A-32. Areas within various isotherms from the thermal plume model (Appendix B) for August variation #3 conditions (determined by computer planimetry). River temperature = 29.4° C (85° F) and river flow = 3,390 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
2.5	30.8	87.5	4,040	375	0.038
2	30.6	87	19,589	1,820	0.182
1.5	30.3	86.5	189,107	17,568	1.757
1	30.0	86	>698,978	>64,935	>6.494
0.5	29.7	85.5	>963,076	>89,470	>8.947

Table A-33. Areas within various isotherms from the thermal plume model (Appendix B) for August typical conditions (determined by computer planimetry). River temperature = 23.7° C (74.6° F) and river flow = 9,209 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
8	28.1	82.6	4,274	397	0.040
7	27.6	81.6	9,193	854	0.085
6	27.0	80.6	17,000	1,579	0.158
5	26.4	79.6	33,680	3,129	0.313
4	25.9	78.6	75,663	7,029	0.703
3	25.3	77.6	218,128	20,264	2.026
2	24.8	76.6	>485,126	>45,068	>4.507

Table A-34. Areas within various isotherms from the thermal plume model (Appendix B) for November variation #1 conditions (determined by computer planimetry). River temperature = 12.8° C (55° F) and river flow = 9,600 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
20	23.9	75	10,931	1,015	0.102
15	21.1	70	28,311	2,630	0.263
10	18.3	65	125,078	11,620	1.162
5	15.6	60	>544,432	>50,578	>5.058

Table A-35. Areas within various isotherms from the thermal plume model (Appendix B) for November variation #2 conditions (determined by computer planimetry). River temperature = 4.4° C (40° F) and river flow = 4,243 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
40	26.7	80	1,971	183	0.018
35	23.9	75	4,116	382	0.038
30	21.1	70	7,744	719	0.072
25	18.3	65	17,116	1,590	0.159
20	15.6	60	49,384	4,588	0.459
15	12.8	55	133,999	12,449	1.245
10	10.0	50	317,031	29,452	2.945
5	7.2	45	>593,859	>55,170	>5.517

Table A-36. Areas within various isotherms from the thermal plume model (Appendix B) for November typical conditions (determined by computer planimetry). River temperature = 4.4° C (40° F) and river flow = 9,600 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
40	26.7	80	2,034	189	0.019
30	21.1	70	5,757	535	0.054
25	18.3	65	11,226	1,043	0.104
20	15.6	60	25,968	2,412	0.241
15	12.8	55	75,430	7,008	0.701
10	10.0	50	177,766	16,515	1.652
5	7.2	45	>465,986	>43,290	>4.329

Table A-37. Areas within various isotherms from the thermal plume model (Appendix B) for January proposed extreme (one unit) conditions (determined by computer planimetry). River temperature = 1.1° C (34° F) and river flow = 3,699 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
45	26.1	79	758	70	0.007
35	20.6	69	2,110	196	0.020
25	15.0	59	7,841	728	0.073
20	12.2	54	27,092	2,517	0.252
10	6.7	44	156,683	14,556	1.456
5	3.9	39	>515,942	>47,931	>4.793

Table A-38. Areas within various isotherms from the thermal plume model (Appendix B) for January proposed extreme (two units, once-through) conditions (determined by computer planimetry). River temperature = 1.1° C (34° F) and river flow = 3,699 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
20	12.2	54	9,301	864	0.086
15	9.4	49	75,419	7,006	0.701
12.5	8.1	46.5	293,471	27,264	2.726
10	6.7	44	>858,788	>79,781	>7.978

Table A-39. Areas within various isotherms from the thermal plume model (Appendix B) for January proposed extreme (one unit, once-through) conditions (determined by computer planimetry). River temperature = 1.1° C (34° F) and river flow = 3,699 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
20	12.2	54	1,967	183	0.018
15	9.4	49	7,852	730	0.073
10	6.7	44	37,911	3,522	0.352
7.5	5.3	41.5	159,951	14,860	1.486
5	3.9	39	>756,393	>70,269	>7.027

Table A-40. Areas within various isotherms from the thermal plume model (Appendix B) for January typical (two units) conditions (determined by computer planimetry). River temperature = 0° C (32° F) and river flow = 7,340 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
45	25.0	77	2,053	191	0.019
35	19.4	67	6,978	648	0.065
25	13.9	57	28,516	2,649	0.265
15	8.3	47	132,039	12,266	1.227
10	5.6	42	345,925	32,136	3.214
5	2.8	37	>588,103	>54,635	>5.464

Table A-41. Areas within various isotherms from the thermal plume model (Appendix B) for January typical (one unit) conditions (determined by computer planimetry). River temperature = 0° C (32° F) and river flow = 7,340 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
45	25.0	77	910	84	0.008
35	19.4	67	2,523	234	0.023
25	13.9	57	7,583	705	0.071
20	11.1	52	18,765	1,743	0.174
10	5.6	42	106,826	9,924	0.992
5	2.8	37	>418,128	>38,844	>3.884

Table A-42. Areas within various isotherms from the thermal plume model (Appendix B) for January typical (two units, once-through) conditions (determined by computer planimetry). River temperature = 0° C (32° F) and river flow = 7,340 cfs.

ΔT	ABSOLUTE TEMPERATURE		AREA		
(F)	(C)	(F)	(ft^2)	(m^2)	(ha)
20	11.1	52	7,982	742	0.074
15	8.3	47	52,055	4,836	0.484
12.5	6.9	44.5	119,314	11,084	1.108
10	5.6	42	548,140	50,922	5.092
5	2.8	37	>1,043,852	>96,974	>9.697

Table A-43. Areas within various isotherms from the thermal plume model (Appendix B) for January typical (one unit, once-through) conditions (determined by computer planimetry). River temperature = 0° C (32° F) and river flow = 7,340 cfs.

ΔT (F)	ABSOLUTE TEMPERATURE (C)	ABSOLUTE TEMPERATURE (F)	AREA (ft^2)	AREA (m^2)	AREA (ha)
20	11.1	52	2,206	205	0.021
15	8.3	47	7,459	693	0.069
10	5.6	42	40,633	3,775	0.378
7.5	4.2	39.5	102,157	9,490	0.949
5	2.8	37	>521,789	>48,474	>4.847

APPENDIX B

THERMAL PLUME MODEL RESULTS

The input conditions and isotherm plots from the thermal plume model study for the alternate discharge (Stone & Webster, 1978a) are presented in this appendix. The area within each isotherm was digitized by computer planimetry, and the results are tabulated in Appendix A.

TABLE 5-1 INPUT DATA FOR THERMAL DISCHARGE ANALYSIS

PROPOSED EXTREME CONDITIONS

MONTH	Qp (cfs) (1)	Tp (°F) (2)	Ta (°F) (3)	Qr (cfs) (4)	WB (°F) (5)
JAN	679	84.8	34.0	3699	34.7
FEB	737	84.8	38.0	3780	36.6
MAR	866	84.8	45.0	4279	47.0
APR	150	85.0	65.0	7623	59.1
MAY	300	89.1	73.0	8475	68.4
JUN 1-15	400	92.0	79.0	6431	73.9
JUN 16-30	1386	88.5	79.0	6431	73.9
JUL	1384	91.5	83.0	4299	77.5
AUG	1381	91.7	85.0	3390	76.1
SEP	1385	86.9	78.0	3680	70.7
OCT	1388	80.8	70.0	4010	63.7
NOV	1390	79.8	55.0	4243	49.7
DEC	845	84.8	44.0	3787	36.5

Notes:
(1) Expected Maximum Blowdown for Future Modified Operation.
(2) Cooling Tower Performance Curves and 24.8°F Condenser Temperature Rise.
(3) Maximum Inlet Temperature - Red Wing Generating Plant (1950-1976).
(4) 7-Day, 10-Year Low Flow - U.S.G.S. Flow Data at Prescott, Wisconsin (1928-1976).
(5) Natural Wet Bulb at Minneapolis which is Exceeded 5% of the Time Plus 2.0°F for Recirculation.

TABLE 5-2 INPUT DATA FOR THERMAL DISCHARGE ANALYSIS

VARIATIONS OF PROPOSED EXTREME CONDITIONS

MONTH	Qp (cfs) (1)	T (°F) (2)	Ta (°F) (3)	Qr (cfs) (4)	WB (°F) (5)
FEB#1	652	84.8	32.0(7)	7088(8)	----
MAR#1	866(6)	84.8	45.0	10614(8)	----
MAR#2	653(6)	84.8	34.0(7)	4279	----
MAR#3	679(6)	84.8	34.0(7)	10614	----
MAY#1	300	89.1	73.0	25586(8)	68.4
MAY#2	300	87.4	60.0	8475	68.4
MAY#3	300	82.3	73.0	8475	52.8(9)
MAY#4	300	80.2	60.0	25586(8)	52.8(9)
JUN#1	400	92.0	79.0	19462(8)	73.9
JUN#2	400	90.7	70.7(7)	6431	73.9
JUN#3	400	86.9	79.0	6431	62.8(9)
JUN#4	400	85.5	70.7(7)	19462(8)	62.8(9)
AUG#1	1381	91.7	85.0	9209(8)	76.1
AUG#2	1391	87.4	74.6(7)	3390	76.1
AUG#3	1375	87.8	85.0	3390	64.8(9)
AUG#4	1385	83.4	74.6(7)	9209(8)	64.8(9)
NOV#1	1390	79.8	55.0	9600(8)	----
NOV#2	770(6)	84.8	40.0(7)	4243	----
NOV#3	770(6)	84.8	40.0(7)	9600(8)	----

Notes:

(1) Expected Maximum Blowdown for Future Operation (unless noted).
(2) From Cooling Tower Performance Curves and 24.8°F Condenser Temperature Rise.
(3) Maximum Inlet Temperature - Red Wing Generating Plant (1950-1976) (unless noted).
(4) 7-Day, 10-Year Low Flow - U.S.G.S. Flow Data at Prescott, Wisconsin (1928-1976) (unless noted).
(5) Natural Wet Bulb at Minneapolis which is Exceeded 5% of the Time Plus 2.0°F for Recirculation (unless noted).
(6) Blowdown Resulting During Partial Recycle to Maintain 60°F Condenser Inlet Temperature.
(7) Median Inlet Temperature - Red Wing Generating Plant (1950-1976).
(8) Median Flow - U.S.G.S. Flow Data at Presc[illegible] Wisconsin (1928-1976).
(9) Natural Wet Bulb at Minneapolis which is Ex[illegible]eded 50% of the Time Plus 2.0°F for Recirculation.

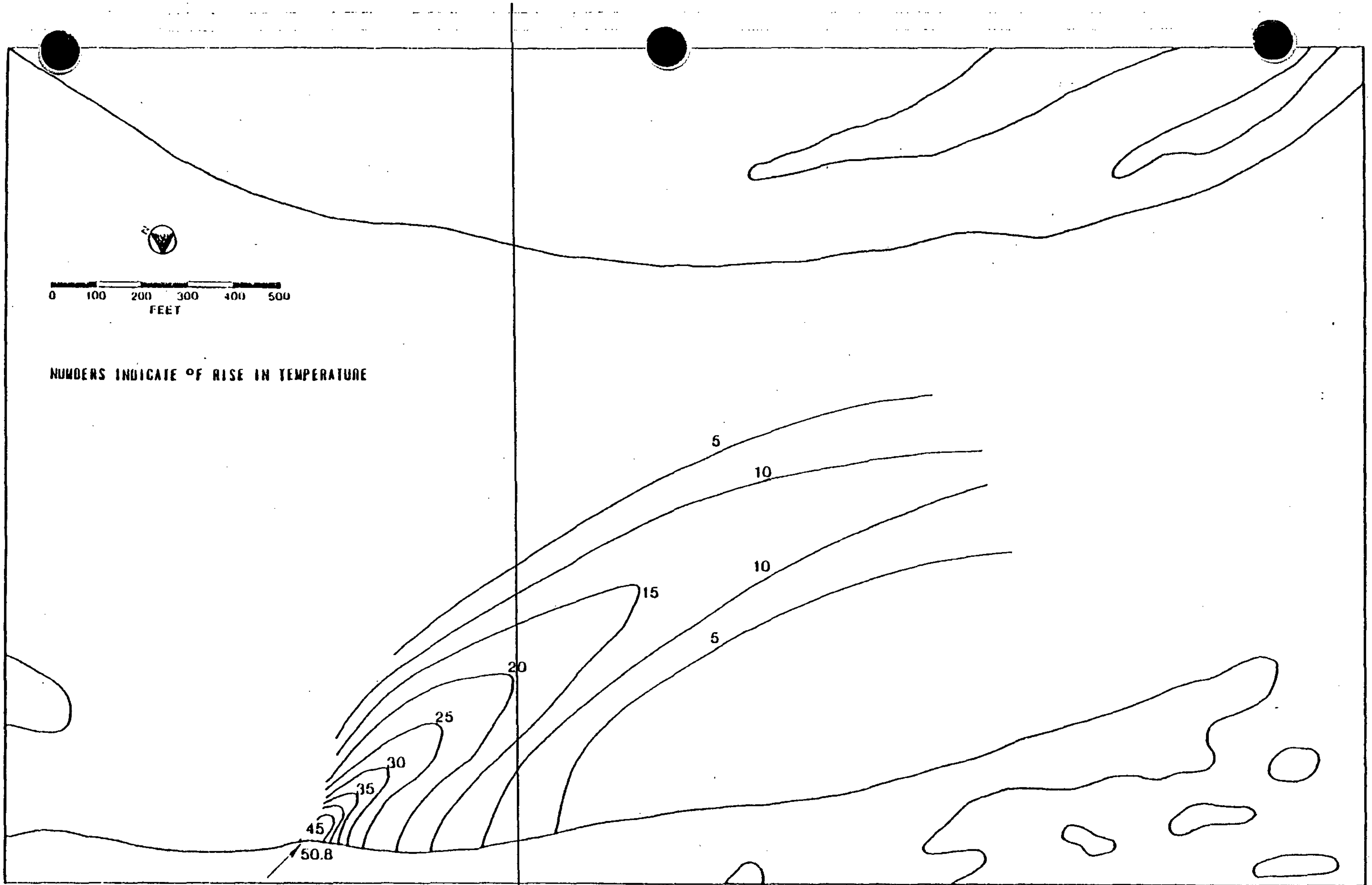


FIGURE 6-2

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, PROPOSED EXTREME CONDITION, JANUARY

THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

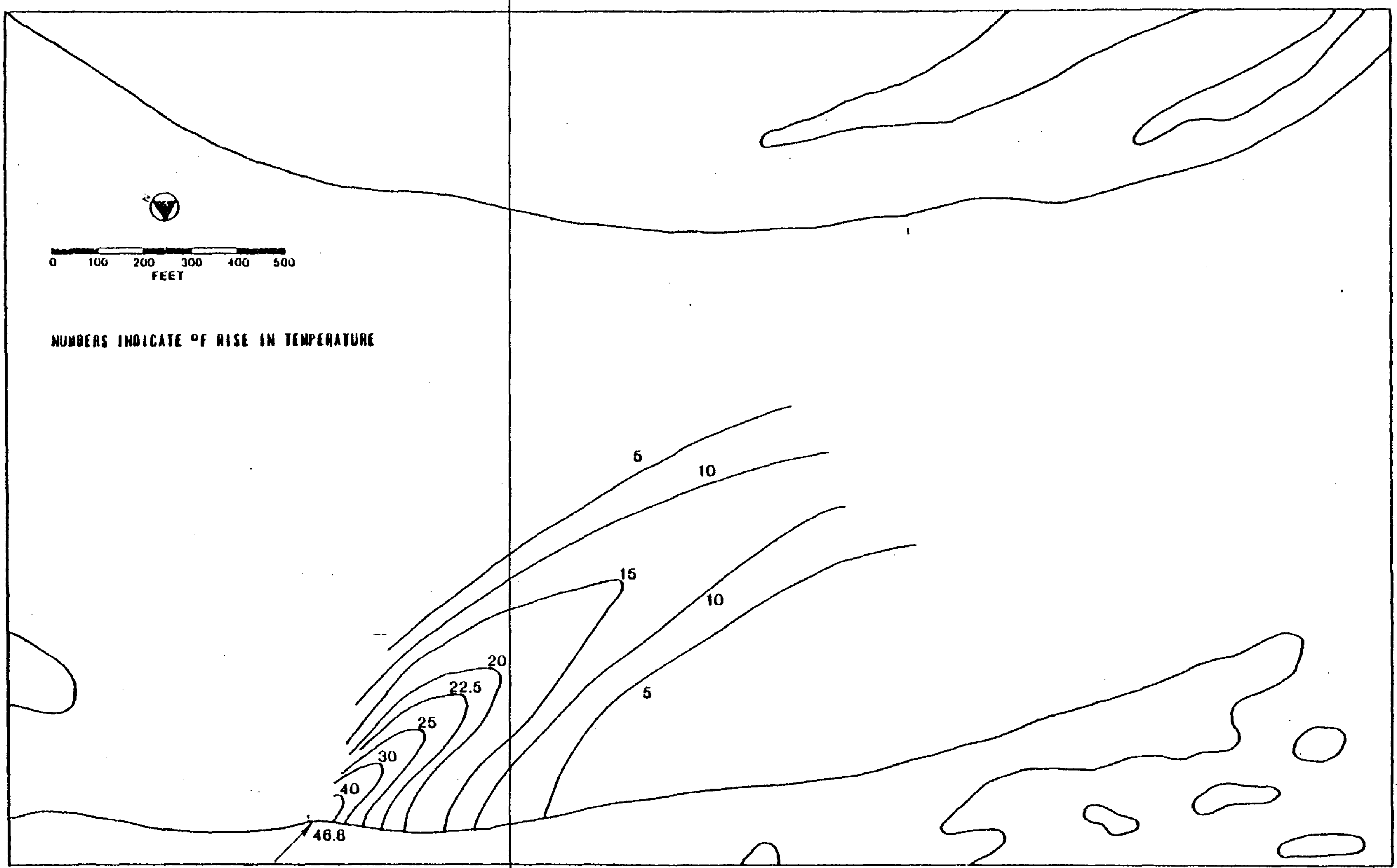


FIGURE 6-3

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER,
PROPOSED EXTREME CONDITION, FEBRUARY
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NOI...ER.. TA... PC...R ...MP...

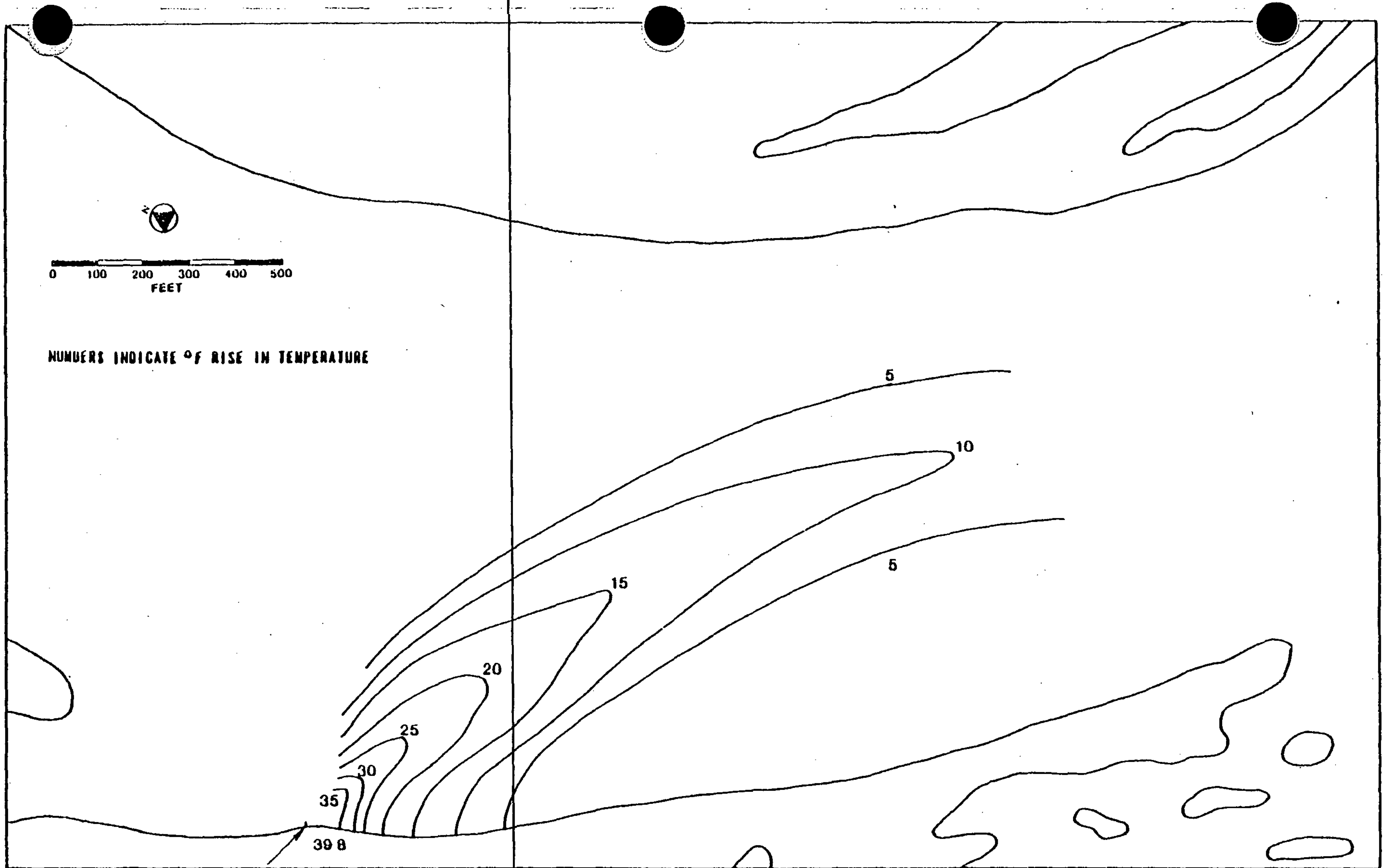


FIGURE 6-4

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, PROPOSED EXTREME CONDITION, MARCH

THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

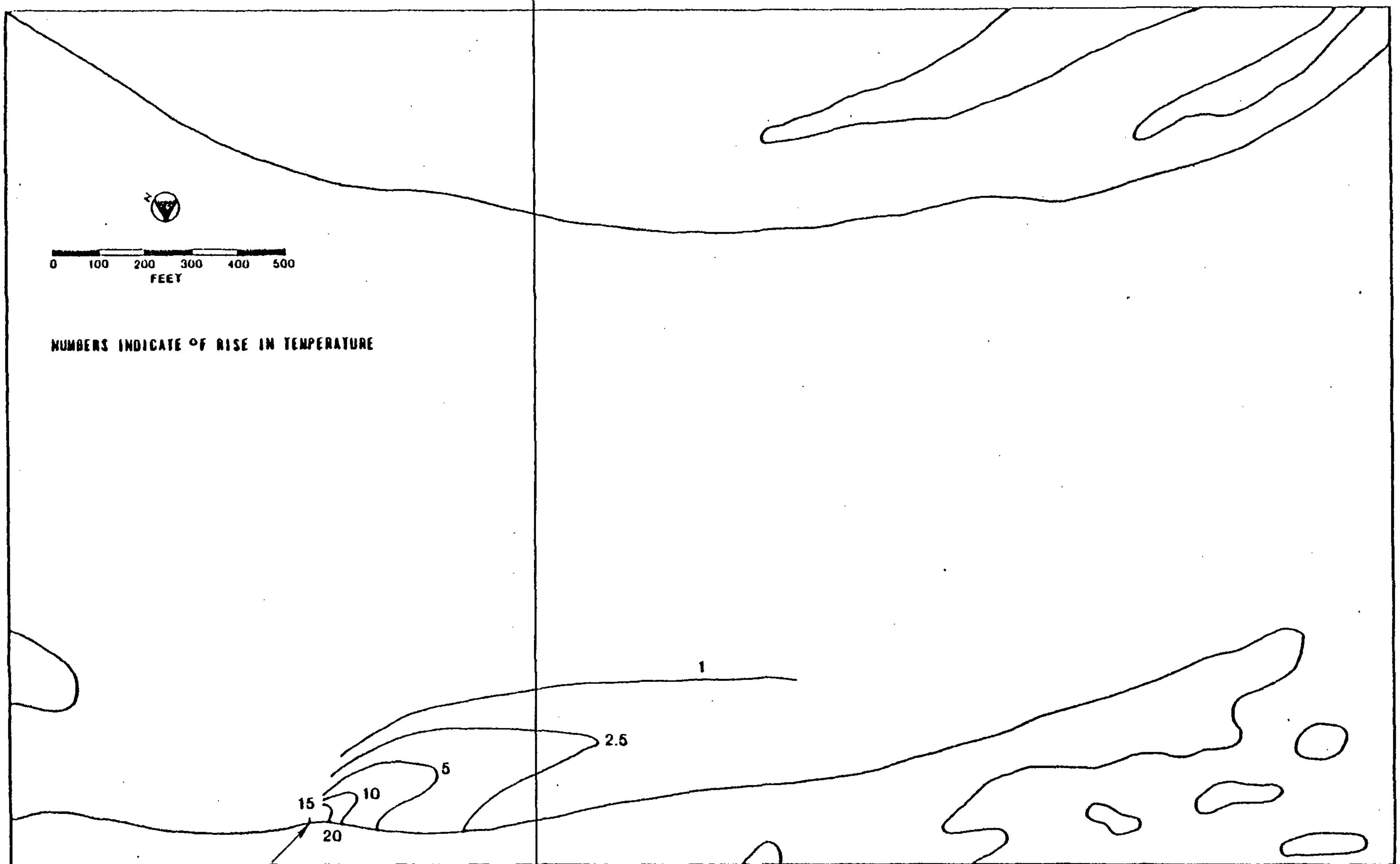


FIGURE 6-5

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, PROPOSED EXTREME CONDITION, APRIL

THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

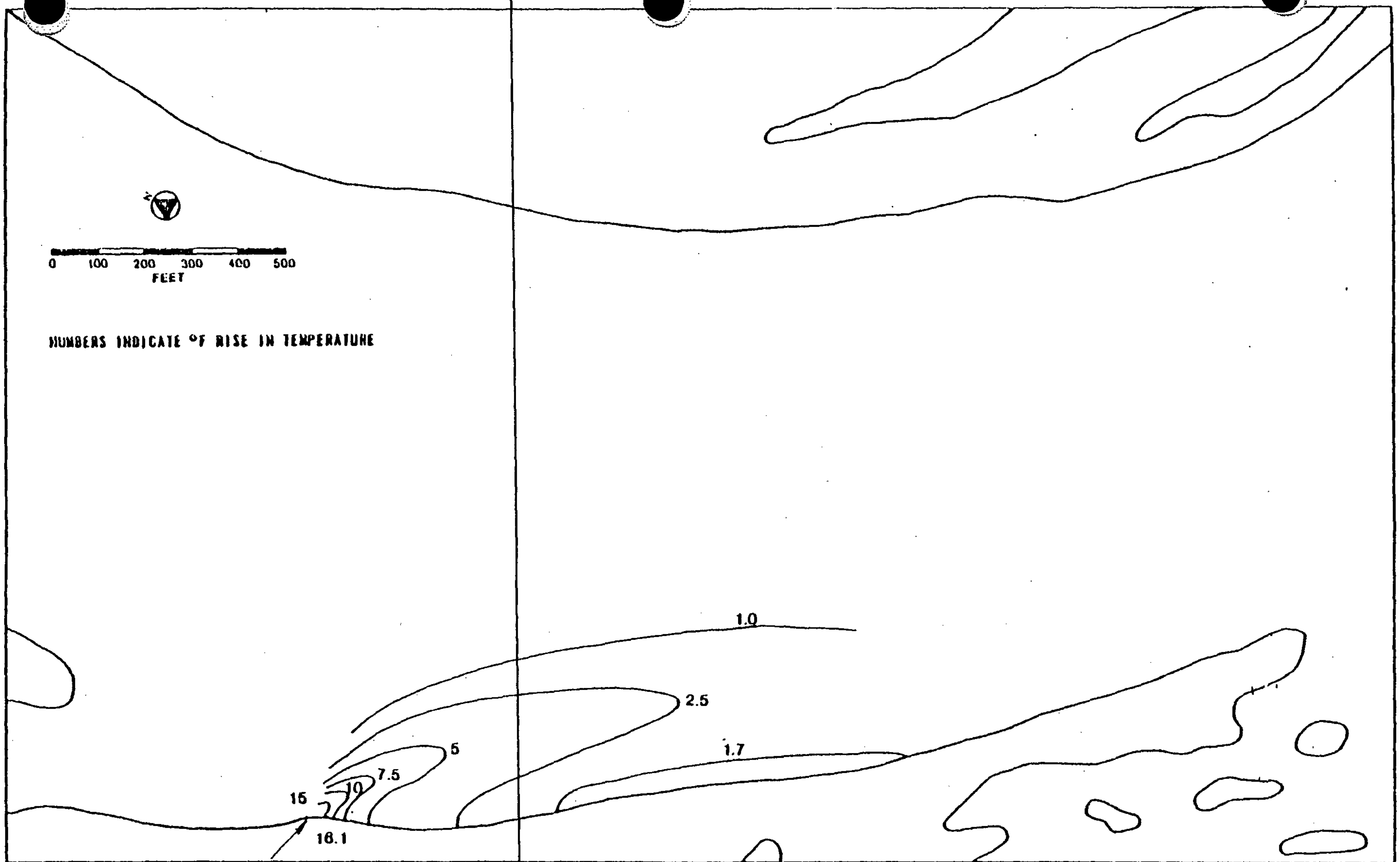
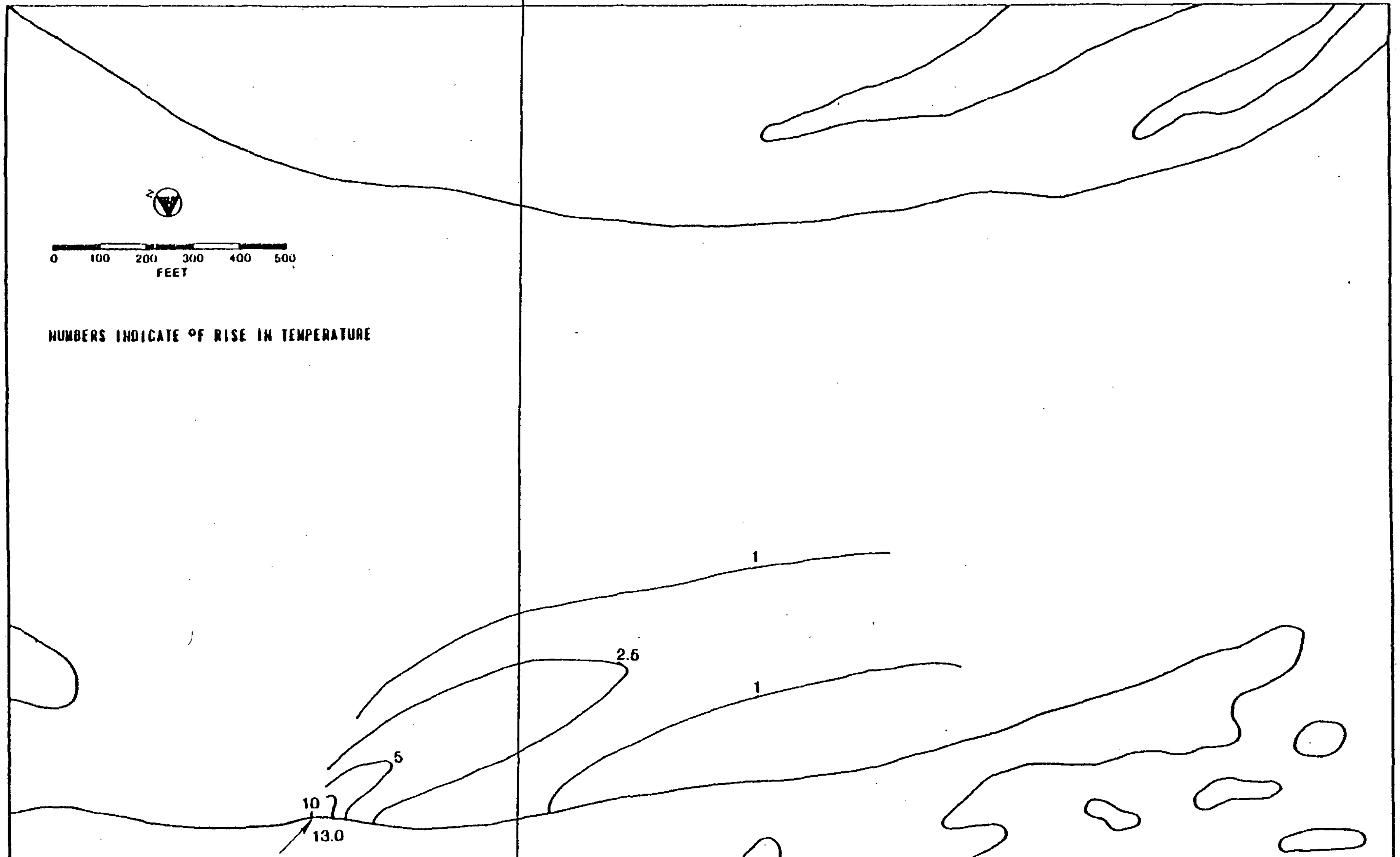


FIGURE 6-6

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, PROPOSED EXTREME CONDITION, MAY
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY



B-9

FIGURE 6-7

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, PROPOSED EXTREME CONDITION, JUNE NO. I
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

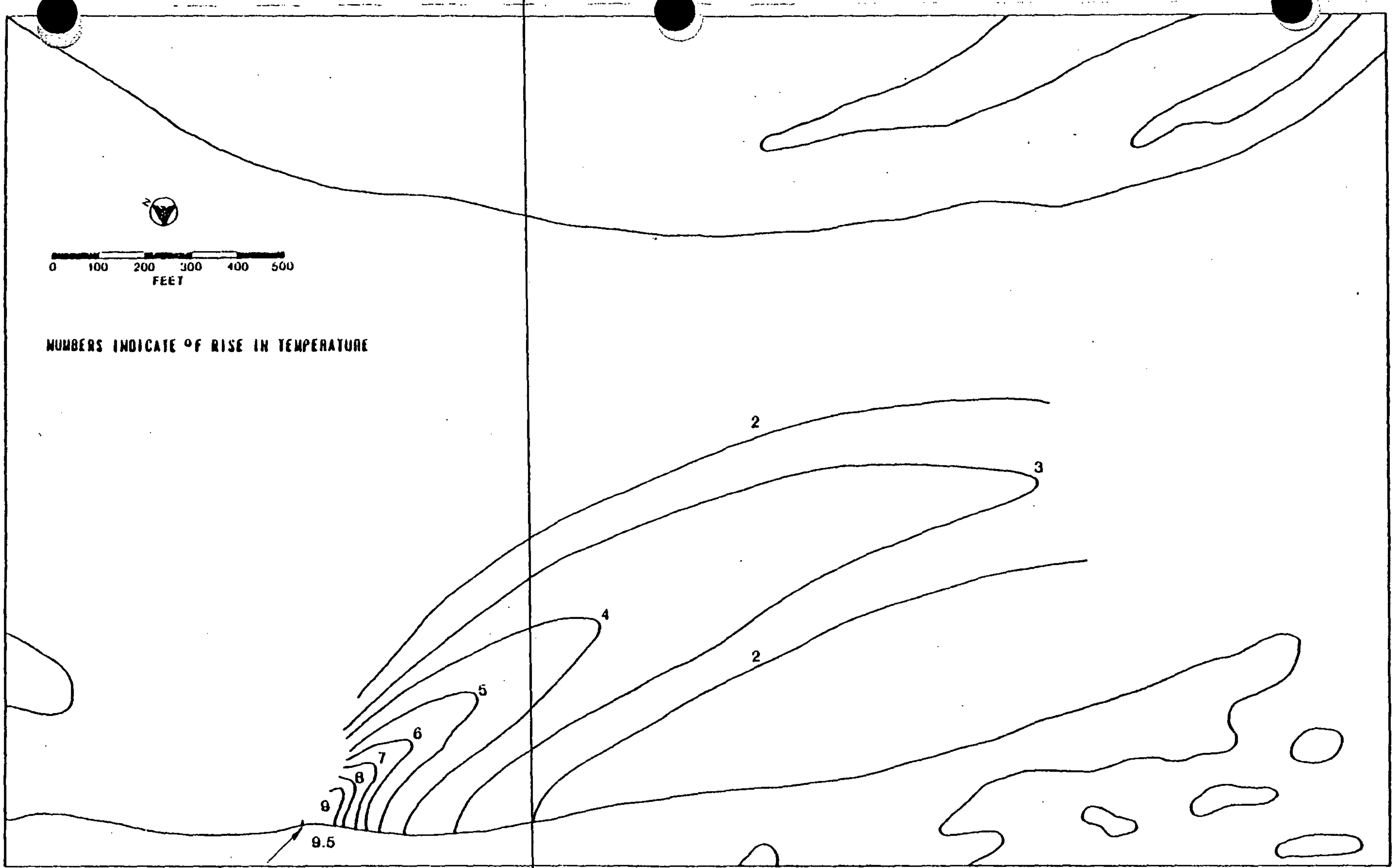


FIGURE 6-8

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, PROPOSED EXTREME CONDITION, JUNE NO. 2
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

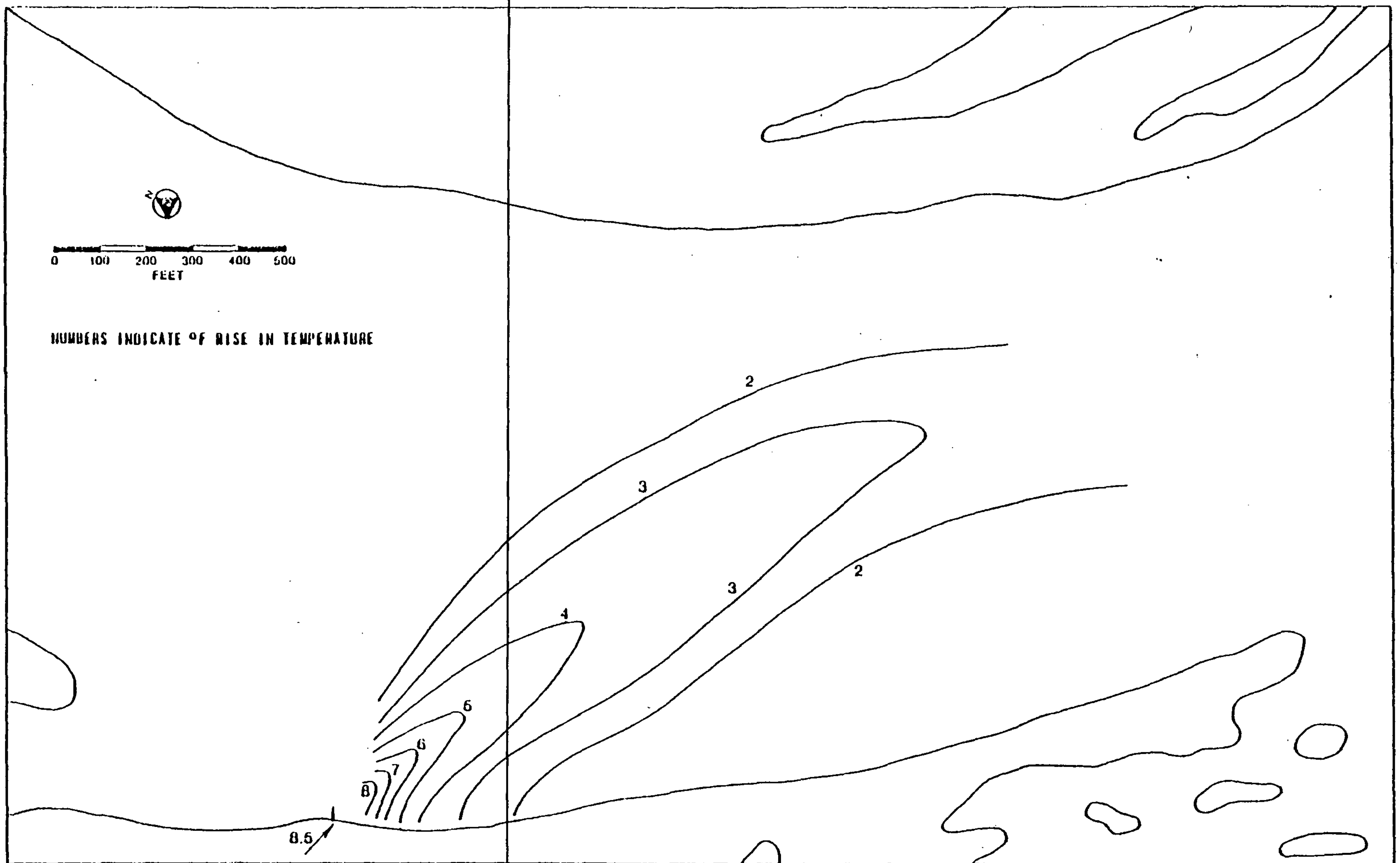


FIGURE 6-9

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, PROPOSED EXTREME CONDITION, JULY
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

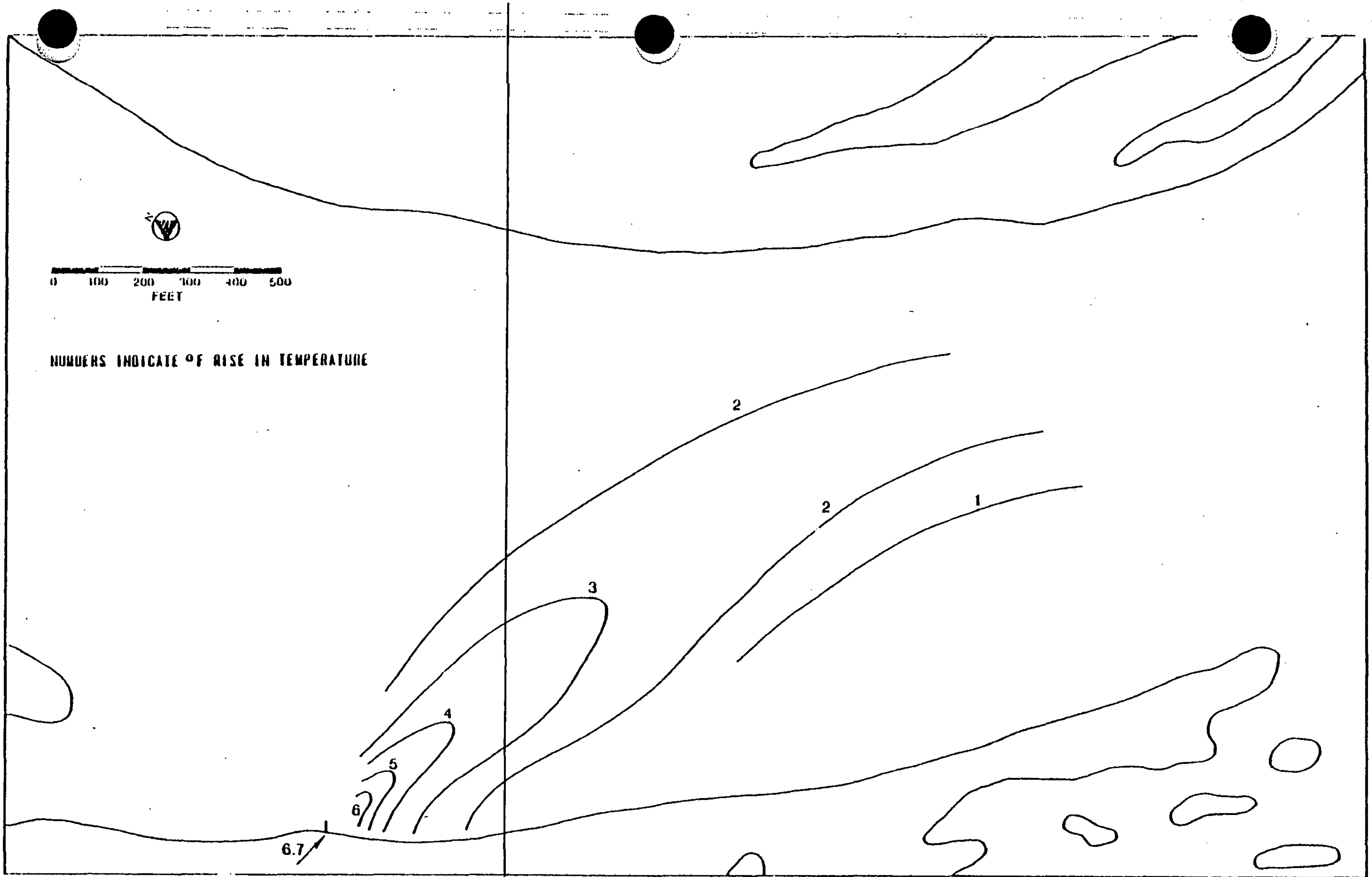


FIGURE 6-10

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, PROPOSED EXTREME CONDITION, AUGUST
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

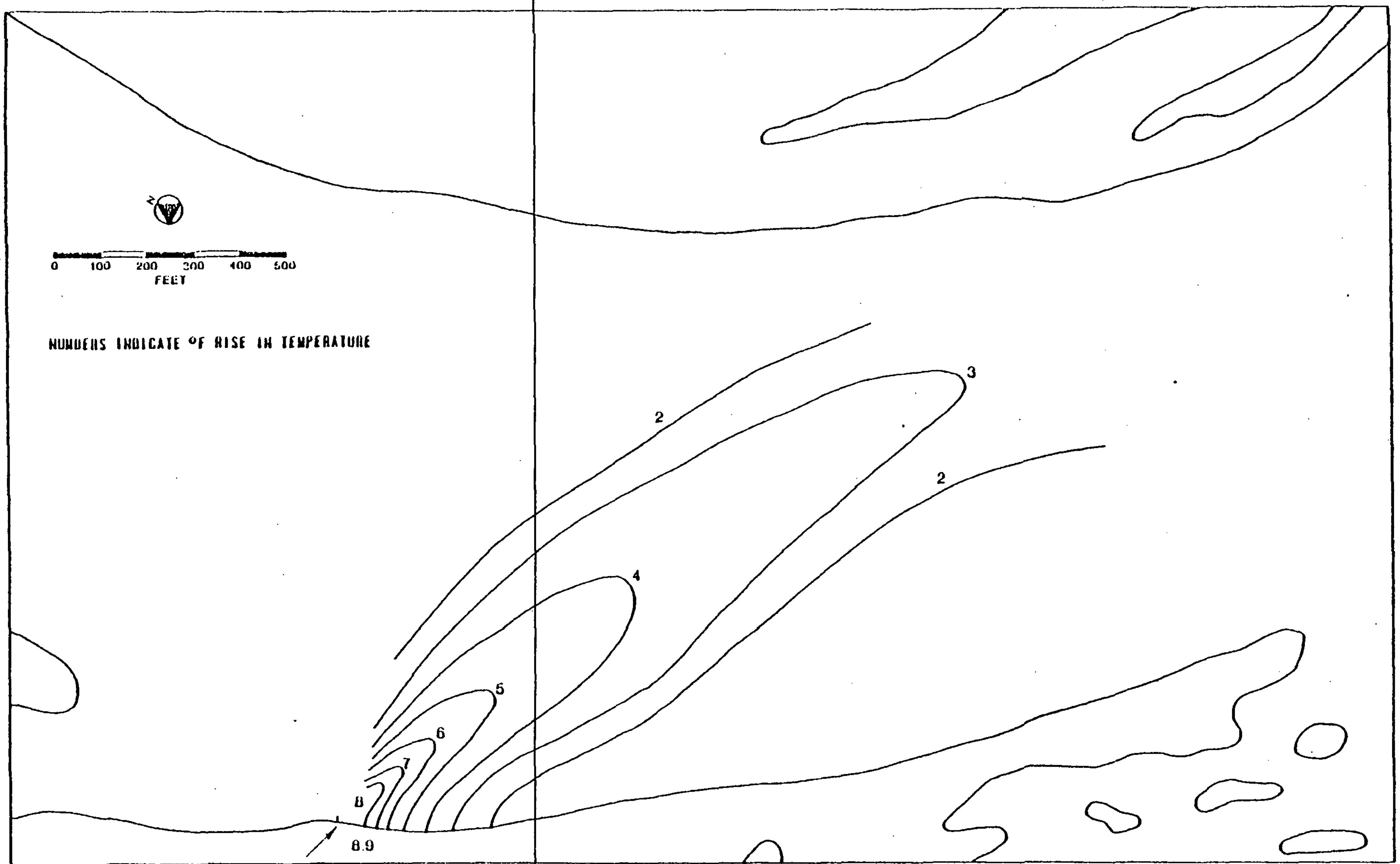


FIGURE 6-11

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, PROPOSED EXTREME CONDITION, SEPTEMBER

THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

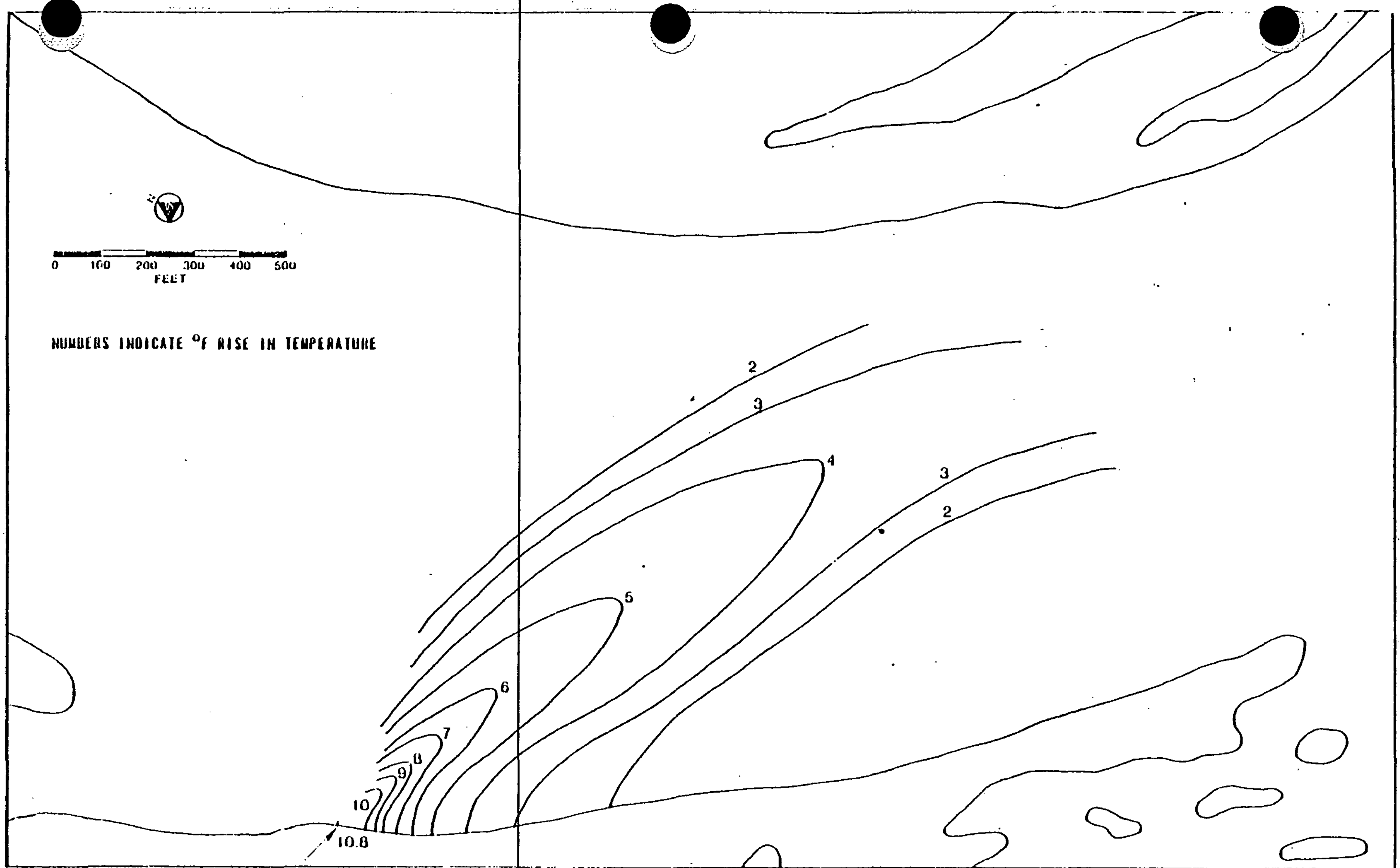


FIGURE 6-12

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, PROPOSED EXTREME CONDITION, OCTOBER
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

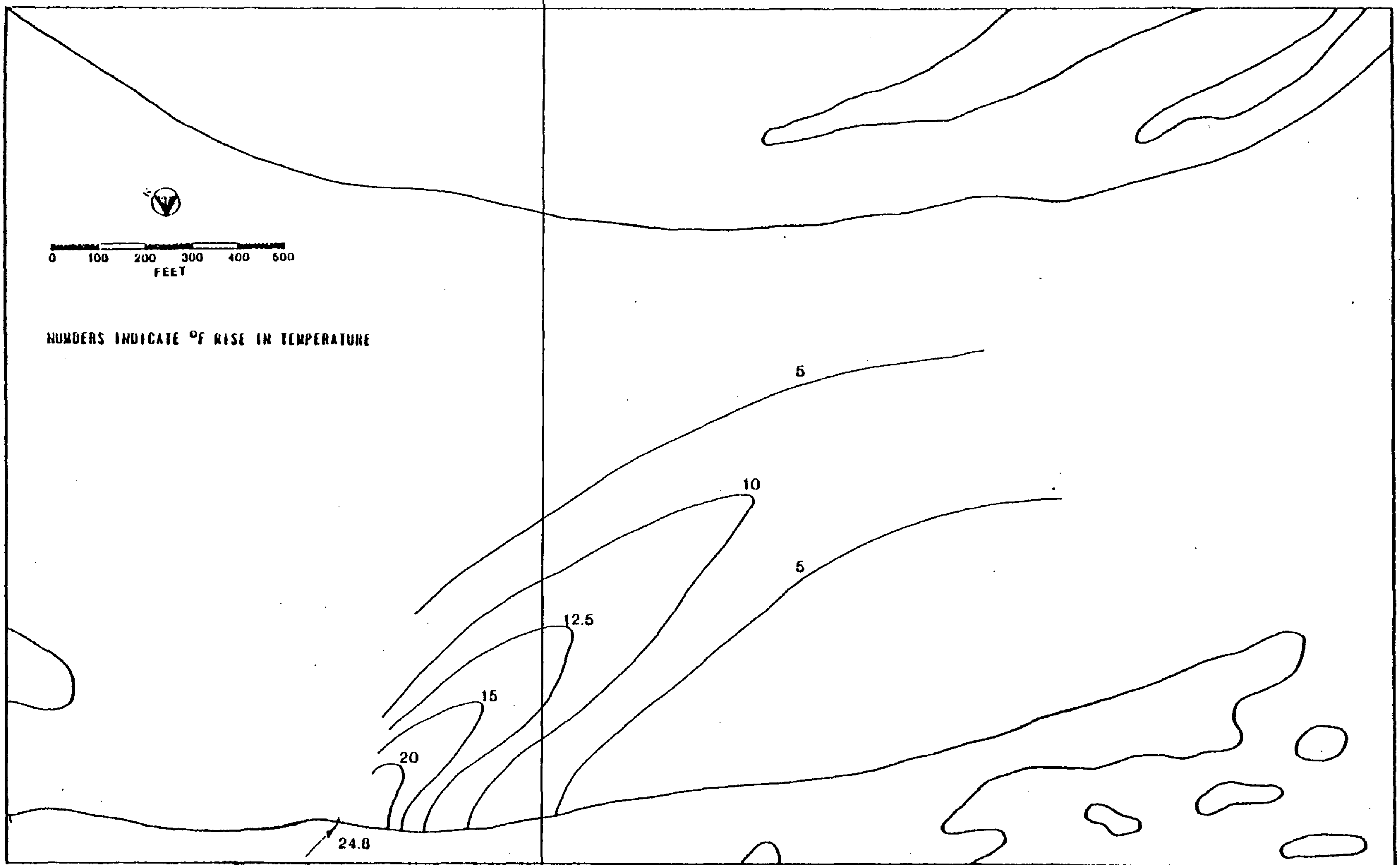


FIGURE 6-13

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, PROPOSED EXTREME CONDITION, NOVEMBER
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

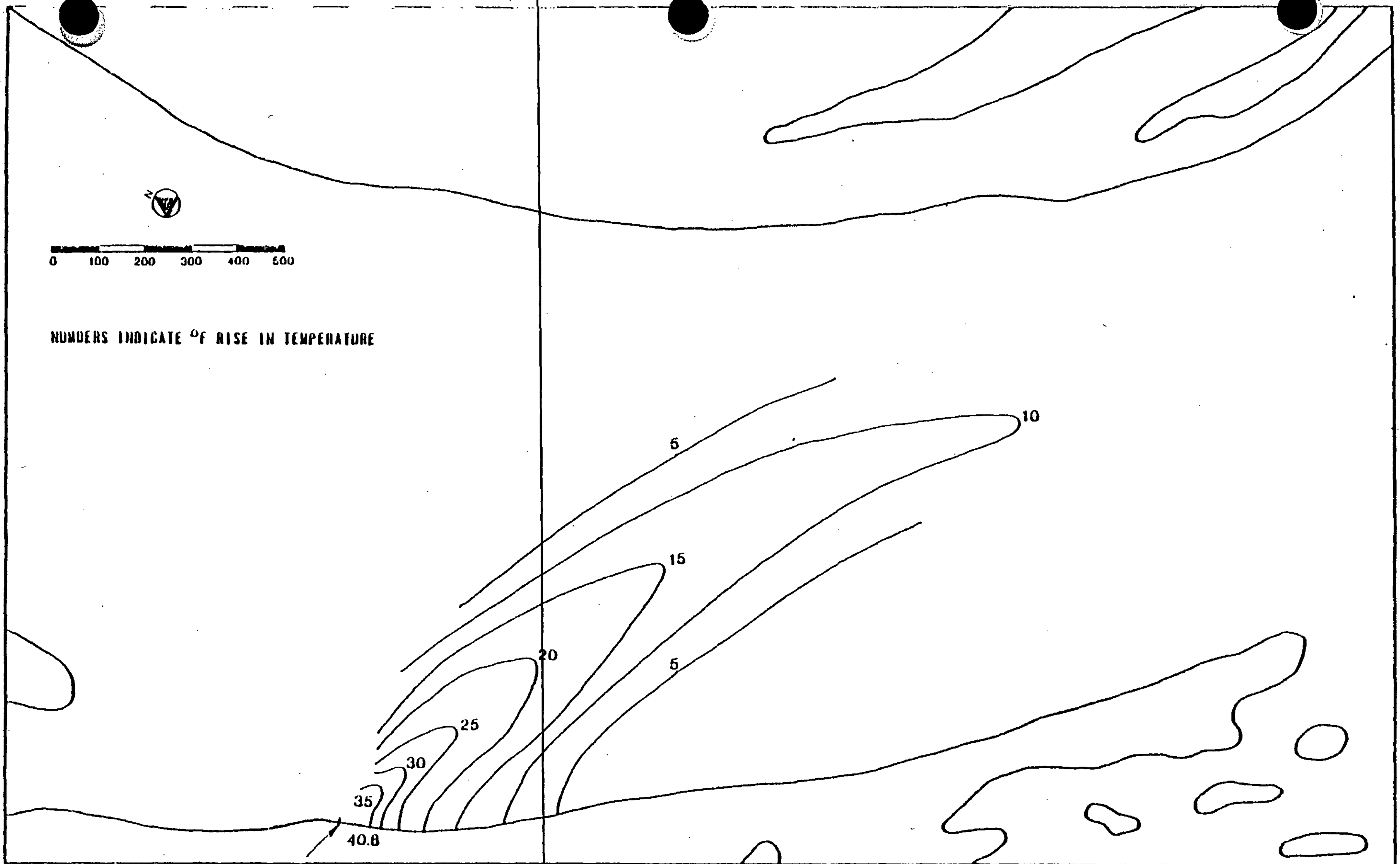


FIGURE 6-14

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, PROPOSED EXTREME CONDITION, DECEMBER
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

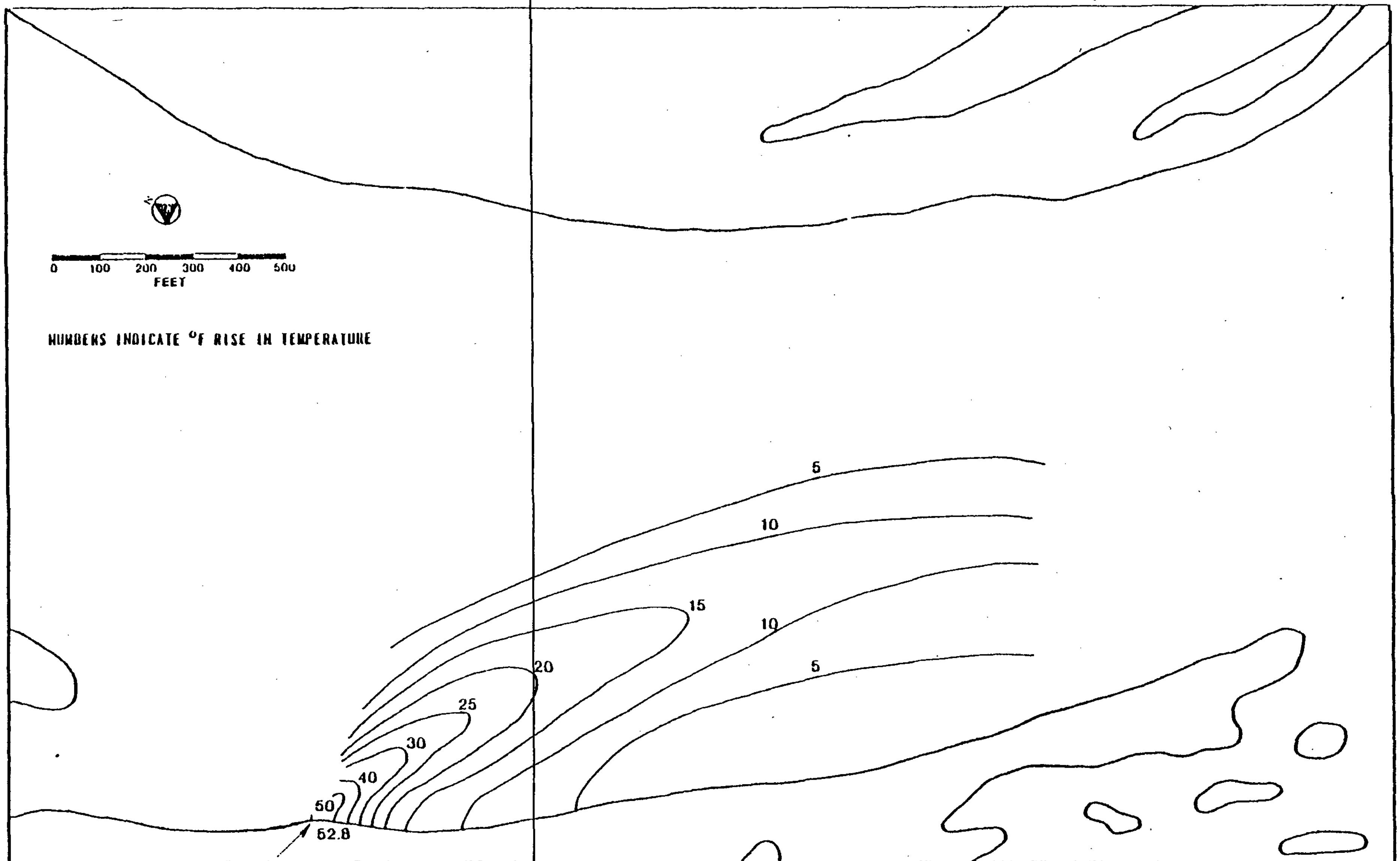


FIGURE 6-15

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, VARIATION OF PROPOSED EXTREME CONDITION, FEBRUARY NO.1

THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

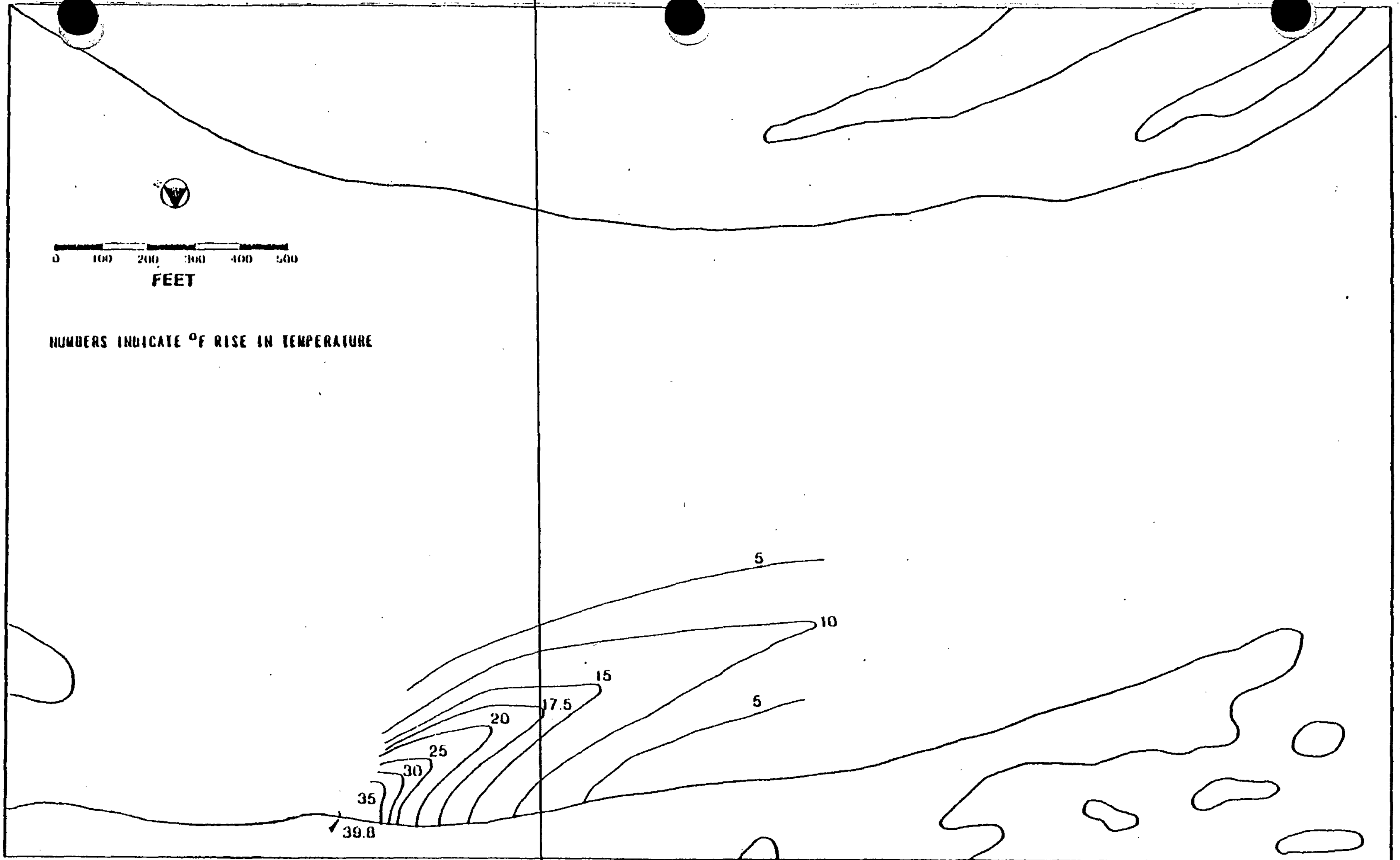


FIGURE 6-16

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, VARIATION OF PROPOSED EXTREME CONDITION, MARCH NO. I
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

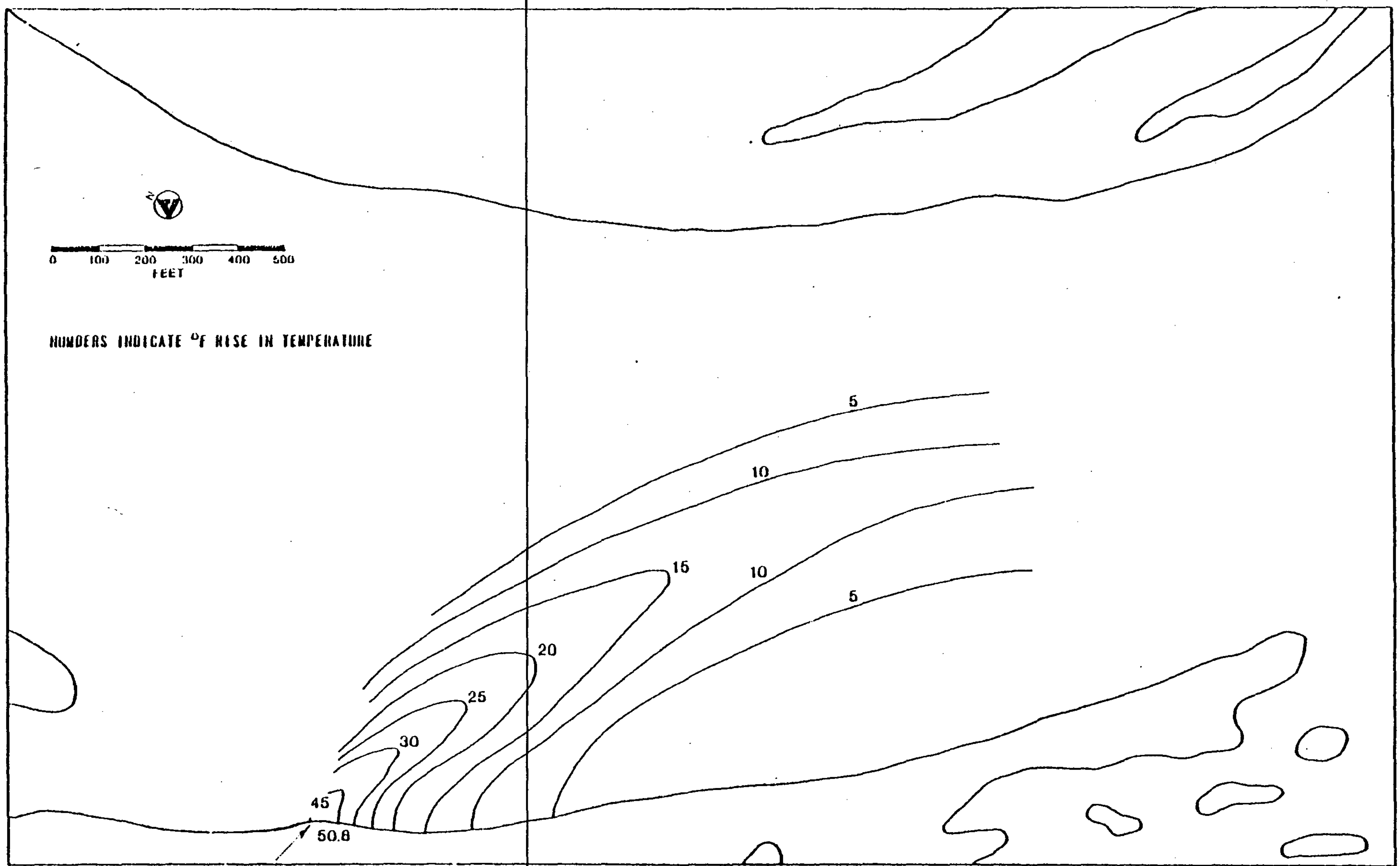


FIGURE 6-17

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, VARIATION OF PROPOSED EXTREME CONDITION, MARCH NO. 2
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

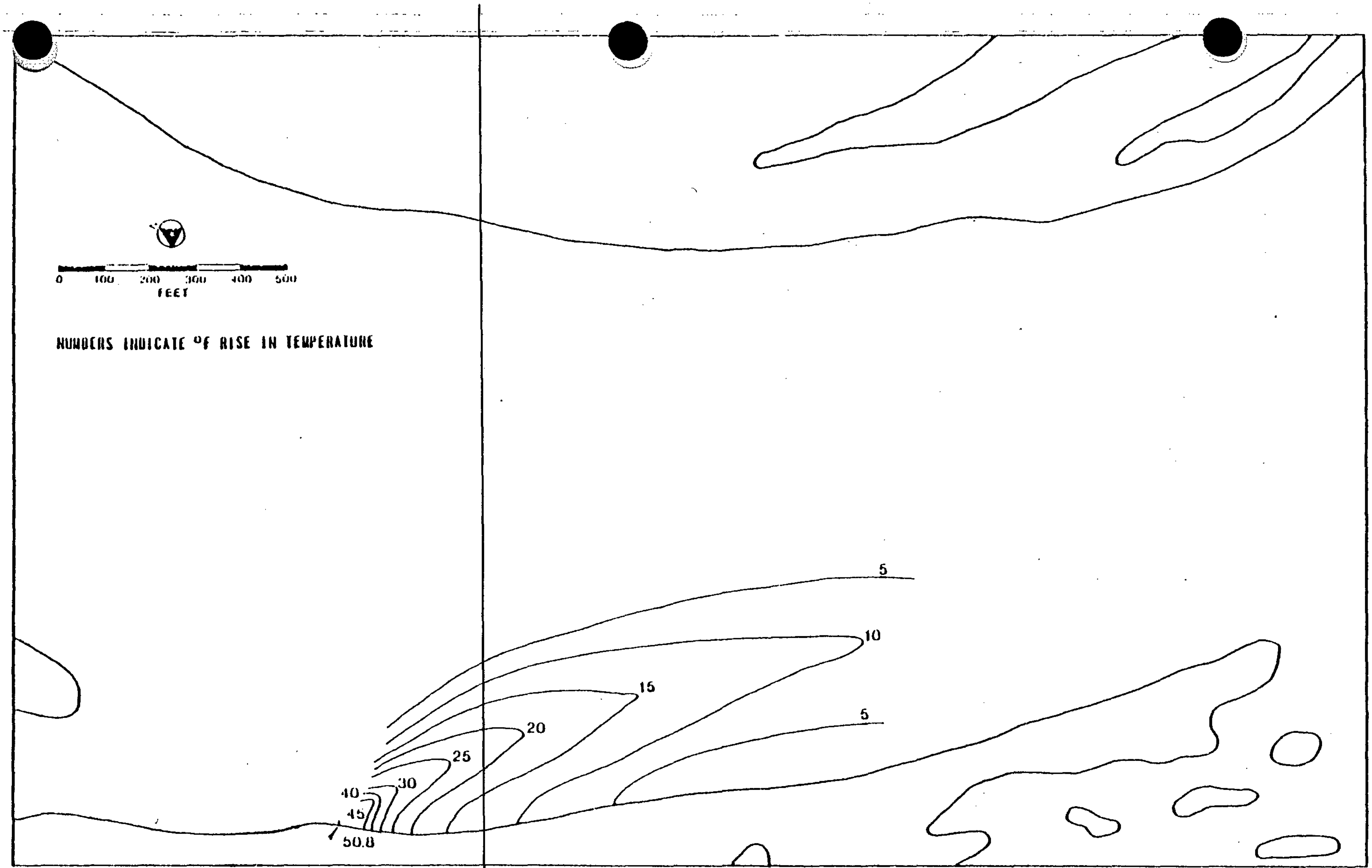


FIGURE 6-18

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, VARIATION OF PROPOSED EXTREME CONDITION, MARCH NO.3
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

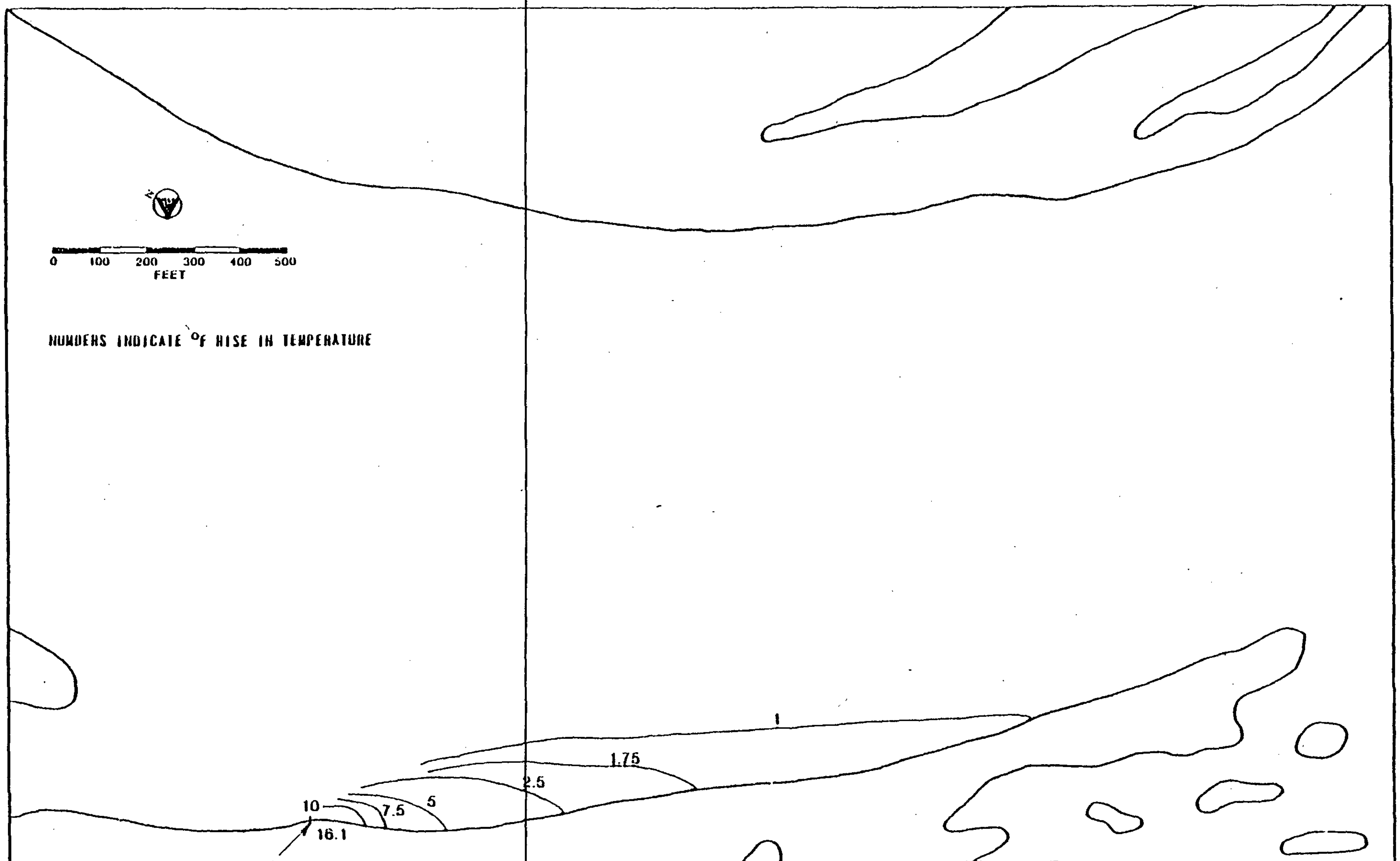


FIGURE 6-19

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, VARIATION OF PROPOSED EXTREME CONDITION, MAY NO. 1

THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

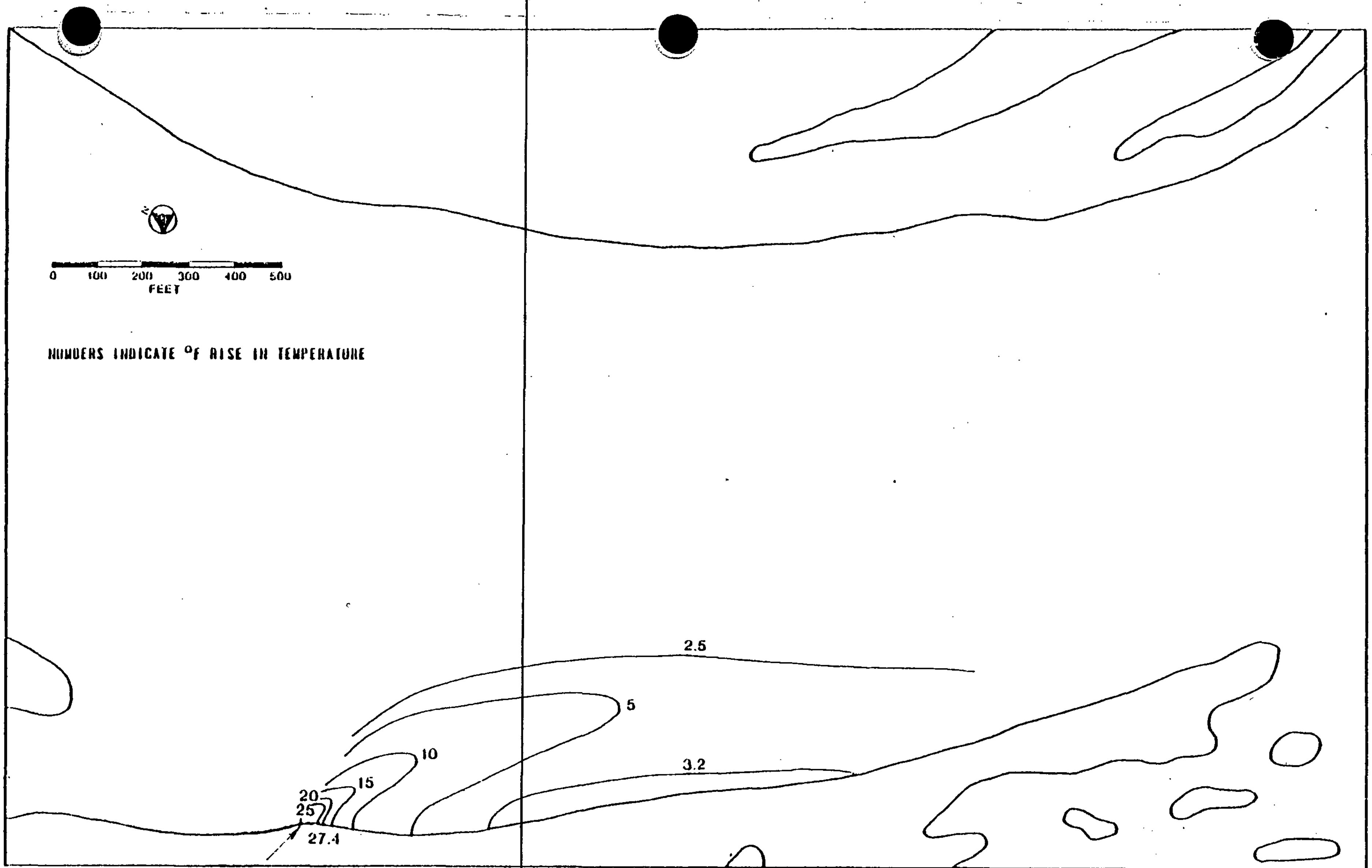


FIGURE 6-20

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, VARIATION OF PROPOSED EXTREME CONDITION, MAY NO. 2
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

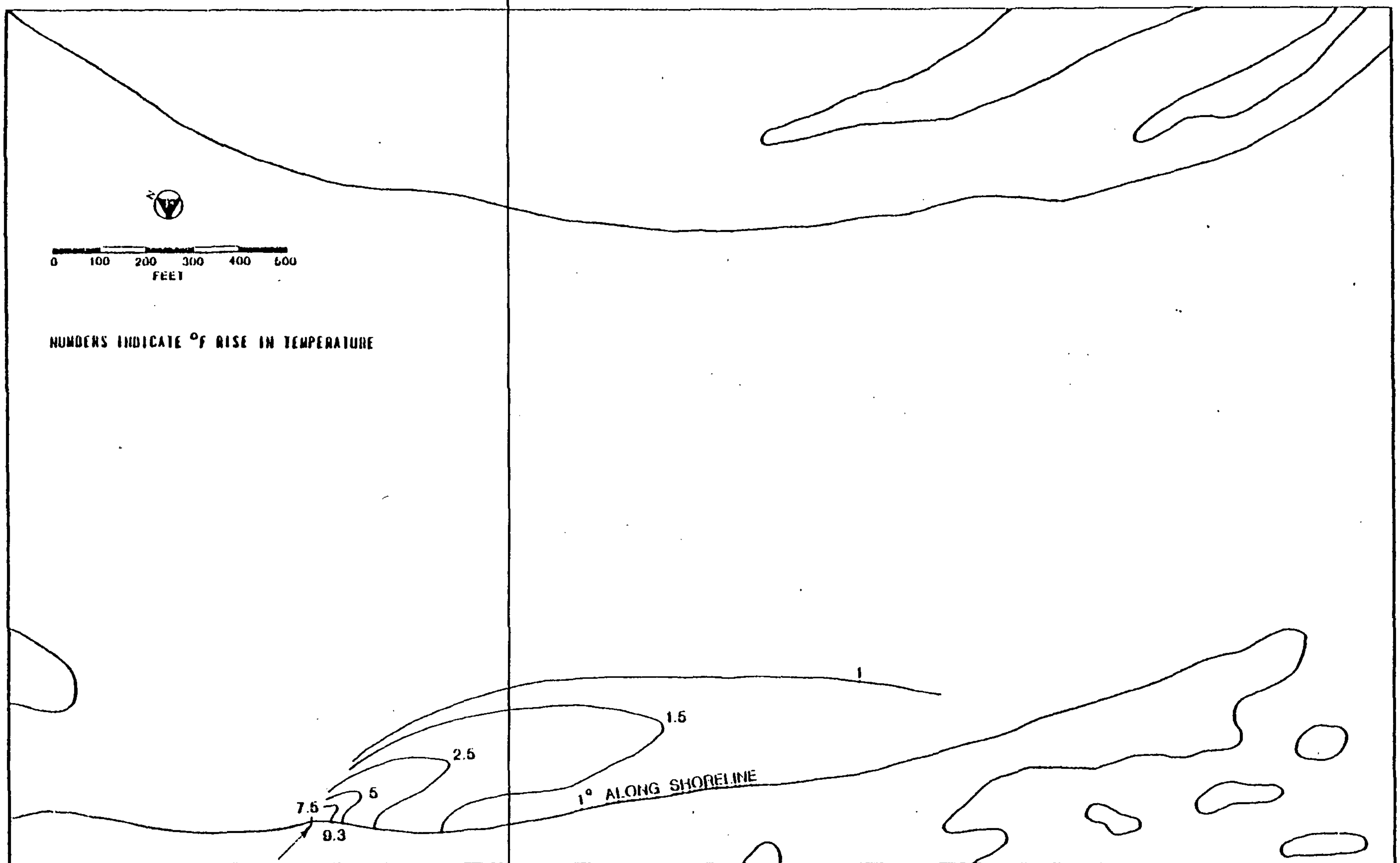


FIGURE 6-21

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, VARIATION OF PROPOSED EXTREME CONDITION, MAY NO. 3
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

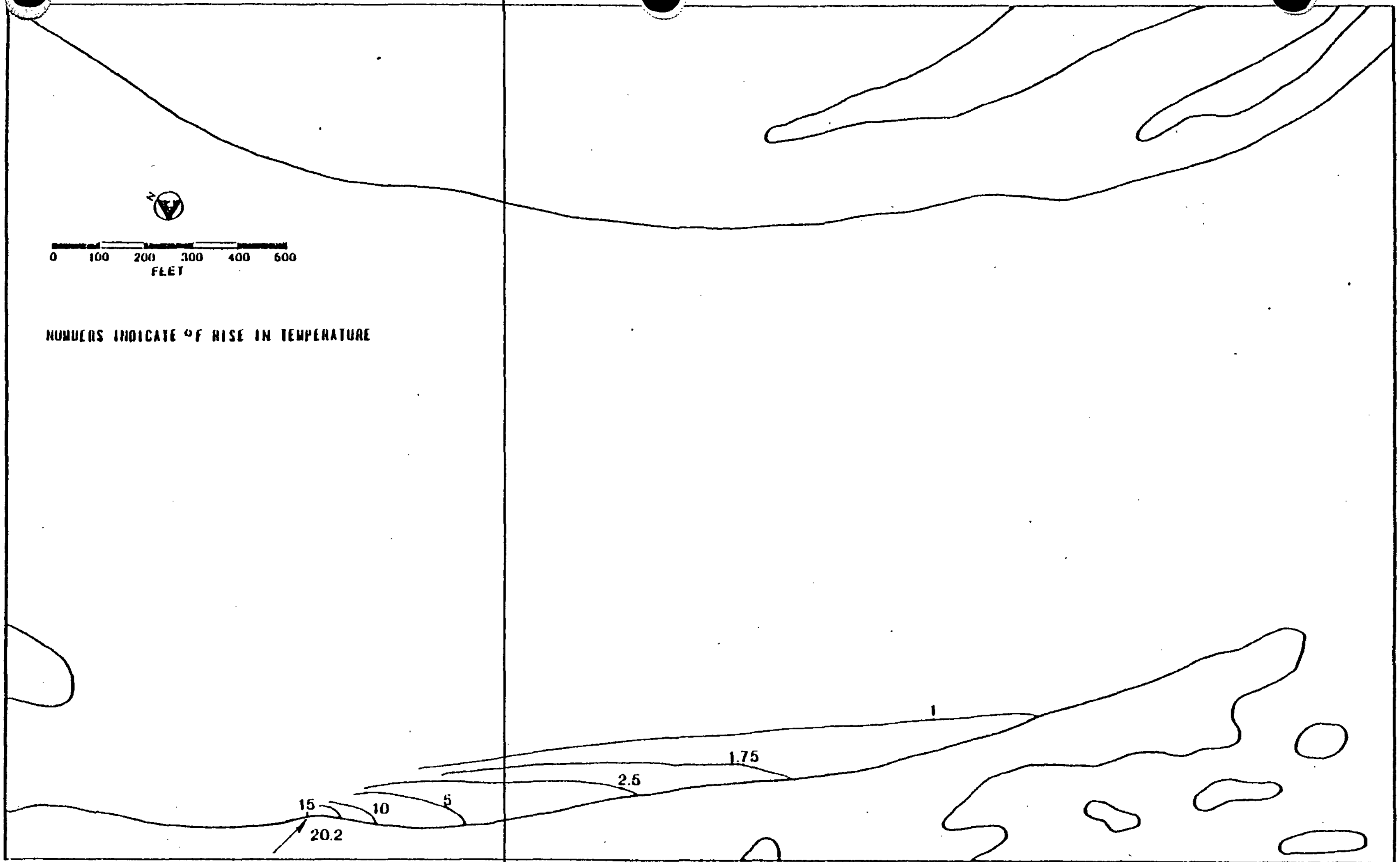


FIGURE 6-22

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, VARIATION OF PROPOSED EXTREME CONDITION, MAY NO. 4
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

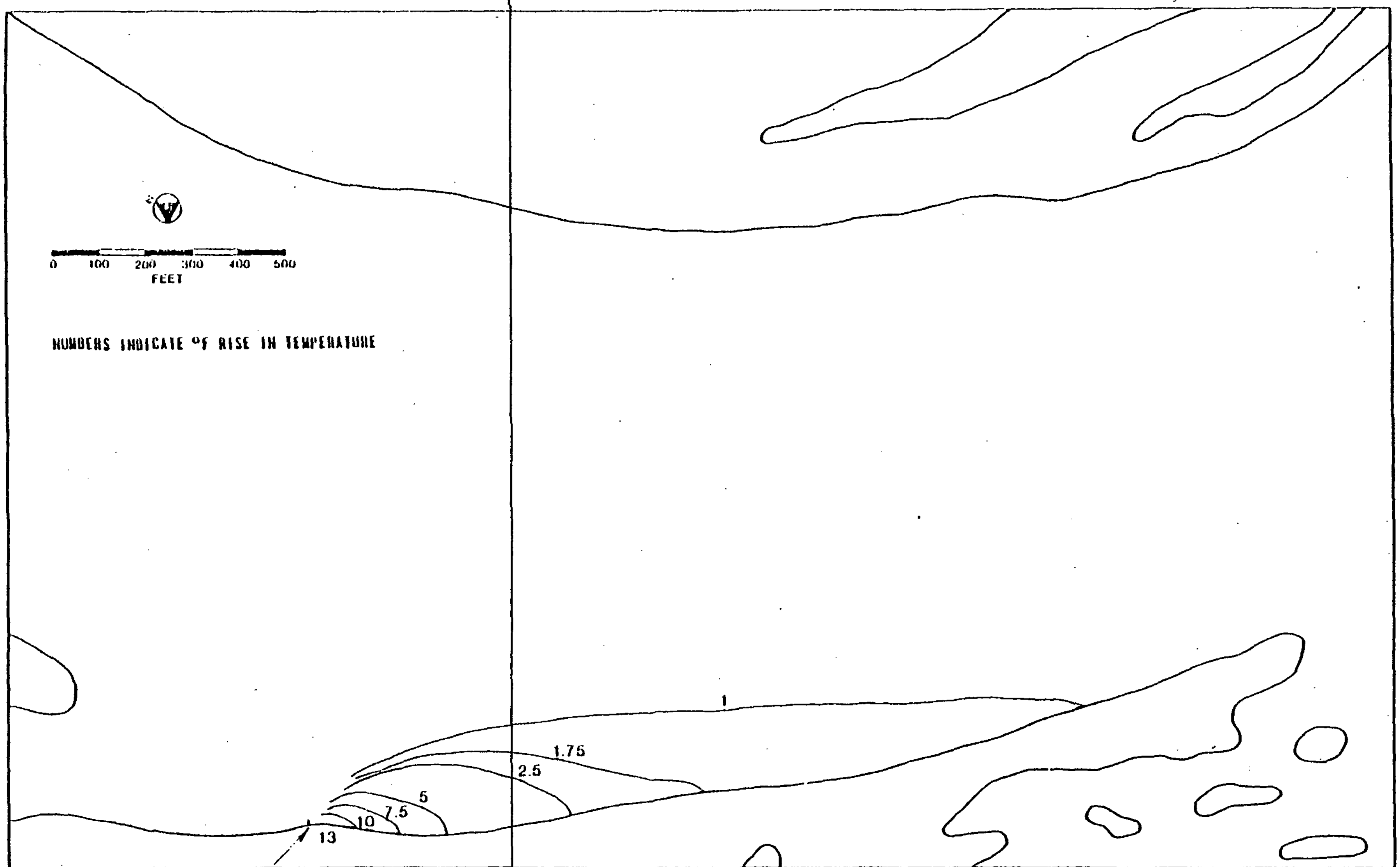


FIGURE 6-23

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, VARIATION OF PROPOSED EXTREME CONDITION, JUNE NO. I
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

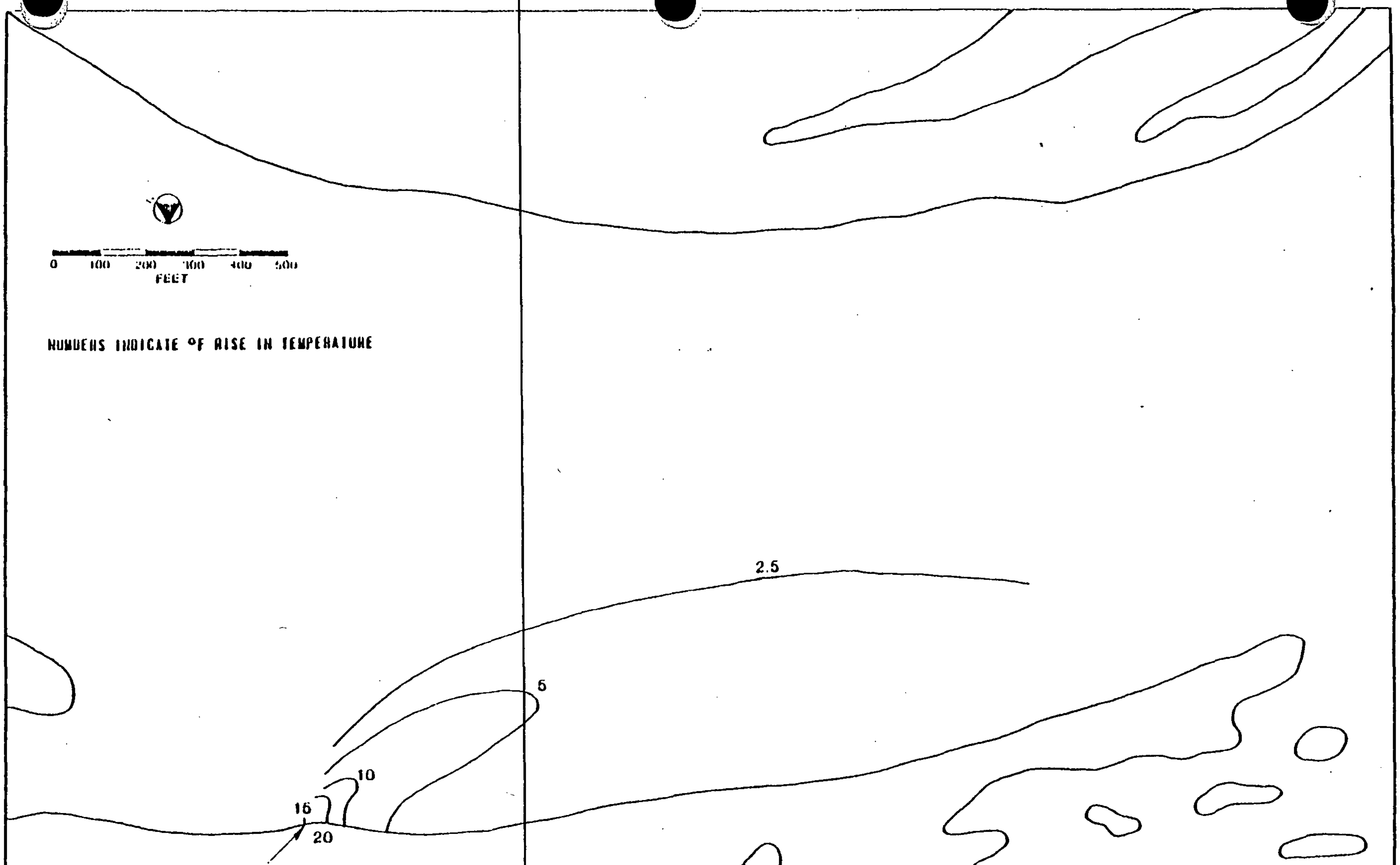


FIGURE 6-24

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, VARIATION OF PROPOSED EXTREME CONDITION, JUNE NO. 2
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

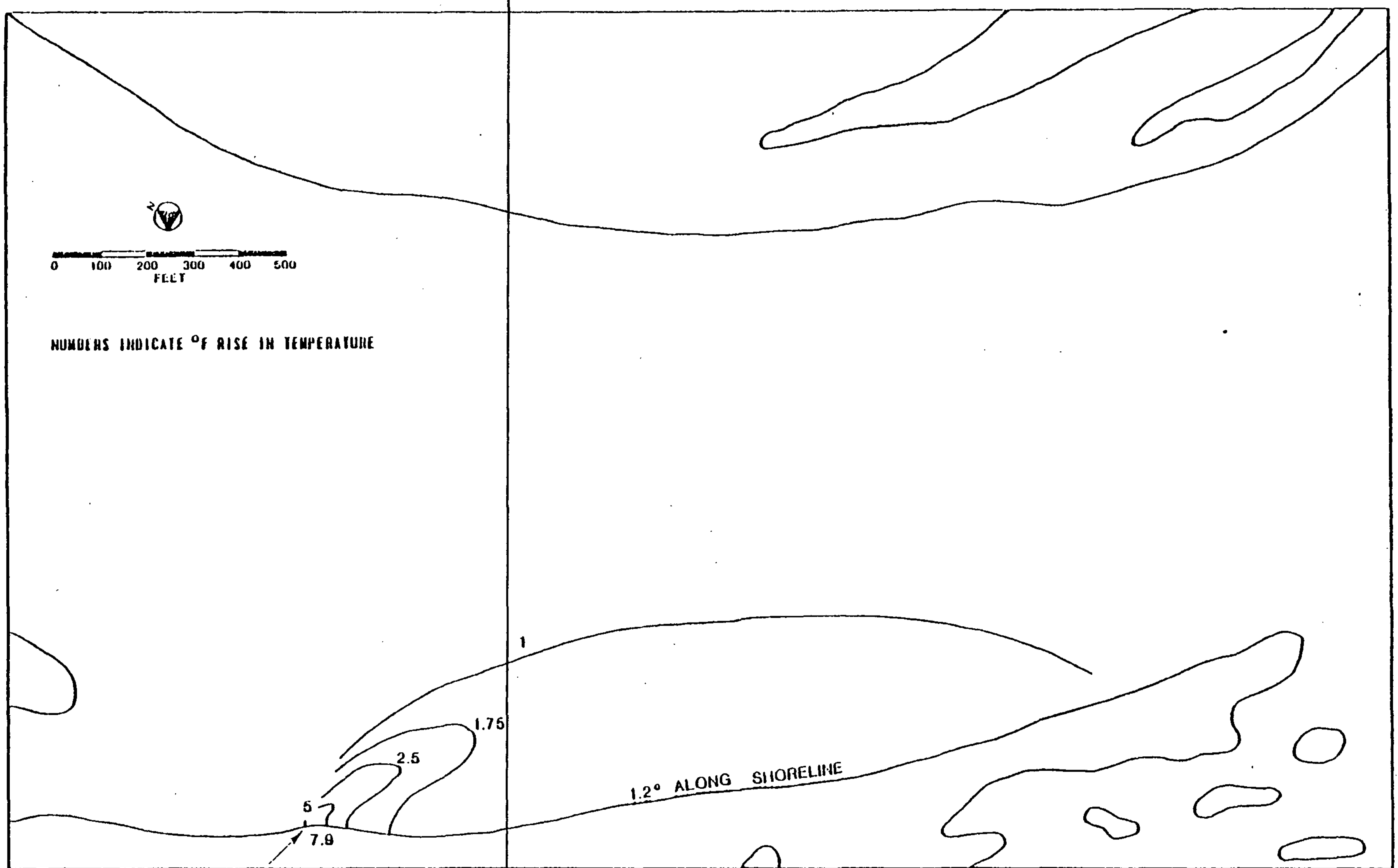
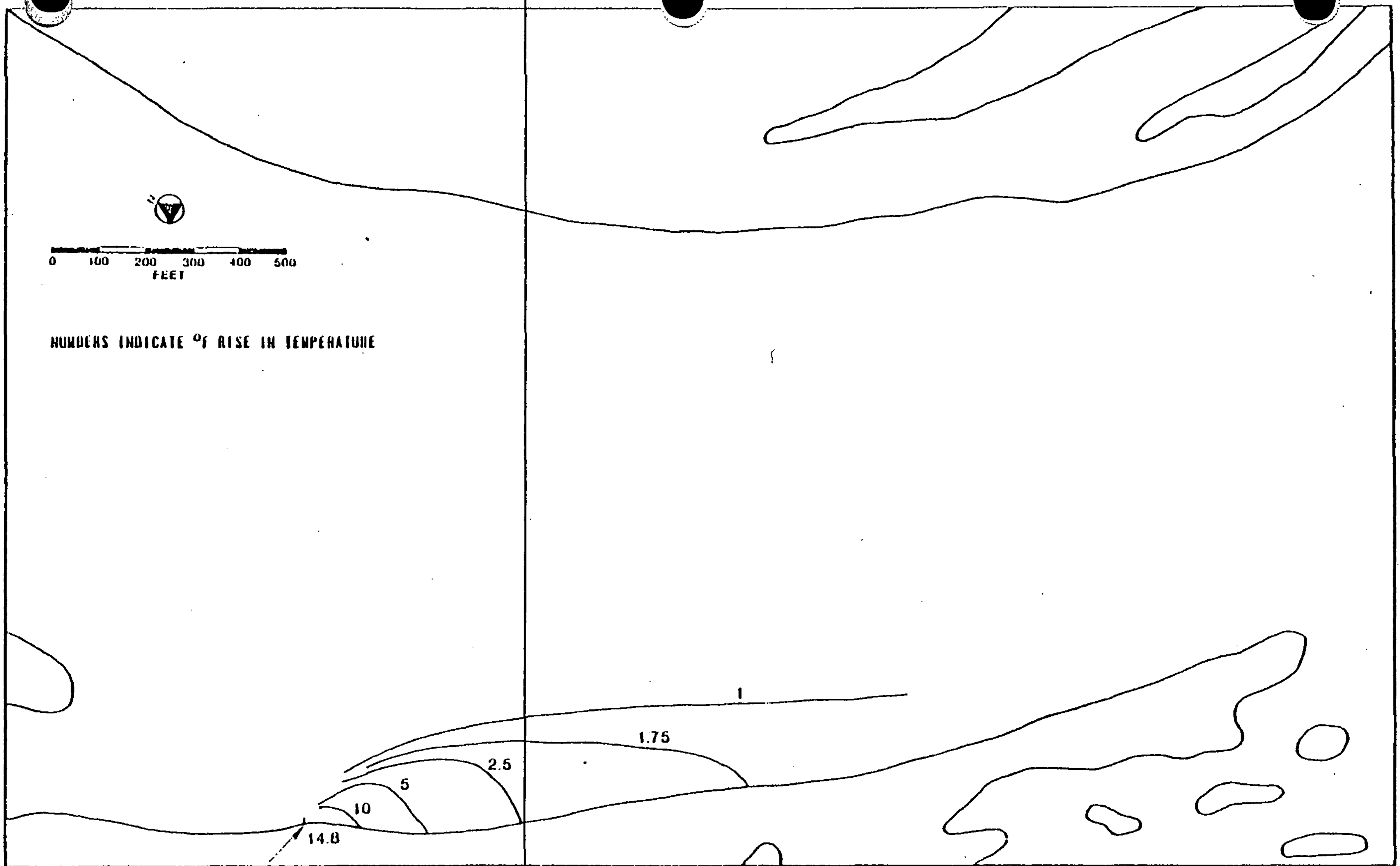


FIGURE 6-25

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, VARIATION OF PROPOSED EXTREME CONDITION, JUNE NO. 3
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY



B-28

FIGURE 6-26

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, VARIATION OF PROPOSED EXTREME CONDITION, JUNE NO. 4
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

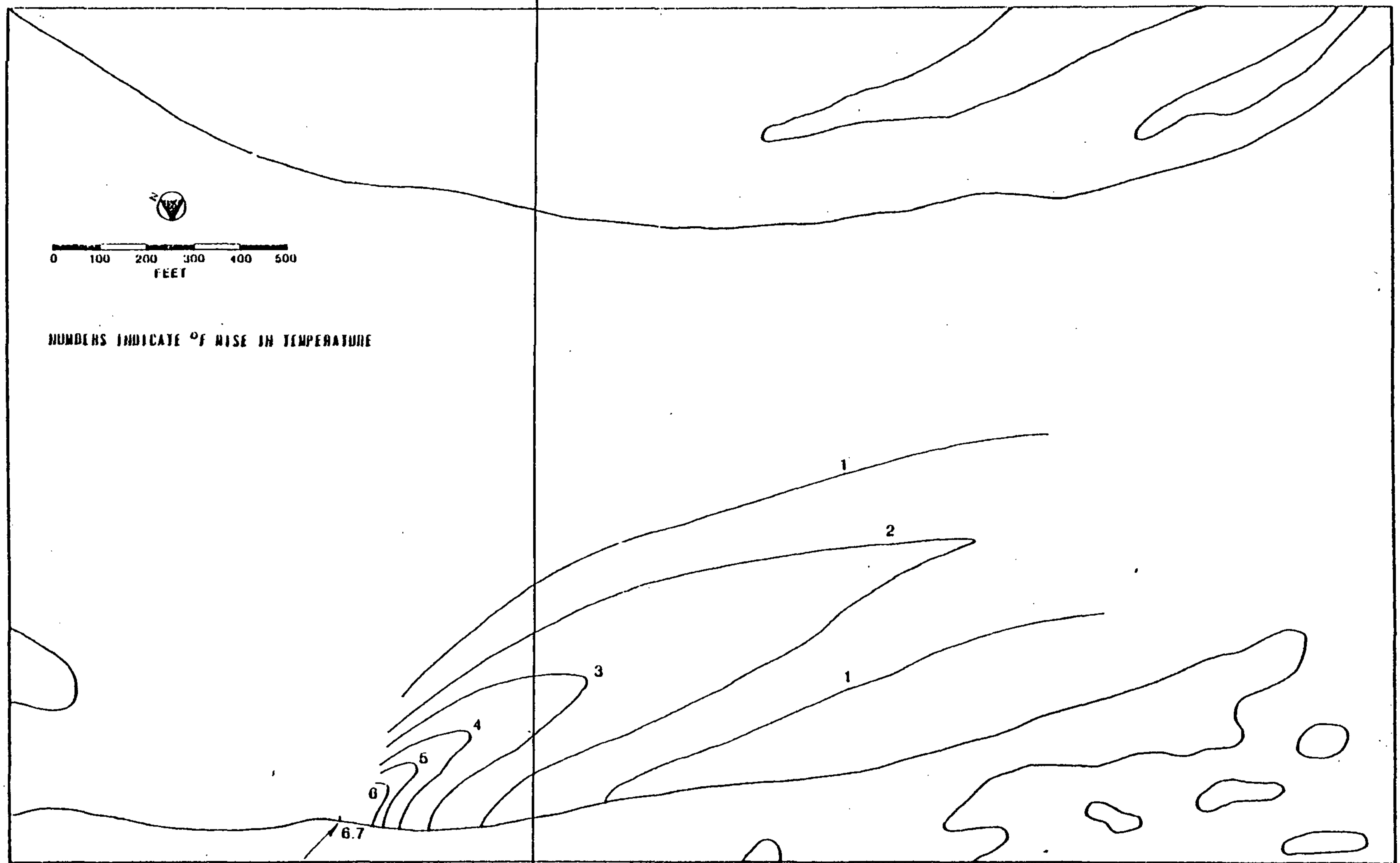
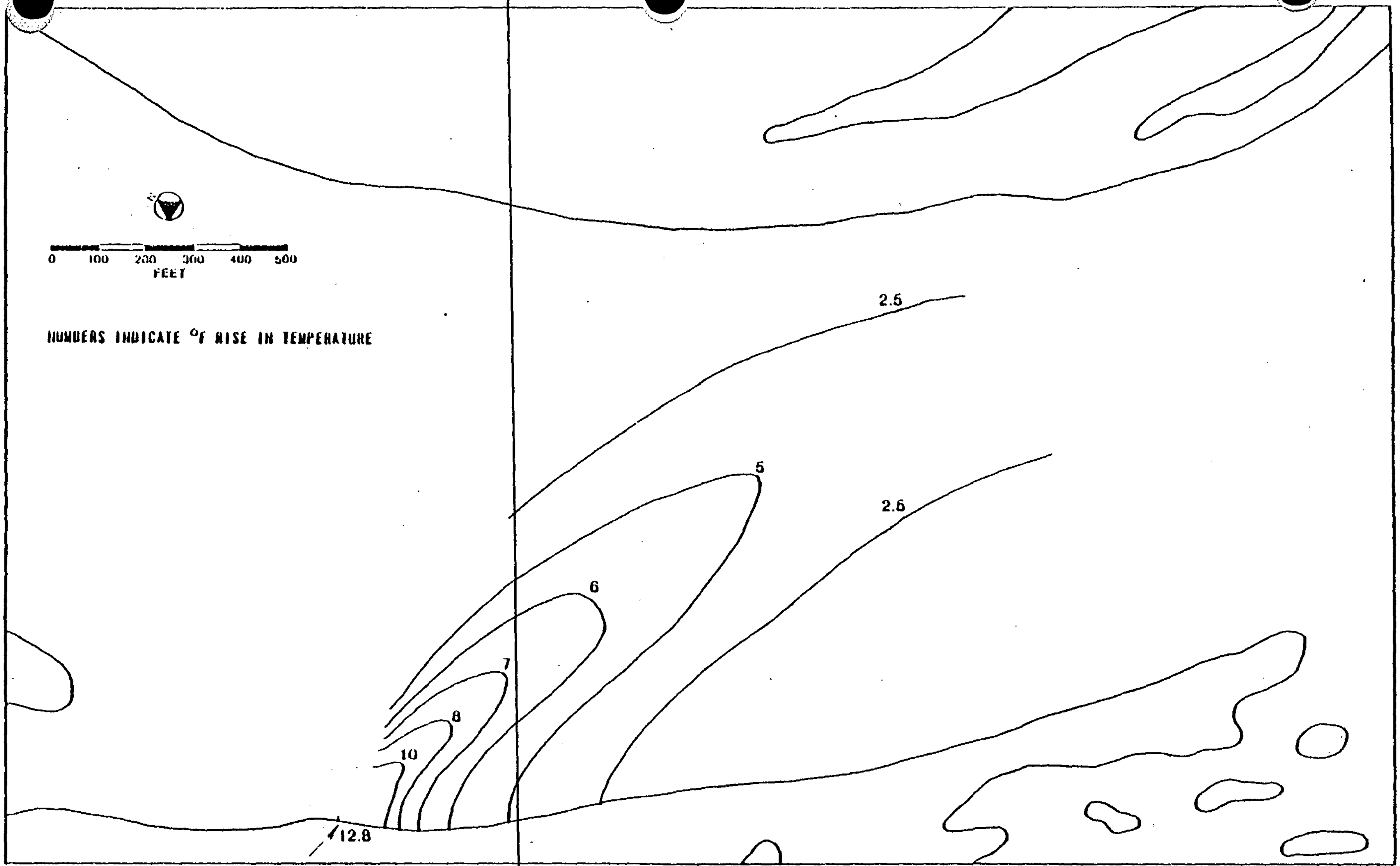


FIGURE 6-27

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, VARIATION OF PROPOSED EXTREME CONDITION, AUGUST NO.1

THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY



B-30

FIGURE 6-28

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, VARIATION OF PROPOSED EXTREME CONDITION, AUGUST NO. 2
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

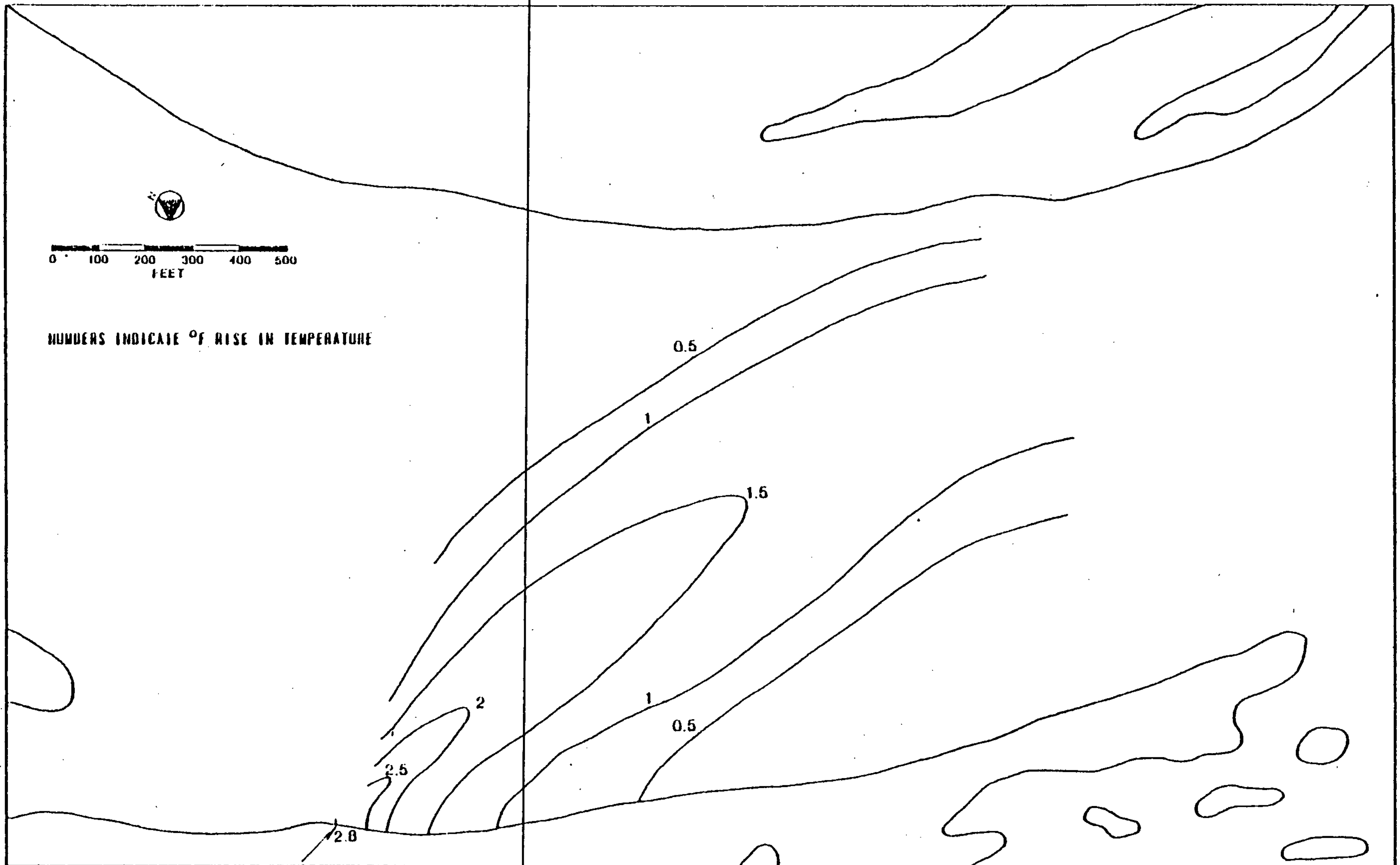
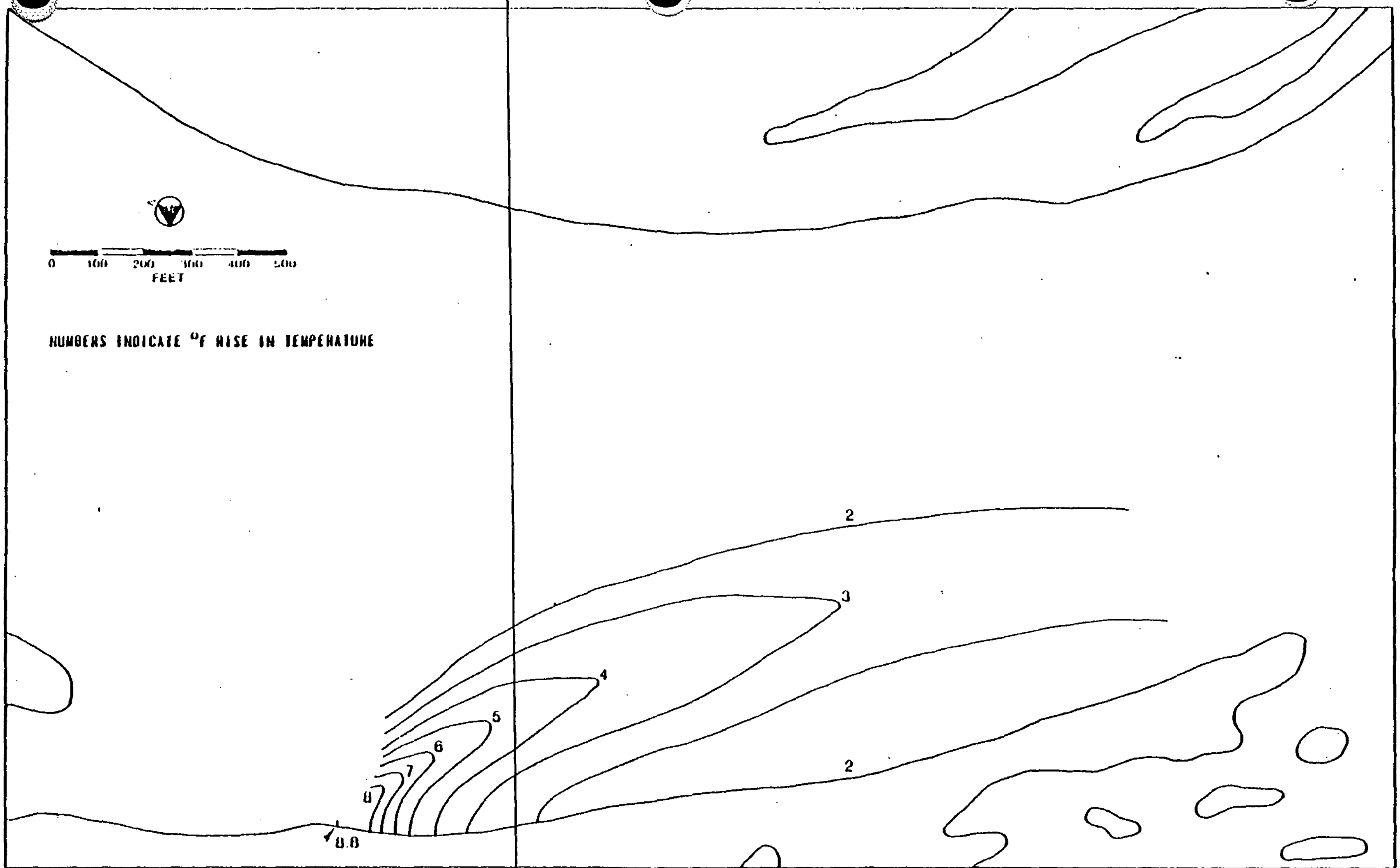


FIGURE 6-29

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, VARIATION OF PROPOSED EXTREME CONDITION, AUGUST NO. 3
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY



B-32

FIGURE 6-30

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, VARIATION OF PROPOSED EXTREME CONDITION, AUGUST NO. 4
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

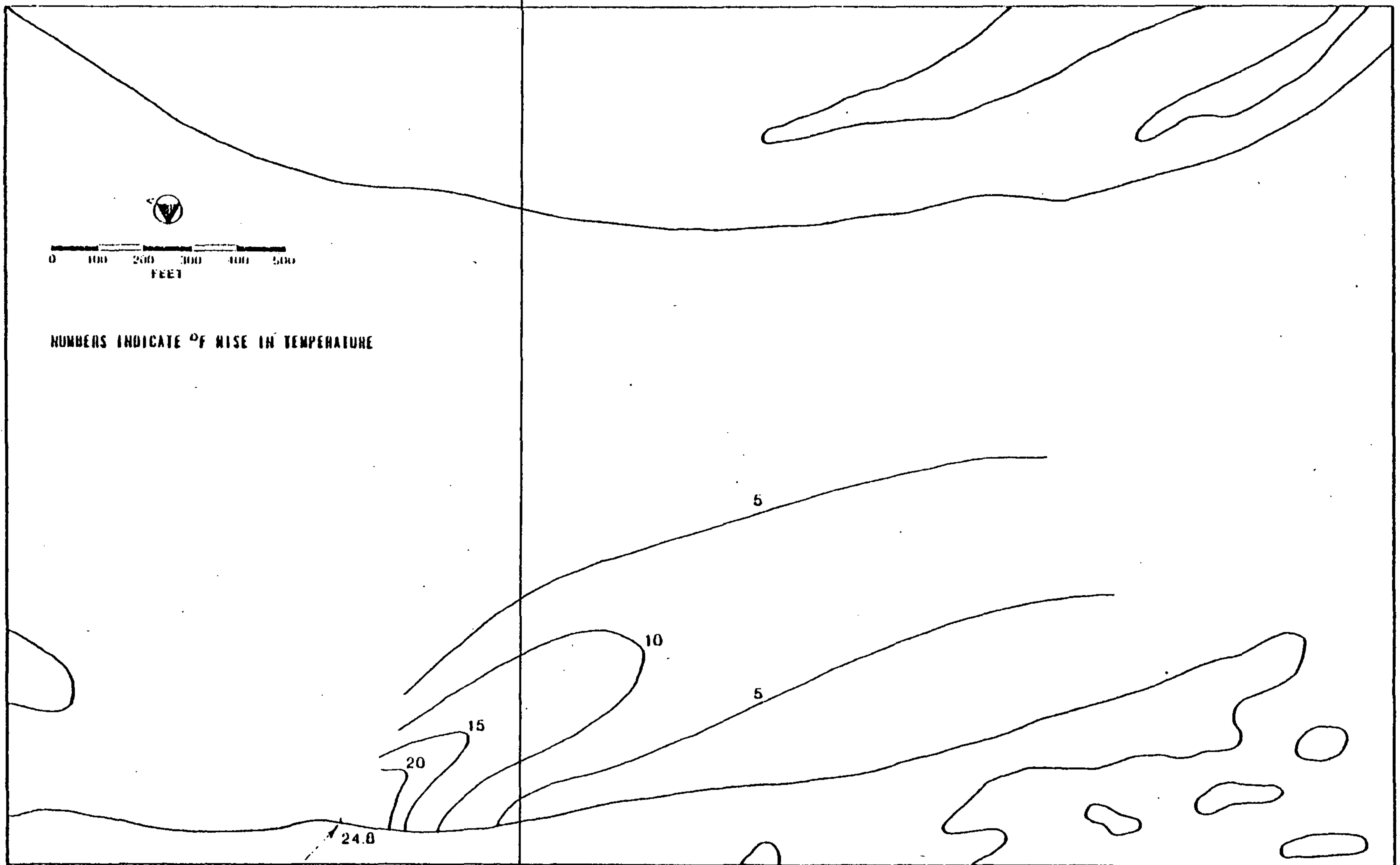


FIGURE 6-31

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, VARIATION OF PROPOSED EXTREME CONDITION, NOVEMBER NO.1
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

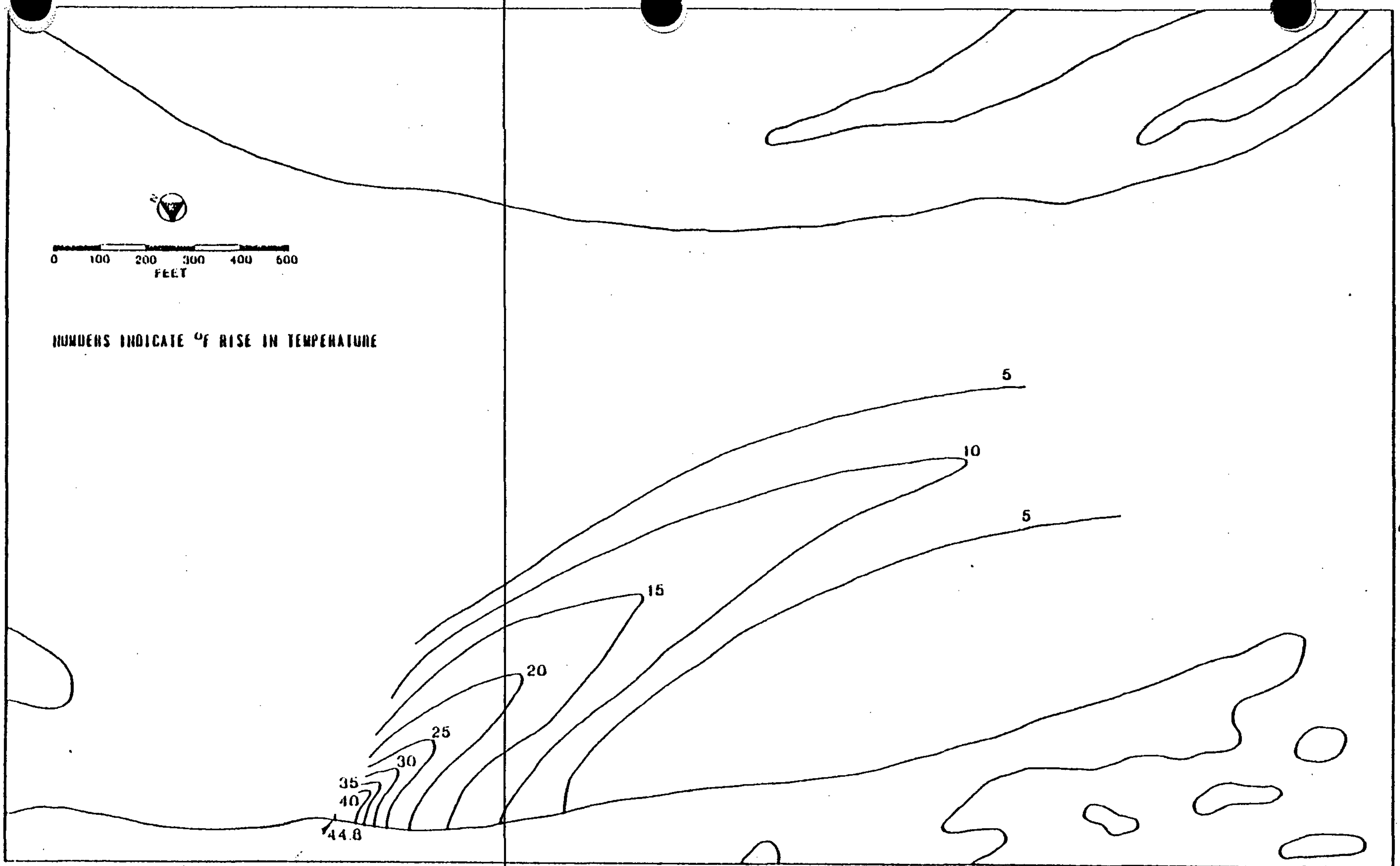


FIGURE 6-32

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, VARIATION OF PROPOSED EXTREME CONDITION, NOVEMBER NO. 2
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

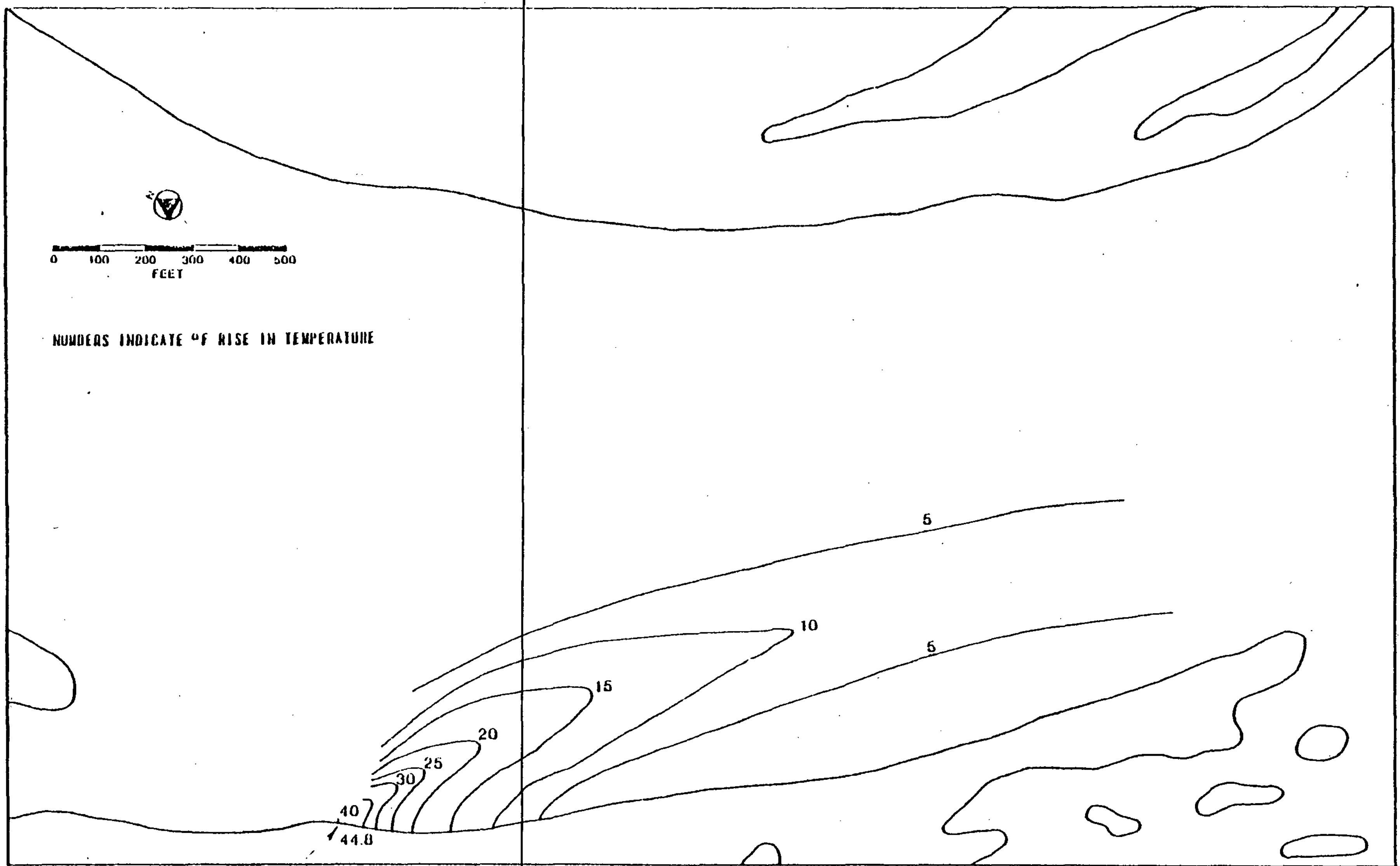


FIGURE 6-33

PREDICTED ISOTHERMAL CONFIGURATION IN THE MISSISSIPPI RIVER, VARIATION OF PROPOSED EXTREME CONDITION, NOVEMBER NO. 3
THERMAL DISCHARGE ANALYSIS
ALTERNATE DISCHARGE SYSTEM
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
N THERN STATES POWER COMPANY

APPENDIX C

UNPUBLISHED LITERATURE

TABLES

The information contained in this appendix was calculated using equations developed by Stone & Webster Engineering Corporation (Stone & Webster, 1979). Computations were based on environmental conditions used in the various model runs and a number of conditions taken from the period 1960 through 1976. The rationale and results are the subject of a report being prepared by NSP, but not completed at the time this document was published.

Surface area within given isotherms and the frequency with which these temperatures occur in the area were computed in order to quantify the predicted biological impacts of the alternate discharge. The results are presented as the percentage of time a particular temperature would be equalled or exceeded within a given area each month (Tables C-1 through C-21). All cases when river ambient temperature exceeded the given temperature were excluded, and the frequency with which ambient temperature exceeded the given temperature was noted. No calculations were made for April, but blowdown would be very low (150 cfs) and river flow would be high, thus, making the isotherms very small.

Table C-22 presents the percentage of time that ambient river temperatures occur each month during the period 1960 through 1976. This is based on intake temperature records at Red Wing Gnerating Plant (RWGP) located about 15 km (9.4 mi) downriver from PINGP.

The percentage of time that various temperatures and ΔTs would occur at a distance of 305, 610, and 915 m (1,000, 2,000, and 3,000 ft) down the centerline of the plume were also calculated for each month (Tables C-23 through C-28) in order to predict whether the plume would comply with state temperature standards.

Table C-1. Summary of the estimated percentage of time that the area within the 18° C (64.4° F) isotherm equals or exceeds the given areas (excluding instances when river temperature exceeds 18° C).

PERCENTAGE OF TIME AREA WITHIN 64.4 F ISOTHERM EQUALS OR EXCEEDS GIVEN AREAS

AREA HECTARES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
= CSSV4216.03840.03944.0 0.04194.03395.03906.03916.03756.03843.03808.04200.0												
1.0E-5	0.0	0.0	4.7	0.0	84.3	7.5	0.0	0.0	37.7	72.3	57.4	1.0
0.0001	0.0	0.0	4.7	0.0	84.3	7.5	0.0	0.0	37.7	72.3	57.4	1.0
0.001	0.0	0.0	4.7	0.0	84.3	7.5	0.0	0.0	37.7	72.3	57.4	1.0
0.005	0.0	0.0	4.3	0.0	82.2	7.5	0.0	0.0	37.7	72.1	57.1	1.0
0.01	0.0	0.0	2.4	0.0	74.5	7.5	0.0	0.0	37.7	70.8	52.3	1.0
0.05	0.0	0.0	0.0	0.0	45.8	7.5	0.0	0.0	36.3	50.5	16.0	0.0
0.1	0.0	0.0	0.0	0.0	33.3	7.3	0.0	0.0	35.3	39.7	9.7	0.0
0.5	0.0	0.0	0.0	0.0	12.6	6.0	0.0	0.0	31.5	23.5	0.2	0.0
1.0	0.0	0.0	0.0	0.0	6.8	4.5	0.0	0.0	26.7	18.5	0.0	0.0
2.5	0.0	0.0	0.0	0.0	3.9	3.9	0.0	0.0	25.5	14.4	0.0	0.0

Table C-2. Summary of the estimated percentage of time that the area within the 19° C (66.2° F) isotherm equals or exceeds the given areas (excluding instances when river temperature exceeds 19° C).

PERCENTAGE OF TIME AREA WITHIN 66.2 F ISOTHERM EQUALS OR EXCEEDS GIVEN AREAS

AREA HECTARES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
~~= CSSV4216.03840.03944.0 0.04194.03395.03906.03916.03756.03843.03808.04200.0~~												
1.0E-5	0.0	0.0	2.2	0.0	91.3	17.4	0.0	0.8	51.7	57.8	41.0	0.8
0.0001	0.0	0.0	2.2	0.0	91.3	17.4	0.0	0.8	51.7	57.8	41.0	0.8
0.001	0.0	0.0	2.2	0.0	91.3	17.4	0.0	0.8	51.7	57.8	41.0	0.8
0.005	0.0	0.0	2.2	0.0	85.4	17.4	0.0	0.8	51.7	57.7	41.0	0.8
0.01	0.0	0.0	1.0	0.0	74.0	17.4	0.0	0.8	51.7	56.3	34.5	0.8
0.05	0.0	0.0	0.0	0.0	37.7	17.1	0.0	0.8	43.7	37.1	10.7	0.0
0.1	0.0	0.0	0.0	0.0	25.3	16.5	0.0	0.8	46.9	28.1	8.0	0.0
0.5	0.0	0.0	0.0	0.0	8.2	13.5	0.0	0.8	39.4	15.3	0.0	0.0
1.0	0.0	0.0	0.0	0.0	6.0	11.8	0.0	0.8	35.3	12.3	0.0	0.0
2.5	0.0	0.0	0.0	0.0	3.7	8.2	0.0	0.8	29.5	7.8	0.0	0.0

Table C-3. Summary of the estimated percentage of time that the area within the 20° C (68.0° F) isotherm equals or exceeds the given areas (excluding instances when river temperature exceeds 20° C).

PERCENTAGE OF TIME AREA WITHIN 68.0 F ISOTHERM EQUALS OR EXCEEDS GIVEN AREAS

AREA HECTARES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
= OBSV4216.03840.03944.0				0.04194.03395.03906.03916.03756.03843.03808.04200.0								
1.0E-5	0.0	0.0	1.0	0.0	93.7	27.7	1.0	2.1	56.1	43.3	27.9	0.2
0.0001	0.0	0.0	1.0	0.0	93.7	27.7	1.0	2.1	56.1	43.3	27.9	0.2
0.001	0.0	0.0	1.0	0.0	93.6	27.7	1.0	2.1	56.1	43.3	27.9	0.2
0.005	0.0	0.0	0.8	0.0	81.2	27.7	1.0	2.1	56.1	43.1	27.7	0.2
0.01	0.0	0.0	0.6	0.0	65.8	27.7	1.0	2.1	56.0	41.8	24.4	0.2
0.05	0.0	0.0	0.0	0.0	24.5	26.6	1.0	2.1	51.7	25.4	9.5	0.0
0.1	0.0	0.0	0.0	0.0	13.3	25.0	1.0	2.1	47.4	18.2	2.5	0.0
0.5	0.0	0.0	0.0	0.0	4.9	13.1	1.0	2.1	33.8	7.5	0.0	0.0
1.0	0.0	0.0	0.0	0.0	3.3	12.8	1.0	2.1	27.3	3.9	0.0	0.0
2.5	0.0	0.0	0.0	0.0	0.7	6.7	1.0	2.0	20.3	1.0	0.0	0.0

Table C-4. Summary of the estimated percentage of time that the area within the 21° C (69.8° F) isotherm equals or exceeds the given areas (excluding instances when river temperature exceeds 21° C).

PERCENTAGE OF TIME AREA WITHIN 69.8 F ISOTHERM EQUALS OR EXCEEDS GIVEN AREAS

AREA HECTARES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
= OBSV4216.03840.03944.0				0.04194.03395.03906.03916.03756.03843.03808.04200.0								
1.0E-5	0.0	0.0	0.6	0.0	96.2	42.6	2.9	6.3	65.1	30.8	22.7	0.0
0.0001	0.0	0.0	0.6	0.0	96.2	42.6	2.9	6.3	65.1	30.8	22.7	0.0
0.001	0.0	0.0	0.6	0.0	96.0	42.6	2.9	6.3	65.1	30.8	22.7	0.0
0.005	0.0	0.0	0.6	0.0	75.3	42.6	2.9	6.3	65.1	30.7	21.0	0.0
0.01	0.0	0.0	0.6	0.0	53.7	42.3	2.9	6.3	64.7	28.8	18.3	0.0
0.05	0.0	0.0	0.0	0.0	14.9	39.4	2.9	6.3	56.2	15.6	6.5	0.0
0.1	0.0	0.0	0.0	0.0	9.4	33.4	2.9	6.3	49.4	10.1	0.2	0.0
0.5	0.0	0.0	0.0	0.0	3.1	20.6	2.9	6.1	32.1	1.2	0.0	0.0
1.0	0.0	0.0	0.0	0.0	1.1	14.8	2.9	5.7	25.3	0.2	0.0	0.0
2.5	0.0	0.0	0.0	0.0	0.0	9.6	2.2	5.2	18.5	0.0	0.0	0.0

Table C-5. Summary of the estimated percentage of time that the area within the 23.3° C (73.9° F) isotherm equals or exceeds the given areas (excluding instances when river temperature exceeds 23.3° C).

PERCENTAGE OF TIME AREA WITHIN 73.9 F ISOTHERM EQUALS OR EXCEEDS GIVEN AREAS

AREA HECTARES	JAN	FES	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
= CBSV4216.03840.03944.0 0.04194.03395.03906.03916.03756.03843.03808.04200.0												
1.0E-5	0.0	0.0	0.0	0.0	90.7	80.7	19.2	32.9	59.6	9.3	8.0	0.0
0.0001	0.0	0.0	0.0	0.0	90.7	80.7	19.2	32.9	59.6	9.3	8.0	0.0
0.001	0.0	0.0	0.0	0.0	89.3	80.7	19.2	32.9	59.6	9.3	8.0	0.0
0.005	0.0	0.0	0.0	0.0	43.7	80.1	19.2	32.9	59.6	9.3	8.0	0.0
0.01	0.0	0.0	0.0	0.0	22.6	77.2	19.2	32.9	59.1	8.7	7.8	0.0
0.05	0.0	0.0	0.0	0.0	4.2	54.1	18.7	32.2	43.6	1.4	0.0	0.0
0.1	0.0	0.0	0.0	0.0	1.6	44.8	18.0	31.2	33.2	0.1	0.0	0.0
0.5	0.0	0.0	0.0	0.0	0.4	28.0	15.6	26.6	19.4	0.0	0.0	0.0
1.0	0.0	0.0	0.0	0.0	0.2	22.8	14.1	23.4	14.2	0.0	0.0	0.0
2.5	0.0	0.0	0.0	0.0	0.0	16.4	11.2	18.5	10.4	0.0	0.0	0.0

Table C-6. Summary of the estimated percentage of time that the area within the 24° C (75.2° F) isotherm equals or exceeds the given areas (excluding instances when river temperature exceeds 24° C).

PERCENTAGE OF TIME AREA WITHIN 75.2 F ISOTHERM EQUALS OR EXCEEDS GIVEN AREAS

AREA HECTARES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
= CBSV4216.03840.03944.0 0.04194.03395.03906.03916.03756.03843.03808.04200.0												
1.0E-5	0.0	0.0	0.0	0.0	83.1	89.8	33.3	54.9	51.1	4.2	4.6	0.0
0.0001	0.0	0.0	0.0	0.0	83.1	89.8	33.3	54.9	51.1	4.2	4.6	0.0
0.001	0.0	0.0	0.0	0.0	81.2	89.8	33.3	54.9	51.1	4.2	4.6	0.0
0.005	0.0	0.0	0.0	0.0	33.4	89.3	33.3	54.9	51.1	4.2	4.6	0.0
0.01	0.0	0.0	0.0	0.0	14.6	83.1	33.2	54.8	50.6	4.1	4.6	0.0
0.05	0.0	0.0	0.0	0.0	1.9	53.4	31.9	52.9	34.2	0.4	0.0	0.0
0.1	0.0	0.0	0.0	0.0	0.5	43.5	30.7	50.6	26.2	0.0	0.0	0.0
0.5	0.0	0.0	0.0	0.0	0.0	25.7	24.7	41.4	13.8	0.0	0.0	0.0
1.0	0.0	0.0	0.0	0.0	0.0	19.5	21.3	37.0	10.3	0.0	0.0	0.0
2.5	0.0	0.0	0.0	0.0	0.0	14.0	18.3	31.2	6.9	0.0	0.0	0.0

Table C-7. Summary of the estimated percentage of time that the area within the 24.5° C (76.1° F) isotherm equals or exceeds the given areas (excluding instances when river temperature exceeds 24.5° C).

PERCENTAGE OF TIME AREA WITHIN 76.1 F ISOTHERM EQUALS OR EXCEEDS GIVEN AREAS

AREA HECTARES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
= OBSV4216.03840.03944.0 0.04194.03395.03906.03916.03756.03843.03808.04200.0												
1.0E-5	0.0	0.0	0.0	0.0	75.7	91.9	46.3	64.2	44.3	2.1	2.1	0.0
0.0001	0.0	0.0	0.0	0.0	75.7	91.9	46.3	64.2	44.3	2.1	2.1	0.0
0.001	0.0	0.0	0.0	0.0	73.4	91.9	46.3	64.2	44.3	2.1	2.1	0.0
0.005	0.0	0.0	0.0	0.0	26.2	89.0	46.3	64.2	44.3	2.1	2.1	0.0
0.01	0.0	0.0	0.0	0.0	11.0	80.2	46.1	64.1	43.8	2.1	2.1	0.0
0.05	0.0	0.0	0.0	0.0	0.7	48.7	43.9	60.4	27.6	0.1	0.0	0.0
0.1	0.0	0.0	0.0	0.0	0.1	38.1	41.4	57.1	20.7	0.0	0.0	0.0
0.5	0.0	0.0	0.0	0.0	0.0	21.0	32.9	44.4	9.9	0.0	0.0	0.0
1.0	0.0	0.0	0.0	0.0	0.0	16.1	29.6	39.0	7.3	0.0	0.0	0.0
2.5	0.0	0.0	0.0	0.0	0.0	10.4	26.2	32.2	4.9	0.0	0.0	0.0

Table C-8. Summary of the estimated percentage of time that the area within the 25° C (77.0° F) isotherm equals or exceeds the given areas (excluding instances when river temperature exceeds 25° C).

PERCENTAGE OF TIME AREA WITHIN 77.0 F ISOTHERM EQUALS OR EXCEEDS GIVEN AREAS

AREA HECTARES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
= OBSV4216.03840.03944.0 0.04194.03395.03906.03916.03756.03843.03808.04200.0												
1.0E-5	0.0	0.0	0.0	0.0	67.4	88.9	45.9	62.3	35.7	1.4	0.4	0.0
0.0001	0.0	0.0	0.0	0.0	67.4	88.9	45.9	62.3	35.7	1.4	0.4	0.0
0.001	0.0	0.0	0.0	0.0	65.7	88.9	45.9	62.3	35.7	1.4	0.4	0.0
0.005	0.0	0.0	0.0	0.0	20.4	84.2	45.9	62.3	35.7	1.4	0.4	0.0
0.01	0.0	0.0	0.0	0.0	7.7	70.3	45.3	62.0	35.3	1.4	0.4	0.0
0.05	0.0	0.0	0.0	0.0	0.2	39.4	40.9	56.5	21.1	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.0	0.0	30.5	36.5	51.1	15.1	0.0	0.0	0.0
0.5	0.0	0.0	0.0	0.0	0.0	13.6	27.8	35.9	6.4	0.0	0.0	0.0
1.0	0.0	0.0	0.0	0.0	0.0	9.3	24.7	29.8	4.4	0.0	0.0	0.0
2.5	0.0	0.0	0.0	0.0	0.0	5.8	21.5	21.8	2.4	0.0	0.0	0.0

Table C-9. Summary of the estimated percentage of time that the area within the 26° C (78.8° F) isotherm equals or exceeds the given areas (excluding instances when river temperature exceeds 26° C).

PERCENTAGE OF TIME AREA WITHIN 78.8 F ISOTHERM EQUALS OR EXCEEDS GIVEN AREAS

AREA HECTARES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
= CBSV4216.03840.03944.0 0.04194.03395.03906.03916.03756.03843.03808.04200.0												
1.0E-5	0.0	0.0	0.0	0.0	51.0	84.8	66.1	79.1	23.9	0.3	0.0	0.0
0.0001	0.0	0.0	0.0	0.0	51.0	84.8	66.1	79.1	23.9	0.3	0.0	0.0
0.001	0.0	0.0	0.0	0.0	49.3	84.8	66.1	79.1	23.9	0.3	0.0	0.0
0.005	0.0	0.0	0.0	0.0	11.3	72.5	66.1	79.0	23.9	0.3	0.0	0.0
0.01	0.0	0.0	0.0	0.0	2.9	57.2	65.1	78.4	23.5	0.3	0.0	0.0
0.05	0.0	0.0	0.0	0.0	0.0	28.3	53.9	66.8	13.4	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.0	0.0	16.5	49.8	57.9	9.6	0.0	0.0	0.0
0.5	0.0	0.0	0.0	0.0	0.0	8.5	39.1	38.7	4.4	0.0	0.0	0.0
1.0	0.0	0.0	0.0	0.0	0.0	6.3	31.4	32.1	3.6	0.0	0.0	0.0
2.5	0.0	0.0	0.0	0.0	0.0	4.3	23.3	24.8	3.0	0.0	0.0	0.0

Table C-10. Summary of the estimated percentage of time that the area within the 27° C (80.6° F) isotherm equals or exceeds the given areas (excluding instances when river temperature exceeds 27° C).

PERCENTAGE OF TIME AREA WITHIN 80.6 F ISOTHERM EQUALS OR EXCEEDS GIVEN AREAS

AREA HECTARES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
= CBSV4216.03840.03944.0 0.04194.03395.03906.03916.03756.03843.03803.04200.0												
1.0E-5	0.0	0.0	0.0	0.0	35.3	71.3	82.7	76.3	13.4	0.0	0.0	0.0
0.0001	0.0	0.0	0.0	0.0	35.3	71.3	82.7	76.3	13.4	0.0	0.0	0.0
0.001	0.0	0.0	0.0	0.0	34.1	71.3	82.7	76.3	13.4	0.0	0.0	0.0
0.005	0.0	0.0	0.0	0.0	5.0	53.0	82.4	76.1	13.4	0.0	0.0	0.0
0.01	0.0	0.0	0.0	0.0	0.9	41.0	79.7	75.3	13.2	0.0	0.0	0.0
0.05	0.0	0.0	0.0	0.0	0.0	13.7	65.6	57.4	7.1	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.0	0.0	8.8	58.1	46.2	4.7	0.0	0.0	0.0
0.5	0.0	0.0	0.0	0.0	0.0	2.7	38.2	26.3	1.9	0.0	0.0	0.0
1.0	0.0	0.0	0.0	0.0	0.0	1.6	32.6	19.7	1.5	0.0	0.0	0.0
2.5	0.0	0.0	0.0	0.0	0.0	0.6	23.9	11.2	0.7	0.0	0.0	0.0

Table C-11. Summary of the estimated percentage of time that the area within the 28.3° C (82.9° F) isotherm equals or exceeds the given areas (excluding instances when river temperature exceeds 28.3° C).

PERCENTAGE OF TIME AREA WITHIN 82.9 F ISOTHERM EQUALS OR EXCEEDS GIVEN AREAS

AREA HECTARES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
= OBSV4216.03840.03944.0 0.04194.03395.03906.03916.03756.03843.03808.04200.0												
1.0E-5	0.0	0.0	0.0	0.0	17.6	44.2	65.6	48.3	5.3	0.0	0.0	0.0
0.0001	0.0	0.0	0.0	0.0	17.6	44.2	65.6	48.3	5.3	0.0	0.0	0.0
0.001	0.0	0.0	0.0	0.0	16.7	44.2	65.6	48.3	5.3	0.0	0.0	0.0
0.005	0.0	0.0	0.0	0.0	1.0	31.0	65.1	48.2	5.3	0.0	0.0	0.0
0.01	0.0	0.0	0.0	0.0	0.0	19.8	62.2	47.1	5.3	0.0	0.0	0.0
0.05	0.0	0.0	0.0	0.0	0.0	4.5	39.6	26.8	2.8	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.0	0.0	2.0	29.2	16.8	1.8	0.0	0.0	0.0
0.5	0.0	0.0	0.0	0.0	0.0	0.1	13.6	3.1	0.1	0.0	0.0	0.0
1.0	0.0	0.0	0.0	0.0	0.0	0.0	8.7	1.4	0.0	0.0	0.0	0.0
2.5	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.5	0.0	0.0	0.0	0.0

Table C-12. Summary of the estimated percentage of time that the area within the 28.4° C (83.1° F) isotherm equals or exceeds the given areas (excluding instances when river temperature exceeds 28.4° C).

PERCENTAGE OF TIME AREA WITHIN 83.1 F ISOTHERM EQUALS OR EXCEEDS GIVEN AREAS

AREA HECTARES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
= OBSV4216.03840.03944.0 0.04194.03395.03906.03916.03756.03843.03808.04200.0												
1.0E-5	0.0	0.0	0.0	0.0	16.2	42.2	63.9	45.1	4.8	0.0	0.0	0.0
0.0001	0.0	0.0	0.0	0.0	16.2	42.2	63.9	45.1	4.8	0.0	0.0	0.0
0.001	0.0	0.0	0.0	0.0	15.4	42.2	63.9	45.1	4.8	0.0	0.0	0.0
0.005	0.0	0.0	0.0	0.0	0.9	29.4	63.3	45.1	4.8	0.0	0.0	0.0
0.01	0.0	0.0	0.0	0.0	0.0	18.3	60.1	44.0	4.7	0.0	0.0	0.0
0.05	0.0	0.0	0.0	0.0	0.0	4.0	33.3	24.1	2.6	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.0	0.0	1.6	28.1	15.0	1.5	0.0	0.0	0.0
0.5	0.0	0.0	0.0	0.0	0.0	0.1	13.1	2.3	0.1	0.0	0.0	0.0
1.0	0.0	0.0	0.0	0.0	0.0	0.0	7.3	1.0	0.0	0.0	0.0	0.0
2.5	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.4	0.0	0.0	0.0	0.0

Table C-13. Summary of the estimated percentage of time that the area within the 29° C (84.2° F) isotherm equals or exceeds the given areas (excluding instances when river temperature exceeds 29° C).

PERCENTAGE OF TIME AREA WITHIN 84.2 F ISOTHERM EQUALS OR EXCEEDS GIVEN AREAS

AREA HECTARES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
= OBSV4216.03840.03944.0 0.04194.03395.03906.03916.03756.03843.03808.04200.0												
1.0E-5	0.0	0.0	0.0	0.0	11.3	31.7	47.1	31.1	3.1	0.0	0.0	0.0
0.0001	0.0	0.0	0.0	0.0	11.3	31.7	47.1	31.1	3.1	0.0	0.0	0.0
0.001	0.0	0.0	0.0	0.0	10.6	31.7	47.1	31.1	3.1	0.0	0.0	0.0
0.005	0.0	0.0	0.0	0.0	0.4	21.1	46.9	31.0	3.1	0.0	0.0	0.0
0.01	0.0	0.0	0.0	0.0	0.0	11.5	44.4	29.8	3.1	0.0	0.0	0.0
0.05	0.0	0.0	0.0	0.0	0.0	1.8	23.4	13.0	1.5	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.0	0.0	0.4	15.8	5.5	0.6	0.0	0.0	0.0
0.5	0.0	0.0	0.0	0.0	0.0	0.0	3.9	0.4	0.0	0.0	0.0	0.0
1.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.1	0.0	0.0	0.0	0.0
2.5	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.1	0.0	0.0	0.0	0.0

Table C-14. Summary of the estimated percentage of time that the area within the 29.5° C (85.1° F) isotherm equals or exceeds the given areas (excluding instances when river temperature exceeds 29.5° C).

PERCENTAGE OF TIME AREA WITHIN 85.1 F ISOTHERM EQUALS OR EXCEEDS GIVEN AREAS

AREA HECTARES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
= OBSV4216.03840.03944.0 0.04194.03395.03906.03916.03756.03843.03808.04200.0												
1.0E-5	0.0	0.0	0.0	0.0	7.6	23.6	34.7	21.1	2.3	0.0	0.0	0.0
0.0001	0.0	0.0	0.0	0.0	7.6	23.6	34.7	21.1	2.3	0.0	0.0	0.0
0.001	0.0	0.0	0.0	0.0	7.2	23.6	34.7	21.1	2.3	0.0	0.0	0.0
0.005	0.0	0.0	0.0	0.0	0.1	14.6	34.5	21.0	2.3	0.0	0.0	0.0
0.01	0.0	0.0	0.0	0.0	0.0	7.0	32.3	20.0	2.3	0.0	0.0	0.0
0.05	0.0	0.0	0.0	0.0	0.0	0.7	14.7	5.7	0.7	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.0	0.0	0.1	8.0	1.7	0.2	0.0	0.0	0.0
0.5	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.1	0.0	0.0	0.0	0.0
1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0

Table C-15. Summary of the estimated percentage of time that the area within the 30° C (86.0° F) isotherm equals or exceeds the given areas (excluding instances when river temperature exceeds 30° C).

PERCENTAGE OF TIME AREA WITHIN 86.0 F ISOTHERM EQUALS OR EXCEEDS GIVEN AREAS

AREA HECTARES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
= CBSV4216.03840.03944.0 0.04194.03395.03906.03916.03756.03843.03808.04200.0												
1.0E-5	0.0	0.0	0.0	0.0	4.6	18.1	24.3	13.7	1.7	0.0	0.0	0.0
0.0001	0.0	0.0	0.0	0.0	4.6	18.1	24.3	13.7	1.7	0.0	0.0	0.0
0.001	0.0	0.0	0.0	0.0	4.4	18.1	24.3	13.7	1.7	0.0	0.0	0.0
0.005	0.0	0.0	0.0	0.0	0.0	9.9	24.1	13.5	1.7	0.0	0.0	0.0
0.01	0.0	0.0	0.0	0.0	0.0	4.4	22.1	12.5	1.7	0.0	0.0	0.0
0.05	0.0	0.0	0.0	0.0	0.0	0.2	7.6	2.3	0.2	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.0	0.0	0.0	2.8	0.5	0.1	0.0	0.0	0.0
0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C-16. Summary of the estimated percentage of time that the area within the 30.1° C (86.2° F) isotherm equals or exceeds the given areas (excluding instances when river temperature exceeds 30.1° C).

PERCENTAGE OF TIME AREA WITHIN 86.2 F ISOTHERM EQUALS OR EXCEEDS GIVEN AREAS

AREA HECTARES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
= CESV4216.03840.03944.0 0.04194.03395.03906.03916.03756.03843.03808.04200.0												
1.0E-5	0.0	0.0	0.0	0.0	4.1	16.3	20.9	10.6	1.5	0.0	0.0	0.0
0.0001	0.0	0.0	0.0	0.0	4.1	16.3	20.9	10.6	1.5	0.0	0.0	0.0
0.001	0.0	0.0	0.0	0.0	4.0	16.3	20.9	10.6	1.5	0.0	0.0	0.0
0.005	0.0	0.0	0.0	0.0	0.0	8.6	20.7	10.6	1.5	0.0	0.0	0.0
0.01	0.0	0.0	0.0	0.0	0.0	3.9	19.2	9.9	1.5	0.0	0.0	0.0
0.05	0.0	0.0	0.0	0.0	0.0	0.1	6.6	1.8	0.2	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.3	0.1	0.0	0.0	0.0
0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C-17. Summary of the estimated percentage of time that the area within the 30.5° C (86.9° F) isotherm equals or exceeds the given areas (excluding instances when river temperature exceeds 30.5° C).

PERCENTAGE OF TIME AREA WITHIN 86.9 F ISOTHERM EQUALS OR EXCEEDS GIVEN AREAS

AREA HECTARES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
= CBSV4216.03840.03944.0				0.04194.03395.03906.03916.03756.03843.03808.04200.0								
1.0E-5	0.0	0.0	0.0	0.0	2.7	12.4	14.4	6.2	1.0	0.0	0.0	0.0
0.0001	0.0	0.0	0.0	0.0	2.7	12.4	14.4	6.2	1.0	0.0	0.0	0.0
0.001	0.0	0.0	0.0	0.0	2.6	12.4	14.4	6.2	1.0	0.0	0.0	0.0
0.005	0.0	0.0	0.0	0.0	0.0	5.4	14.2	6.1	1.0	0.0	0.0	0.0
0.01	0.0	0.0	0.0	0.0	0.0	2.5	13.3	5.6	1.0	0.0	0.0	0.0
0.05	0.0	0.0	0.0	0.0	0.0	0.0	3.1	0.5	0.1	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.1	0.0	0.0	0.0	0.0
0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C-18. Summary of the estimated percentage of time that the area within the 31° C (87.8° F) isotherm equals or exceeds the given areas (excluding instances when river temperature exceeds 31° C).

PERCENTAGE OF TIME AREA WITHIN 87.8 F ISOTHERM EQUALS OR EXCEEDS GIVEN AREAS

AREA HECTARES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
= CBSV4216.03840.03944.0				0.04194.03395.03906.03916.03756.03843.03808.04200.0								
1.0E-5	0.0	0.0	0.0	0.0	1.6	7.7	8.2	2.8	0.6	0.0	0.0	0.0
0.0001	0.0	0.0	0.0	0.0	1.6	7.7	8.2	2.8	0.6	0.0	0.0	0.0
0.001	0.0	0.0	0.0	0.0	1.5	7.7	8.2	2.8	0.6	0.0	0.0	0.0
0.005	0.0	0.0	0.0	0.0	0.0	2.7	8.1	2.8	0.6	0.0	0.0	0.0
0.01	0.0	0.0	0.0	0.0	0.0	1.2	7.5	2.2	0.6	0.0	0.0	0.0
0.05	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.1	0.1	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C-19. Summary of the estimated percentage of time that the area within the 31.9° C (89.4° F) isotherm equals or exceeds the given areas (excluding instances when river temperature exceeds 31.9° C).

PERCENTAGE OF TIME AREA WITHIN 89.4 F ISOTHERM EQUALS OR EXCEEDS GIVEN AREAS

AREA HECTARES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
= OBSV	4216.0	3840.0	3944.0	0.0	4194.0	3395.0	3906.0	3916.0	3756.0	3843.0	3808.0	4200.0
1.0E-5	0.0	0.0	0.0	0.0	0.4	2.3	2.0	0.3	0.2	0.0	0.0	0.0
0.0001	0.0	0.0	0.0	0.0	0.4	2.3	2.0	0.3	0.2	0.0	0.0	0.0
0.001	0.0	0.0	0.0	0.0	0.4	2.3	2.0	0.3	0.2	0.0	0.0	0.0
0.005	0.0	0.0	0.0	0.0	0.0	0.6	1.9	0.3	0.2	0.0	0.0	0.0
0.01	0.0	0.0	0.0	0.0	0.0	0.3	1.8	0.2	0.2	0.0	0.0	0.0
0.05	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C-20. Summary of the estimated percentage of time that the area within the 33.6° C (92.5° F) isotherm equals or exceeds the given areas (excluding instances when river temperature exceeds 33.6° C).

PERCENTAGE OF TIME AREA WITHIN 92.5 F ISOTHERM EQUALS OR EXCEEDS GIVEN AREAS

AREA HECTARES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
= OBSV	4216.0	3840.0	3944.0	0.0	4194.0	3395.0	3906.0	3916.0	3756.0	3843.0	3808.0	4200.0
1.0E-5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C-21. Summary of the estimated percentage of time that the area within the 35.2° C (95.4° F) isotherm equals or exceeds the given areas (excluding instances when river temperature exceeds 35.2° C).

PERCENTAGE OF TIME AREA WITHIN 95.4 F ISOTHERM EQUALS OR EXCEEDS GIVEN AREAS

AREA HECTARES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
= OBSV	4216.0	3840.0	3944.0	0.0	4194.0	3395.0	3906.0	3916.0	3756.0	3843.0	3808.0	4200.0
1.0E-5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C-22. Percentage of time river ambient temperatures were equalled or exceeded during the period 1960 through 1976.

PERCENTAGE OF TIME AMBIENT TEMPERATURE IS EQUALLED OR EXCEEDED

TEMP F	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
83							1.1					
82							3.0	0.4				
81							6.3	0.9				
80							18.4	4.7				
79						0.8	29.8	10.8				
78						1.8	42.3	23.5	1.8			
77						5.9	53.1	34.3	2.9			
76						9.0	66.4	44.6	3.9			
75						13.7	75.5	54.1	5.3			
74						20.4	81.0	67.0	7.1			
73					0.8	29.2	87.1	75.1	10.0			
72					0.9	37.1	91.8	82.7	14.7			
71					1.9	47.3	94.7	89.6	19.8			
70					3.6	58.2	97.2	93.9	27.5			
69					4.9	64.3	97.9	96.6	32.7			
68					6.6	73.9	99.1	97.9	40.0			
67					9.1	84.1	100.0	99.2	46.9			
66					12.1	90.0	100.0	99.4	53.1	0.4		
65					16.1	93.7	100.0	100.0	61.6	0.9		
64					20.7	95.5	100.0	100.0	70.0	3.4		
63					26.4	97.8	100.0	100.0	76.1	9.1		
62					34.9	98.8	100.0	100.0	82.7	13.3		
61					41.2	100.0	100.0	100.0	88.2	15.6		
60					49.3	100.0	100.0	100.0	92.9	22.0		
59				0.4	55.0	100.0	100.0	100.0	95.1	26.9		
58				1.6	60.3	100.0	100.0	100.0	96.7	33.8		
57				3.3	67.0	100.0	100.0	100.0	97.8	38.5		
56				5.3	77.2	100.0	100.0	100.0	98.6	43.5		
55				8.0	81.8	100.0	100.0	100.0	98.6	51.4		
54				10.6	84.4	100.0	100.0	100.0	99.2	57.5		
53				14.7	90.1	100.0	100.0	100.0	99.4	65.1	0.4	
52				17.3	92.6	100.0	100.0	100.0	99.8	71.3	2.0	
51				21.0	95.1	100.0	100.0	100.0	100.0	75.3	4.3	
50				26.1	96.4	100.0	100.0	100.0	100.0	82.7	7.5	
49				30.2	93.5	100.0	100.0	100.0	100.0	86.9	8.4	
48				35.1	98.9	100.0	100.0	100.0	100.0	90.1	9.8	
47				39.0	99.6	100.0	100.0	100.0	100.0	92.8	12.2	
46				46.5	100.0	100.0	100.0	100.0	100.0	94.9	16.5	
45			0.6	53.3	100.0	100.0	100.0	100.0	100.0	98.5	21.2	
44			0.9	60.8	100.0	100.0	100.0	100.0	100.0	100.0	26.1	0.2
43			1.5	66.3	100.0	100.0	100.0	100.0	100.0	100.0	31.0	0.4
42			2.1	70.2	100.0	100.0	100.0	100.0	100.0	100.0	38.2	0.8
41			2.8	74.5	100.0	100.0	100.0	100.0	100.0	100.0	43.7	0.9
40			4.4	79.2	100.0	100.0	100.0	100.0	100.0	100.0	53.5	0.9
39			6.8	82.5	100.0	100.0	100.0	100.0	100.0	100.0	59.4	1.1
38		0.6	14.6	88.6	100.0	100.0	100.0	100.0	100.0	100.0	67.1	2.1
37		1.0	21.6	90.6	100.0	100.0	100.0	100.0	100.0	100.0	75.5	3.4
36		1.3	31.3	93.7	100.0	100.0	100.0	100.0	100.0	100.0	81.0	5.5
35		3.8	45.2	96.7	100.0	100.0	100.0	100.0	100.0	100.0	87.1	10.6
34	0.6	11.5	60.9	99.2	100.0	100.0	100.0	100.0	100.0	100.0	90.0	18.6
33	8.4	29.0	68.7	99.6	100.0	100.0	100.0	100.0	100.0	100.0	92.2	36.1
32	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table C-23. Percentage of time the calculated mixed temperature 305 m (1,000 ft) downstream from the discharge along the plume centerline is equalled or exceeded.

PERCENTAGE OF TIME MIXED TEMPERATURE AT 1000 FEET IS EQUALLED OR EXCEEDED

TEMP F	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
86							0.1					
85							0.6					
84							2.5	0.2				
83							7.1	0.9				
82						0.1	17.3	3.9	0.0			
81						0.7	30.6	12.4	0.8			
80						1.9	44.5	26.6	1.9			
79						5.4	56.2	38.4	3.1			
78						9.0	68.6	49.1	4.6			
77						13.2	76.9	61.2	6.8			
76						20.6	82.0	72.2	9.8			
75						27.8	87.8	80.2	14.4			
74						38.2	92.9	88.5	19.6			
73					0.5	47.2	96.3	93.9	27.8			
72					1.1	54.4	97.6	96.7	33.8			
71					2.1	62.9	98.6	98.3	42.0			
70					3.4	69.4	99.3	99.2	49.4	0.1		
69					6.2	77.1	100.0	99.7	57.9	0.7		
68					9.0	83.3	100.0	100.0	66.2	2.5		
67					11.6	90.0	100.0	100.0	74.5	7.1		
66					15.2	94.2	100.0	100.0	81.2	12.2		
65					19.2	96.4	100.0	100.0	87.5	15.4		
64					24.3	97.6	100.0	100.0	91.3	19.9		
63					33.6	99.1	100.0	100.0	94.2	25.6		
62					41.5	99.7	100.0	100.0	96.5	33.2		
61					49.1	100.0	100.0	100.0	97.8	39.6	0.6	
60					54.7	100.0	100.0	100.0	98.5	45.0	2.5	
59					61.4	100.0	100.0	100.0	98.9	53.5	5.3	
58					69.4	100.0	100.0	100.0	99.3	62.3	8.2	
57					78.0	100.0	100.0	100.0	99.6	69.5	8.3	
56					81.8	100.0	100.0	100.0	100.0	76.2	9.5	
55					85.2	100.0	100.0	100.0	100.0	82.9	12.0	
54					91.0	100.0	100.0	100.0	100.0	88.1	16.0	
53			0.6		93.0	100.0	100.0	100.0	100.0	92.2	19.1	
52			0.6		95.0	100.0	100.0	100.0	100.0	96.1	25.2	0.2
51			0.8		96.8	100.0	100.0	100.0	100.0	99.0	29.0	0.4
50			0.8		98.5	100.0	100.0	100.0	100.0	99.4	36.1	0.8
49			2.0		98.9	100.0	100.0	100.0	100.0	99.9	46.2	1.0
48		1.0	8.3		99.7	100.0	100.0	100.0	100.0	100.0	57.8	3.2
47		4.0	20.9		100.0	100.0	100.0	100.0	100.0	100.0	69.3	7.0
46	0.3	10.8	38.5		100.0	100.0	100.0	100.0	100.0	100.0	81.9	17.5
45	21.6	30.8	52.7		100.0	100.0	100.0	100.0	100.0	100.0	87.2	35.0
44	68.9	79.6	76.1		100.0	100.0	100.0	100.0	100.0	100.0	91.4	63.2
43	93.5	96.5	85.4		100.0	100.0	100.0	100.0	100.0	100.0	98.3	95.0
42	100.0	97.5	90.3		100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.6
41	100.0	99.4	94.1		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
40	100.0	100.0	95.3		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
39	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
38	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
37	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
36	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
35	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
34	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
33	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
32	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table C-24. Percentage of time the calculated mixed ΔT at 305 m (1,000 ft) downstream from the discharge along the plume centerline is equalled or exceeded.

PERCENTAGE OF TIME MIXED DELTA T AT 1000 FEET IS EQUALLED OR EXCEEDED

TEMP F	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
13	16.5	12.9	1.8								2.7	16.6
12	66.2	70.4	38.5								9.9	55.6
11	93.9	95.8	58.8								18.9	85.1
10	100.0	97.1	70.2								29.4	93.3
9	100.0	99.0	78.5							0.2	46.6	98.7
8	100.0	100.0	87.2							1.5	75.4	99.8
7	100.0	100.0	94.9						0.1	6.5	83.6	99.8
6	100.0	100.0	96.6					0.0	1.0	20.6	92.0	100.0
5	100.0	100.0	98.4			0.2	0.0	0.8	6.4	47.7	98.5	100.0
4	100.0	100.0	100.0			3.1	1.4	8.6	38.0	80.0	100.0	100.0
3	100.0	100.0	100.0		0.1	21.4	26.6	47.3	85.6	97.8	100.0	100.0
2	100.0	100.0	100.0		16.4	59.1	86.1	91.4	97.8	100.0	100.0	100.0
1	100.0	100.0	100.0		84.3	97.2	99.2	99.2	99.9	100.0	100.0	100.0
0	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table C-25. Percentage of time the calculated mixed temperature 610 m (2,000 ft) downstream from the discharge along the plume centerline is equalled or exceeded.

PERCENTAGE OF TIME MIXED TEMPERATURE AT 2000 FEET IS EQUALLED OR EXCEEDED

TEMP F	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
85							0.2					
84							1.4	0.1				
83							4.2	0.4				
82							12.4	2.1				
81						0.4	22.8	6.7	0.0			
80						1.1	37.0	18.8	1.3			
79						2.9	49.3	31.8	2.4			
78						6.8	61.5	42.8	3.8			
77						10.0	72.5	53.2	5.1			
76						15.5	78.8	64.9	7.6			
75						22.6	84.4	75.0	10.8			
74						31.8	89.9	83.0	16.1			
73					0.5	41.4	94.2	90.3	21.4			
72					0.7	49.3	96.9	94.7	29.3			
71					1.6	57.8	97.8	97.1	35.6			
70					3.1	64.5	98.7	98.5	43.3			
69					4.6	72.0	99.6	99.3	50.6	0.2		
68					7.2	80.1	100.0	99.8	59.1	0.7		
67					10.1	87.4	100.0	100.0	67.5	2.8		
66					13.4	92.4	100.0	100.0	75.3	7.5		
65					16.5	95.4	100.0	100.0	81.7	12.6		
64					21.9	96.8	100.0	100.0	88.3	15.6		
63					29.9	98.2	100.0	100.0	91.8	20.3		
62					37.4	99.1	100.0	100.0	94.4	26.0		
61					45.5	100.0	100.0	100.0	96.6	33.4		
60					52.9	100.0	100.0	100.0	97.8	39.6		
59					57.8	100.0	100.0	100.0	98.5	44.6	0.6	
58					64.2	100.0	100.0	100.0	98.9	52.5	2.5	
57					73.3	100.0	100.0	100.0	99.3	61.2	5.3	
56					80.5	100.0	100.0	100.0	99.6	68.9	8.2	
55					83.0	100.0	100.0	100.0	99.9	74.8	8.3	
54					88.2	100.0	100.0	100.0	100.0	81.7	9.7	
53					92.1	100.0	100.0	100.0	100.0	86.4	12.2	
52					94.5	100.0	100.0	100.0	100.0	90.7	16.0	
51			0.6		96.3	100.0	100.0	100.0	100.0	95.0	19.7	
50			0.6		98.1	100.0	100.0	100.0	100.0	98.2	25.8	0.2
49			0.8		98.7	100.0	100.0	100.0	100.0	99.3	30.0	0.4
48			1.0		99.5	100.0	100.0	100.0	100.0	99.9	37.0	0.8
47			1.3		99.8	100.0	100.0	100.0	100.0	100.0	48.1	1.0
46		0.2	5.5		100.0	100.0	100.0	100.0	100.0	100.0	57.1	2.9
45		2.3	15.2		100.0	100.0	100.0	100.0	100.0	100.0	67.0	6.3
44	0.6	6.7	32.9		100.0	100.0	100.0	100.0	100.0	100.0	82.8	14.7
43	1.7	14.4	48.9		100.0	100.0	100.0	100.0	100.0	100.0	87.2	23.0
42	45.0	61.0	71.0		100.0	100.0	100.0	100.0	100.0	100.0	89.9	54.7
41	93.2	96.0	84.8		100.0	100.0	100.0	100.0	100.0	100.0	96.4	89.3
40	100.0	97.3	89.7		100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.6
39	100.0	99.4	94.1		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
38	100.0	100.0	95.7		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
37	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
36	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
35	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
34	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
33	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
32	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table C-26. Percentage of time the calculated mixed ΔT at 610 m (2,000 ft) downstream from the discharge along the plume centerline is equalled or exceeded.

PERCENTAGE OF TIME MIXED DELTA T AT 2000 FEET IS EQUALLED OR EXCEEDED

TEMP F	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
11											1.7	6.3
10	38.7	42.5	21.5								6.1	39.0
9	93.5	94.6	53.1								16.2	77.7
8	100.0	96.9	68.8								27.5	92.4
7	100.0	99.0	77.9							0.4	46.4	98.7
6	100.0	100.0	87.8							3.4	76.3	99.8
5	100.0	100.0	94.9						0.6	14.7	86.6	99.8
4	100.0	100.0	97.6			0.1		0.6	5.2	44.5	97.1	100.0
3	100.0	100.0	99.4			3.7	2.4	12.0	48.3	84.0	100.0	100.0
2	100.0	100.0	100.0		0.5	32.3	56.7	73.9	93.5	99.0	100.0	100.0
1	100.0	100.0	100.0		52.0	81.5	96.7	98.0	99.7	100.0	100.0	100.0
0	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table C-27. Percentage of time the calculated mixed temperature 915 m (3,000 ft) downstream from the discharge along the plume centerline is equalled or exceeded.

PERCENTAGE OF TIME MIXED TEMPERATURE AT 3000 FEET IS EQUALLED OR EXCEEDED

TEMP F	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
85							0.1					
84							1.1	0.0				
83							3.6	0.4				
82							9.5	1.6				
81						0.1	19.7	5.4				
80						0.8	33.5	15.6	0.8			
79						1.8	46.3	29.0	2.2			
78						5.9	58.0	39.8	3.5			
77						9.1	69.8	49.9	4.8			
76						14.0	77.1	61.7	7.1			
75						21.0	82.3	72.6	9.8			
74						28.7	88.2	80.3	15.0			
73					0.5	39.1	92.8	88.2	19.4			
72					0.7	48.1	96.4	93.8	28.0			
71					1.6	56.0	97.5	96.5	33.6			
70					3.1	63.2	98.5	98.1	41.4			
69					4.5	70.8	99.2	99.2	48.1	0.1		
68					6.9	78.5	100.0	99.5	56.1	0.6		
67					9.8	85.8	100.0	100.0	64.5	1.7		
66					12.9	90.5	100.0	100.0	72.8	6.0		
65					16.0	94.8	100.0	100.0	79.2	11.2		
64					21.0	96.7	100.0	100.0	86.0	14.8		
63					28.1	97.8	100.0	100.0	90.1	17.9		
62					36.6	99.1	100.0	100.0	93.7	23.7		
61					44.2	100.0	100.0	100.0	95.8	30.7		
60					50.8	100.0	100.0	100.0	97.6	37.5		
59					56.5	100.0	100.0	100.0	98.3	42.6		
58					62.6	100.0	100.0	100.0	98.6	49.4	0.6	
57					72.2	100.0	100.0	100.0	99.0	58.5	2.5	
56					79.5	100.0	100.0	100.0	99.4	65.3	5.9	
55					82.5	100.0	100.0	100.0	99.8	71.7	8.4	
54					87.0	100.0	100.0	100.0	100.0	78.6	9.0	
53					91.6	100.0	100.0	100.0	100.0	84.0	9.9	
52					94.1	100.0	100.0	100.0	100.0	88.5	13.0	
51					95.7	100.0	100.0	100.0	100.0	93.2	17.9	
50			0.6		97.8	100.0	100.0	100.0	100.0	96.5	20.6	
49			0.6		98.7	100.0	100.0	100.0	100.0	99.2	27.1	0.2
48			0.8		99.4	100.0	100.0	100.0	100.0	99.4	31.9	0.4
47			1.4		99.8	100.0	100.0	100.0	100.0	99.9	38.9	0.8
46			2.4		100.0	100.0	100.0	100.0	100.0	100.0	50.0	1.0
45		0.6	8.1		100.0	100.0	100.0	100.0	100.0	100.0	58.4	2.9
44		3.1	20.1		100.0	100.0	100.0	100.0	100.0	100.0	69.7	6.7
43	0.6	8.1	35.5		100.0	100.0	100.0	100.0	100.0	100.0	83.6	17.0
42	11.8	22.1	50.3		100.0	100.0	100.0	100.0	100.0	100.0	87.8	31.8
41	59.8	76.0	75.3		100.0	100.0	100.0	100.0	100.0	100.0	90.8	64.0
40	96.4	96.0	85.4		100.0	100.0	100.0	100.0	100.0	100.0	96.8	91.2
39	100.0	97.1	90.1		100.0	100.0	100.0	100.0	100.0	100.0	99.6	99.6
38	100.0	99.2	93.3		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
37	100.0	100.0	95.1		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
36	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
35	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
34	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
33	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
32	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table C-28. Percentage of time the calculated mixed ΔT at 915 m (3,000 ft) downstream from the discharge along the plume centerline is equalled or exceeded.

PERCENTAGE OF TIME MIXED DELTA T AT 3000 FEET IS EQUALLED OR EXCEEDED

TEMP F	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
10	8.3	7.3	1.2								2.5	14.1
9	55.2	60.2	33.1								8.4	50.7
8	96.8	95.0	54.8								17.0	80.8
7	100.0	96.7	68.6							0.1	27.1	92.4
6	100.0	98.7	77.3							1.1	51.9	98.7
5	100.0	100.0	88.0						0.1	7.5	79.0	99.8
4	100.0	100.0	96.1					0.1	1.8	29.7	90.3	100.0
3	100.0	100.0	98.4			1.1	0.2	3.9	26.1	69.8	99.2	100.0
2	100.0	100.0	100.0			21.4	33.2	56.4	88.7	97.0	100.0	100.0
1	100.0	100.0	100.0		34.5	71.5	94.8	97.1	99.6	100.0	100.0	100.0
0	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

LARVAL IMPINGEMENT SURVIVAL STUDY

PRAIRIE ISLAND NUCLEAR GENERATING PLANT

NORTHERN STATES POWER COMPANY

January, 1980

STONE & WEBSTER ENGINEERING CORPORATION
BOSTON, MASSACHUSETTS

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SECTION 1

SUMMARY AND CONCLUSIONS

In May 1979, Stone & Webster Engineering Corporation (S&W) initiated a study program for Northern States Power Company (NSP) to evaluate the survival potential of larval fish impinged on a fine-mesh screen. The study was conducted at Alden Research Laboratories (ARL) in Holden, Massachusetts, under the direction of S&W biologists and ARL hydraulic engineers and modeling personnel.

The study program had two major objectives:

1. To determine the survival potential of larvae of several fish species which commonly occur at the Prairie Island Nuclear Generating Plant (PINGP) following impingement and removal from a fine-mesh screen; and

2. To identify engineering factors which contribute to mortality and thereby develop reasonable design criteria for a proposed fine screening system at PINGP.

Results of this program would therefore aid in determining the potential biological effectiveness of the proposed screening system. Accordingly, laboratory conditions were established to test parameters which could be important under field conditions.

Testing consisted of impinging groups of organisms on fine screening panels over a range of velocities from 0.5 to 3.0 fps for durations from 2 to 16 minutes. These conditions more than cover the range which would be expected to occur at a fine screening facility at PINGP.

A total of 882 tests were conducted over a 10-week period with larvae of walleye, channel catfish and bluegill. Subsequent to each test, impinged larvae were removed from the test screen and were held for 96 hr to determine latent survivorship. A separate group of controls was held for comparison to determine mortality resulting from handling and holding.

Walleye testing was hampered by high mortality among both test and control larvae. Since it was evident from control data that the high mortalities observed were largely a function of handling and holding problems and not impingement stress, it was necessary to evaluate the 24-hr mortality data rather than data obtained over longer periods. Under the velocity/impingement duration conditions proposed for the fine screening installation at PINGP (0.5 fps/4 min), mean test mortality for 24 hr was approximately 32 percent. Due to the holding problems experienced during the study, this estimate has a large variance. It does appear that walleye are capable of withstanding impingement and surviving under the conditions proposed for PINGP; however, it is not possible to determine the exact level of survival which would occur.

Testing with channel catfish and bluegill larvae indicated that these two species are very hardy. Handling and holding problems were not encountered, and it was possible, therefore, to obtain 96-hr mortality determinations.

In general, both species exhibited high survival under many of the test conditions. Under the design conditions anticipated for PINGP, test mortality alone was less than 5 percent. When adjusted for control data, mortalities were less than 1 percent.

In conclusion, it appears that, of the three species tested, channel catfish and bluegill are capable of high survival following impingement and removal from a fine-mesh screen. A 96-hr estimate of survival for walleye larvae was not possible due to problems which arose in maintaining this species under laboratory conditions. However, under the conditions tested, it appears that the design parameters anticipated for the PINGP intake offer the best potential for walleye survival (based on 24-hr survival data). Since channel catfish and bluegill larvae showed high survival under conditions which were much more severe than those anticipated for PINGP, it is expected that these species will suffer little mortality if exposed to a fine-mesh intake screen.

SECTION 2

BACKGROUND AND TESTING RATIONALE

2.1 BACKGROUND

In December 1976, Northern States Power Company (NSP) authorized Stone & Webster Engineering Corporation (S&W) to develop conceptual designs of various intake alternatives which could potentially reduce fish impingement and ichthyoplankton entrainment mortality at the Prairie Island Nuclear Generating Plant (PINGP) on the Mississippi River. The basic objectives of the study program were as follows:

1. Develop and evaluate designs which would permit the utilization of intake flows up to 1,410 cfs (open cycle) while maintaining impingement and entrainment mortality at or below baseline levels associated with the existing system operating at a 188 cfs withdrawal rate.

2. Estimate the capital costs of construction and operation for those designs which combine the best potential for biological effectiveness and commercial availability.

As a result of this effort, three alternative intake designs were selected as being practicable to construct and operate in addition to being potentially effective in protecting organisms: center-flow traveling screens, angled traveling screens, and modified, conventional traveling screens with fish lifting buckets and low-pressure sprays. A detailed description of each design was presented in a separate report (Stone & Webster, 1977).

All three designs selected for possible application at PINGP would operate on the same basic protection concept, namely, impingement and removal of fish eggs and larvae from a fine-mesh screening medium. Later life stages (juveniles and adults) would also be similarly collected by center-flow or modified screens, but would be diverted to a bypass without impingement if the angled screen system were utilized.

Subsequent to the alternative intake design effort, NSP made the decision to proceed with the retrofitting of a fish protection system at PINGP, pending regulatory agency review and approval. The center-flow screen was tentatively selected as the preferred alternative for three reasons:

1. The screen is commercially available and has proven to be operationally reliable in many applications with fine-mesh screening;

2. Biologically, the center-flow design is similar to the other designs in that all three function as collection (impingement) and removal systems;

3. The center-flow design costs were approximately one-half those of the next most costly alternative. Accordingly, the center-flow screen was deemed to offer the most cost-effective means for reducing entrainment and impingement losses at PINGP.

Although fine screening technology is progressing rapidly in the U.S., relatively few studies have been conducted to quantify the survival potential of ichthyoplankton following collection on a fine-mesh screen. These studies are summarized below.

The only operational data available from a power plant comes from the Central Power and Light Barney Davis Station in Corpus Christi, Texas. The 0.5 mm-mesh center-flow traveling screens are operated continuously at a travel speed of 14 fpm and have an overhead 40 to 60 psi spraywash system. From 1975 to 1977, biological sampling was conducted to determine species composition and mortality. The majority of the organisms recovered in sampling nets located in a screen-wash debris collection pit consisted of penaeid shrimps, which showed high survival. Of approximately 50 fish species collected, the dominant species were the bay anchovy (Anchoa mitchilli) and the gulf menhaden (Brevoortia patronus) ranging in mean length from 15 to 30 mm. Of about 12,000 organisms collected in 1977, 86 percent were recovered alive (Murray and Jinnette 1978). Average survival of bay anchovy and gulf menhaden over the year was 69 and 90 percent, respectively.

Several laboratory and field studies also demonstrate the potential for high survival of ichthyoplankton following impingement. In 1977, Consolidated Edison Company of New York sponsored an evaluation of a fine-mesh through-flow traveling screen at the Indian Point Generation Station - Unit 1 on the Hudson River (Ecological Analysts, Inc. 1977). One traveling water screen was backfitted with a 2.5-mm nylon mesh and modified with fish buckets, a low-pressure spray header, and a collection trough on the rear side of the screen. Collection efficiency studies were conducted with 12- and 14-day-old post-yolk-sac hatchery striped bass (Morone saxatilis) with mean lengths of 7 to 9 mm. Survival estimates were obtained with wild fish, primarily late post-yolk-sac (mean length of 15 mm) and early juvenile (mean length of 19 mm) striped bass. In all tests, the screen approach velocity was approximately 0.9 fps and the screen travel speed was 10 fpm. The results of these studies showed that 7 to 9 mm larvae were not effectively retained by the 2.5-mm mesh. It was concluded that 10- to 18-mm larvae may be the smallest size that can be collected on mesh of this size. Initial and latent (96-hr) survival estimates of late post-yolk-sac larvae washed from the screen were 68 and 47 percent, respectively. Initial and latent survival estimates of early juveniles were 100 and 88 percent, respectively (Ecological Analysts, Inc. 1977).

The Indian Point study results are relatively consistent with those obtained in laboratory and field studies conducted by the Tennessee Valley Authority (Tomljanovich, Heuer, and Voightlander 1977). In these studies, the effects of screen mesh size, water velocity, and impingement time on the efficiency of screening and mortality of 10 species, including largemouth bass (Micropterus salmoides) and smallmouth bass (M. dolomieui), were evaluated. It was determined that of the screen sizes tested, 0.5 mm yielded the greatest screening efficiency (90 percent for larval fish with lengths as small as 5.5 to 7.5 mm). Smallmouth bass showed greater than 95 percent survival at 48 hours under all test conditions. Largemouth bass exhibited higher latent mortality at impingement durations greater than 8 minutes. Latent survival of this species average 91.6 percent at an approach velocity of 0.5 fps, but dropped to 66.4 and 49.3 percent at velocities of 1.0 and 1.5 fps, respectively. In general, a negative relationship was found between fish survival and impingement duration and velocity indicating that the longer the impingement time and/or the higher the velocity, the lower the survival rate.

Additional studies by TVA further substantiate the survival potential of larvae following impingement on a fine-mesh screen. Tomljanovich and Heuer (1979) have demonstrated that survival of 3 to 19 day old larvae (mean total length of 5 to 14 mm) of 5 species can be high under conditions which are achievable in a power plant intake structure. Four species, paddlefish (Polyodon spathula); northern pike (Esox lucius); white sucker (Catastomus comersoni); and channel catfish (Ictalurus punctatus)) showed greater than 90 percent survival 24 hr after impingement, air exposure, and spilling into a collection trough. Walleye (Stizostedion vitreum) and largemouth bass tested under the same conditions showed 24 hr survival rates of greater than 62 percent (adjusted for control mortality). Higher survival (69 to 97 percent) was obtained when the duration of air exposure was reduced from 3 minutes to 1 minute. The only species which did not perform well was the striped bass; however, control mortalities were also very high and much of the mortality observed was attributed to the problems of maintaining this fragile species under laboratory conditions.

In laboratory studies (Sazaki, Heuback, and Skinner 1972; Skinner 1974), it was found that steelhead trout (Salmo gairdneri) ranging in length from 22 to 36 mm could be impinged for up to 50 minutes at 1.5 fps and still exhibit greater than 90 percent survivorship. Survival decreased rapidly when impingement time exceeded 10 minutes for both king (chinook) salmon (Oncorhyncus tshawytscha; 36-56 mm) and steelhead trout when velocity increased to 2.5 fps. Striped bass were found to exhibit close to 100 percent survival with impingement times up to 4 minutes at screen approach velocities of less than 0.8 fps. This same study suggests that it may be feasible to impinge striped bass eggs for up to 6 minutes at velocities of up to 0.8 fps with egg survival of over 80 percent.

Prentice and Ossiander (1974) present data which indicate that chinook salmon fry ranging in size from 26 to 170 mm can be impinged on a 0.7-mm-mesh screen for up to 15 minutes at water velocities up to 1.5 fps with greater than 94 percent survival (18-hour observation). With a screen approach velocity of 0.5 fps, survival of the smallest fish was virtually 100 percent for impingements of up to 60 minutes. At higher velocities, they found greatly decreased survival when impingement time was increased to over 15 minutes; i.e., at 0.5 fps, survival was independent of impingement time, but at 1.5 fps, survival decreased as impingement time increased from 6 to 60 minutes.

While available information indicates that the survival of many species can be high, few data were available which would have permitted a quantitative estimate to be made of the survival which might be expected with the species of fish occurring at PINGP. Accordingly, in late 1978, NSP authorized S&W to conduct an impingement study in the laboratory to obtain data on the survival potential of selected, important species occurring at the site. This report presents the findings of this laboratory study.

2.2 TESTING RATIONALE

Each of the intake alternatives developed for PINGP were designed to achieve a maximum screen face velocity of 0.5 fps at a plant flow rate of 1,410 cfs. Further, each screen type would be capable of traveling at a speed which could limit impingement duration on the fine-mesh screen panels to approximately 2 minutes. Therefore, a primary objective of the impingement survival study was to verify that selected, important species can survive these conditions. Since the presence of debris on the mesh of a traveling screen can act to create localized areas of higher velocity, it was desirable to extend the range of test velocities to higher values to permit a clear definition of velocity effects. A maximum velocity of 3.0 fps was selected for this study.

Although the traveling screens which might be applied to PINGP could operate at high travel speeds to minimize impingement duration, it would be desirable to reduce the speed to alleviate operational and maintenance problems and costs. Accordingly, impingement durations of up to 16 minutes were selected for evaluation.

These primary test variables of velocity and impingement duration were tested via a 5 by 4 matrix, as shown below:

		VELOCITY (FPS)				
		0.5	1.0	1.5	2.0	3.0
IMPINGEMENT DURATION (MINUTES)	2					
	4					
	8					
	16					

Thus, a replicate series consisted of a completed matrix of 20 individual velocity/impingement duration combinations. All species were tested initially by completing an entire replicate series over several days of testing, i.e., while the fish were of a consistent size. After several replicate series had been completed, the data were evaluated, particularly with regard to velocity/duration combinations for which high mortality rates were found. At this point, a judgement was made concerning future testing protocol. Thus, repetitive completion of the testing matrix for each species was not required. Generally, the decision was made to focus further testing on combinations with higher mortality on the assumption that reductions in the mortality rates under these conditions would also be reflected in the rates under other conditions.

Test results were constantly updated and reviewed and modifications to the testing program were made as needed. In this way, flexibility was retained to eliminate unnecessary effort and to increase testing which could yield more productive results. As with the initial matrix development, any testing program changes were based in part on the ability of the revised matrix to provide statistically testable data.

The modifications to the initial testing matrix resulted in a limited ability to analyze the resulting data as a whole. Consequently, analytical procedures were applied to portions of the data, as appropriate, and the results are reported accordingly. To the extent possible, conclusions have been drawn over the entire range of test conditions for each species tested.

An additional factor which must be considered in fine-mesh screening is the mesh size utilized. It had been determined based on the available literature that 0.5 mm mesh could be required at PINGP to ensure retention of all important species/life stages. While it is possible that a larger mesh size might prove equally effective in collecting ichthyoplankton with acceptable rates of survival, the decision was made to conduct all tests with a 0.5 mm nylon mesh to ensure complete retention. In this way, the study results would not be confounded by potential problems with selective retention of certain species or sizes within species.

A final consideration in the fine screening of small organisms was the actual screen design. Center-flow and through-flow screens incorporate semi-circular and flat-panel baskets, respectively. While the center-flow screen had been selected by NSP as the preferred design for PINGP, a flat-panel test screen was utilized in the laboratory for three reasons. First, the semi-circular basket creates slightly non-uniform hydraulic conditions due to its curvature and the presence of a protruding trash lip. Since the purpose of this study was to develop impingement survival data at discrete velocity intervals, a non-uniform and variable velocity distribution across the test screen panel was undesirable. Second, it had not been determined at the time of the study that a center-flow screen design would receive agency approval. Further, since the range of velocities tested more than covered the range that would occur in actual application of either screen, the factors considered most important in determining impingement survival could be tested without the basket shape being closely simulated. Finally, studies by TVA (Tomljanovich and Heuer, 1979) indicate that basket shape alone may not be an important factor in impingement survival. Therefore, the flat-panel design was selected for its ease of operation.

It was originally intended that walleye, white bass (Morone chrysops) and freshwater drum (Aplodinotus grunniens) would be evaluated in the laboratory. These species are among those which are considered important at PINGP. Unfortunately, white bass and drum were not available due to unusual weather conditions during the spring spawning season in 1979. Accordingly, channel catfish and bluegill (Lepomis macrochirus) were substituted for these species.

The experience of other researchers indicated that walleye are extremely difficult to culture under artificial conditions when they are in the larval stage of development. Nickum (1978) quotes the National Task Force on Public Fish Hatchery Policy: "The inability to rear the tiny delicate larvae of species like striped bass and walleye on artificial diets (is) the most crucial bottleneck in the national fish-culture program." Extensive efforts have gone into determining the causative agents in mortality among walleye in intensive culture. Despite attempts to rear fry on dry diets, all efforts have failed to produce more than a few hundred fish. Experience at a number of state hatcheries has consistently shown that walleye fry can be maintained for 2 to 3 weeks, after which the majority of the fish die for no apparent reason (Nickum 1978).

In light of the anticipated problems in holding walleye, special holding facilities were established to maximize survival potential. Further, plans were made to conduct the majority of the walleye tests in as short a time as possible to avoid problems in conducting survival tests (to 96 hr) when natural fish condition could be deteriorating steadily. This approach did permit many tests to be run in a period of days. However, handling and holding problems did occur which affected the ability to draw clear conclusions from the data, as discussed in Section 5 of this report.

SECTION 3

DESCRIPTION OF THE TEST FACILITY

A 10-ft-long by 2.1-ft-wide by 1.3-ft-deep flume, as shown in Figure 3-1, was utilized for testing. The flume was divided into two channels (segments), each 1-ft-wide, to facilitate testing. The two channels were similar in design and received flow from a common upstream reservoir. Flow depth was adjusted by a common downstream gate while flow control was achieved by a valve in the 12-inch supply line, which also contained a venturi meter for flow determination.

The test section was centrally located in the flume and contained a pneumatically operated screen frame mounted on a track, as shown in Figure 3-2. The bottom of the frame contained a lifting bucket which was recessed into the flume floor. Gaskets on the floor, sidewalls and central pier sealed the frame in its lowered position to prevent leakage around the frame. The frame supported a 0.5-mm-square-weave polyester screen which was used for impingement testing. Details of the lifting bucket and screen support can be seen in Figure 3-3, which shows the screen frame in its raised position.

Fine mesh screens (0.25 mm) were used both upstream and downstream of the test section to retain organisms that swam off, or passed through, the test screen. The location and orientation of these screens are shown in Figure 3-1.

The flume was located on top of a water supply sump of 5,000-gal capacity. A pump supplied flow to the flume with a gravity return system.

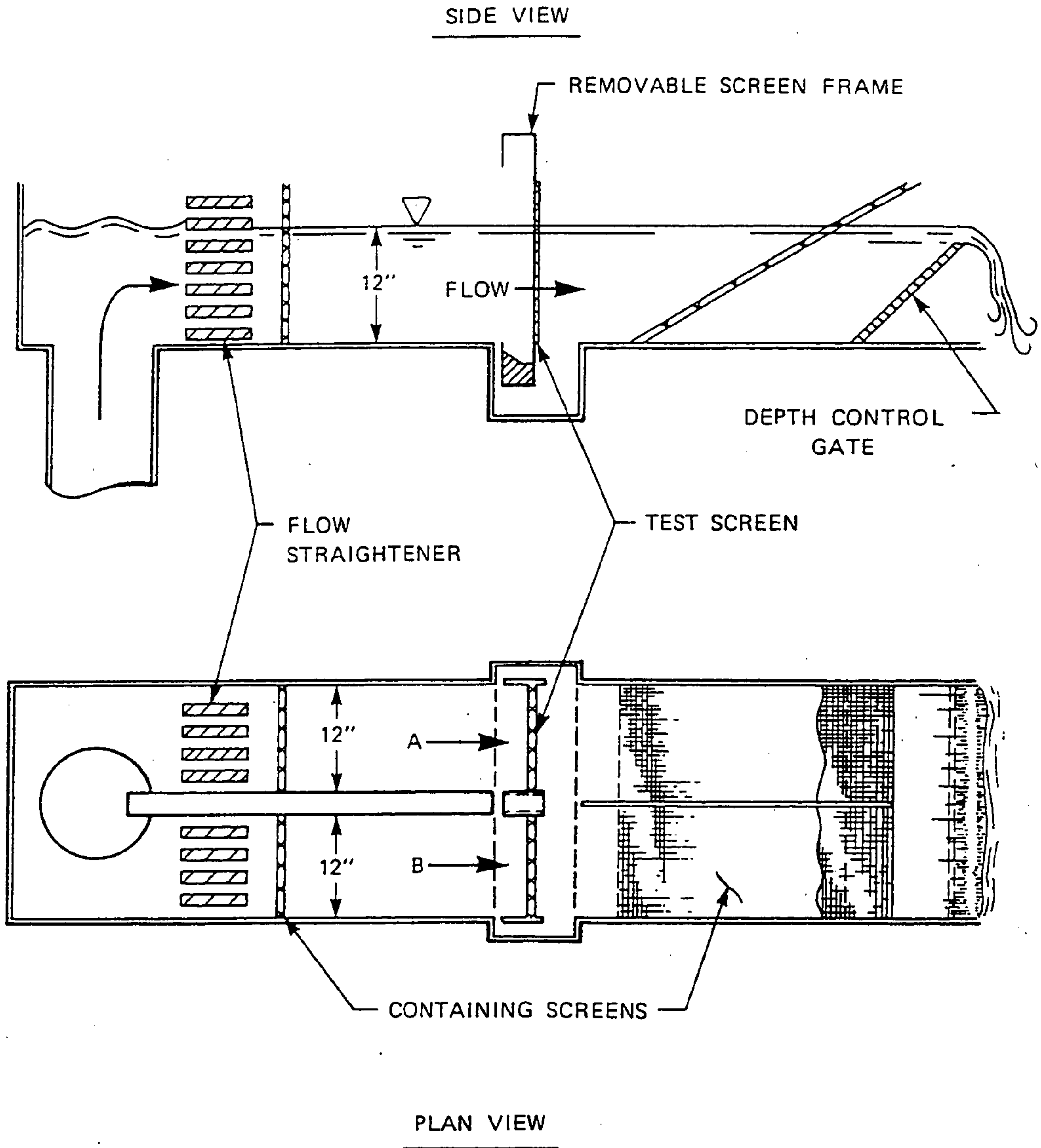
Larval Holding Facility

All larvae were held in a closed-cycle, fresh water rearing facility. The holding facility consisted of 2 tables partitioned into 10 tanks, with each table connected to a common biological filter (Figure 3-4). This filter served to remove uneaten food and fish wastes from the system.

Water was pumped from the biological filter into the bottom of the tanks to induce an upwelling flow that kept food in suspension and provided a flow to which the larvae could orient. As water entered a tank, an equal amount of water drained out through a screened overflow pipe, leading back to the biological filter. The capacity of each of the 20 tanks was approximately 100 liters and the turnover rate was about 300 liter/hr/tank. A 50 to 75 percent water change was made daily in order to maintain water clarity and quality.

Larvae were fed a combination of live *Artemia* nauplii and two dry diets: EWOS larvstart and W-7 (which is used by the U.S. Fish and Wildlife Service). All three species consumed the brine shrimp nauplii; only the channel catfish consumed both dry foods throughout the study.

The conceptual design of the rearing tables was an attempt to conform to the state-of-the-art in culturing walleye fry, a species not yet reared successfully for long periods of time in a laboratory situation (Nickum 1978). Although walleye fry did not survive beyond three weeks from hatching, the rearing of channel catfish and bluegill was successful.



LARVAL IMPINGEMENT TEST FACILITY

FIGURE 3-1

LARVAL IMPINGEMENT TEST FACILITY

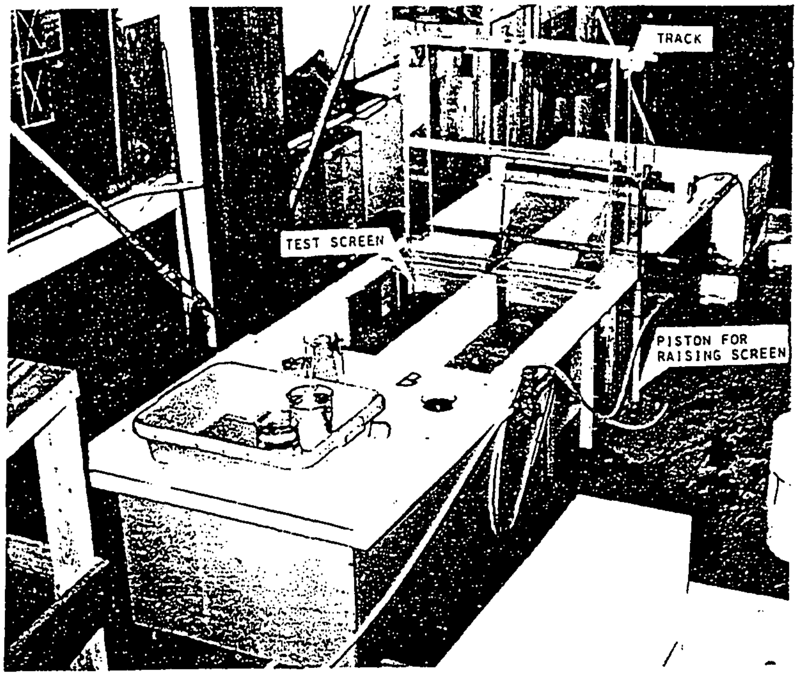


FIGURE 3-2
IMPINGEMENT FLUME

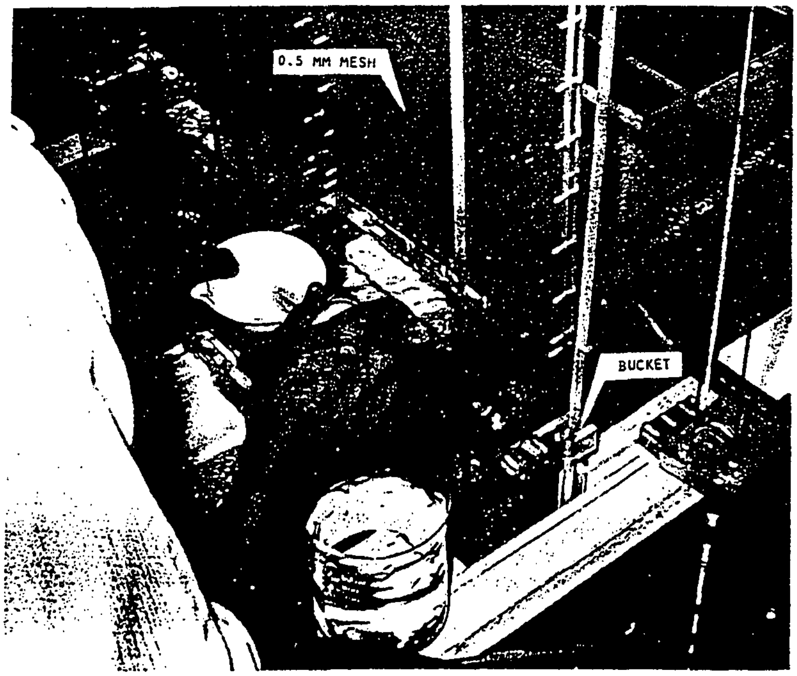
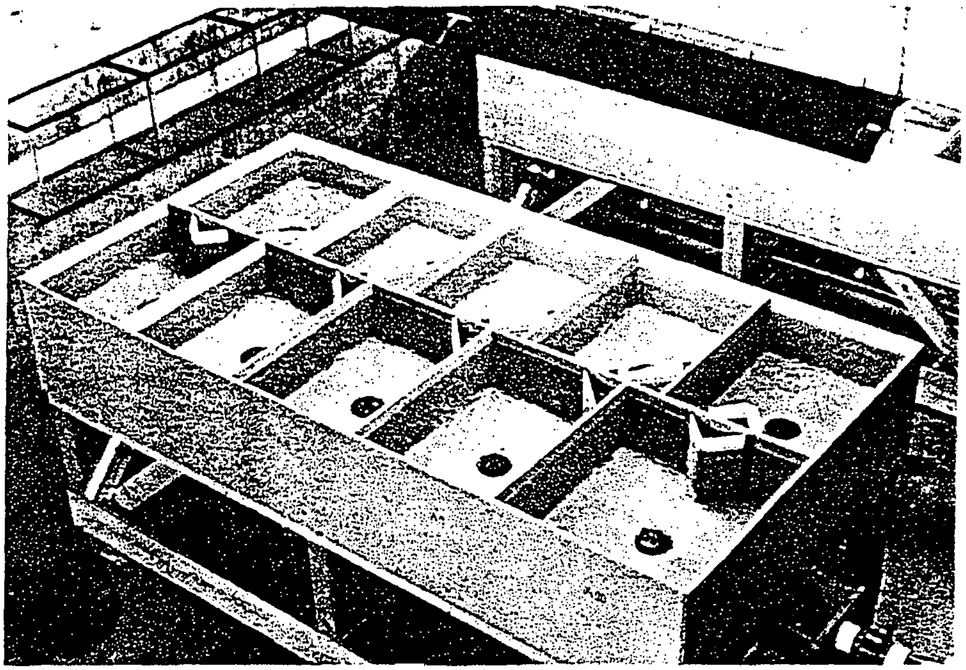
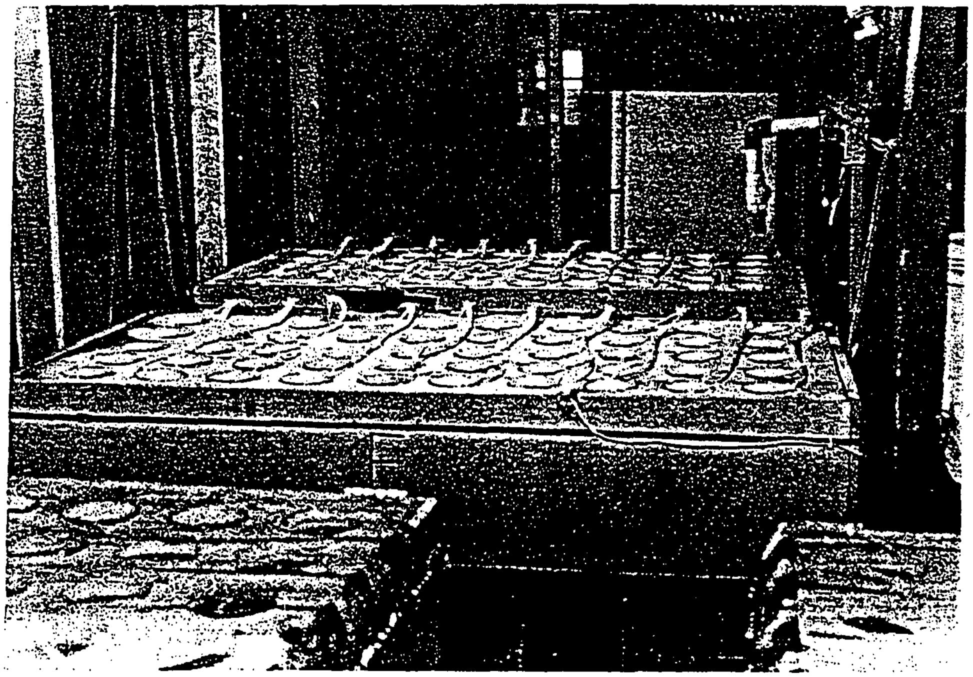


FIGURE 3-3
LIFTING BUCKET AND SCREEN MESH

FIGURES 3-2, 3-3
DETAILS OF IMPINGEMENT FLUME



A) STOCK TANKS



B) LATENT MORTALITY BEAKERS

FIGURE 3-4
LARVAL HOLDING FACILITIES

96-Hour Holding Facility

Test and control larvae were held in 1-liter glass beakers for 96 hr following each test to monitor latent survival. The beakers were individually aerated, and temperature was controlled by submerging them in a temperature-regulated water bath table (Figure 3-4). Capacity of the system was 300 beakers (50 beakers per water bath table; 6 tables.)

During the early stages of the testing program, a maximum of 25 larvae (sac fry and young larvae) were held in each beaker. As body length of larvae increased beyond 15 mm, the larvae from each test were divided into two or more beakers to avoid overcrowding.

Larvae held in the beakers for 96 hr were fed on the same schedule as the stock holding tanks. Water quality was monitored in the same manner as for the main holding tanks.

SECTION 4

BIOLOGICAL TESTING PROCEDURES

From May to August 1979, larvae of walleye, channel catfish, and bluegill were tested in the impingement model. Fish were tested according to the following schedule, which reflects the growth of each species during their individual test periods:

Species	Age at Delivery	Test Period	Length Range
Walleye	3 days	May 29-June 15	8.4-12.4 mm
Channel catfish	3 days	June 21-July 31	11.5-25.7 mm
Bluegill	14 days	July 19-August 16	15.3-21.0 mm

Twenty-five larvae were used in each test. These larvae were removed from the stock holding tanks at the time of each test, placed in glass beakers, and then transferred to the flume area for acclimation prior to testing. In general, several series of tests were conducted each day with one or more species, depending on availability. Prior to each test series, a separate control lot of 25 larvae was taken from the holding tanks, handled as the test organisms, and placed in the collection bucket of the impingement screen for 16 minutes (representing the longest impingement duration tested). The larvae were then removed and held for 96 hr to determine latent mortality. Therefore, these larvae experienced the entire testing procedure except actual impingement. In addition, a second control group of 25 larvae were removed from the stock tanks and placed directly into holding jars for 96 hr. This group was utilized to determine mortality arising solely from handling or temperature differences.

Five velocities (0.5, 1.0, 1.5, 2.0, and 3.0 fps) and four impingement durations (2, 4, 8, and 16 minutes) were investigated in the impingement model. The velocity to be tested was established in the flume based on manometer readings prior to testing. Periodic readings were taken across the flume with a flowmeter to confirm manometer settings. To start each test, a clock was activated and larvae were introduced into a segment of the model upstream of the fine-mesh screens; a second lot of larvae were introduced into the second segment either concurrently or later, depending on the desired test conditions. Observations were made during each test of the distribution of the larvae: swimming upstream, swimming in the screen collection bucket, or impinged on the screens. Water temperatures of the holding tank and flume and air temperature were also recorded.

At the conclusion of each test, the screens were raised and impinged larvae were gently washed from the screens into the collection buckets. Larvae were then carefully removed from the buckets, enumerated and placed in numbered 1-liter glass holding beakers. Larvae which had been swimming upstream of the screens during the test or those which had been impinged but had "popped" off the screens when they were raised (to be collected on the downstream retention screens) were removed from the model. These organisms were not held for latent mortality since they were not impinged at the conclusion of the test.

The beakers containing larvae which had been impinged were returned to the water bath tables (see description of holding facility). A count of initially live and dead larvae was made approximately 1 hr after the completion of the test, to allow those larvae which were "stunned" by impingement time to recover or die. Thereafter, mortality was recorded at intervals of 24, 48, 72, and 96 hr.

At the end of the 96-hr holding period, beakers were siphoned down, and the number of live larvae was recorded. Cannibalism among the larvae was a problem with walleye. Missing larvae were generally assumed to have been cannibalized. In the interest of conservatism, however, missing larvae were assumed to have died and were included in the overall test mortality figures (initial mortality plus 96 hr).

Statistical Analysis

The data were analyzed by analysis of covariance models which enabled the simultaneous testing of categorical and continuous independent variables (Kemp 1972). The categorical independent variables included the approach velocity and the impingement duration. Two test segments were used in the test program; therefore, differences in the segments were also analyzed. The covariants included mean larval length and the difference in water temperature between holding tanks and the flume.

Mortality recorded at 24, 48, 72, and 96 hr was used to calculate percent cumulative mortalities for each time period. These percentages were used to correct for differences in the number of larvae recovered and held during each test. Control mortality was analyzed for each species to establish the mortality attributed to the holding and handling conditions.

The computer program used for the analyses was a least-squares procedure, which allows an unequal number of observations in each experimental cell (Kemp 1972). Independent variables and/or interactions which had an $\alpha \leq 0.05$ were considered significant.

Least significant difference (LSD) tests, the Tukey method of multiple comparisons, and confidence intervals for the difference between two means were employed to estimate the difference between mean mortality values for each velocity/duration combination and to decide which means differed significantly. In some cases, the LSD test showed a significant difference between means, although the 95 percent confidence intervals around each mean overlapped. Since the analysis studied all differences between pairs of means, some differences could have been erroneously declared significant (Snedecor and Cochran, 1967). To limit the effect of this problem, the LSD test was used only when the F statistic was significant. The results of the LSD test and the degree of overlap in the confidence intervals were both considered in evaluating significant differences in mortality rates.

SECTION 5

TEST RESULTS

A total of 882 impingement survival tests were conducted with walleye, channel catfish and bluegill between May 29 and August 16, 1979. The results of testing with each species are presented individually in the following discussions.

5.1 WALLEYE

5.1.1 Analytical Results

The results of 308 tests with walleye, ranging in length from 8.4 mm to 12.0 mm, were analyzed. The test results are summarized in Appendix A-1. Additional tests were conducted on a subsequent day when the larvae reached 12.4 mm in length, but control mortality had reached 100 percent. Results of these tests were thus excluded from the analyses.

Statistical analyses conducted both during the testing period and at its conclusion indicated that the mortality rates of larvae tested under all velocity/duration combinations were quite high. As previously discussed, the difficulties of obtaining high laboratory survivorship for walleye larvae have been well documented both in basic and applied research (Nickum 1978). Therefore, to determine whether the walleye, during the present study, were being adversely affected by the artificial laboratory conditions, walleye control data were studied.

An analysis was conducted on control larvae that were simply held and those which were handled and held according to the test procedures. Based on the analysis, there was no significant difference between the two control groups. Therefore, handling did not significantly increase the mortality rates. The length of the larvae influenced control mortality, with a trend toward increasing mortality as the larvae grew. In addition, the relationship between control mortality and length depends upon holding durations (refer to Figure 5.1-1). Mean control mortalities and 95 percent confidence intervals for each observational period are summarized in Table 5.1-1.

The presence of high or highly variable control mortality makes the evaluation of additional effects of impingement stress on test organisms difficult. It was necessary, therefore, to evaluate test effects, relative to controls, on the basis of shorter holding periods. Thus, the 24-hr test results were selected, since these results had the lowest control mortalities.

The analysis of the test matrix data was necessarily partitioned due to the unequal number of observations at the various velocity/duration combinations. Analyses of covariance were performed to determine the relationship between mortality after 24 hr (the dependent variable) and the independent variables: impingment duration, velocity, mean larval length, temperature difference between the holding tank and flume, and model segment.

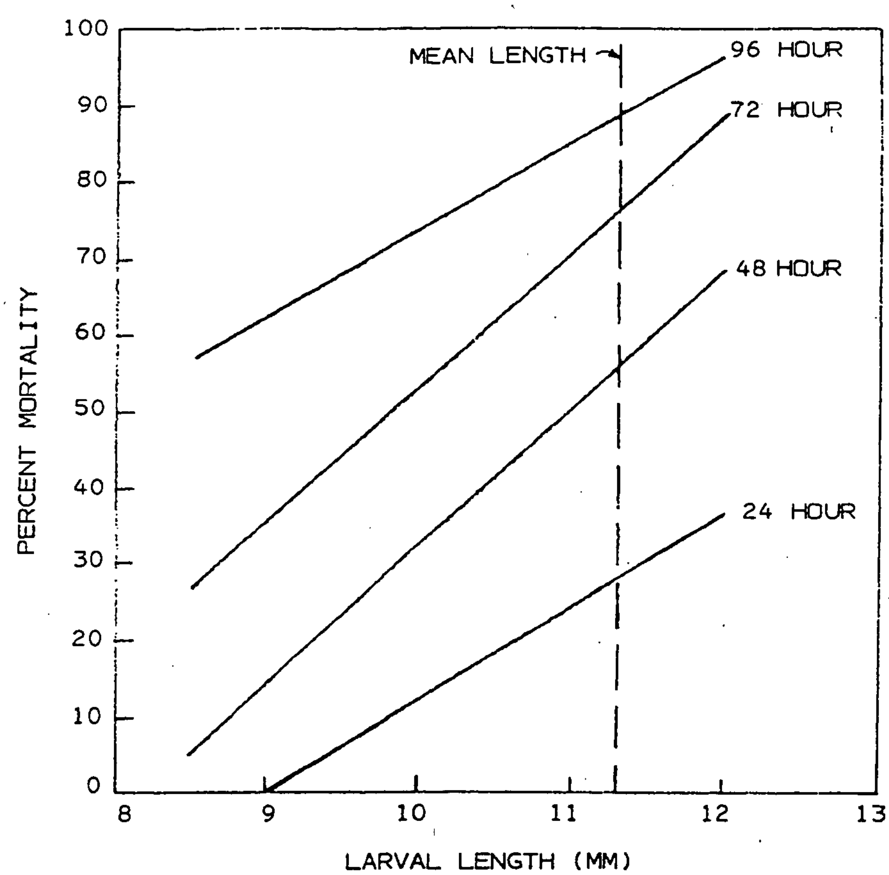


FIGURE 5.1-1

WALLEYE CONTROL MORTALITY

During the testing period, the holding tank and flume temperatures remained relatively constant. Tank temperature ranged from 14°C to 19°C, flume temperature ranged from 16°C to 21.5°C. For each test, the flume temperature was equal to, or warmer than, the holding tank temperature. The temperature difference (ΔT) ranged from 0.0°C to 3.5°C.

The first analysis of covariance was conducted on larvae impinged for 2 and 4 minutes at all velocities. The results of the statistical analysis are presented in Table 5.1-2. Within the range of independent variables tested, impingement duration, velocity, and mean larval length significantly influenced mortality. Temperature difference and model segment were not significantly related to the mortality rates. The significant interactions were velocity - duration and velocity - length.

Following this analysis, the independent variables with $\alpha \leq 0.05$ were eliminated from the model and a second analysis was conducted (refer to Table 5.1-2). This reduced model accounts for 48.9 percent of the total variability as compared to 49.8 percent for the full model. The following conclusions can be drawn:

1. Mortality rates of larvae impinged at 0.5, 1.5, and 2.0 fps did not increase as the impingement duration was increased from 2 to 4 minutes.

2. Mortality rates of larvae impinged for 2 minutes significantly increased as the velocity increased from 0.5 to 1.0 fps. There was no significant difference in the mortality rates of larvae tested at 1.0, 1.5, and 2.0 fps for this impingement duration.

3. Mortality rates of larvae impinged for 4 minutes significantly increased as velocity increased from 0.5 to 1.0 fps. There was no significant difference in the mortality rates of larvae tested at 1.5 and 2.0 fps.

The longer impingement durations of 8 and 16 minutes were also analyzed by analysis of covariance. Temperature difference and model segment were not included in the subsequent analyses since, based on the first analysis, they were not significant.

The 0.5 and 1.0 fps velocity tests had a similar number of observations and were thus partitioned and analyzed together. The results of the analysis are presented in Table 5.1-3. The significant independent variables were velocity and duration. Mean larval length and the interaction between velocity and duration were not significant.

The remaining velocities (1.5 fps to 3.0 fps for 8 and 16 minute impingement durations) were subjected to the same analysis of covariance design. The results of this analysis are presented in Table 5.1-4. The significant independent variables were velocity, duration, and length. A least significant difference test for the three velocities showed that all were significantly different at $\alpha \leq 0.05$ except 2.0 and 3.0 fps.

The mean mortalities and 95 percent confidence intervals for each velocity/duration combination are presented in Table 5.1-5.

Thus, the analyses of the 24-hr testing and holding mortalities indicate that velocity and duration are important considerations with a general increase in mortality as both these variables increase. For some test conditions, combinations of velocity and duration have an interactive effect, such that the difference between two velocities may depend upon which duration is under consideration. The length of the larvae, although significant for some of the analyses, appears to be less important than the velocity and duration. Generally, mortalities increased as the larvae grew in length.

The use of the 24-hr test results shifts the emphasis of the analysis to identifying the relative importance of velocities, impingement duration, and larval length, since no long-term (96 hr) estimates can be provided. The mortality estimates summarized in Table 5.1-5 are presented for a relative comparison since the effect of handling and holding have not been removed.

5.1.2 Discussion

The problems which arose in maintaining walleye larvae in the laboratory limit the interpretation of the test results for this species. As shown on Figure 5.1-1, two major problems were encountered:

1. Control mortalities over the 96-hr observation periods reached very high values which limited the usefulness of these data; accordingly, it was necessary to utilize only those values up to 24 hr.

2. Mortalities at all observation times increased as the larvae grew; based on experience with other species, the opposite trend would be expected.

The high control mortalities experienced during the study are believed to be a function of the difficulty of maintaining this species under artificial conditions. Therefore, it is reasonable to assume that correspondingly high test mortalities were also partly a function of holding rather than impingement stress.

The fact that mortality among test groups increased as the larvae grew (Figure 5.1-1) is another indication of the holding problems which many researchers have experienced with walleye larvae. Experience with other species (see Sections 5.2 and 5.3) indicates that mortality among test organisms should not increase substantially as they develop. In fact, decreases were shown for the channel catfish and bluegill tested concurrently with the walleye. Therefore, it is believed that the observed relationship between larval length and mortality for walleye is more a function of deterioration in condition over time than some length- or age-specific factor which reduces the survival potential of walleye as they grow.

If it is assumed that deterioration over time is a major factor in both test and control mortalities, then survival values obtained early in the study may better reflect the survival potential of walleye than those obtained later in the testing period. Figure 5.1-2 shows the relationship between larval length and 24-hr mortality for the 0.5 fps/4 minute duration test condition. It can be seen that the general trend in test mortality is similar to the trend in control mortality (Figure 5.1-1). Thus, testing does not appear to drastically modify the trend of mortality over holding time. As can be seen, the survival of walleye larvae at 24 hr is high under the 0.5 fps test condition, particularly at the shorter impingement durations. Since the proposed PINGP modified intake has been designed for this low velocity condition, it would appear that the design criteria selected would offer the best potential for walleye survival.

The mortality values given in Table 5.1-5 are very similar to results obtained by the Tennessee Valley Authority (Tomlganovich and Hueur 1979) which has conducted similar impingement survival studies with walleye larvae. Since there appears to be reasonable agreement between the results of two independent studies, it is believed that the survival values obtained in the laboratory accurately reflect the mortalities expected to occur under the conditions tested. The introduction of other parameters (such as debris) which would exist in the field make it difficult to predict how these values might change in an actual fine screening installation at PINGP. However, it is clear that, of the conditions tested, the anticipated intake design incorporates the velocity and impingement duration which offers the best potential for protecting walleye larvae.

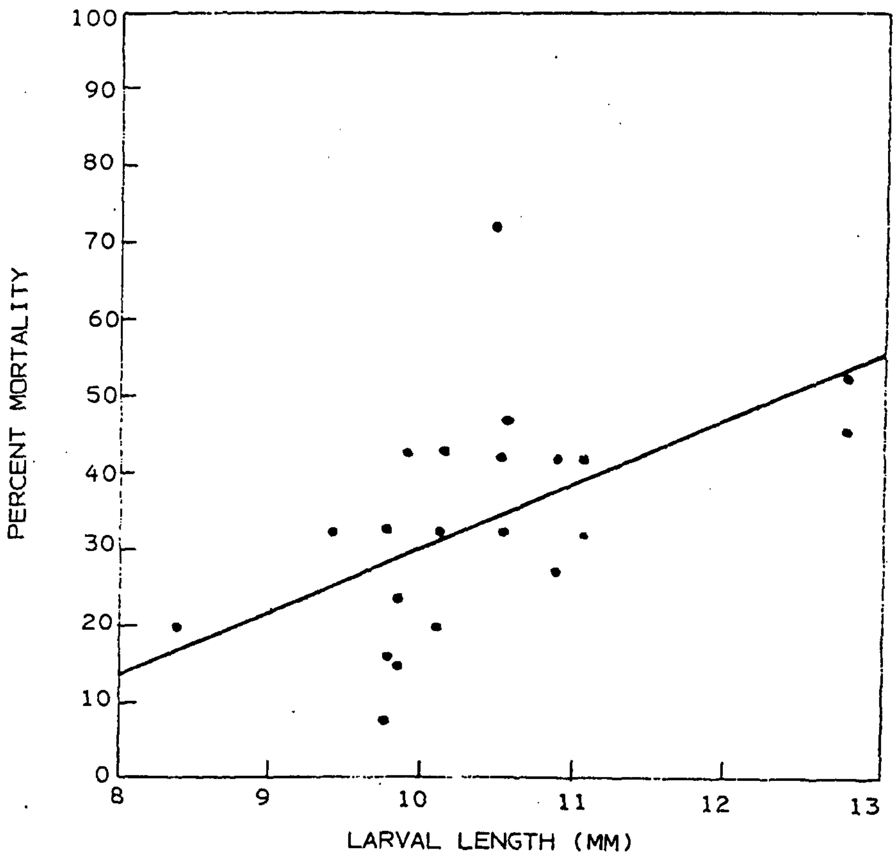


FIGURE 5.1-2

TEST MORTALITY AT THE 0.5 FPS/4 MIN TEST CONDITION AFTER 24 HOURS

TABLE 5.1-1

MEAN CONTROL MORTALITIES AND
95 PERCENT CONFIDENCE INTERVALS
WALLEYE LARVAE

Observational Period	Mean Mortality ± 95% CI
24 hr	26.8 ± 7.4
48 hr	55.4 ± 9.9
72 hr	75.8 ± 11.0
96 hr	87.8 ± 9.4

TABLE 5.1-2

RESULTS OF ANALYSIS OF COVARIANCE OF 24-HR MORTALITY FOR 0.5 TO 3.0 FPS AND 2 TO 4 MINUTES IMPINGEMENT OF WALLEYE

FULL MODEL

Source of Variation	df	Sum of Squares	Mean Squares	F Ratio	α Probability
Velocity (V)	4	24427.065	6106.766	25.922	0.0000*
Duration (D)	1	3866.941	3866.941	16.415	0.0001*
Segment	1	359.454	359.54	1.526	0.2183
V x D	4	2499.846	624.961	2.653	0.0347*
L x V	4	3474.756	868.689	3.687	0.0066*
L x D	1	154.881	154.881	0.657	0.4186
Temp Diff	1	213.105	213.105	0.905	0.3428
Length (L)	1	1372.470	1372.470	5.826	0.0168*
Residual	176	41462.027	235.580		
Total	193	82580.625			

Note: *Significant at $\alpha \leq 0.05$

REDUCED MODEL

Source of Variation	df	Sum of Squares	Mean Squares	F Ratio	α Probability
Velocity (V)	4	27229.402	6807.348	28.878	0.0000*
Duration (D)	1	3769.490	3769.490	15.991	0.0001*
V x D	4	2598.796	649.699	2.756	0.0294*
L x V	4	3423.895	855.974	3.631	0.0072*
Length (L)	1	1199.425	1199.425	5.088	0.0253*
Residual	179	42194.602	235.724		
Total	193	82580.625			

Note: *Significant at $\alpha \leq 0.05$

TABLE 5.1-3

RESULTS OF ANALYSIS OF COVARIANCE OF 24-HR MORTALITY FOR 0.5 TO 1.0 FPS AND 8 TO 16 MINUTES IMPINGEMENT OF WALLEYE

Source of Variation	df	Sum of Squares	Mean Squares	F Ratio	α Probability
Velocity (V)	1	15,454.88	15,454.88	39.090	0.0000*
Duration (D)	1	1,633.38	1,633.38	4.131	0.0455*
V x D	1	41.62	41.62	0.105	0.7465
Length (L)	1	488.68	488.68	1.236	0.2697
Residual	77	30,443.15			
Total	81	47,741.20			

Note: *Significant at α≤0.05

TABLE 5.1-4

RESULTS OF ANALYSIS OF COVARIANCE OF 24-HR MORTALITY FOR 1.5 TO 3.0 FPS AND 8 TO 16 MINUTES IMPINGEMENT OF WALLEYE

Source of Variability	df	Sum of Squares	Mean Squares	F Ratio	α Probability
Velocity (V)	2	4,069.07	2,034.53	8.651	0.0014*
Duration (D)	1	2,069.04	2,069.04	8.798	0.0065*
V x D	2	112.75	56.38	0.240	0.7886
Length (L)	1	1,728.66	1,728.66	7.351	0.0119*
Residual	25	5,879.36			
Total	31	12,417.43			

Note: *Significant at α≤0.05

TABLE 5.1-5

SUMMARY OF 24-HR MORTALITY ANALYSIS FOR WALLEYE LARVAE

Velocity (fps)	Impingement Duration (Minutes) 2	4	8	16
0.5	31.9± 6.5	35.2± 6.5	31.9± 8.5	39.5± 8.5
1.0	42.9± 6.5	55.5± 6.5	58.4±10.2	69.9±10.2
1.5	38.2± 6.6	46.1± 6.6	60.6±12.2	80.6±14.4
2.0	46.6± 7.9	45.0± 7.9	79.6±16.2	100±39.6
3.0	66.2±10.9	91.3±10.9	94.7±24.5	100±39.6

Note:

Values given are mean mortalities ± 95 percent confidence intervals. These estimated values are derived from the ANCOVA's given in Tables 5.1-1 through 5.1-4. No adjustments have been made for control mortality.

5.2 CHANNEL CATFISH

5.2.1 Analytical Results

The channel catfish testing program was conducted in two phases, referred to herein as Phase I and Phase II. During the first phase, larvae ranging in length from 11.2 mm to 15.5 mm were tested in the impingement model over the full range of approach velocities and impingement durations. There were 180 tests conducted, 9 tests per velocity/duration combination. During the second phase of testing, channel catfish larvae measuring 15.5 mm to 25.7 mm in length were studied. One hundred tests were performed at 2.0 and 3.0 fps for 4 and 16 minutes. The results of the entire testing program are summarized in Appendix A-2.

The holding tank and the test flume temperatures remained relatively constant throughout the testing program. During the first phase, the tank temperature ranged from 15.3°C to 20.5°C and the flume temperature ranged from 17.5°C to 22.5°C. In each test, flume temperature was slightly warmer than tank temperature. The temperature difference (tank temperature minus flume temperature) ranged from -3.1°C to -0.2°C. During the second phase, tank and flume temperatures ranged from 17.3°C to 23.4°C and 19.8°C to 24.8°C, respectively. The temperature difference ranged from -2.6°C to 0.1°C.

Test results from the two testing phases were separately analyzed by analyses of covariance. An analysis conducted on the Phase I data revealed that the temperature differences and model segments did not influence larval mortality (refer to Table 5.2-1). Therefore, these factors were not included in subsequent Phase I analyses.

The analysis summarized in Table 5.2-2 indicates that, within the range of independent variables examined during Phase I, impingement duration, approach velocity, and mean larval length significantly influenced mortality, and accounted for 12 percent, 12 percent and 7 percent of the total variability, respectively. All two-way interactions were significant. Since the interaction between velocity and duration was important, both factors must be specified to accurately predict larval mortality. In addition, the relationship between mean larval length and mortality differed for each level of approach velocity or impingement duration. The model summarized in Table 5.2-2 accounted for 61 percent of the overall variability.

The mean mortalities and 95 percent confidence intervals were estimated for all velocity/duration combinations (Table 5.2-3). A Tukey test of multiple comparisons indicated that the mean mortality rate predicted for the 3 fps/16-minute condition was significantly greater than the predicted mean mortalities for all other conditions. This was the only significantly different mean.

Additional analyses of the data, stratified by velocity, revealed that the mortality rates of larvae tested at 0.5 fps did not significantly decrease as the larvae increased in length. However, mean larval length was significantly related to the mortality rates of larvae tested at the higher approach velocities. The magnitude and direction of the relationship between mean larval length and mortality depends upon the duration. Table 5.2-4 summarizes the analyses stratified by velocity. Figure 5.2-1 depicts the relationship between mean larval length and mortality for each velocity examined.

Phase II of testing involved 15.5 mm to 25.7 mm larvae at approach velocities of 2.0 fps and 3.0 fps and impingement durations of 4 and 16 minutes. A preliminary analysis of covariance similar to the Phase I analysis is presented in the first part of Table 5.2-5. The analysis revealed that the temperature difference did not influence larval mortality. However, mortalities of larvae tested in segment A were significantly lower than the mortalities of larvae tested in segment B.

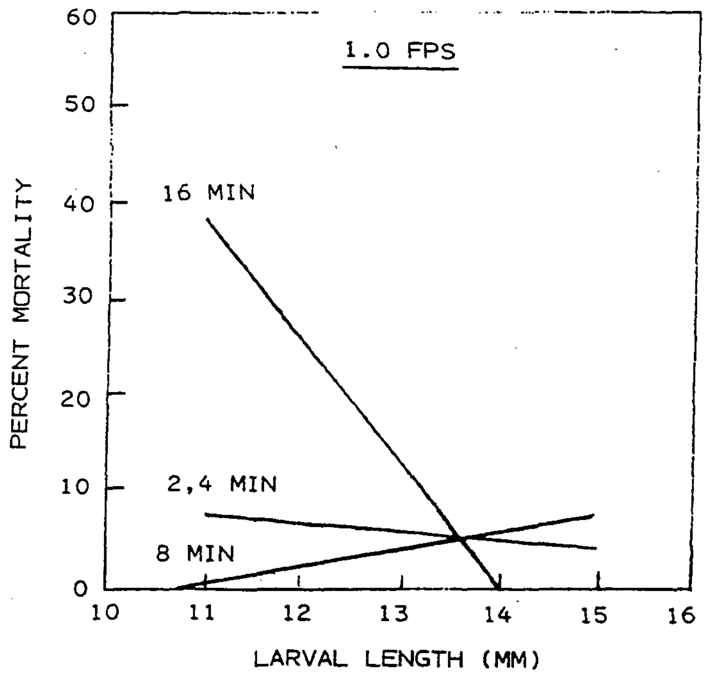
A second analysis, including interactions but excluding temperature difference, was then conducted. The second part of Table 5.2-5 summarizes the results of the analyses. The nonsignificant interaction between mean larval length and duration was then eliminated and a final analysis was performed. The results of the reduced analysis are summarized in the same table. The reduced model accounted for 49.6 percent of the total variability. Twenty-eight percent of the total variability was explained by duration, 3.4 percent by velocity and 4.7 percent by the combined effects of duration and velocity. Mean larval length accounted for 7 percent and the combined effects of length and velocity explained 3.9 percent of the variability. Model segment accounted for 2.6 percent of the total variability. Average mortalities and 95 percent confidence intervals for each velocity/duration combination and for each segment are presented in Table 5.2-6.

Channel catfish controls were studied to determine the mortality attributable to handling and holding. Table 5.2-7 summarizes the results of the analysis of covariance. Since the mortality rates did not significantly differ between the two control groups, handling did not increase mortality. The control mortality also was not associated with the mean larval lengths. The mean control mortality rate for all tests was 3.9 percent with a 95 percent confidence interval of 1.82 percent to 5.98 percent.

The mortality attributable to holding and handling, as determined by control groups, was low. As shown in Table 5.2-8, this mortality was not significantly affected by the group of fish tested or larval length. Since both test and control mortalities were very low, no attempt was made to adjust test mortality.

5.2.2 Discussion

Channel catfish testing was conducted in two phases in order to enhance data collection. Prior to testing, survival under anticipated test conditions was unpredictable. Accordingly, the entire testing matrix was run as the larvae grew from 11.2 to 15.5 mm. Review of test results indicated that survival was high under almost all conditions. Accordingly, the test procedures were modified by eliminating tests at the 2-minute duration, for which mortalitites were consistently low, and considering only the two highest velocities. This procedure limited the amount of testing necessary while monitoring mortality rates under conditions which would induce the highest mortalities as the larvae continued to grow from 15.5 to 25.7 mm.



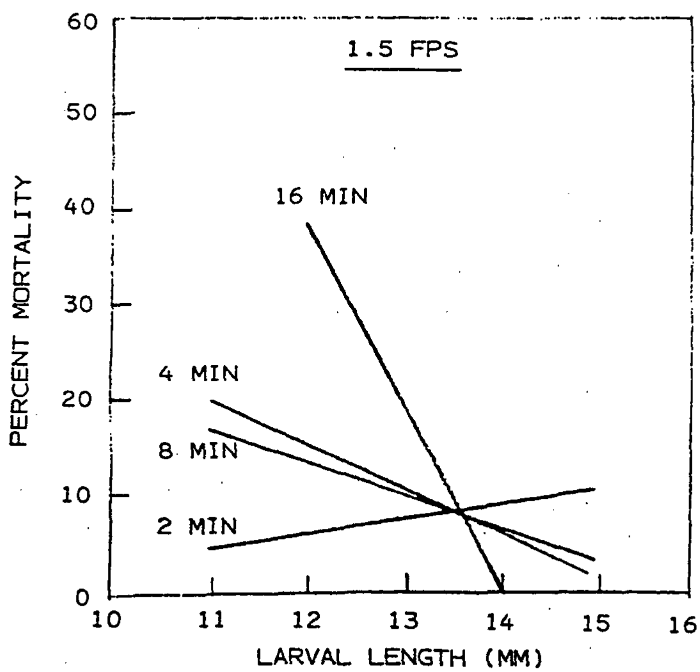


FIGURE 5.2-1
CHANNEL CATFISH MORTALITY
VERSUS LARVAL LENGTH
(BY VELOCITY)

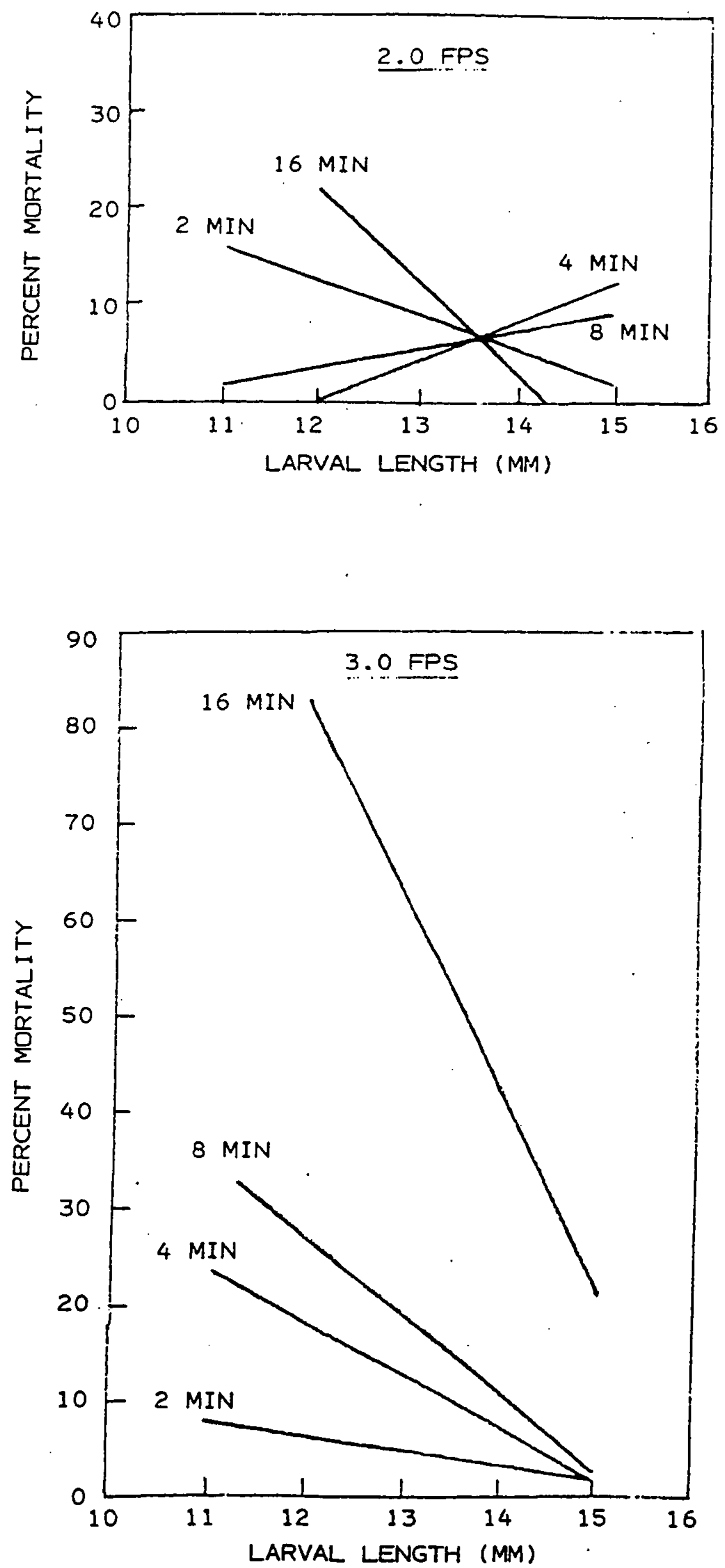


FIGURE 5.2-1 (CONT)

CHANNEL CATFISH MORTALITY
VERSUS LARVAL LENGTH
(BY VELOCITY)

The results of the previously described analyses have shown that velocity and impingement duration had only a small influence on 96-hr mortality, since survival of this species was very high under most test conditions. The 96-hr mortality values given in Table 5.2-3 indicate, therefore, that catfish mortality should be low even under conditions far more extreme than those anticipated for PINGP. These values are based on mortality estimates at the mean larval length. While larval length was found to have a significant effect on mortality, the magnitude of the effect was generally small, particularly under shorter impingement durations (Figure 5.2-1). At 0.5 fps, larval length was not a significant factor; therefore, the 0.5 fps values given in Table 5.2-3 are indicative of mortalities at all lengths tested. If these data are adjusted for control mortality (mean = 3.9 percent), it can be concluded that the mortality associated with impingement under the conditions tested would not exceed 1.0 percent.

Results of the second phase of testing verified the assumption that mortality under selected velocity/duration conditions would not change to any great extent as the larvae continued to grow (compare Table 5.2-3 to Table 5.2-6). The reason for the significant difference between the two test segments during Phase II is unclear; however, the difference is small and does not affect any conclusions relative to design criteria.

TABLE 5.2-1

PRELIMINARY ANALYSIS OF COVARIANCE - CHANNEL CATFISH MORTALITY
PHASE I - 11.2 to 15.5 mm LARVAE

Source of Variation	df	Sum of Squares	Mean Squares	F Ratio	α Probability
Velocity	4	5839.599	1459.8997	7.181	0.0000*
Duration	3	6161.035	2053.678	10.101	0.0000*
Segment	1	114.454	114.454	0.563	0.4544
ΔT	1	296.688	296.688	1.459	0.2286
Length	1	3019.854	3019.854	14.854	0.0002*
Residual	169	34358.684	203.306		
Total	179	50343.618			

Note: *Significant at $\alpha \leq 0.05$

TABLE 5.2-2

ANCOVA - FIRST PHASE
CHANNEL CATFISH 11.2-15.5 mm
96-HR LATENT MORTALITY RATE

Source of Variation	df	Sum of Squares	Mean Squares	F Ratio	α Probability
Duration (D)	4	5870.5	1467.63	11.46	0.0000*
Velocity (V)	3	6237.3	2079.10	16.235	0.0000*
D x V	12	7379.6	614.96	4.002	0.0000*
L x V	4	2447.9	611.97	4.779	0.0012*
L x D	3	5476.7	1825.56	14.225	0.0000*
Length (L)	1	3466.5	3466.47	27.069	0.0000*
Residual	152	19465.2	128.06		
Total	179	50343.6			

Note: *Significant at $\alpha \leq 0.05$

MODEL

$$Y_{ijk} = 8.52 + V_i + D_j + (VD_{ij}) + [(LV_i + LD_j - 3.87)(L_{ijk} - 13.6)] + e_{ijk}$$

where:

Y_{ijk} = 96-hr mortality

V_i = effect of the i^{th} velocity

D_j = effect of the j^{th} duration

L_{ijk} = mean larval length of the ijk^{th} test

e_{ijk} = the residual variance

TABLE 5.2-3

CHANNEL CATFISH MORTALITY
GIVEN AS MEAN MORTALITY
FIRST PHASE - 11.2 TO 15.5 mm LARVAE

		Impingement Duration (Minutes)			
		2	4	8	16
	0.5	1.4	4.8	3.0	3.1
	1.0	2.2	5.2	3.1	9.3
Velocity (fps)	1.5	4.5	9.2	5.4	13.8
	2.0	3.2	5.2	3.6	15.8
	3.0	4.3	9.2	13.9	50.3

Notes:

1. Only the 3.0 fps/16 minute combination was significantly different from the other values.

2. 95 percent confidence interval around all values = ±8.7 percent.

3. The mean mortality was estimated at a mean larval length of 13.6 mm.

4. Mean control mortality and 95 percent confidence interval = 3.9 ± 2.1 percent.

TABLE 5.2-4

ANCOVA STRATIFIED BY VELOCITY

a. 0.5 fps

Source of Variation	df	Sum of Squares	Mean Squares	F Ratio	α Probability
Duration (D)	3	54.924	18.308	1.165	0.3405
L x D	3	86.916	28.972	1.844	0.1621
Length (L)	1	0.316	0.3116	0.020	0.8890
Residual	28	439.923	15.7117		
Total	35	582.08			

b. 1.0 fps

Source of Variation	df	Sum of Squares	Mean Squares	F Ratio	α Probability
Duration (D)	3	269.89	89.96	1.198	0.3285
L x D	3	1538.54	512.85	6.831	0.0013*
Length (L)	1	347.17	347.173	4.624	0.0403*
Residual	28	2102.28	75.08		
Total	35	4257.87			

Note: *Significant at $\alpha \leq 0.05$

c. 1.5 fps

Source of Variation	df	Sum of Squares	Mean Squares	F Ratio	α Probability
Duration (D)	3	483.878	161.293	1.000	0.4073
L x D	3	2521.604	840.535	5.212	0.0055*
Length (L)	1	1783.086	1783.086	11.056	0.0025*
Residual	28	4515.86	161.2808		
Total	35	9304.43			

Note: *Significant at $\alpha \leq 0.05$

TABLE 5.2-4 (Cont)

d. 2.0 fps

Source of Variation	df	Sum of Squares	Mean Squares	F Ratio	α Probability
Duration (D)	3	958.491	319.497	2.440	0.0853
L x D	3	1308.872	436.291	3.331	0.0337*
Length (L)	1	116.498	116.4976	0.890	0.3537
Residual	28	3066.944	130.9623		
Total	35	6050.8008			

Note: *Significant at $\alpha \leq 0.05$

e. 3.0 fps

Source of Variation	df	Sum of Squares	Mean Squares	F Ratio	α Probability
Duration (D)	3	11849.678	3949.89	17.403	0.0000*
L x D	3	2405.8915	801.96	3.533	0.0274*
Length (L)	1	3667.2707	3667.27	16.158	0.0004*
Residual	28	6355.0938	226.968		
Total	35	24277.910			

Note: *Significant at $\alpha \leq 0.05$

TABLE 5.2-5

ANCOVA - SECOND PHASE
CHANNEL CATFISH: 15.5 mm - 25.7 mm LARVAE

PRELIMINARY ANALYSIS

Source of Variation	df	Sum of Squares	Mean Squares	F Ratio	α Probability
Velocity	1	1153.46	1153.46	4.389	0.0388*
Duration	1	11642.184	11642.184	44.303	0.0000*
Segment	1	1088.894	1088.894	4.144	0.0446*
ΔT	1	197.464	197.464	0.751	0.3882
Length	1	2816.594	2816.594	10.718	0.0015*
Residual	94	24701.8086	262.785		
Total	99	42322.277			

Note: *Significant at α≤0.05

FULL MODEL

Source of Variation	df	Sum of Squares	Mean Squares	F Ratio	α Probability
Velocity (V)	1	1455.422	1455.422	6.273	0.0140*
Duration (D)	1	11900.623	11900.623	51.292	0.0000*
Segment	1	1083.070	1083.07	4.668	0.0330*
V x D	1	2000.771	2000.771	8.623	0.0042*
L x V	1	1552.299	1552.299	6.690	0.0113*
L x D	1	0.7582	0.7582	0.003	0.9545
Length (L)	1	2659.708	2659.708	11.463	0.0010*
Residual	92	21345.43	232.016		
Total	99	42322.277			

REDUCED MODEL

Source of Variation	df	Sum of Squares	Mean Squares	F Ratio	α Probability
Velocity (V)	1	1455.422	1455.422	6.341	0.0135*
Duration (D)	1	11900.623	11900.623	51.848	0.0000*
Segment	1	1083.070	1083.07	4.719	0.0324*
V x D	1	2000.771	2000.771	8.717	0.0040*
L x V	1	1552.299	1552.299	6.763	0.0108*
Length (L)	1	2659.708	2659.708	11.588	0.0010*
Residual	93	21346.18	229.5288		
Total	99	42322.277			

Note: *Significant at α≤0.05

TABLE 5.2-6

CHANNEL CATFISH MORTALITY
GIVEN AS MEAN MORTALITY
SECOND PHASE - 15.5 mm - 25.7 mm LARVAE

		Impingement Duration	
		4	16
Velocity	2.0	6.8	19.6
	3.0	5.4	36.1

Note: 1. 95 percent confidence interval around mean mortalities = ±6.3
2. The mean mortalities are estimated at a mean larval length of 18.7 mm

MEAN MORTALITY AND 95 PERCENT
CONFIDENCE INTERVAL BY TEST SEGMENT

Segment	Mean Mortality
A	13.6 ± 4.4
B	20.2 ± 4.2

TABLE 5.2-7

ANALYSIS OF COVARIANCE CONTROL MORTALITY

Source of Variation	df	Sum of Squares	Mean Squares	F Rates	α Probability
Group	1	9.999	9.999	0.226	0.6372
Length	1	1.2267	1.2267	0.028	0.8686
Residual	37	1636.37	44.226		
Total	39	1647.599			

5.3 BLUEGILL

5.3.1 Analytical Results

Bluegill larvae ranging in length from 15.3 mm to 21.0 mm were tested in the impingement model over the full range of approach velocities and impingement durations. Two hundred and ninety four tests were conducted. The results of the entire testing program are presented in Appendix A-3. During the testing period, the holding tank and flume temperatures ranged from 17.0°C to 24.8°C and 19.7°C to 25.8°C. The temperature recorded in the flume was a maximum of 4.4°C warmer than the tank temperature.

Ninety-six hr mortality rates for initial tests performed at 0.5 fps (all impingement durations) were generally less than 10 percent. Results from previous larval testing indicated that mortality should decrease as the larvae grew in length. Since mortality rates were low, and the supply of bluegill larvae was limited, only 28 tests were conducted at 0.5 fps. The mean mortality and 95 percent confidence interval for these tests was 3.4 ± 1.76 (refer to Figure 5.3-1).

An analysis of covariance (ANCOVA) was performed on the remainder of the tests (conducted at velocities higher than 0.5 fps) to determine the relationship between larval mortality (the dependent variable) and the independent variables: impingement duration (2, 4, 8, and 16 minutes); approach velocity (1.0, 1.5, 2.0, and 3.0 fps); temperature difference; and test segment (A or B). The relationship between larval length and mortality was not investigated since the bluegill larvae arrived at the laboratory from different parental stocks and were hatched on different dates. Consequently, from the start of the testing program, the larval lengths varied appreciably resulting in a heterogenous group being tested daily.

A histogram of the mortality data obtained at velocities from 1.0 to 3.0 fps all impingement durations) is given in Figure 5.3-2. It is clear that the distribution is non-uniform. Therefore, prior to performing the ANCOVA, an angular transformation of the dependent variable was necessary to satisfy the assumptions for the analysis and to stabilize the variance of the error terms.

The ANCOVA presented in Table 5.3-1 indicates that, within the range of independent variables tested, impingement duration, velocity and temperature difference significantly influenced bluegill larval mortality. Test segment was not important. The significant two-way interaction between impingement duration and velocity indicates that these two factors were not independent.

The independent variables with $\alpha<0.05$ were eliminated from the model and a second analysis was conducted. Temperature difference remained significant (Table 5.3-2). However, this factor explained less than 1 percent of the total variability. Therefore, temperature difference was eliminated from the model, and a third analysis was performed. As shown in Table 5.3-3, velocity, impingement duration, and their interaction remained significant. The least squares equation for the reduced model presented in Table 5.3-3 accounts for 81 percent of the total variability. Based on the results

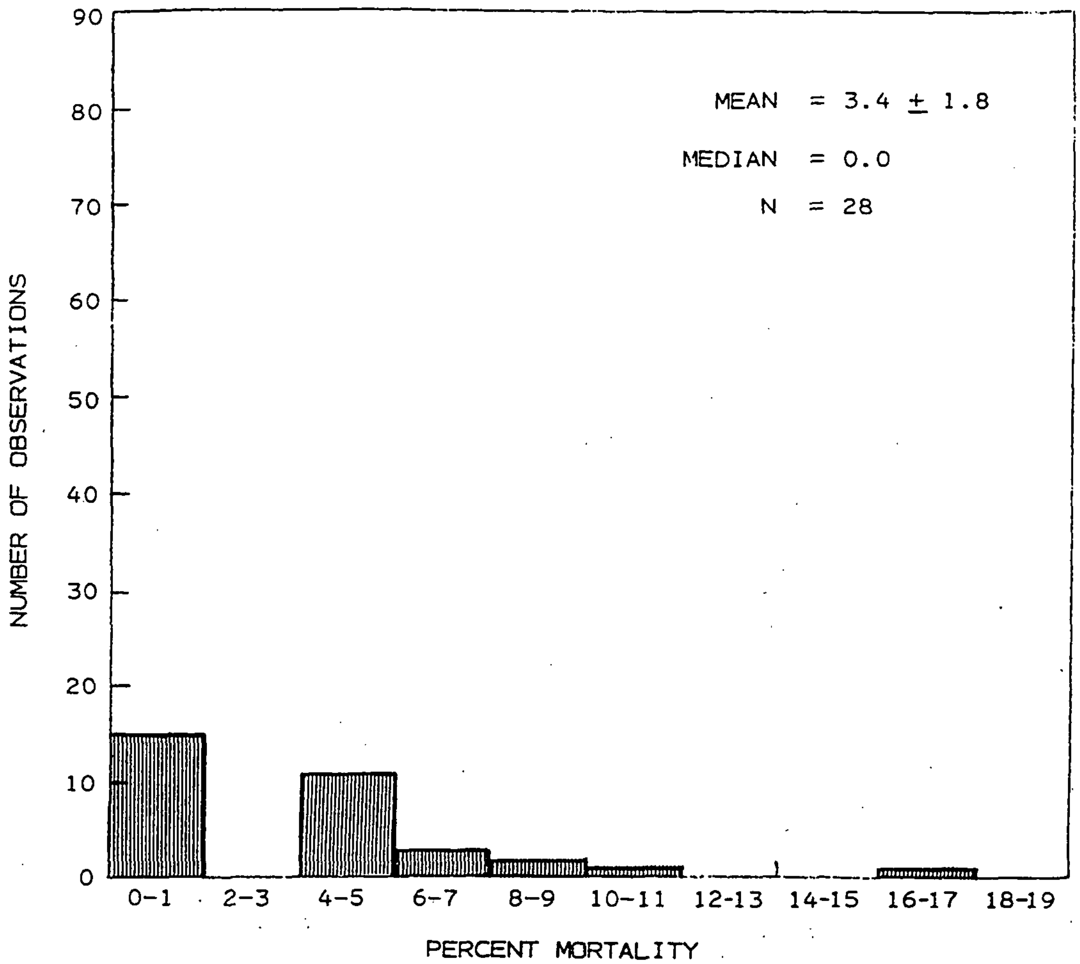


FIGURE 5.3-1

MORTALITY OF BLUEGILL LARVAE TESTED AT 0.5FPS

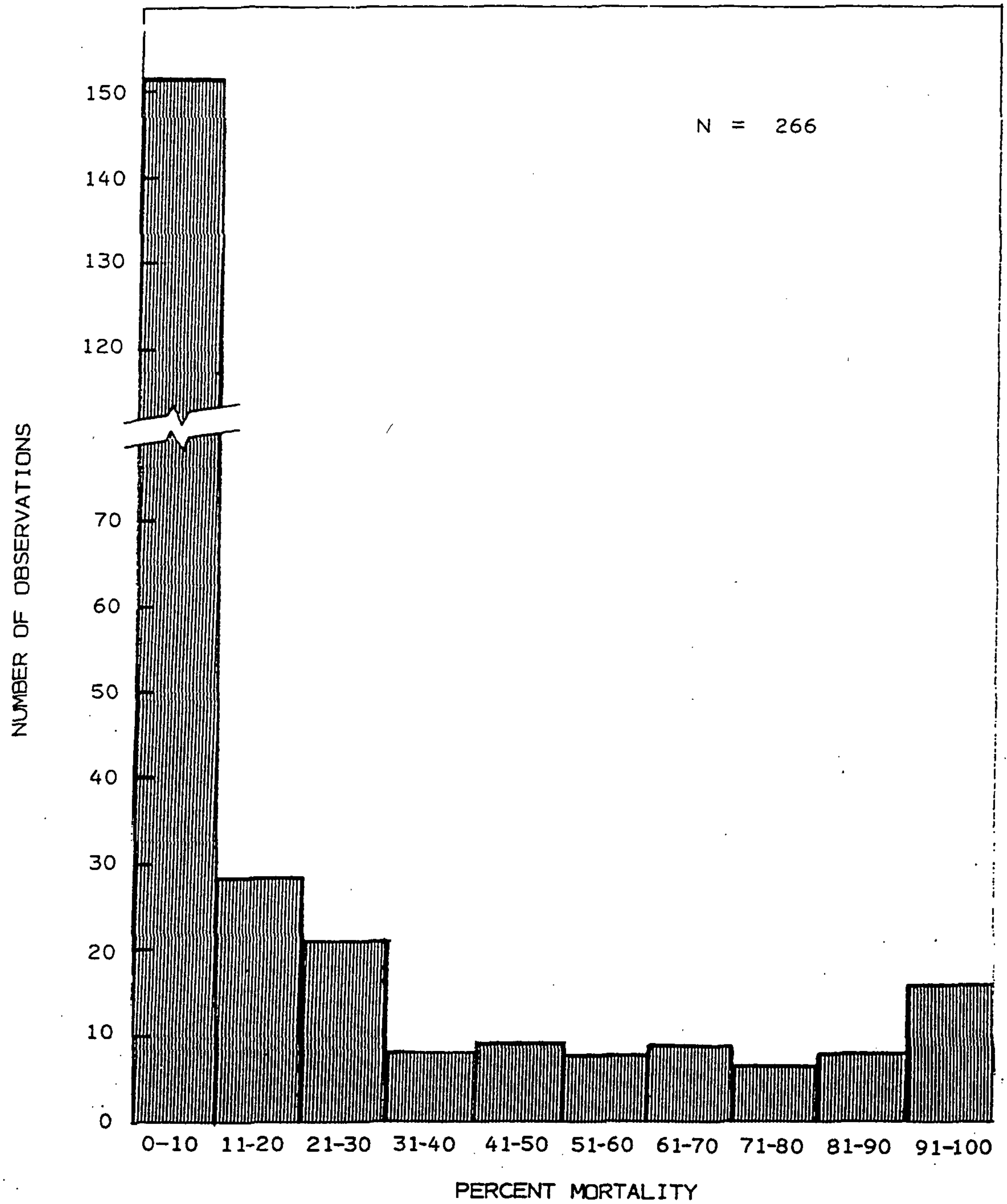


FIGURE 5.3-2

MORTALITY OF BLUEGILL LARVAE TESTED AT 1.0-3.0FPS of the analysis, 42 percent of the total variability was explained by impingement duration, 22 percent by velocity, and 17 percent by the combined effects of duration and velocity. Therefore, both impingement duration and water velocity must be specified to accurately predict larval mortality.

The statistical model was evaluated at each approach velocity and impingement duration. Table 5.3-4 shows the predicted mean mortality rates and 95 percent confidence intervals for each velocity/duration combination. Based on the analysis of covariance, the following conclusions can be drawn:

1. Mortality rates of larvae tested at 1.0 fps were not influenced by impingement duration.

2. The mortality rates of larvae impinged for 2 and 4 minutes at the higher velocities were not significantly different, although the mortality increased significantly as the impingement duration increased from 4 to 8 minutes and from 8 to 16 minutes.

3. The mortality rates of larvae impinged for 2 and 4 minutes did not significantly increase as the velocity increased.

To determine the mortality attributable to handling and holding of the test organisms during the study, two control groups were studied; larvae which were simply held and larvae which were handled and held. A t-test was conducted to determine whether the mortality rates differed. Results indicated that the mortality rates observed for the two control groups did not differ significantly. It appears that no additional stress was placed upon the larvae due to handling. Therefore, handling was not a significant factor in test mortality.

The two control groups were combined to determine the mean mortality rate among these organisms. On the average, 2.7 percent of the fish died, with a 95 percent confidence interval of 1.0 to 4.4 percent.

In conclusion, the 96-hr mortality rates for bluegill larvae were significantly influenced by both the approach velocity and duration of impingement. Mean mortality rates of larvae impinged for 2 and 4 minutes did not significantly differ for each approach velocity examined. In addition, the mean mortalities observed at 8 and 16 minutes for larvae tested at 0.5 and 1.0 fps were not significantly different and were similar to the mean mortalities observed for the lower impingement durations.

Higher mortality rates were observed for larvae impinged for 8 and 16 minutes at approach velocities of 1.5, 2.0, and 3.0 fps. The mortality rate increased as impingement duration increased and/or the approach velocity increased.

Within the range of independent variables examined, test segment did not significantly influence the mortalities. Temperature difference explained less than 1 percent of the total variability.

The mortality attributed to holding and handling was quite low. The lower bound of the 95 percent confidence interval, 1.0 percent, can be viewed as the most conservative estimate of control larvae mortality for purpose of adjusting test mortality.

5.3.2 Discussion

As with the channel catfish, survival of bluegill larvae at 96 hr was high under many of the impingement conditions. As expected, velocity and impingement duration were the significant factors in explaining mortality. However, as shown on Table 5.3-4, these variables acted to increase mortality primarily under conditions of high velocity coupled with long impingement duration. Under the conditions anticipated for the intake at PINGP (0.5 fps/4 min impingement), mean mortality was only 3.4 percent. If adjusted for mean control mortality, this value becomes less than 1 percent. Therefore, it is concluded that a fine screening intake should allow for the safe collection of bluegill larvae with very high survival.

TABLE 5.3-1

RESULTS OF ANALYSIS OF VARIANCE OF
96-HR BLUEGILL MORTALITY - FULL MODEL

Source of Variation	df	Sum of Squares	Mean Squares	F Ratio	α Probability
Velocity (V)	3	10.1450	3.3817	100.882	0.0000*
Duration (D)	3	19.1367	6.3789	190.294	0.0000*
Segment	1	0.0112	0.0112	0.335	0.5635
V x D	9	7.9355	0.8817	26.303	0.0000*
ΔT	1	0.2291	0.2291	6.835	0.0095*
Residual	248	8.3133	0.0335		
Total	265	45.7082			

TABLE 5.3-2

RESULTS OF ANALYSIS OF VARIANCE OF
96-HR BLUEGILL MORTALITY - REDUCED MODEL

Source of Variation	df	Sum of Squares	Mean Squares	F Ratio	α Probability
Velocity (V)	3	10.1473	3.3824	101.175	0.0000*
Duration (D)	3	19.2600	6.4200	192.033	0.0000*
V x D	9	7.9427	0.8825	26.398	0.0000*
ΔT	1	0.2288	0.2288	6.845	0.0094*
Residual	249	8.3245			
Total	265	45.7082			

Note:* Significant at $\alpha \leq 0.05$

TABLE 5.3-3

RESULTS OF ANALYSIS OF VARIANCE OF 96-HR BLUEGILL MORTALITY - FINAL MODEL

Source of Variation	df	Sum of Squares	Mean Squares	F Ratio	α Probability
Velocity (V)	3	9.960	3.320	97.041	0.0000*
Duration (D)	3	19.171	6.390	186.782	0.0000*
V x D	9	7.986	0.887	25.934	0.0000*
Residual	250	8.553	0.0342		
Total	265	45.708			

Note: Significant at $\alpha \leq 0.05$

MODEL

$$\arcsin\ (Y_{ijk}) = 0.4087 + D_i + V_j + (DV_{ij}) + e_{ijk}$$

where:

Y_{ijk} = predicted mortality

D_i = effect of the i^{th} duration

V_j = effect of the j^{th} velocity

e_{ijk} = the residual variance

TABLE 5.3-4

PREDICTED MEAN MORTALITY RATES AND
95 PERCENT CONFIDENCE INTERVALS - BLUEGILL

Velocity (fps)	Impingement Duration (Minutes) 2	4	8	16
0.5	3.4 ± 1.76	3.4 ± 1.76	3.4 ± 1.76	3.4 ± 1.76
1.0	0.3 < 2.3 < 6.1	0.13 < 1.8 < 5.3	0.1 < 1.5 < 4.8	1 < 4 < 8.7
1.5	0.1 < 1.4 < 4.6	0.4 < 2.5 < 6.5	8.3 < 14.3 < 21.5	33.6 < 42.8 < 52.3
2.0	0.4 < 2.5 < 6.3	0.3 < 2.3 < 6	18.4 < 26.3 < 35	56.2 < 65.5 < 74.2
3.0	0.8 < 2.1 < 5.5	4.4 < 9.4 < 15.8	52 < 61.1 < 69.8	93.3 < 97.3 < 99.6

Notes: Vel/duration combinations contained within dotted lines were not significantly different ($\alpha \leq 0.05$) than adjacent boxes.

Mean control mortality and 95 percent confidence interval = 2.7 ± 1.7 percent.

SECTION 6

CONCLUSIONS

The objective of this study was to determine whether the concept of collecting and removing larval fish from a fine-mesh screening system offers a potentially effective means of alleviating existing entrainment losses at PINGP. The results indicate that two of the test species, channel catfish and bluegill, are relatively hardy and experienced low mortality following exposure to such a system. The ability to draw firm conclusions on survivorship to 96 hr from walleye test data is limited due to problems which occurred in maintaining this species under laboratory conditions. It could not be clearly determined to what extent the high mortalities observed among test organisms were due to holding problems rather than impingement stress. However, based on observations made during the study, it would appear that holding was a major factor in mortality. This conclusion is supported by the experience of other researchers, as discussed in Section 2. Therefore, it might be expected that, under actual operating conditions at PINGP where the larvae would not be exposed to the extensive handling and holding stresses which occurred in the laboratory, survival could be greater than indicated by these study results.

Despite the difficulties in estimating the long-term survival potential of walleye, two main conclusions can be drawn from the results of testing with all three species:

1. The concept of collecting and removing larval fish from a fine-mesh screen appears to offer a potentially effective means of mitigating entrainment losses; and

2. Velocity and impingement duration are two of the main factors which must be considered if mortality is to be minimized.

It is clear that, if a system were to be designed for hardy species such as channel catfish and bluegill, a relatively wide range of values for each important parameter would be available for use. However, if the system must incorporate conditions which would maximize the survival potential of the least hardy species (in this case walleye), then the range of acceptable velocities and impingement durations becomes limited. Therefore, if walleye were the limiting species at PINGP, it would be necessary to implement velocity/duration conditions similar to the lower range of those tested in this study.

In conclusion, it would appear that a fine screening system for PINGP affords a practical and potentially effective means of minimizing entrainment losses. It is difficult to determine the survival potential of other species of importance at this site based on these study results. However, recent impingement survival studies, particularly those conducted by TVA (1977; 1979), indicate that many species would exhibit survival rates in the range of those obtained for walleye, channel catfish and bluegill.

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APPENDIX A

LARVAL IMPINGEMENT TEST DATA

TABLE A-1

LARVAL IMPINGEMENT SURVIVAL STUDY
WALLEYE TEST DATA

CONDITIONS: VELOCITY = 0.5, 1.0, 1.5 FPS
DURATION = 2 and 4 MINUTES

Test No.	Larval Length (mm)	Velocity	Duration	Initial Survival No.	Initial Mortality No.	24 Hour Mortality No.	48 Hour Mortality No.	72 Hour Mortality No.	96 Hour Mortality %	No. Tested	Initial Mortality Ratio	No. Dead 24 Hour	24 Hour Mortality Ratio	No. Dead 48 Hour	48 Hour Mortality Ratio	No. Dead 72 Hour	72 Hour Mortality Ratio
1.	8.39	1.	1.	23.	2.	4.	5.	4.	72.0	25.	0.1	6.	0.2	11.	0.4	15.	0.6
2.	8.39	1.	2.	23.	2.	3.	4.	1.	44.0	25.	0.1	5.	0.2	9.	0.4	10.	0.4
5.	8.39	2.	1.	25.	0.	0.	0.	5.	32.0	25.	0.0	0.	0.0	0.	0.0	5.	0.2
6.	8.39	2.	2.	25.	0.	6.	6.	4.	68.0	25.	0.0	6.	0.2	12.	0.5	16.	0.6
9.	8.83	3.	1.	24.	1.	4.	0.	3.	48.0	25.	0.0	5.	0.2	5.	0.2	8.	0.3
10.	8.83	3.	2.	17.	7.	4.	2.	2.	66.7	24.	0.3	11.	0.5	13.	0.5	15.	0.6
21.	9.41	1.	1.	25.	0.	7.	4.	3.	64.0	25.	0.0	7.	0.3	11.	0.4	14.	0.6
22.	9.41	1.	2.	25.	0.	8.	6.	3.	68.0	25.	0.0	8.	0.3	14.	0.6	17.	0.7
25.	9.41	2.	1.	23.	2.	7.	7.	1.	76.0	25.	0.1	9.	0.4	16.	0.6	17.	0.7
26.	9.41	2.	2.	9.	16.	1.	1.	0.	76.0	25.	0.6	17.	0.7	18.	0.7	18.	0.7
29.	9.41	3.	1.	23.	2.	4.	9.	1.	64.0	25.	0.1	6.	0.2	15.	0.6	16.	0.6
30.	9.41	3.	2.	19.	6.	4.	5.	2.	76.0	25.	0.2	10.	0.4	15.	0.6	17.	0.7
39.	9.72	1.	1.	25.	0.	4.	5.	4.	52.0	25.	0.0	4.	0.2	9.	0.4	13.	0.5
40.	9.72	1.	2.	22.	3.	5.	4.	1.	60.0	25.	0.1	8.	0.3	12.	0.5	13.	0.5
43.	9.72	2.	1.	22.	3.	6.	2.	2.	56.0	25.	0.1	9.	0.4	11.	0.4	13.	0.5
44.	9.72	2.	2.	21.	4.	3.	2.	1.	40.0	25.	0.2	7.	0.3	9.	0.4	10.	0.4
47.	9.72	3.	1.	20.	5.	5.	2.	2.	56.0	25.	0.2	10.	0.4	12.	0.5	14.	0.6
48.	9.72	3.	2.	23.	2.	0.	2.	2.	28.0	25.	0.1	2.	0.1	4.	0.2	6.	0.2
61.	9.72	1.	1.	25.	0.	8.	7.	1.	68.0	25.	0.0	8.	0.3	15.	0.6	16.	0.6
62.	9.72	1.	2.	24.	1.	1.	0.	0.	8.0	25.	0.0	2.	0.1	2.	0.1	2.	0.1
65.	9.72	2.	1.	19.	4.	4.	2.	0.	43.5	23.	0.2	8.	0.3	10.	0.4	10.	0.4
66.	9.72	2.	2.	16.	9.	7.	2.	0.	76.0	25.	0.4	16.	0.6	18.	0.7	18.	0.7
69.	9.72	3.	1.	25.	0.	7.	6.	1.	60.0	25.	0.0	7.	0.3	13.	0.5	14.	0.6
70.	9.72	3.	2.	23.	2.	4.	4.	1.	44.0	25.	0.1	6.	0.2	10.	0.4	11.	0.4
71.	9.72	1.	1.	24.	1.	2.	0.	0.	24.0	25.	0.0	3.	0.1	3.	0.1	3	0.1
72.	9.72	1.	2.	24.	1.	3.	0.	0.	16.0	25.	0.0	4.	0.2	4.	0.2	4.	0.2
75.	9.72	2.	1.	25.	0.	5.	1.	1.	44.0	25.	0.0	5.	0.2	6.	0.2	7.	0.3
76.	9.72	2.	2.	22.	3.	7.	1.	0.	44.0	25.	0.1	10.	0.4	11.	0.4	11.	0.4
79.	9.72	2.	1.	25.	0.	9.	0.	1.	48.0	25.	0.0	9.	0.4	9.	0.4	10.	0.4
80.	9.72	2.	2.	18.	7.	2.	3.	0.	52.0	25.	0.3	9.	0.4	12.	0.5	12.	0.5
81.	9.87	1.	1.	25.	0.	5.	1.	0.	24.0	25.	0.0	5.	0.2	6.	0.2	6.	0.2
82.	9.87	1.	2.	24.	1.	5.	0.	3.	48.0	25.	0.0	6.	0.2	6.	0.2	9.	0.4
85.	9.87	1.	1.	24.	1.	5.	2.	0.	44.0	25.	0.0	6.	0.2	8.	0.3	8.	0.3
86.	9.87	1.	2.	20.	5.	6.	0.	0.	48.0	25.	0.2	11.	0.4	11.	0.4	11.	0.4
89.	9.87	2.	1.	19.	6.	6.	1.	5.	80.0	25.	0.2	12.	0.5	13.	0.5	18.	0.7
90.	9.87	2.	2.	13.	12.	6.	1.	1.	92.0	25.	0.5	18.	0.7	19.	0.8	20.	0.8
93.	9.87	2.	1.	24.	1.	7.	2.	2.	76.0	25.	0.0	8.	0.3	10.	0.4	12.	0.5
44.	9.87	2.	2.	9.	17.	0.	0.	1.	76.9	26.	0.7	17.	0.7	17.	0.7	18.	0.7
97.	9.87	3.	1.	22.	3.	2.	0.	2.	64.0	25.	0.1	5.	0.2	5.	0.2	7.	0.3
98.	9.87	3.	2.	13.	14.	3.	0.	1.	70.4	27.	0.5	17.	0.6	17.	0.6	18.	0.7
99.	9.87	3.	1.	19.	7.	1.	0.	1.	38.5	26.	0.3	8.	0.3	8.	0.3	9.	0.3
100.	9.87	3.	2.	17.	8.	3.	0.	0.	64.0	25.	0.3	11.	0.4	11.	0.4	11.	0.4
105.	9.87	1.	1.	24.	1.	8.	0.	3.	64.0	25.	0.0	9.	0.4	9.	0.4	12.	0.5
106.	9.87	1.	2.	25.	1.	3.	0.	4.	69.2	26.	0.0	4.	0.2	4.	0.2	8.	0.3
109.	9.87	2.	1.	16.	9.	2.	0.	2.	64.0	25.	0.4	11.	0.4	11.	0.4	13.	0.5
110.	9.87	2.	2.	6.	19.	3.	0.	0.	92.0	25.	0.8	22.	0.9	22.	0.9	22.	0.9
111.	10.16	1.	1.	24.	1.	0.	6.	7.	96.0	25.	0.0	1.	0.0	7.	0.3	14.	0.6
112.	10.16	1.	2.	23.	2.	3.	1.	5.	72.0	25.	0.1	5.	0.2	6.	0.2	11.	0.4
115.	10.16	1.	1.	25.	0.	9.	3.	3.	88.0	25.	0.0	9.	0.4	12.	0.5	15.	0.6
116.	10.16	1.	2.	22.	3.	5.	1.	2.	88.0	25.	0.1	8.	0.3	9.	0.4	11.	0.4
119.	10.16	2.	1.	20.	6.	7.	2.	4.	92.3	26.	0.2	13.	0.5	15.	0.6	19.	0.7
120.	10.16	2.	2.	13.	12.	7.	3.	1.	96.0	25.	0.5	19.	0.8	22.	0.9	23.	0.9
121.	10.16	2.	1.	18.	7.	7.	0.	6.	100.0	25.	0.3	14.	0.6	14.	0.6	20.	0.8

LEGEND:	Velocity (FPS)	Duration (Min)	Segment
	1=0.5	1=2	1-A
	2=1.0	2=4	2=B
	3=1.5	3=8	
	4=2.0	4=16	
	5=3.0		

TABLE A-1 (Cont.)

LARVAL IMPINGEMENT SURVIVAL STUDY
WALLEYE TEST DATA

CONDITIONS: VELOCITY = 0.5, 1.0, 1.5 FPS
DURATION = 2 and 4 MINUTES

Test No.	Larval Length (mm)	Velocity	Duration	Initial Survival No.	Initial Mortality No.	24 Hour Mortality No.	48 Hour Mortality No.	72 Hour Mortality No.	96 Hour Mortality %	No. Tested	Initial Mortality Ratio	No. Dead 24 Hour	24 Hour Mortality Ratio	No. Dead 48 Hour	48 Hour Mortality Ratio	No. Dead 72 Hour	72 Hour Mortality Ratio
122.	10.16	2.	2.	8.	18.	3.	2.	2.	96.2	26.	0.7	21.	0.8	23.	0.9	25.	1.0
123.	10.16	3.	1.	21.	3.	7.	1.	5.	83.3	24.	0.1	10.	0.4	11.	0.5	16.	0.7
124.	10.16	3.	2.	12.	13.	3.	1.	5.	92.0	25.	0.5	16.	0.6	17.	0.7	22.	0.9
125.	10.16	3.	1.	16.	9.	6.	1.	1.	84.0	25.	0.4	15.	0.6	16.	0.6	17.	0.7
126.	10.16	3.	2.	13.	12.	6.	4.	1.	92.0	25.	0.5	18.	0.7	22.	0.9	23.	0.9
131.	10.16	1.	1.	20.	5.	2.	5.	6.	72.0	25.	0.2	7.	0.3	12.	0.5	18.	0.7
132.	10.16	1.	2.	23.	2.	6.	3.	7.	84.0	25.	0.1	8.	0.3	11.	0.4	18.	0.7
135.	10.16	1.	1.	23.	2.	3.	10.	5.	96.0	25.	0.1	5.	0.2	15.	0.6	20.	0.8
136.	10.16	1.	2.	20.	5.	6.	6.	2.	84.0	25.	0.2	11.	0.4	17.	0.7	19.	0.8
139.	10.16	2.	1.	19.	6.	5.	4.	2.	92.0	25.	0.2	11.	0.4	15.	0.6	17.	0.7
140.	10.16	2.	2.	16.	9.	9.	1.	0.	88.0	25.	0.4	18.	0.7	19.	0.8	19.	0.8
141.	10.16	2.	1.	22.	3.	11.	3.	1.	92.0	25.	0.1	14.	0.6	17.	0.7	18.	0.7
142.	10.16	2.	2.	12.	13.	5.	3.	2.	92.0	25.	0.5	18.	0.7	21.	0.8	23.	0.9
143.	10.16	3.	1.	21.	4.	12.	3.	0.	88.0	25.	0.2	16.	0.6	19.	0.8	19.	0.8
144.	10.16	3.	2.	19.	5.	9.	3.	4.	91.7	24.	0.2	14.	0.6	17.	0.7	21.	0.9
145.	10.16	3.	1.	19.	5.	6.	5.	4.	95.8	24.	0.2	11.	0.5	16.	0.7	20.	0.8
146.	10.16	3.	2.	18.	7.	11.	3.	2.	100.0	25.	0.3	18.	0.7	21.	0.8	23.	0.9
147.	10.45	1.	1.	24.	1.	7.	7.	9.	100.0	25.	0.0	8.	0.3	15.	0.6	24.	1.0
148.	10.45	1.	2.	20.	4.	6.	11.	1.	95.8	24.	0.2	10.	0.4	21.	0.9	22.	0.9
151.	10.45	1.	1.	20.	5.	7.	4.	6.	96.0	25.	0.2	12.	0.5	16.	0.6	22.	0.9
152.	10.45	1.	2.	16.	9.	9.	4.	2.	100.0	25.	0.4	18.	0.7	22.	0.9	24.	1.0
155.	10.45	2.	1.	20.	4.	10.	4.	3.	91.7	24.	0.2	14.	0.6	18.	0.8	21.	0.9
156.	10.45	2.	2.	19.	6.	7.	4.	3.	92.0	25.	0.2	13.	0.5	17.	0.7	20.	0.8
157.	10.45	2.	1.	20.	5.	8.	7.	3.	100.0	25.	0.2	13.	0.5	20.	0.8	23.	0.9
158.	10.45	2.	2.	17.	9.	7.	5.	11.	100.0	26.	0.3	16.	0.6	21.	0.8	32.	1.2
159.	10.45	3.	1.	18.	7.	10.	6.	2.	100.0	25.	0.3	17.	0.7	23.	0.9	25.	1.0
160.	10.45	3.	2.	22.	3.	6.	7.	3.	100.0	25.	0.1	9.	0.4	16.	0.6	19.	0.8
161.	10.45	3.	1.	23.	3.	12.	3.	4.	92.3	26.	0.1	15.	0.6	18.	0.7	22.	0.8
162.	10.45	3.	2.	19.	6.	9.	0.	2.	92.0	25.	0.2	15.	0.6	15.	0.6	17.	0.7
163.	10.54	1.	1.	24.	1.	3.	15.	3.	88.0	25.	0.0	4.	0.2	19.	0.8	22.	0.9
164.	10.54	1.	2.	17.	7.	1.	7.	6.	95.8	24.	0.3	8.	0.3	15.	0.6	21.	0.9
167.	10.54	1.	1.	21.	4.	4.	9.	2.	92.0	25.	0.2	8.	0.3	17.	0.7	19.	0.8
168.	10.54	1.	2.	20.	5.	7.	8.	3.	92.0	25.	0.2	12.	0.5	20.	0.8	23.	0.9
171.	10.54	2.	1.	17.	8.	10.	4.	3.	100.0	25.	0.3	18.	0.7	22.	0.9	25.	1.0
172.	10.54	2.	2.	22.	3.	10.	8.	2.	96.0	25.	0.1	13.	0.5	21.	0.8	23.	0.9
175.	10.54	2.	1.	15.	10.	10.	5.	0.	100.0	25.	0.4	20.	0.8	25.	1.0	25.	1.0
176.	10.54	2.	2.	15.	10.	8.	4.	0.	96.0	25.	0.4	18.	0.7	22.	0.9	22.	0.9
179.	10.54	3.	1.	17.	8.	6.	8.	0.	96.0	25.	0.3	14.	0.6	22.	0.9	22.	0.9
180.	10.54	3.	2.	14.	11.	1.	11.	1.	100.0	25.	0.4	12.	0.5	23.	0.9	24.	1.0
181.	10.54	3.	1.	23.	2.	10.	9.	3.	100.0	25.	0.1	12.	0.5	21.	0.8	24.	1.0
182.	10.54	3.	2.	18.	7.	4.	9.	1.	88.0	25.	0.3	11.	0.4	20.	0.8	21.	0.8
187.	10.87	1.	1.	27.	0.	12.	4.	5.	92.6	27.	0.0	12.	0.4	16.	0.6	21.	0.8
188.	10.87	1.	1.	25.	0.	7.	5.	3.	84.0	25.	0.0	7.	0.3	12.	0.5	15.	0.6
189.	10.87	1.	2.	24.	1.	6.	6.	5.	100.0	25.	0.0	7.	0.3	13.	0.5	18.	0.7
190.	10.87	1.	2.	23.	1.	9.	2.	2.	95.8	24.	0.0	10.	0.4	12.	0.5	14.	0.6
195.	10.87	2.	1.	25.	0.	10.	7.	1.	96.0	25.	0.0	10.	0.4	17.	0.7	18.	0.7
196.	10.87	2.	1.	25.	0.	10.	5.	6.	92.0	25.	0.0	10.	0.4	15.	0.6	21.	0.8
197.	10.87	2.	2.	25.	0.	8.	8.	4.	96.0	25.	0.0	8.	0.3	16.	0.6	20.	0.8
198.	10.87	2.	2.	24.	1.	10.	5.	6.	96.0	25.	0.0	11.	0.4	16.	0.6	22.	0.9
203.	10.87	3.	1.	22.	3.	4.	8.	8.	100.0	25.	0.1	7.	0.3	15.	0.6	23.	0.9
204.	10.87	3.	1.	24.	1.	6.	9.	4.	88.0	25.	0.0	7.	0.3	16.	0.6	20.	0.8
205.	10.87	3.	2.	25.	0.	7.	6.	7.	96.0	25.	0.0	7.	0.3	13.	0.5	20.	0.8
206.	10.87	3.	2.	26.	0.	4.	8.	10.	92.3	26.	0.0	4.	0.2	12.	0.5	22.	0.8

LEGEND:

Velocity (FPS)	Duration (Min)	Segment
1=0.5	1=2	1-A
2=1.0	2=4	2=B
3=1.5	3=8	
4=2.0	4=16	
5=3.0		

TABLE A-1 (Cont.)

LARVAL IMPINGEMENT SURVIVAL STUDY
WALLEYE TEST DATA

CONDITIONS: VELOCITY = 0.5, 1.0, 1.5 FPS
DURATION = 2 and 4 MINUTES

Test No.	Larval Length (mm)	Velocity	Duration	Initial Survival No.	Initial Mortality No.	24 Hour Mortality No.	48 Hour Mortality No.	72 Hour Mortality No.	96 Hour Mortality %	No. Tested	Initial Mortality Ratio	No. Dead 24 Hour	24 Hour Mortality Ratio	No. Dead 48 Hour	48 Hour Mortality Ratio	No. Dead 72 Hour	72 Hour Mortality Ratio
211.	11.16	1.	1.	25.	0.	4.	7.	6.	84.0	25.	0.0	4.	0.2	11.	0.4	17.	0.7
212.	11.16	1.	1.	25.	0.	10.	10.	2.	92.0	25.	0.0	10.	0.4	20.	0.8	22.	0.9
213.	11.16	1.	2.	23.	2.	6.	8.	3.	96.0	25.	0.1	8.	0.3	16.	0.6	19.	0.8
214.	11.16	1.	2.	25.	1.	10.	8.	4.	96.2	26.	0.0	11.	0.4	19.	0.7	23.	0.9
219.	11.16	2.	1.	25.	0.	11.	8.	3.	92.0	25.	0.0	11.	0.4	19.	0.8	22.	0.9
220.	11.16	2.	1.	24.	1.	7.	9.	3.	96.0	25.	0.0	8.	0.3	17.	0.7	20.	0.8
221.	11.16	2.	2.	24.	1.	11.	10.	2.	100.0	25.	0.0	12.	0.5	22.	0.9	24.	1.0
222.	11.16	2.	2.	25.	0.	9.	8.	1.	80.0	25.	0.0	9.	0.4	17.	0.7	18.	0.7
227.	11.16	3.	1.	25.	0.	6.	10.	6.	100.0	25.	0.0	6.	0.2	16.	0.6	22.	0.9
228.	11.16	3.	1.	24.	1.	1.	9.	6.	76.0	25.	0.0	2.	0.1	11.	0.4	17.	0.7
229.	11.16	3.	2.	24.	0.	6.	7.	6.	91.7	24.	0.0	6.	0.3	13.	0.5	19.	0.8
230.	11.16	3.	2.	25.	0.	10.	6.	2.	96.0	25.	0.0	10.	0.4	16.	0.6	18.	0.7
241.	12.73	1.	1.	23.	2.	12.	8.	0.	96.0	25.	0.1	14.	0.6	22.	0.9	22.	0.9
242.	12.73	1.	1.	23.	2.	17.	4.	0.	100.0	25.	0.1	19.	0.8	23.	0.9	23.	0.9
243.	12.73	1.	2.	23.	3.	9.	10.	3.	100.0	26.	0.1	12.	0.5	22.	0.8	25.	1.0
244.	12.73	1.	2.	19.	6.	7.	7.	1.	92.0	25.	0.2	13.	0.5	20.	0.8	21.	0.8
249.	12.73	2.	1.	24.	1.	10.	7.	2.	88.0	25.	0.0	11.	0.4	18.	0.7	20.	0.8
250.	12.73	2.	1.	22.	1.	9.	6.	4.	91.3	23.	0.0	10.	0.4	16.	0.7	20.	0.9
251.	12.73	2.	2.	25.	0.	8.	8.	1.	80.0	25.	0.0	8.	0.3	16.	0.6	17.	0.7
252.	12.73	2.	2.	21.	2.	11.	5.	3.	91.3	23.	0.1	13.	0.6	18.	0.8	21.	0.9
257.	12.73	3.	1.	22.	3.	7.	7.	6.	92.0	25.	0.1	10.	0.4	17.	0.7	23.	0.9
258.	12.73	3.	1.	22.	3.	7.	6.	2.	80.0	25.	0.1	10.	0.4	16.	0.6	18.	0.7
259.	12.73	3.	2.	21.	3.	10.	2.	1.	95.8	24.	0.1	13.	0.5	15.	0.6	16.	0.7
260.	12.73	3.	2.	19.	5.	10.	4.	3.	91.7	24.	0.2	15.	0.6	19.	0.8	22.	0.9
275.	12.02	1.	1.	24.	1.	14.	5.	2.	92.0	25.	0.0	15.	0.6	20.	0.8	22.	0.9
276.	12.02	1.	1.	25.	0.	6.	7.	6.	92.0	25.	0.0	6.	0.2	13.	0.5	19.	0.8
277.	12.02	1.	2.	24.	1.	10.	6.	2.	88.0	25.	0.0	11.	0.4	17.	0.7	19.	0.8
278.	12.02	1.	2.	25.	0.	8.	7.	5.	92.0	25.	0.0	8.	0.3	15.	0.6	20.	0.8
283.	12.02	2.	1.	25.	0.	7.	5.	1.	80.0	25.	0.0	7.	0.3	12.	0.5	13.	0.5
284.	12.02	2.	1.	24.	1.	9.	6.	7.	100.0	25.	0.0	10.	0.4	16.	0.6	23.	0.9
285.	12.02	2.	2.	21.	4.	11.	5.	5.	100.0	25.	0.2	15.	0.6	20.	0.8	25.	1.0
286.	12.02	2.	2.	24.	1.	8.	4.	4.	92.0	25.	0.0	9.	0.4	13.	0.5	17.	0.7
291.	12.02	3.	1.	23.	2.	6.	7.	5.	88.0	25.	0.1	8.	0.3	15.	0.6	20.	0.8
292.	12.02	3.	1.	24.	2.	8.	9.	3.	92.3	26.	0.1	10.	0.4	19.	0.7	22.	0.8
293.	12.02	3.	2.	16.	9.	6.	6.	0.	96.0	25.	0.4	15.	0.6	21.	0.8	21.	0.8
294.	12.02	3.	2.	15.	10.	5.	3.	2.	96.0	25.	0.4	15.	0.6	18.	0.7	20.	0.8

LEGEND:

Velocity (FPS)	Duration (Min)	Segment
1=0.5	1=2	1=A
2=1.0	2=4	2=B
3=1.5	3=8	
4=2.0	4=16	
5=3.0		

TABLE A-1 (Cont.)

LARVAL IMPINGEMENT SURVIVAL STUDY
WALLEYE TEST DATA

CONDITIONS: VELOCITY = 2.0, 3.0 FPS
DURATION = 2 and 4 MINUTES

Test No.	Larval Length (mm)	Velocity	Duration	Initial Survival No.	Initial Mortality No.	24 Hour Mortality No.	48 Hour Mortality No.	72 Hour Mortality No.	96 Hour Mortality %	No. Tested	Initial Mortality %	No. Dead 24 Hour	24 Hour Mortality %	No. Dead 48 Hour	48 Hour Mortality %	No. Dead 72 Hour	72 Hour Mortality %	Segment
13.	8.83	4.	1.	13.	12.	5.	0.	2.	76.0	25.	48.0	17.	68.0	17.	68.0	19.	76.0	1.
14.	8.83	4.	2.	17.	8.	5.	0.	2.	60.0	25.	32.0	13.	52.0	13.	52.0	15.	60.0	1.
17.	8.83	5.	1.	8.	16.	1.	0.	0.	75.0	24.	66.7	17.	70.8	17.	70.8	17.	70.8	2.
18.	8.83	5.	2.	11.	14.	2.	1.	1.	76.0	25.	56.0	16.	64.0	17.	68.0	18.	72.0	2.
33.	9.41	4.	1.	15.	9.	2.	6.	3.	91.7	24.	37.5	11.	45.8	17.	70.8	20.	83.3	1.
34.	9.41	4.	2.	19.	7.	2.	4.	4.	65.4	26.	26.9	9.	34.6	13.	50.0	17.	65.4	1.
37.	9.41	5.	1.	10.	14.	2.	2.	1.	83.3	24.	58.3	16.	66.7	18.	75.0	19.	79.2	2.
38.	9.41	5.	2.	6.	20.	3.	0.	2.	96.2	26.	76.9	23.	88.5	23.	88.5	25.	96.2	2.
51.	9.72	4.	1.	20.	5.	10.	2.	1.	72.0	25.	20.0	15.	60.0	17.	68.0	18.	72.0	1.
52.	9.72	4.	2.	21.	3.	2.	6.	2.	62.5	24.	12.5	5.	20.8	11.	45.8	13.	54.2	1.
55.	9.72	5.	1.	16.	10.	2.	2.	1.	57.7	26.	38.5	12.	46.2	14.	53.8	15.	57.7	2.
56.	9.72	5.	2.	3.	22.	2.	0.	0.	96.0	25.	88.0	24.	96.0	24.	96.0	24.	96.0	2.
101.	9.87	4.	1.	22.	3.	4.	0.	5.	80.0	25.	12.0	7.	28.0	7.	28.0	12.	48.0	1.
102.	9.87	4.	2.	10.	17.	1.	0.	1.	74.1	27.	63.0	18.	66.7	18.	66.7	19.	70.4	1.
103.	9.87	4.	1.	11.	13.	4.	0.	2.	95.8	24.	54.2	17.	70.8	17.	70.8	19.	79.2	1.
104.	9.87	4.	2.	5.	20.	0.	0.	0.	88.0	25.	80.0	20.	80.0	20.	80.0	20.	80.0	1.
127.	10.16	4.	1.	22.	3.	3.	2.	2.	60.0	25.	12.0	6.	24.0	8.	32.0	10.	40.0	1.
128.	10.16	4.	2.	13.	13.	2.	1.	1.	80.8	26.	50.0	15.	57.7	16.	61.5	17.	65.4	1.
129.	10.16	4.	1.	14.	11.	3.	2.	4.	100.0	25.	44.0	14.	56.0	16.	64.0	20.	80.0	1.
130.	10.16	4.	2.	12.	13.	2.	0.	2.	80.0	25.	52.0	15.	60.0	15.	60.0	17.	68.0	1.
183.	10.54	4.	1.	14.	11.	6.	5.	0.	96.0	25.	44.0	17.	68.0	22.	88.0	22.	88.0	1.
184.	10.54	4.	2.	14.	11.	2.	10.	1.	96.0	25.	44.0	13.	52.0	23.	92.0	24.	96.0	1.
185.	10.54	4.	1.	21.	3.	3.	7.	4.	87.5	24.	12.5	6.	25.0	13.	54.2	17.	70.8	1.
186.	10.54	4.	2.	23.	2.	4.	1.	2.	22.0	25.	8.0	6.	24.0	7.	28.0	9.	36.0	1.
207.	10.87	4.	1.	24.	1.	10.	6.	2.	92.0	25.	4.0	11.	44.0	17.	68.0	19.	76.0	1.
208.	10.87	4.	1.	23.	2.	6.	3.	5.	88.0	25.	8.0	8.	32.0	11.	44.0	16.	64.0	1.
209.	10.87	4.	2.	24.	0.	9.	3.	4.	91.7	24.	0.0	9.	37.5	12.	50.0	16.	66.7	1.
210.	10.87	4.	2.	25.	0.	9.	4.	5.	84.0	25.	0.0	9.	36.0	13.	52.0	18.	72.0	1.
233.	11.16	4.	1.	23.	2.	10.	8.	2.	92.0	25.	8.0	12.	48.0	20.	80.0	22.	88.0	1.
234.	11.16	4.	1.	25.	0.	7.	9.	4.	92.0	25.	0.0	7.	28.0	16.	64.0	20.	80.0	1.
235.	11.16	4.	2.	24.	1.	6.	11.	2.	96.0	25.	4.0	7.	28.0	18.	72.0	20.	80.0	1.
236.	11.16	4.	2.	22.	3.	5.	10.	1.	100.0	25.	12.0	8.	32.0	18.	72.0	19.	76.0	1.
237.	11.16	5.	1.	18.	7.	6.	6.	3.	92.0	25.	28.0	13.	52.0	19.	76.0	22.	88.0	2.
238.	11.16	5.	1.	11.	13.	4.	2.	1.	95.8	24.	54.2	17.	70.8	19.	79.2	20.	83.3	2.
239.	11.16	5.	2.	3.	21.	2.	0.	0.	100.0	24.	87.5	23.	95.8	23.	95.8	23.	95.8	2.
240.	11.16	5.	2.	2.	23.	2.	0.	0.	100.0	25.	92.0	25.	****	25.	100.0	25.	100.0	2.
265.	12.73	4.	1.	24.	0.	9.	8.	1.	79.2	24.	0.0	9.	37.5	17.	70.8	18.	75.0	1.
266.	12.73	4.	1.	22.	3.	11.	3.	3.	80.0	25.	12.0	14.	56.0	17.	68.0	20.	80.0	1.
267.	11.44	4.	2.	20.	5.	5.	7.	1.	84.0	25.	20.0	10.	40.0	17.	68.0	18.	72.0	1.
268.	11.44	4.	2.	18.	7.	8.	3.	0.	72.0	25.	28.0	15.	60.0	18.	72.0	18.	72.0	1.
271.	11.44	5.	1.	14.	11.	4.	1.	2.	76.0	25.	44.0	15.	60.0	16.	64.0	18.	72.0	2.
272.	11.44	5.	1.	13.	12.	7.	1.	1.	88.0	25.	48.0	19.	76.0	20.	80.0	21.	84.0	2.
273.	11.44	5.	2.	0.	25.	0.	0.	0.	100.0	25.	****	25.	****	25.	100.0	25.	100.0	2.
274.	11.44	5.	2.	1.	24.	0.	1.	0.	100.0	25.	96.0	24.	96.0	25.	100.0	25.	100.0	2.
299.	12.02	4.	1.	17.	8.	5.	4.	3.	92.0	25.	32.0	13.	52.0	17.	68.0	20.	80.0	1.
300.	12.02	4.	1.	20.	5.	5.	3.	4.	92.0	25.	20.0	10.	40.0	13.	52.0	17.	68.0	1.
301.	12.02	4.	2.	21.	4.	6.	8.	3.	100.0	25.	16.0	10.	40.0	18.	72.0	21.	84.0	1.
302.	12.02	4.	2.	20.	5.	6.	9.	2.	96.0	25.	20.0	11.	44.0	20.	80.0	22.	88.0	1.
305.	12.02	5.	1.	11.	14.	6.	3.	2.	100.0	25.	56.0	20.	80.0	23.	92.0	25.	100.0	2.
306.	12.02	5.	1.	6.	19.	2.	2.	0.	100.0	25.	76.0	21.	84.0	23.	92.0	23.	92.0	2.
307.	12.02	5.	2.	2.	23.	1.	0.	1.	100.0	25.	92.0	24.	96.0	24.	96.0	25.	100.0	2.
308.	12.02	5.	2.	2.	23.	1.	1.	0.	100.0	25.	92.0	24.	96.0	25.	100.0	25.	100.0	2.

LEGEND:

Velocity (FPS)	Duration (Min)	Segment
1=0.5	1=2	1-A
2=1.0	2=4	2-B
3=1.5	3=8	
4=2.0	4=16	
5=3.0		

TABLE A-1 (Cont.)

LARVAL IMPINGEMENT SURVIVAL STUDY
WALLEYE TEST DATA
CONDITIONS: VELOCITY= 0.5, 1.0 FPS
DURATION= 8 and 16 MINUTES

Test No.	Larval Length (mm)	Velocity	Duration	Initial Survival No.	Initial Mortality No.	24 Hour Mortality No.	48 Hour Mortality No.	72 Hour Mortality No.	96 Hour Mortality %	No. Tested	Initial Mortality %	No. Dead 24 Hour	24 Hour Mortality %	No. Dead 48 Hour	48 Hour Mortality %	No. Dead 72 Hour	72 Hour Mortality %	Segment
3.	8.39	1.	3.	18.	7.	5.	5.	1.	72.0	25.	28.0	12.	48.0	17.	68.0	18.	72.0	1.
4.	8.39	1.	4.	20.	5.	2.	2.	4.	72.0	25.	20.0	7.	28.0	9.	36.0	13.	52.0	2.
7.	8.39	2.	3.	24.	1.	3.	3.	9.	76.0	25.	4.0	4.	16.0	7.	28.0	16.	64.0	1.
8.	8.39	2.	4.	12.	13.	2.	2.	2.	84.0	25.	52.0	15.	60.0	17.	68.0	19.	76.0	2.
23.	9.41	1.	3.	20.	5.	10.	1.	3.	80.0	25.	20.0	15.	60.0	16.	64.0	19.	76.0	1.
24.	9.41	1.	4.	16.	9.	7.	4.	2.	92.0	25.	36.0	16.	64.0	20.	80.0	22.	88.0	2.
27.	9.41	2.	3.	11.	14.	7.	3.	0.	96.0	25.	56.0	21.	84.0	24.	96.0	24.	96.0	1.
28.	9.41	2.	4.	5.	20.	1.	1.	0.	88.0	25.	80.0	21.	84.0	22.	88.0	22.	88.0	2.
41.	9.72	1.	3.	23.	2.	2.	5.	0.	40.0	25.	8.0	4.	16.0	9.	36.0	9.	36.0	1.
42.	9.72	1.	4.	22.	2.	4.	2.	0.	33.3	24.	8.3	6.	25.0	8.	33.3	8.	33.3	2.
45.	9.72	2.	3.	8.	17.	3.	1.	0.	92.0	25.	68.0	20.	80.0	21.	84.0	21.	84.0	1.
46.	9.72	2.	4.	14.	11.	8.	4.	0.	92.0	25.	44.0	19.	76.0	23.	92.0	23.	92.0	2.
63.	9.72	1.	3.	26.	0.	0.	1.	1.	15.4	26.	0.0	0.	0.0	1.	3.8	2.	7.7	1.
64.	9.72	1.	4.	17.	8.	8.	3.	0.	76.0	25.	32.0	16.	64.0	19.	76.0	19.	76.0	2.
67.	9.72	2.	3.	16.	9.	5.	4.	0.	72.0	25.	36.0	14.	56.0	18.	72.0	18.	72.0	1.
68.	9.72	2.	4.	6.	19.	4.	0.	0.	96.0	25.	76.0	23.	92.0	23.	92.0	23.	92.0	2.
73.	9.72	1.	3.	23.	0.	0.	2.	0.	8.7	23.	0.0	0.	0.0	2.	8.7	2.	8.7	1.
74.	9.72	1.	4.	25.	1.	0.	1.	1.	26.9	26.	3.8	1.	3.8	2.	7.7	3.	11.5	2.
77.	9.72	2.	3.	17.	8.	9.	1.	0.	72.0	25.	32.0	17.	68.0	18.	72.0	18.	72.0	1.
78.	9.72	2.	4.	4.	21.	4.	0.	0.	100.0	25.	84.0	25.	100.0	25.	100.0	25.	100.0	2.
83.	9.87	1.	3.	20.	5.	10.	2.	2.	84.0	25.	20.0	15.	60.0	17.	68.0	19.	76.0	1.
84.	9.87	1.	4.	17.	8.	7.	0.	0.	64.0	25.	32.0	15.	60.0	15.	60.0	15.	60.0	2.
87.	9.87	1.	3.	23.	2.	7.	1.	2.	68.0	25.	8.0	9.	36.0	10.	40.0	12.	48.0	1.
88.	9.87	1.	4.	25.	0.	2.	3.	2.	32.0	25.	0.0	2.	8.0	5.	20.0	7.	28.0	2.
91.	9.87	2.	3.	6.	19.	1.	0.	0.	92.0	25.	76.0	20.	80.0	20.	80.0	20.	80.0	1.
92.	9.87	2.	4.	6.	19.	3.	3.	0.	100.0	25.	76.0	22.	88.0	25.	100.0	25.	100.0	2.
95.	9.87	2.	3.	6.	19.	2.	0.	0.	96.0	25.	76.0	21.	84.0	21.	84.0	21.	84.0	1.
96.	9.87	2.	4.	1.	24.	0.	0.	0.	100.0	25.	96.0	24.	96.0	24.	96.0	24.	96.0	2.
107.	9.87	1.	3.	25.	0.	2.	4.	0.	40.0	25.	0.0	2.	8.0	6.	24.0	6.	24.0	1.
108.	9.87	1.	4.	23.	2.	0.	1.	7.	56.0	25.	8.0	2.	8.0	3.	12.0	10.	40.0	2.
113.	10.16	1.	3.	19.	6.	5.	6.	7.	100.0	25.	24.0	11.	44.0	17.	68.0	24.	96.0	1.
114.	10.16	1.	4.	22.	2.	12.	2.	5.	100.0	24.	8.3	14.	58.3	16.	66.7	21.	87.5	2.
117.	10.16	1.	3.	23.	2.	8.	3.	5.	84.0	25.	8.0	10.	40.0	13.	52.0	18.	72.0	1.
118.	10.16	1.	4.	22.	2.	6.	4.	5.	87.5	24.	8.3	8.	33.3	12.	50.0	17.	70.8	2.
133.	10.16	1.	3.	19.	6.	2.	5.	4.	92.0	25.	24.0	8.	32.0	13.	52.0	17.	68.0	1.
134.	10.16	1.	4.	24.	4.	11.	3.	4.	92.9	28.	14.3	15.	53.6	18.	64.3	22.	78.6	2.
137.	10.16	1.	3.	23.	2.	3.	4.	11.	92.0	25.	8.0	5.	20.0	9.	36.0	20.	80.0	1.
138.	10.16	1.	4.	17.	8.	2.	3.	4.	92.0	25.	32.0	10.	40.0	13.	52.0	17.	68.0	2.
149.	10.45	1.	3.	18.	6.	3.	6.	7.	100.0	24.	25.0	9.	37.5	15.	62.5	22.	91.7	1.
150.	10.45	1.	4.	16.	8.	5.	5.	5.	95.8	24.	33.3	13.	54.2	18.	75.0	23.	95.8	2.
153.	10.45	1.	3.	19.	7.	5.	5.	5.	96.2	26.	26.9	12.	46.2	17.	65.4	22.	84.6	1.
154.	10.45	1.	4.	21.	4.	6.	4.	4.	88.0	25.	16.0	10.	40.0	14.	56.0	18.	72.0	2.
165.	10.54	1.	3.	25.	0.	7.	12.	2.	96.0	25.	0.0	7.	28.0	19.	76.0	21.	84.0	1.
166.	10.54	1.	4.	20.	5.	6.	9.	3.	96.0	25.	20.0	11.	44.0	20.	80.0	23.	92.0	2.
169.	10.54	1.	3.	23.	2.	8.	7.	2.	88.0	25.	8.0	10.	40.0	17.	68.0	19.	76.0	1.
170.	10.54	1.	4.	18.	7.	8.	6.	3.	100.0	25.	28.0	15.	60.0	21.	84.0	24.	96.0	2.
173.	10.54	2.	3.	3.	22.	0.	2.	0.	96.0	25.	88.0	22.	88.0	24.	96.0	24.	96.0	1.
174.	10.54	2.	4.	2.	25.	1.	0.	0.	96.3	27.	92.6	26.	96.3	26.	96.3	26.	96.3	2.
177.	10.54	2.	3.	11.	15.	4.	7.	0.	100.0	26.	57.7	19.	73.1	26.	100.0	26.	100.0	1.
178.	10.54	2.	4.	0.	25.	0.	0.	0.	100.0	25.	100.0	25.	100.0	25.	100.0	25.	100.0	2.
191.	10.87	1.	3.	24.	1.	5.	3.	6.	92.0	25.	4.0	6.	24.0	9.	36.0	15.	60.0	1.
192.	10.87	1.	3.	25.	0.	6.	5.	4.	88.0	25.	0.0	6.	24.0	11.	44.0	15.	60.0	1.
193.	10.87	1.	4.	25.	0.	8.	5.	5.	88.0	25.	0.0	8.	32.0	13.	52.0	18.	72.0	2.

TABLE A-1 (Cont.)

Test No.	Larval Length (mm)	Velocity	Duration	Initial Survival No.	Initial Mortality No.	24 Hour Mortality No.	48 Hour Mortality No.	72 Hour Mortality No.	96 Hour Mortality %	No. Tested	Initial Mortality %	No. Dead 24 Hour	24 Hour Mortality %	No. Dead 48 Hour	48 Hour Mortality %	No. Dead 72 Hour	72 Hour Mortality %	Segment
194.	10.87	1.	4.	23.	0.	8.	4.	6.	95.7	23.	0.0	8.	34.8	12.	52.2	18.	78.3	2.
199.	10.87	2.	3.	24.	1.	11.	3.	4.	92.0	25.	4.0	12.	48.0	15.	60.0	19.	76.0	1.
200.	10.87	2.	3.	23.	2.	5.	7.	4.	96.0	25.	8.0	7.	28.0	14.	56.0	18.	72.0	1.
201.	10.87	2.	4.	22.	2.	9.	9.	2.	91.7	24.	8.3	11.	45.8	20.	83.3	22.	91.7	2.
202.	10.87	2.	4.	24.	1.	9.	3.	10.	100.0	25.	4.0	10.	40.0	13.	52.0	23.	92.0	2.
215.	11.16	1.	3.	24.	0.	4.	12.	6.	100.0	24.	0.0	4.	16.7	16.	66.7	22.	91.7	1.
216.	11.16	1.	3.	25.	0.	5.	14.	3.	100.0	25.	0.0	5.	20.0	19.	76.0	22.	88.0	1.
217.	11.16	1.	4.	25.	0.	7.	9.	5.	100.0	25.	0.0	7.	28.0	16.	64.0	21.	84.0	2.
218.	11.16	1.	4.	25.	0.	9.	9.	4.	92.0	25.	0.0	9.	36.0	18.	72.0	22.	88.0	2.
223.	11.16	2.	3.	25.	0.	12.	7.	2.	92.0	25.	0.0	12.	48.0	19.	76.0	21.	84.0	1.
224.	11.16	2.	3.	25.	0.	11.	6.	2.	84.0	25.	0.0	11.	44.0	17.	68.0	19.	76.0	1.
225.	11.16	2.	4.	19.	6.	4.	9.	3.	96.0	25.	24.0	10.	40.0	19.	76.0	22.	88.0	2.
226.	11.16	2.	4.	20.	5.	2.	7.	2.	76.0	25.	20.0	7.	28.0	14.	56.0	16.	64.0	2.
245.	12.73	1.	3.	24.	1.	9.	6.	5.	84.0	25.	4.0	10.	40.0	16.	64.0	21.	84.0	1.
246.	12.73	1.	3.	24.	1.	12.	3.	4.	88.0	25.	4.0	13.	52.0	16.	64.0	20.	80.0	1.
247.	12.73	1.	4.	20.	5.	11.	6.	1.	92.0	25.	20.0	16.	64.0	22.	88.0	23.	92.0	2.
248.	12.73	1.	4.	24.	1.	8.	13.	1.	92.0	25.	4.0	9.	36.0	22.	88.0	23.	92.0	2.
253.	12.73	2.	3.	21.	4.	9.	7.	3.	96.0	25.	16.0	13.	52.0	20.	80.0	23.	92.0	1.
254.	12.73	2.	3.	22.	3.	12.	6.	2.	92.0	25.	12.0	15.	60.0	21.	84.0	23.	92.0	1.
255.	12.73	2.	4.	20.	5.	8.	8.	2.	92.0	25.	20.0	13.	52.0	21.	84.0	23.	92.0	2.
256.	12.73	2.	4.	19.	6.	8.	8.	0.	88.0	25.	24.0	14.	56.0	22.	88.0	22.	88.0	2.
279.	12.02	1.	3.	22.	3.	8.	8.	3.	96.0	25.	12.0	11.	44.0	19.	76.0	22.	88.0	1.
280.	12.02	1.	3.	25.	0.	8.	7.	5.	100.0	25.	0.0	8.	32.0	15.	60.0	20.	80.0	1.
281.	12.02	1.	4.	25.	0.	7.	5.	8.	96.0	25.	0.0	7.	28.0	12.	48.0	20.	80.0	2.
282.	12.02	1.	4.	25.	0.	12.	5.	4.	96.0	25.	0.0	12.	48.0	17.	68.0	21.	84.0	2.
287.	12.02	2.	3.	22.	3.	10.	3.	4.	92.0	25.	12.0	13.	52.0	16.	64.0	20.	80.0	1.
288.	12.02	2.	3.	24.	1.	6.	9.	1.	88.0	25.	4.0	7.	28.0	16.	64.0	17.	68.0	1.
289.	12.02	2.	4.	19.	7.	9.	4.	4.	96.2	26.	26.9	16.	61.5	20.	76.9	24.	92.3	2.
290.	12.02	2.	4.	19.	6.	7.	4.	3.	84.0	25.	24.0	13.	52.0	17.	68.0	20.	80.0	2.

TABLE A-1 (Cont.)

LARVAL IMPINGEMENT SURVIVAL STUDY
WALLEYE TEST DATA

CONDITIONS: VELOCITY = 1.5, 2.0, 3.0 FPS
DURATION = 8 and 16 MINUTES

Test No.	Larval Length (mm)	Velocity	Duration	Initial Survival No.	Initial Mortality No.	24 Hour Mortality No.	48 Hour Mortality No.	72 Hour Mortality No.	96 Hour Mortality %	No. Tested	Initial Mortality %	No. Dead 24 Hour	24 Hour Mortality %	No. Dead 48 Hour	48 Hour Mortality %	No. Dead 72 Hour	72 Hour Mortality %	Segment
11.	8.83	3.	3.	22.	3.	7.	3.	3.	72.0	25.	12.0	10.	40.0	13.	52.0	16.	64.0	1.
12.	8.83	3.	4.	15.	10.	3.	1.	1.	68.0	25.	40.0	13.	52.0	14.	56.0	15.	60.0	2.
15.	8.83	4.	3.	17.	8.	1.	0.	0.	44.0	25.	32.0	9.	36.0	9.	36.0	9.	36.0	1.
16.	8.83	4.	4.	0.	26.	0.	0.	0.	100.0	26.	100.0	26.	100.0	26.	100.0	26.	100.0	2.
19.	8.83	5.	3.	2.	24.	0.	1.	0.	96.2	26.	92.3	24.	92.3	25.	96.2	25.	96.2	1.
20.	8.83	5.	4.	0.	25.	0.	0.	0.	100.0	25.	100.0	25.	100.0	25.	100.0	25.	100.0	2.
31.	9.41	3.	3.	20.	6.	6.	6.	3.	80.8	26.	23.1	12.	46.2	18.	69.2	21.	80.8	1.
32.	9.41	3.	4.	2.	24.	0.	1.	0.	96.2	26.	92.3	24.	92.3	25.	96.2	25.	96.2	2.
35.	9.41	4.	3.	5.	20.	1.	0.	1.	88.0	25.	80.0	21.	84.0	21.	84.0	22.	88.0	1.
36.	9.41	4.	4.	0.	25.	0.	0.	0.	100.0	25.	100.0	25.	100.0	25.	100.0	25.	100.0	2.
49.	9.72	3.	3.	9.	17.	0.	1.	1.	73.1	26.	65.4	17.	65.4	18.	69.2	19.	73.1	1.
50.	9.72	3.	4.	6.	20.	1.	0.	0.	84.6	26.	76.9	21.	80.8	21.	80.8	21.	80.8	2.
53.	9.72	4.	3.	1.	24.	0.	1.	0.	100.0	25.	96.0	24.	96.0	25.	100.0	25.	100.0	1.
54.	9.72	4.	4.	5.	20.	1.	1.	0.	88.0	25.	80.0	21.	84.0	22.	88.0	22.	88.0	2.
57.	9.72	5.	3.	0.	25.	0.	0.	0.	100.0	25.	100.0	25.	100.0	25.	100.0	25.	100.0	1.
58.	9.72	5.	4.	0.	25.	0.	0.	0.	100.0	25.	100.0	25.	100.0	25.	100.0	25.	100.0	2.
59.	9.72	5.	3.	0.	25.	0.	0.	0.	100.0	25.	100.0	25.	100.0	25.	100.0	25.	100.0	1.
60.	9.72	5.	4.	0.	25.	0.	0.	0.	100.0	25.	100.0	25.	100.0	25.	100.0	25.	100.0	2.
231.	11.16	3.	3.	18.	7.	2.	12.	3.	96.0	25.	28.0	9.	36.0	21.	84.0	24.	96.0	1.
232.	11.16	3.	3.	14.	12.	5.	7.	0.	96.2	26.	46.2	17.	65.4	24.	92.3	24.	92.3	1.
261.	12.73	3.	3.	13.	11.	7.	4.	0.	91.7	24.	45.8	18.	75.0	22.	91.7	22.	91.7	1.
262.	12.73	3.	3.	6.	19.	2.	3.	0.	96.0	25.	76.0	21.	84.0	24.	96.0	24.	96.0	1.
263.	12.73	3.	4.	5.	19.	3.	2.	0.	100.0	24.	79.2	22.	91.7	24.	100.0	24.	100.0	2.
264.	12.73	3.	4.	7.	20.	1.	3.	1.	96.3	27.	74.1	21.	77.8	24.	88.9	25.	92.6	2.
269.	11.44	4.	3.	11.	14.	5.	2.	1.	88.0	25.	56.0	19.	76.0	21.	84.0	22.	88.0	1.
270.	11.44	4.	3.	3.	22.	1.	0.	1.	96.0	25.	88.0	23.	92.0	23.	92.0	24.	96.0	1.
295.	12.02	3.	3.	13.	12.	6.	1.	6.	100.0	25.	48.0	18.	72.0	19.	76.0	25.	100.0	1.
296.	12.02	3.	3.	2.	23.	0.	1.	0.	100.0	25.	92.0	23.	92.0	24.	96.0	24.	96.0	1.
297.	12.02	3.	4.	4.	22.	3.	0.	0.	96.2	26.	84.6	25.	96.2	25.	96.2	25.	96.2	2.
298.	12.02	3.	4.	1.	24.	0.	1.	0.	100.0	25.	96.0	24.	96.0	25.	100.0	25.	100.0	2.
303.	12.02	4.	3.	4.	21.	2.	0.	1.	100.0	25.	84.0	23.	92.0	23.	92.0	24.	96.0	1.
304.	12.02	5.	3.	6.	19.	0.	1.	1.	88.0	25.	76.0	19.	76.0	20.	80.0	21.	84.0	1.

TABLE A-2

LARVAL IMPINGEMENT SURVIVAL STUDY
CHANNEL CATFISH TEST DATA

CONDITIONS: VELOCITY = 0.5, 1.0, 1.5, 2.0, 3.0 FPS
DURATION = 2, 4, 8, and 16 MINUTES

Test No.	ΔT, °C	Larval Length, mm	Velocity	Duration	Segment	96 Hour Mortality, %
1.	-2.2	11.54	1.	1.	1.	0.0
2.	-2.2	11.54	1.	2.	2.	0.0
3.	-2.2	11.54	1.	3.	1.	8.3
4.	-2.2	11.54	1.	4.	2.	3.8
5.	-2.5	11.54	2.	1.	1.	0.0
6.	-2.5	11.54	2.	2.	2.	0.0
7.	-2.8	11.54	2.	3.	1.	0.0
8.	-2.8	11.54	2.	4.	2.	64.0
9.	-2.7	11.54	3.	1.	1.	8.0
10.	-2.7	11.54	3.	2.	2.	36.0
11.	-2.2	11.54	3.	3.	1.	20.8
12.	-2.2	11.54	3.	4.	2.	88.0
13.	-3.1	11.54	4.	1.	1.	20.8
14.	-3.1	11.54	4.	2.	2.	0 0
15.	-3.0	11.54	4.	3.	1.	4.0
16.	-3.0	11.54	4.	4.	2.	64.0
17.	-3.0	11.54	5.	1.	1.	7.4
18.	-3.0	11.54	5.	2.	2.	38.5
19.	-3.0	11.54	5.	3.	1.	64.0
20.	-3.0	11.54	5.	4.	2.	100.0
21.	-2.8	12.23	1.	1.	1.	4.2
22.	-2.8	12.23	1.	2.	2.	4.3
23.	-2.8	12.23	1.	3.	2.	4.0
24.	-2.8	12.23	1.	4.	1.	4.0
25.	-3.0	12.23	2.	1.	2.	7.7
26.	-3.0	12.23	2.	2.	1.	7.7
27.	-3.0	12.23	2.	3.	2.	0.0
28.	-3.0	12.23	2.	4.	1.	8.0
29.	-2.4	12.23	3.	1.	2.	0.0
30.	-2.4	12.23	3.	2.	1.	0.0
31.	-2.6	12.23	3.	3.	2.	4.0
32.	-2.6	12.23	3.	4.	1.	20.0
33.	-2.6	12.23	4.	1.	2.	0.0
34.	-2.6	12.23	4.	2.	1.	0.0
35.	-2.5	12.23	4.	3.	2.	0.0
36.	-2.5	12.23	4.	4.	1.	11.5
37.	-2.5	12.23	5.	1.	2.	7.1
38.	-2.5	12.23	5.	2.	1.	0.0
39.	-2.5	12.23	5.	3.	2.	3.8
40.	-2.5	12.23	5.	4.	1.	73.1
41.	-1.4	13.38	1.	1.	2.	0.0
42.	-1.4	13.38	1.	2.	1.	0.0
43.	-1.4	13.38	1.	3.	1.	5.3
44.	-1.4	13.38	1.	4.	2.	4.5
45.	-1.5	13.38	2.	1.	1.	4.0
46.	-1.5	13.38	2.	2.	2.	0.0
47.	-1.4	13.38	2.	3.	1.	0.0
48.	-1.4	13.38	2.	4.	2.	3.8
49.	-2.0	13.38	3.	1.	1.	0.0
50.	-2.0	13.38	3.	2.	2.	4.0
51.	-2.0	13.38	3.	3.	1.	4.0
52.	-2.0	13.38	3.	4.	2.	4.0
53.	-2.1	13.38	4.	1.	1.	0.0
54.	-2.1	13.38	4.	2.	2.	0.0
55.	-2.1	13.38	4.	3.	1.	0.0
56.	-2.1	13.38	4.	4.	2.	0.0
57.	-2.3	13.38	5.	1.	1.	0.0
58.	-2.3	13.38	5.	2.	2.	0.0
59.	-2.3	13.38	5.	3.	1.	0.0
60.	-2.3	13.38	5.	4.	2.	60.0
61.	-2.2	12.88	1.	1.	1.	0.0
62.	-2.2	12.88	1.	2.	2.	0.0
63.	-2.2	12.88	1.	3.	2.	0.0
64.	-2.2	12.88	1.	4.	1.	4.0
65.	-2.5	12.88	2.	1.	2.	4.0
66.	-2.5	12.88	2.	2.	1.	4.0
67.	-2.5	12.88	2.	3.	2.	4.0
68.	-2.5	12.88	2.	4.	1.	4.0
69.	-2.6	12.88	3.	1.	2.	0.0
70.	-2.6	12.88	3.	2.	1.	0.0
71.	-2.6	12.88	3.	3.	2.	4.0
72.	-2.6	12.88	3.	4.	1.	8.0
73.	-2.1	12.88	4.	1.	2.	0.0
74.	-2.1	12.88	4.	2.	1.	0.0
75.	-2.2	12.88	4.	3.	2.	0.0
76.	-2.2	12.88	4.	4.	1.	0.0
77.	-2.3	12.88	5.	1.	2.	8.0
78.	-2.3	12.88	5.	2.	1.	4.0
79.	-2.3	12.88	5.	3.	2.	8.0
80.	-2.3	12.88	5.	4.	1.	84.0
81.	-1.2	13.87	1.	1.	1.	8.0
82.	-1.2	13.87	1.	2.	2.	0.0
83.	-1.2	13.87	1.	3.	1.	0.0
84.	-1.2	13.87	1.	4.	2.	0.0
85.	-0.9	13.87	2.	1.	1.	0.0
86.	-0.9	13.87	2.	2.	2.	16.0
87.	-0.9	13.87	2.	3.	1.	4.0
88.	-0.9	13.87	2.	4.	2.	4.0
89.	-1.0	13.87	3.	1.	1.	0.0
90.	-1.0	13.87	3.	2.	2.	4.0
91.	-1.1	13.87	3.	3.	1.	0.0
92.	-1.1	13.87	3.	4.	2.	0.0
93.	-1.1	13.87	4.	1.	1.	4.0
94.	-1.1	13.87	4.	2.	2.	0.0
95.	-1.2	13.87	4.	3.	1.	0.0
96.	-1.2	13.87	4.	4.	2.	38.5
97.	-1.5	13.87	5.	1.	1.	4.0
98.	-1.5	13.87	5.	2.	2.	20.0
99.	-1.5	13.87	5.	3.	1.	8.0
100.	-1.5	13.87	5.	4.	2.	20.0
101.	-1.0	14.13	1.	1.	2.	0.0
102.	-1.0	14.13	1.	2.	1.	20.0
103.	-1.5	14.13	1.	3.	2.	4.0
104.	-1.5	14.13	1.	4.	1.	0.0
105.	-1.6	14.13	2.	1.	2.	0.0
106.	-1.6	14.13	2.	2.	1.	0.0

LEGEND:

VELOCITY (FPS)	DURATION (MIN)	SEGMENT
1 = 0.5	1 = 2	1 = A
2 = 1.0	2 = 4	2 = B
3 = 1.5	3 = 8	
4 = 2.0	4 = 16	
5 = 3.0		

TABLE A-2 (Cont.)

LARVAL IMPINGEMENT SURVIVAL STUDY
CHANNEL CATFISH TEST DATA

CONDITIONS: VELOCITY = 0.5, 1.0, 1.5, 2.0, 3.0 FPS
DURATION = 2, 4, 8, and 16 MINUTES

Test No.	ΔT, °C	Larval Length, mm	Velocity	Duration	Segment	96 Hour Mortality, %
107.	-1.6	14.13	2.	3.	2.	0.0
108.	-1.6	14.13	2.	4.	1.	0.0
109.	-1.5	14.13	3.	1.	2.	4.2
110.	-1.5	14.13	3.	2.	1.	30.8
111.	-1.8	14.13	3.	3.	2.	4.0
112.	-1.8	14.13	3.	4.	1.	4.0
113.	-2.1	14.13	4.	1.	2.	4.0
114.	-2.1	14.13	4.	2.	1.	0.0
115.	-2.1	14.13	4.	3.	2.	8.0
116.	-2.1	14.13	4.	4.	1.	12.0
117.	-2.2	14.13	5.	1.	2.	0.0
118.	-2.2	14.13	5.	2.	1.	12.0
119.	-2.2	14.13	5.	3.	2.	8.0
120.	-2.2	14.13	5.	4.	1.	19.2
121.	-0.2	14.62	1.	1.	1.	0.0
122.	-0.2	14.62	1.	1.	2.	0.0
123.	-0.2	14.62	1.	2.	1.	7.7
124.	-0.2	14.62	1.	2.	2.	7.1
125.	-0.2	14.62	1.	3.	1.	0.0
126.	-0.2	14.62	1.	3.	2.	5.0
127.	-0.2	14.62	1.	4.	1.	6.7
128.	-0.4	14.62	1.	4.	2.	0.0
129.	-0.6	14.62	2.	1.	1.	0.0
130.	-0.6	14.62	2.	1.	2.	4.2
131.	-0.6	14.62	2.	2.	1.	11.5
132.	-0.6	14.62	2.	2.	2.	8.0
133.	-0.6	14.62	2.	3.	1.	4.0
134.	-0.6	14.62	2.	3.	2.	16.0
135.	-0.6	14.62	2.	4.	1.	0.0
136.	-0.6	14.62	2.	4.	2.	0.0
137.	-1.1	14.62	3.	1.	1.	20.0
138.	-1.1	14.62	3.	1.	2.	8.0
139.	-1.1	14.62	3.	2.	1.	4.0
140.	-1.1	14.62	3.	2.	2.	4.0
141.	-1.1	14.62	3.	3.	1.	0.0
142.	-1.1	14.62	3.	3.	2.	12.0
143.	-1.4	14.62	3.	4.	1.	0.0
144.	-1.4	14.62	3.	4.	2.	0.0
145.	-1.4	14.62	4.	1.	1.	0.0
146.	-1.4	14.62	4.	1.	2.	0.0
147.	-1.4	14.62	4.	2.	1.	19.0
148.	-1.4	14.62	4.	2.	2.	24.0
149.	-1.8	14.62	4.	3.	1.	4.0
150.	-1.8	14.62	4.	3.	2.	0.0
151.	-1.8	14.62	4.	4.	1.	0.0
152.	-1.8	14.62	4.	4.	2.	4.0
153.	-1.9	14.62	5.	1.	1.	0.0
154.	-1.9	14.62	5.	1.	2.	3.8
155.	-1.9	14.62	5.	2.	1.	0.0
156.	-1.9	14.62	5.	2.	2.	8.0
157.	-1.9	14.62	5.	3.	1.	8.0
158.	-1.9	14.62	5.	3.	2.	16.0
159.	-1.9	14.62	5.	4.	1.	24.0
160.	-1.9	14.62	5.	4.	2.	16.0
161.	-1.3	15.16	1.	1.	1.	0.0
162.	-1.3	15.16	1.	2.	2.	4.5
163.	-1.3	15.16	1.	3.	1.	0.0
164.	-1.3	15.16	1.	4.	2.	5.0
165.	-1.7	15.16	2.	1.	1.	0.0
166.	-1.7	15.16	2.	2.	2.	0.0
167.	-2.0	15.16	2.	[illegible]	1.	0.0
168.	-2.0	15.16	2.	4.	2.	0.0
169.	-2.1	15.16	3.	1.	1.	0.0
170.	-2.1	15.16	3.	2.	2.	0.0
171.	-2.2	15.16	3.	3.	1.	0.0
172.	-2.2	15.16	3.	4.	2.	0.0
173.	-2.3	15.16	4.	1.	1.	0.0
174.	-2.3	15.16	4.	2.	2.	4.0
175.	-2.3	15.16	4.	3.	1.	16.0
176.	-2.3	15.16	4.	4.	2.	12.0
177.	-2.7	15.16	5.	1.	1.	8.0
178.	-2.7	15.16	5.	2.	2.	0.0
179.	-2.7	15.16	5.	3.	1.	9.1
180.	-2.7	15.16	5.	4.	2.	56.0
181.	-2.5	15.50	4.	2.	1.	0.0
182.	-2.5	15.50	4.	2.	2.	4.0
183.	-2.5	15.50	4.	4.	1.	24.0
184.	-2.5	15.50	4.	4.	2.	28.0
185.	-2.6	15.50	5.	2.	1.	4.2
186.	-2.6	15.50	5.	2.	2.	4.0
187.	-2.6	15.50	5.	4.	1.	46.2
188.	-2.6	15.50	5.	4.	2.	56.0
189.	-0.2	15.21	4.	2.	1.	4.0
190.	-0.2	15.21	4.	2.	2.	4.0
191.	-0.2	15.21	4.	4.	1.	16.0
192.	-0.2	15.21	4.	4.	2.	18.5
193.	-0.9	15.21	5.	2.	1.	0.0
194.	-0.9	15.21	5.	2.	2.	4.5
195.	-1.0	15.21	5.	4.	1.	40.0
196.	-1.0	15.21	5.	4.	2.	40.0
197.	-0.3	16.36	4.	2.	1.	0.0
198.	-0.3	16.36	4.	2.	2.	8.0
199.	-0.8	16.36	4.	4.	1.	15.4
200.	-0.8	16.36	4.	4.	2.	11.5
201.	-1.0	16.36	5.	2.	1.	0.0
202.	-1.0	16.36	5.	2.	2.	4.2
203.	-1.5	16.36	5.	4.	1.	4.0
204.	-1.5	16.36	5.	4.	2.	4.2
205.	-0.7	16.24	4.	2.	1.	0.0
206.	-0.7	16.24	4.	2.	2.	0.0
207.	-0.7	16.24	4.	4.	1.	4.0
208.	-0.7	16.24	4.	4.	2.	0 0
209.	-1.1	16.24	5.	2.	1.	0.0
210.	-1.1	16.24	5.	2.	2.	0.0
211.	-1.1	16.24	5.	4.	1.	8.0
212.	-1.1	16.24	5.	4.	2.	20.0

LEGEND:

VELOCITY (FPS)	DURATION (MIN)	SEGMENT
1 = 0.5	1 = 2	1 = A
2 = 1.0	2 = 4	2 = B
3 = 1.5	3 = 8	
4 = 2.0	4 = 16	
5 = 3.0		

TABLE A-2 (Cont.)

LARVAL IMPINGEMENT SURVIVAL STUDY
CHANNEL CATFISH TEST DATA

CONDITIONS: VELOCITY = 0.5, 1.0, 1.5, 2.0, 3.0 FPS
DURATION = 2, 4, 8, and 16 MINUTES

Test No.	ΔT, °C	Larval Length, mm	Velocity	Duration	Segment	96 Hour Mortality, %
213.	-1.1	17.37	4.	2.	1.	0.0
214.	-1.1	17.37	4.	2.	2.	0.0
215.	-1.1	17.37	4.	4.	1.	4.0
216.	-1.1	17.37	4.	4.	2.	11.5
217.	-1.8	17.37	5.	2.	1.	0.0
218.	-1.8	17.37	5.	2.	2.	8.3
219.	-1.8	17.37	5.	4.	1.	36.0
220.	-1.8	17.37	5.	4.	2.	64.0
221.	0.1	16.96	4.	2.	1.	0.0
222.	0.1	16.96	4.	2.	2.	4.0
223.	0.1	16.96	4.	4.	1.	0.0
224.	0.1	16.96	4.	4.	2.	8.0
225.	0.0	16.96	5.	2.	1.	4.0
226.	0.0	16.96	5.	2.	2.	0.0
227.	0.0	16.96	5.	4.	1.	4.0
228.	0.0	16.96	5.	4.	2.	20.0
229.	0.0	17.66	4.	2.	1.	16.0
230.	0.0	17.66	4.	2.	2.	0.0
231.	0.0	17.66	4.	4.	1.	4.0
232.	0.0	17.66	4.	4.	2.	16.0
233.	0.0	17.66	5.	2.	1.	4.0
234.	0.0	17.66	5.	2.	2.	0.0
235.	0.0	17.66	5.	4.	1.	68.0
236.	0.0	17.66	5.	4.	2.	48.0
237.	-0.9	19.69	4.	2.	1.	0.0
238.	-0.9	19.69	4.	2.	2.	12.0
239.	-0.9	19.69	4.	4.	1.	8.0
240.	-0.9	19.69	4.	4.	2.	32.0
241.	-1.0	19.69	5.	2.	1.	0.0
242.	-1.0	19.69	5.	2.	2.	12.0
243.	-1.0	19.69	5.	4.	1.	44.0
244.	-1.0	19.69	5.	4.	2.	44.0
245.	-2.0	17.23	4.	2.	1.	4.0
246.	-2.0	17.23	4.	2.	2.	0.0
247.	-2.1	17.23	4.	4.	1.	12.0
248.	-2.1	17.23	4.	4.	2.	8.0
249.	-2.1	17.23	5.	2.	1.	0.0
250.	-2.1	17.23	5.	2.	2.	12.0
251.	-2.1	17.23	5.	4.	1.	12.0
252.	-2.1	17.23	5.	4.	2.	68.0
253.	-2.0	19.66	4.	2.	1.	0.0
254.	-2.0	19.66	4.	2.	2.	4.0
255.	-2.0	19.66	4.	4.	1.	8.0
256.	-2.0	19.66	4.	4.	2.	16.0
257.	-2.0	19.66	5.	2.	1.	4.2
258.	-2.0	19.66	5.	2.	2.	12.0
259.	-2.0	19.66	5.	4.	1.	52.0
260.	-2.0	19.66	5.	4.	2.	65.4
261.	-0.6	22.70	4.	2.	1.	33.3
262.	-0.6	22.70	4.	2.	2.	8.0
263.	-0.6	22.70	4.	4.	1.	40.0
264.	-0.6	22.70	4.	4.	2.	100.0
265.	-1.4	22.70	5.	2.	1.	16.0
266.	-1.4	22.70	5.	2.	2.	16.0
267.	-1.4	22.70	5.	4.	1.	40.0
268.	-1.4	22.70	5.	4.	2.	66.7
269.	0.0	25.74	4.	2.	1.	8.3
270.	0.0	25.74	4.	2.	2.	56.5
271.	0.0	25.74	4.	2.	2.	4.2
272.	-0.8	25.74	4.	4.	1.	20.0
273.	-0.8	25.74	4.	4.	2.	45.5
274.	-0.9	25.74	4.	4.	2.	41.7
275.	-0.9	25.74	5.	2.	1.	12.0
276.	-0.9	25.74	5.	2.	2.	12.0
277.	-0.9	25.74	5.	2.	2.	8.0
278.	-1.0	25.74	5.	4.	1.	12.0
279.	-1.0	25.74	5.	4.	2.	12.0
280.	-1.0	25.74	5.	4.	2.	32.0

LEGEND:

VELOCITY (FPS)	DURATION (MIN)	SEGMENT
1 = 0.5	1 = 2	1 = A
2 = 1.0	2 = 4	2 = B
3 = 1.5	3 = 8	
4 = 2.0	4 = 16	
5 = 3.0		

TABLE A-3

LARVAL IMPINGEMENT SURVIVAL STUDY
BLUEGILL TEST DATA

CONDITIONS: VELOCITY = 0.5, 1.0, 1.5, 2.0, 3.0 FPS
DURATION = 2, 4, 8, and 16 MINUTES

Test No.	ΔT, °C	Larval Length, mm	Velocity	Duration	Segment	96 Hour Mortality, %
1.	-1.0	19.76	1.	1.	1.	0.0
2.	-1.0	19.76	1.	2.	2.	5.6
3.	-1.2	19.76	1.	3.	1.	6.7
4.	-1.2	19.76	1.	4.	2.	0.0
5.	-1.9	19.76	2.	1.	1.	5.0
6.	-1.9	19.76	2.	2.	2.	20.0
7.	-2.0	19.76	2.	3.	1.	10.0
8.	-2.0	19.76	2.	4.	2.	25.0
9.	-2.0	19.76	3.	1.	1.	0.0
10.	-2.0	19.76	3.	2.	2.	5.0
11.	-2.0	19.76	3.	3.	1.	30.0
12.	-2.0	19.76	3.	4.	2.	45.0
13.	-2.3	19.76	4.	1.	1.	10.0
14.	-2.3	19.76	4.	2.	2.	10.5
15.	-2.5	19.76	4.	3.	1.	25.0
16.	-2.5	19.76	4.	4.	2.	40.0
17.	-2.2	19.76	5.	1.	1.	0.0
18.	-2.2	19.76	5.	2.	2.	5.0
19.	-2.8	19.76	5.	3.	1.	40.0
20.	-2.8	19.76	5.	4.	2.	75.0
21.	-1.9	19.56	1.	1.	1.	0.0
22.	-1.9	19.56	1.	1.	2.	0.0
23.	-1.9	19.56	1.	2.	1.	0.0
24.	-1.9	19.56	1.	2.	2.	0.0
25.	-2.6	19.56	1.	3.	1.	0.0
26.	-2.6	19.56	1.	3.	2.	8.7
27.	-2.6	19.56	1.	4.	1.	0.0
28.	-2.6	19.56	1.	4.	2.	0.0
29.	-2.7	19.56	2.	1.	1.	0.0
30.	-2.7	19.56	2.	1.	2.	0.0
31.	-2.7	19.56	2.	2.	1.	4.0
32.	-2.7	19.56	2.	2.	2.	0.0
33.	-2.7	19.56	2.	3.	1.	0.0
34.	-2.7	19.56	2.	3.	2.	4.2
35.	-2.7	19.56	2.	4.	1.	0.0
36.	-2.7	19.56	2.	4.	2.	0.0
37.	-2.9	19.56	3.	1.	1.	0.0
38.	-2.9	19.56	3.	1.	2.	8.0
39.	-2.9	19.56	3.	2.	1.	4.0
40.	-2.9	19.56	3.	2.	2.	4.0
41.	-3.4	19.56	3.	3.	1.	11.1
42.	-3.4	19.56	3.	3.	2.	4.0
43.	-3.4	19.56	3.	4.	1.	11.5
44.	-3.4	19.56	3.	4.	2.	32.0
45.	-3.7	19.56	4.	1.	1.	12.0
46.	-3.7	19.56	4.	1.	2.	8.0
47.	-3.7	19.56	4.	2.	1.	0.0
48.	-3.7	19.56	4.	2.	2.	0.0
49.	-3.7	19.56	4.	3.	1.	4.0
50.	-3.7	19.56	4.	3.	2.	8.0
51.	-3.7	19.56	4.	4.	1.	21.7
52.	-3.7	19.56	4.	4.	2.	56.0
53.	-3.8	19.56	5.	1.	1.	8.0
54.	-3.8	19.56	5.	1.	2.	8.0
55.	-3.8	19.56	5.	2.	1.	12.0
56.	-3.8	19.56	5.	2.	2.	0.0
57.	-3.8	19.56	5.	3.	1.	20.0
58.	-3.8	19.56	5.	3.	2.	20.0
59.	-3.8	19.56	5.	4.	1.	92.0
60.	-3.8	19.56	5.	4.	2.	88.0
61.	-1.3	20.96	2.	1.	1.	0.0
62.	-1.3	20.96	2.	1.	2.	0.0
63.	-1.0	20.96	2.	2.	1.	0.0
64.	-1.0	20.96	2.	2.	2.	0.0
65.	-1.0	20.96	2.	3.	1.	0.0
66.	-1.0	20.96	2.	3.	2.	0.0
67.	-1.5	20.96	2.	4.	1.	4.2
68.	-1.5	20.96	2.	4.	2.	0.0
69.	-1.3	20.96	3.	1.	1.	0.0
70.	-1.3	20.96	3.	1.	2.	0.0
71.	-1.3	20.96	3.	2.	1.	4.5
72.	-1.3	20.96	3.	2.	2.	0.0
73.	-1.5	20.96	3.	3.	1.	4.2
74.	-1.5	20.96	3.	3.	2.	28.0
75.	-1.8	20.96	3.	4.	1.	4.2
76.	-1.8	20.96	3.	4.	2.	29.2
77.	-2.3	20.96	4.	1.	1.	0.0
78.	-2.3	20.96	4.	1.	2.	0.0
79.	-2.3	20.96	4.	2.	1.	0.0
80.	-2.3	20.96	4.	2.	2.	0.0
81.	-2.3	20.96	4.	3.	1.	18.2
82.	-2.3	20.96	4.	3.	2.	25.9
83.	-2.3	20.96	4.	4.	1.	33.3
84.	-2.3	20.96	4.	4.	2.	86.4
85.	-2.5	20.96	5.	1.	1.	0.0
86.	-2.5	20.96	5.	1.	2.	3.8
87.	-2.5	20.96	5.	2.	1.	4.3
88.	-2.5	20.96	5.	2.	2.	20.0
89.	-2.5	20.96	5.	3.	1.	50.0
90.	-2.5	20.96	5.	3.	2.	76.0
91.	-2.5	20.96	5.	4.	1.	100.0
92.	-2.5	20.96	5.	4.	2.	95.7
93.	0.0	20.23	5.	3.	1.	68.0
94.	0.0	20.23	5.	4.	2.	96.0
95.	0.0	20.23	5.	1.	1.	0.0
96.	0.0	20.23	5.	2.	2.	0.0
97.	-0.8	20.23	4.	3.	1.	23.1
98.	-0.8	20.23	4.	4.	2.	70.8
99.	-1.0	20.23	4.	1.	1.	0.0
100.	-1.0	20.23	4.	2.	2.	4.3
101.	-1.0	20.23	3.	3.	1.	12.0
102.	-1.0	20.23	3.	4.	2.	12.5
103.	-0.5	15.27	1.	1.	1.	9.1
104.	-0.5	15.27	1.	2.	2.	4.3
105.	-0.5	15.27	1.	3.	1.	0.0
106.	-0.5	15.27	1.	4.	2.	4.3

LEGEND:

VELOCITY (FPS)	DURATION (MIN)	SEGMENT
1 = 0.5	1 = 2	1 = A
2 = 1.0	2 = 4	2 = B
3 = 1.5	3 = 8	
4 = 2.0	4 = 16	
5 = 3.0		

TABLE A-3 (Cont.)

LARVAL IMPINGEMENT SURVIVAL STUDY
BLUEGILL TEST DATA

CONDITIONS: VELOCITY = 0.5, 1.0, 1.5, 2.0, 3.0 FPS
DURATION = 2, 4, 8, and 16 MINUTES

Test No.	ΔT, °C	Larval Length, mm	Velocity	Duration	Segment	96 Hour Mortality, %
107.	-0.8	15.27	2.	1.	1.	12.5
108.	-0.8	15.27	2.	2.	2.	0.0
109.	-0.8	15.27	2.	3.	1.	4.3
110.	-0.8	15.27	2.	4.	2.	4.0
111.	-0.8	15.27	3.	1.	1.	8.0
112.	-0.8	15.27	3.	2.	2.	0.0
113.	-0.8	15.27	3.	3.	1.	13.0
114.	-0.8	15.27	3.	4.	2.	20.0
115.	-1.2	15.27	4.	1.	1.	12.0
116.	-1.2	15.27	4.	2.	2.	12.0
117.	-1.6	15.27	4.	3.	1.	20.0
118.	-1.6	15.27	4.	4.	2.	56.0
119.	-1.8	15.27	5.	1.	1.	8.0
120.	-1.8	15.27	5.	2.	2.	12.0
121.	-1.8	15.27	5.	3.	1.	52.0
122.	-1.8	15.27	5.	4.	2.	96.0
123.	-0.1	15.80	2.	2.	1.	4.0
124.	-0.1	15.80	2.	1.	2.	8.7
125.	-0.1	15.80	2.	4.	1.	8.7
126.	-0.1	15.80	2.	3.	2.	8.3
127.	-0.3	15.80	3.	2.	1.	9.5
128.	-0.3	15.80	3.	1.	2.	4.3
129.	-0.3	15.80	3.	4.	1.	30.4
130.	-0.3	15.80	3.	3.	2.	4.2
131.	-0.4	15.80	4.	2.	1.	0.0
132.	-0.4	15.80	4.	1.	2.	0.0
133.	-0.6	15.80	4.	4.	1.	25.0
134.	-0.6	15.80	4.	3.	2.	8.0
135.	-0.7	15.80	5.	2.	1.	8.3
136.	-0.7	15.80	5.	1.	2.	20.0
137.	-0.7	15.80	5.	4.	1.	88.0
138.	-0.7	15.80	5.	3.	2.	48.0
139.	-1.0	17.73	2.	1.	2.	0.0
140.	-1.0	17.73	2.	2.	1.	4.8
141.	-1.0	17.73	2.	3.	1.	0.0
142.	-1.0	17.73	2.	4.	2.	16.7
143.	-1.0	17.73	3.	1.	1.	9.5
144.	-1.0	17.73	3.	2.	2.	8.0
145.	-1.1	17.73	3.	3.	1.	25.0
146.	-1.1	17.73	3.	4.	2.	60.0
147.	-1.5	17.73	4.	1.	1.	4.5
148.	-1.5	17.73	4.	2.	2.	0.0
149.	-1.6	17.73	4.	3.	1.	26.1
150.	-1.6	17.73	4.	4.	2.	64.0
151.	-1.7	17.73	5.	1.	1.	8.3
152.	-1.7	17.73	5.	2.	2.	16.0
153.	-1.7	17.73	5.	3.	1.	91.7
154.	-1.7	17.73	5.	4.	2.	100.0
155.	0.0	16.65	1.	1.	1.	7.7
156.	0.0	16.65	1.	2.	2.	6.7
157.	0.0	16.65	1.	3.	1.	11.8
158.	0.0	16.65	1.	4.	2.	5.6
159.	-0.3	16.65	2.	1.	1.	5.6
160.	-0.3	16.65	2.	2.	2.	13.0
161.	-0.5	16.65	2.	3.	1.	4.0
162.	-0.5	16.65	2.	4.	2.	7.4
163.	-0.7	16.65	3.	1.	1.	0.0
164.	-0.7	16.65	3.	2.	2.	0.0
165.	-0.7	16.65	3.	3.	1.	16.0
166.	-0.7	16.65	3.	4.	2.	60.0
167.	-0.8	16.65	4.	1.	1.	4.0
168.	-0.8	16.65	4.	2.	2.	8.0
169.	-0.8	16.65	4.	3.	1.	28.0
170.	-0.8	16.65	4.	4.	2.	96.0
171.	-0.8	16.65	5.	1.	1.	0.0
172.	-0.9	16.65	5.	2.	2.	16.0
173.	-0.9	16.65	5.	3.	1.	92.0
174.	-0.9	16.65	5.	4.	2.	100.0
175.	-0.5	15.79	1.	1.	2.	0.0
176.	-0.5	15.79	1.	2.	1.	4.3
177.	-0.5	15.79	1.	3.	2.	0.0
178.	-0.5	15.79	1.	4.	1.	17.4
179.	-1.0	15.79	2.	1.	2.	8.0
180.	-1.0	15.79	2.	2.	1.	0.0
181.	-1.0	15.79	2.	3.	2.	4.2
182.	-1.0	15.79	2.	4.	1.	8.0
183.	-1.1	15.79	3.	1.	2.	8.0
184.	-1.1	15.79	3.	2.	1.	0.0
185.	-1.1	15.79	3.	3.	2.	24.0
186.	-1.1	15.79	3.	4.	1.	72.0
187.	-1.3	15.79	4.	1.	2.	4.0
188.	-1.3	15.79	4.	2.	1.	0.0
189.	-1.3	15.79	4.	3.	2.	24.0
190.	-1.3	15.79	4.	4.	1.	83.3
191.	-1.8	15.79	5.	1.	2.	0.0
192.	-1.8	15.79	5.	2.	1.	8.3
193.	-1.8	15.79	5.	3.	2.	60.0
194.	-1.8	15.79	5.	4.	1.	100.0
195.	-1.0	17.87	1.	1.	1.	0.0
196.	-1.0	17.87	1.	2.	2.	0.0
197.	-1.0	17.87	1.	3.	1.	0.0
198.	-1.0	17.87	1.	4.	2.	4.0
199.	-1.1	17.87	2.	1.	1.	4.5
200.	-1.1	17.87	2.	2.	2.	0.0
201.	-1.5	17.87	2.	3.	1.	0.0
202.	-1.5	17.87	2.	4.	2.	8.3
203.	-1.5	17.87	3.	1.	1.	9.1
204.	-1.5	17.87	3.	2.	2.	0.0
205.	-1.5	17.87	3.	3.	1.	27.3
206.	-1.5	17.87	3.	4.	2.	84.0
207.	-1.9	17.87	4.	1.	1.	12.5
208.	-1.9	17.87	4.	2.	2.	8.3
209.	-1.9	17.87	4.	3.	1.	56.0
210.	-1.9	17.87	4.	4.	2.	84.0
211.	-2.0	17.87	5.	1.	1.	0.0
212.	-2.0	17.87	5.	1.	2.	32.0

LEGEND:

VELOCITY (FPS)	DURATION (MIN)	SEGMENT
1 = 0.5	1 = 2	1 = A
2 = 1.0	2 = 4	2 = B
3 = 1.5	3 = 8	
4 = 2.0	4 = 16	
5 = 3.0		

TABLE A-3 (Cont.)

LARVAL IMPINGEMENT SURVIVAL STUDY
BLUEGILL TEST DATA

CONDITIONS: VELOCITY = 0.5, 1.0, 1.5, 2.0, 3.0 FPS
DURATION = 2, 4, 8, and 16 MINUTES

Test No.	ΔT, °C	Larval Length, mm	Velocity	Duration	Segment	96 Hour Mortality, %
213.	-2.0	17.87	5.	3.	1.	92.0
214.	-2.0	17.87	5.	4.	2.	100.0
215.	-1.0	17.48	2.	1.	2.	0.0
216.	-1.0	17.48	2.	2.	1.	4.0
217.	-1.0	17.48	2.	3.	2.	8.7
218.	-1.0	17.48	2.	4.	1.	4.0
219.	-1.5	17.48	3.	1.	2.	0.0
220.	-1.5	17.48	3.	2.	1.	0.0
221.	-1.5	17.48	3.	3.	2.	8.0
222.	-1.5	17.48	3.	4.	1.	44.0
223.	0.0	17.48	4.	1.	2.	0.0
224.	0.0	17.48	4.	2.	1.	0.0
225.	0.0	17.48	4.	3.	2.	48.0
226.	0.0	17.48	4.	4.	1.	64.0
227.	-0.5	17.48	5.	1.	2.	0.0
228.	-0.5	17.48	5.	2.	1.	41.7
229.	-0.5	17.48	5.	3.	2.	64.0
230.	-0.5	17.48	5.	4.	1.	100.0
231.	-2.2	17.40	2.	1.	1.	8.3
232.	-2.2	17.40	2.	2.	2.	8.3
233.	-2.3	17.40	2.	3.	1.	0.0
234.	-2.3	17.40	2.	4.	2.	4.3
235.	-2.5	17.40	3.	1.	1.	0.0
236.	-2.5	17.40	3.	2.	2.	8.0
237.	-2.5	17.40	3.	3.	1.	16.7
238.	-2.5	17.40	3.	4.	2.	72.0
239.	-2.3	17.40	4.	1.	1.	4.2
240.	-2.3	17.40	4.	2.	2.	24.0
241.	-2.3	17.40	4.	3.	1.	44.0
242.	-2.3	17.40	4.	4.	2.	68.0
243.	-2.5	17.40	5.	1.	1.	0.0
244.	-2.5	17.40	5.	2.	2.	27.3
245.	-2.7	17.40	5.	3.	1.	84.0
246.	-2.7	17.40	5.	4.	2.	92.0
247.	-2.1	20.26	2.	1.	2.	4.3
248.	-2.1	20.26	2.	2.	1.	4.0
249.	-2.2	20.26	2.	3.	2.	0.0
250.	-2.2	20.26	2.	4.	1.	8.7
251.	-2.2	20.26	3.	1.	2.	0.0
252.	-2.2	20.26	3.	2.	1.	20.8
253.	-2.4	20.26	3.	3.	2.	20.0

Test No.	ΔT, °C	Larval Length, mm	Velocity	Duration	Segment	96 Hour Mortality, %
254.	-2.4	20.26	3.	4.	1.	40.0
255.	-2.8	20.26	4.	1.	2.	4.0
256.	-2.8	20.26	4.	2.	1.	4.2
257.	-3.0	20.26	4.	3.	2.	28.0
258.	-3.0	20.26	4.	4.	1.	84.0
259.	-3.4	20.26	5.	1.	2.	0.0
260.	-3.4	20.26	5.	2.	1.	8.3
261.	-3.4	20.26	5.	3.	2.	60.9
262.	-3.4	20.26	5.	4.	1.	96.0
263.	-2.5	18.50	2.	1.	1.	0.0
264.	-2.5	18.50	2.	2.	2.	0.0
265.	-2.7	18.50	2.	3.	1.	0.0
266.	-2.7	18.50	2.	4.	2.	0.0
267.	-3.2	18.50	3.	1.	1.	4.2
268.	-3.2	18.50	3.	2.	2.	12.0
269.	-3.2	18.50	3.	3.	1.	32.0
270.	-3.2	18.50	3.	4.	2.	76.0
271.	-3.2	18.50	4.	1.	1.	0.0
272.	-3.2	18.50	4.	2.	2.	4.0
273.	-3.4	18.50	4.	3.	1.	48.0
274.	-3.4	18.50	4.	4.	2.	72.0
275.	-3.4	18.50	5.	1.	1.	4.0
276.	-3.4	18.50	5.	2.	2.	4.2
277.	-3.4	18.50	5.	3.	1.	66.7
278.	-3.4	18.50	5.	4.	2.	100.0
279.	-3.2	17.94	2.	1.	2.	0.0
280.	-3.2	17.94	2.	2.	1.	0.0
281.	-3.3	17.94	2.	3.	2.	4.2
282.	-3.3	17.94	2.	4.	1.	0.0
283.	-3.7	17.94	3.	1.	2.	0.0
284.	-3.7	17.94	3.	2.	1.	0.0
285.	-4.0	17.94	3.	3.	2.	0.0
286.	-4.0	17.94	3.	4.	1.	45.8
287.	-4.2	17.94	4.	1.	2.	0.0
288.	-4.2	17.94	4.	2.	1.	4.2
289.	-4.2	17.94	4.	3.	2.	36.0
290.	-4.2	17.94	4.	4.	1.	84.0
291.	-4.4	17.94	5.	1.	2.	0.0
292.	-4.4	17.94	5.	2.	1.	4.0
293.	-4.4	17.94	5.	3.	2.	56.0
294.	-4.4	17.94	5.	3.	1.	26.9

LEGEND:

VELOCITY (FPS)	DURATION (MIN)	SEGMENT
1 = 0.5	1 = 2	1 = A
2 = 1.0	2 = 4	2 = B
3 = 1.5	3 = 8	
4 = 2.0	4 = 16	
5 = 3.0		

Appendix C—Intake System Description

SWEC J.O. No. 12911.09 March 1983
NSP J.O. No. E-78Y073

MODIFY CIRCULATING WATER INTAKE AND DISCHARGE

SYSTEM DESCRIPTION AND DESIGN CRITERIA

PRAIRIE ISLAND NUCLEAR GENERATING PLANT

0648B

CONTENTS

1.0 SUMMARY

The intake and discharge modifications are required to reduce the impact of the Prairie Island Nuclear Generating Plant on aquatic organisms in the Mississippi River.

The intake modifications prevent fish, larvae and eggs from entering the plant cooling water intake canal by removing and transporting them downstream, where they are returned to the river at a location which is outside of the influence of intake flow.

The discharge modifications provide a submerged jet discharge to promote rapid mixing, exclude fish from the system, minimize fish cold shock potential and prevent recirculation of warm water back to the intake (outside the system). By removing this heat source, the potential for attracting fish to the area of the intake screenhouse is minimized.

The reduced intake temperatures also result in greater plant efficiency. Increased water appropriation and changes in operating modes prevent excessive circulating water temperature variations to the operating plant.

1.1 DESIGN CRITERIA

1.1.1 General

The modifications to the intake and discharge systems are designed to exclude aquatic organisms from the circulating water system and eliminate cold shock to fish. This has been accomplished with construction of an intake screenhouse with traveling water screens, a fish return system, a deicing pumphouse, an environmental monitoring laboratory, a screen storage building, and a discharge structure with submerged jet discharge for rapid thermal mixing.

The intake screenhouse is located on the north side of the intake channel. The structure contains equipment to remove aquatic organisms and debris from the intake flow. Traveling water screens are equipped with fish lift buckets. Bypass gates have been provided to maintain a continuous flow in the event that flow through the screens is reduced because of extraordinary clogging. A deicing system is available to distribute warm water across the inside face of the structure to prevent formation of ice on the exposed surfaces. Aquatic organisms, washed off the traveling water screens, are collected in a trough which feeds into the fish return line for return to the river.

The discharge structure is located approximately 500 ft. downstream of Barney's Point, 2150 ft. downstream of the former discharge, and provides a submerged jet discharge at an angle of 45 degrees to the main channel flow of the Mississippi River. Dikes convey discharge flow from the distribution basin to the discharge structure through an extension of the discharge canal. The former dike, downstream of the former discharge has been removed.

A flood and drain gate has been installed in the west dike to provide flooding and draining capability for an area, west of the dike, to be used by the Minnesota Department of Natural Resources as a water fowl sanctuary.

The design bases, system design and operating considerations of the circulating water system are given in Section 10.2.9 of the Prairie Island Final Safety Analysis Report (subsequently referred to as the FSAR).

1.1.2 Hydraulic

1.1.2.1 Water Levels - Mississippi River *

Maximum Operating Water Level (Pool 3)	EL. 678.0 ft.
Normal Operating Water Level (Pool 3)	EL. 673.5 ft.
Extreme Low Water Level (Pool 3)	EL. 672.5 ft.
Flat Pool (Pool 3)	EL. 674.5 ft.
10 yr. flood	EL. 682.5 ft.
100 yr. flood	EL. 687.4 ft.
150 yr. flood	EL. 688.1 ft.

*M.S.L. 1929 adjustment

The 150 year flood level was used as a basis for determining deck elevations such that motors and electrical equipment will not be inundated.

1.1.2.2 Velocities and Flow Rates

In accordance with permit requirements, the average face velocity through the gross area of the 0.5 millimeter mesh screen material should not exceed 0.5 fps based on low water level and corresponding to a discharge flow rate of 800 cfs.

The average face velocity through the gross area of the 3/8 inch screen material should not exceed 0.88 fps corresponding to a maximum intake flow rate of 1410 cfs.

For exclusion of fish from the discharge system and for rapid thermal mixing, velocity in the discharge pipes is a minimum of 8 fps and a maximum of 10 fps. Minimum pipe length is 80 ft.

The combination of the 8 fps velocity and the 80 ft. pipe length forms a barrier through which the local fish cannot swim. A maximum velocity of 10 fps was established in order to limit head loss across the structure to a maximum of 3 ft.

The velocity limit at the edge of the navigation channel is 4 ft/sec. for barge traffic. This is the maximum limit of the average velocity component normal to river flow.

1.1.2.3 Deicing

Warm deicing water is provided during cold weather to prevent the formation of ice on trash racks, traveling water screens and bypass gates. Warm water is pumped from the discharge channel, immediately downstream of the distribution basin. Minimum water temperature at the intake after deicing is 32.5°F. For design purposes, the given plant discharge water temperatures are 57°F for one unit operation and 82°F for two unit operation. Two unit operation normally entails partial recirculation. One unit operation will be open cycle with no recirculation.

1.1.3 Environmental

1.1.3.1 Traveling Water Screens

Traveling water screens are of the through flow type of sufficient area to screen the desired intake flow. The screens are equipped with buckets to transport aquatic organisms to the return system.

1.1.3.2 Mesh Size

During the period April 16 to August 31, the screen mesh size is 0.5 mm or as fine as practicable. During the remainder of the year, a screen mesh size of up to 3/8 inch may be used. Screen panels are replaceable and interchangeable.

1.1.3.3 Screen Speeds

The traveling speeds of the screens have been designed to resist clogging and to minimize the impact on aquatic organisms. The drives provide flexibility to vary speeds, as required, during various periods of the year.

1.1.3.4 Fish Return System

Aquatic organisms impinged on the traveling water screens and in the attached buckets are lifted to the level of the fish sprays and washed off within 4 minutes into a fish collection trough. Removal of the fish and organisms is accomplished on the upward travel side with a low pressure (10 psi) inside spray when fine mesh is used and with a low pressure (20 psi) outside spray when coarse mesh screen is used. Debris is removed by a backside interior high pressure (50 psi for fine mesh and 100 psi for coarse mesh) spray system. The pump supplying the 50 psi fine mesh spray can be run at a higher speed to provide a 125 psi spray to supplement the 100 psi coarse mesh spray during periods of high trash loads. Separate fish and debris troughs combine to form a pipeline which transports the effluent to a point near the downstream end of the existing discharge channel.

Diverting troughs or taps have been provided for sampling capability at the intake screenhouse and near the discharge. Debris can be collected in a trash basket during sampling periods and during high river flow periods.

The fish return line has been designed for velocities between 3 and 5 fps with higher velocities (less than 10 fps) being encountered for a short duration to dissipate energy prior to discharge to the river. All internal surfaces are smooth, to preclude abrasion damage. Organisms are discharged from the pipeline below the mean low water elevation at a depth (below Elev. 670) which ensures submergence below the ice cover.

1.1.3.5 Thermal Limitations

Effective on the date the discharge structure becomes operational and lasting until June 30, 1985, the following thermal limitations, as set forth in the final NPDES Permit #MN0004006, shall be in effect:

- From April 1 through November 30, the temperature of the receiving water, as measured immediately below Lock and Dam No. 3, shall not be raised by more than 5°F above natural, based on the monthly averages of the maximum daily temperatures, except in no case shall it exceed a daily average temperature of 86°F.

- From December 1 through March 31, the mixed river temperature immediately below Lock and Dam No. 3 shall not be raised above 43°F for an extended period of time. Should the mixed river temperature equals or exceeds 43°F for two consecutive days the Director and the Minnesota Department of Natural Resources shall be notified.

1.1.4 Geotechnical

1.1.4.1 Design

The design criteria are based upon information contained in the Prairie Island FSAR Volume 5 supplemented by "Report on Test Borings", dated June 13, 1980 by Stone and Webster Engineering Corporation (Subsequently referred to as SWEC) and by Geotechnical calculations.

1.1.4.2 Allowable Bearing Capacity

Allowable bearing pressure for structures founded on the sandy soils at Prairie Island vary with the size and shape of footing and the depth of embedment. Net maximum bearing capacity for the de-icing pumphouse is 4000 psf. Net maximum bearing capacity for the discharge structure was 2500 psf allowing for a settlement of less than 1.5 in., 3000 psf for less than 1.8 in. The screenhouse was designed for a net bearing capacity of 8000 psf.

1.1.4.3 Soil Properties

Intake Screenhouse and Pumphouse Areas

In situ soil above El. 640 γSAT = 126 pcf, γMoist = 116 pcf, ϕ=33°
In situ soil below El. 640 γSAT = 133 pcf, ϕ = 35°

Discharge Structure

Sand fill above El. 671 γSAT = 127 pcf, γMoist = 119 pcf, ϕ = 33°
Clay El. 671 -665 γSAT = 113 pcf, for C = 0 psf. ϕ = 27 °
before 1st stage dike Construction for ϕ = 0°, C = 400 psf
after 1st stage dike Construction for ϕ = 0°, C = 750 psf
Sand below El. 671 γSAT = 124 pcf

Other soil properties were determined by the Lead Geotechnical Engineer, as required, from the above soils information and boring logs.

1.1.4.4 Permeability

Permeabilities determined from a well pump test as referenced in Volume 5, Section 3.14 of the Prairie Island FSAR range from 0.093 - 0.37 feet per minute.

1.1.4.5 Earth Pressure Coefficients

Active and passive earth pressures are a function of wall deformation. The relationships between the active and passive earth pressure coefficients, Ka and Kp, versus wall deformation are presented in Figure 1, page 28. It is important to note that these relationships were developed for the conditions of insitu soils, vertical wall, nonsloping backfill, and no wall friction. The Lead Geotechnical Engineer established values for Ka and Kp for conditions differing from those assumed above on an individual basis.

1.1.4.6 Emergency Cooling Water Intake Piping

No sheetpile was driven within a 20 foot radius of the emergency cooling water pipe.

1.1.4.7 Cut Slopes

Side slopes of the intake and discharge canals and dikes are one vertical to three horizontal except as noted on the drawings. The slope of the approach canal to the intake screenhouse are one vertical to five horizontal. On the exit side of the screenhouse the channel slope is one vertical to four horizontal.

1.1.4.8 Intake Canal Cutoff

The intake canal cutoff was designed for overtopping as well as a differential head of 5 ft.

1.1.4.9 Erosion Protection

The discharge dike overflow section and the intake cutoff dike has been protected with rockfill to prevent erosion when overtopped.

The discharge structure approach and discharge basin has been protected by riprap with an average diameter of 12 inches.

Riprap has also been provided immediately upstream and downstream of the intake screenhouse on the north bank of the intake canal.

Discharge dike slopes were covered with topsoil and seeded as shown on drawings.

1.1.5 Structural

The purpose of these criteria is to provide the structural information used to design the intake screenhouse, discharge structure, and de-icing pumphouse. In general, the structural design criteria and the component design criteria from Appendix B, Section B.6 and B.7, respectively, of the FSAR for the Prairie Island Nuclear Generating Plant were used.

The intake screenhouse, discharge structure and de-icing pump house and components were designed as QA Type III structures.

1.1.5.1 Codes

As a minimum, structures were designed in accordance with the applicable codes as listed.

A. American Concrete Institute Codes; ACI 318-77, ACI 301-(R75), and other sections of the ACI Codes as applicable.

B. American Institute of Steel Construction "Specification for the Design, Fabrication and Erection of Structural Steel Buildings," 1980 Edition.

C. International Conference of Building Officials "Uniform Building Code," 1979 Edition.

D. Current versions of applicable codes except for piping and valves are listed in paragraph B.3 Appendix B of the FSAR.

E. Project Analysis report.

1.1.5.2 Loads

All structures and components were designed to withstand various kinds and combinations of loads.

The different kinds of loads treated in the design are described in the subsequent paragraphs.

A. Environmental Loads

These consist of snow and wind loads:

Snow load (SL) of 50 lbs. per sq. ft. of horizontal projected area was used in the design of structures and components exposed to snow.

Normal wind loads (WL) applied to the structure were as described herein. Wind loads are based on ANSI Standard A58.1-1972 which formalizes the recommendations of the American Society of Civil Engineer's paper ASCE 3269 "Wind Forces on Structures." A 100 mph design wind speed was used per the FSAR.

B. Live Loads (LL) consist of loadings not permanently on the structure. The following live loads were used.

The screenhouse deck was designed for a live load of not less than 250 psf or an H10 truck loading plus 10 percent impact, whichever governs.

The decks of the discharge structure and de-icing pumphouse were designed for a live load of at least 100 psf. The storage building floor slab and the floor of the environmental lab were designed for a live load of not less than 200 psf. The floor of the office in the environmental lab was designed for a live load of not less than 80 psf.

C. Dead Loads

Dead loads consist of the weight of structural steel, concrete, and equipment. The weight of the equipment was as specified on the manufacturer's drawings. Soil loads were considered to be a Dead Load.

D. Load Allowances

Load allowances are provided to account for concentrations of minor unknown loads from pipe hangers, cable supports, lighting fixtures, etc. Steel beams and girders were designed to support the following concentrated loads applied to the midspan of the members:

Roof Beams or Joists	3.0 Kips
Roof Girders	6.0 Kips
All Other Beams	5.0 Kips
All Other Girders	8.0 Kips

Reactions of beam load allowances were not accumulated into girders and only girder load allowances were carried to the columns.

E. Seismic Loads

The seismic loads used were in accordance with the requirements of the Uniform Building Code. This code specifies the location of the plant site to be in "Zero" earthquake area. However, for conservatism earthquake loads applicable to Zone 1 areas were used in the design.

1.1.5.3 Load Combinations

The following combinations of loads were used to design the structures:

A. Normal Operating: Dead and Live loads together with Environmental loads (wind and snow, separately).

DL + LL
DL + LL + WL
DL + LL + SL

B. Other: Dead and Live loads together with Uniform Building Code Earthquake.

DL + LL + UBC Zone 1 Earthquake.

1.1.5.4 Stress Design Criteria

Concrete allowable stresses were from ACI 318-77 with no increase in stresses for earthquake, wind, or snow conditions. Structural steel allowable stresses were from AISC-1980 with no increase in stresses for earthquake, wind or snow conditions.

1.1.5.5 Materials

A. Structural Steel and Bolts: All structural steel conforms to ASTM-A36. All primary bolted connections were made with ASTM A325 bolts. Secondary bolted connections considered to be girt, purlin, stair, ladder and handrail connections were bolted with either ASTM A307 or A325 bolts. Anchor bolts conform to ASTM A36.

B. Concrete and Reinforcing Steel: Concrete has a minimum compressive strength of 4,000 psi at 28 days. Reinforcing steel conforms to ASTM Standard Specification for Deformed Billet-Steel Bars for Concrete Reinforcement, ASTM-A615, Grade 60.

1.1.5.6 Stability

The intake screenhouse and discharge structure were analyzed for stability using the following Factors of Safety:

	Normal Conditions	Extreme Conditions
FS Against Overturning	1.5	1.3
FS Against Sliding	1.5	1.3
FS Against Flotation	1.1	1.1

Extreme conditions consist of earthquake or flood (150 yr.).

A. Stability of Intake Screenhouse

When analyzing for stability of the intake screenhouse, 2 adjacent bays were considered dewatered. The following cases were considered:

	Case 1	Case 2	Case 3	Case 4
Water Level	678.0	678.0	678.0	678.0
Equipment in Place	No	No	Yes	Yes
Vertical EQ.	No	No	Yes	No
Horiz. EQ.	No	No	No	Yes
Wind Load on Superst.	No	Yes	No	No

B. Stability of Discharge Structure

When analyzing for stability of the discharge structure, one bay was considered dewatered. The following Cases were considered:

	Case 1	Case 2	Case 3	Case 4
Water Level	678.0	678.0	678.0	685.0
Equipment in Place	Yes	Yes	Yes	Yes
Vertical EQ.	No	No	Yes	No
Horiz. EQ	No	Yes	No	No

1.1.6 Electrical

The purpose of these criteria is to provide the electrical bases required to support the intake and discharge modifications to the Prairie Island Nuclear Generating Plant. The electrical design was based on a combination of design criteria from the Prairie Island FSAR, Prairie Island Project Design Manual and on SWEC design standards.

1.1.6.1 NSP Furnished Criteria

A. General Electrical Design Bases

Design bases for the plant electrical systems are given in Section 8.1 of the FSAR.

B. 480-volt Auxiliary System

480-volt system design is given in Section 8.3.6 of the FSAR.

C. 120 VAC Instrument Bus System

120 VAC Instrument Bus System design is given in Section 8.3.8 of the FSAR.

D. Circulating water system

The design bases, system design and operation considerations for the circulating water system are given in Section 10.2.9 of the FSAR.

E. General Instrumentation and control

The design bases for instrumentation and control are given in Section 7 of the FSAR.

F. Main Control Board

The design and layout of the Main Control Board is given in Section 7.7.3 of the FSAR.

G. Raceway

Raceway conforms to Section 4, Index 324.52 and 324.53 of the Prairie Island Project Design Manual. This section includes, but is not limited to, the design criteria, material requirements, separation criteria, cable spacing and tie down requirements in trays, normal voltage restrictions for cables entering the control room and grounding requirements used for the original raceway design. Raceway coding and identification conform to Section 4 Index 3.24.54 of the Prairie Island project Design Manual. NSP has assigned identification numbers to raceway. NSP provided routing for cable in the turbine building cable tray system as required.

H. Wire and Cable

Cable derating, routing, fire protection, separation, tray and other considerations are given in Section 8.3.11 of the FSAR. Electrical wire and cable was used from the Northern States Power Company's existing plant surplus when possible. Wire and cable coding and identification conforms to Section 4, Index 324.54 of the Prairie Island Project Design Manual. NSP has assigned identification numbers to wire and cable.

I. Classifications

Design classifications and QA classifications are consistent with those used for the original plant. These definitions are provided in Appendix C of the FSAR.

J. Fire Stops

NSP provided up to date cable seal and fire stop requirements for insertion into the installation specification.

1.1.6.2 SWEC Modified Criteria

A. Raceway

Conduit is rigid steel or electrical metallic tubing. Conduit size and fill are based on National Electric Code recommendations (1981 revision). Conduit is in accordance with SWEC standard design drawings STD-ME-1-1-4 and 1-3-5 (copies provided in Appendix A), unless otherwise specified in the drawings. The existing cable tray system was used when possible.

B. Wire and Cable

Wire and cable were specified and purchased as QA Type III and met the intent of IEEE 383-1974. All power cable was provided with an overall interlocked aluminum or galvanized steel armor. All new cable had copper conductors. Power cable was selected and sized in accordance with IEEE S-135, IPCEA P-46-426 power cable ampacity tables.

C. Grounding

Grounding is in accordance with SWEC standard design drawings STD-ME-2-1-6 and 2-2-7 (copies provided in Appendix A) unless otherwise specified.

D. Motors

All motors were provided with the driven equipment. Induction motor data sheets SWEC form SM-34-9, 74 (copy provided in Appendix A), were prepared for all motors.

E. Instrumentation and Control

Instrumentation and control requirements and operation for the specific system are given in logic descriptions in Appendix B. Instrument data sheets were completed for all instruments.

F. Power Sources

All electrical power sources required to support the modification were selected on the basis of the following:

1. QA Classification
2. Maintaining equipment required to support other equipment on the same bus as the supported equipment
3. Maintaining redundant or backup equipment on different buses where possible.
4. Not exceeding the capacity of any power source
5. Load balancing between buses when possible.

G. Modification to Turbine Building Equipment

All modifications to the turbine building cable tray system or main control board were accomplished without impairing the original integrity or violating the original design classification of the modified equipment. All modifications to said equipment were approved by NSP prior to modification. Cable tray systems and main control board were visually inspected prior to preparation of the modification drawings to verify the accuracy of the existing drawings.

H. Additional Electrical, Instrumentation, and Control Equipment

All modifications to the main control board used equipment that was consistent with that presently in use at Prairie Island and was approved by NSP.

1.1.7 <u>Mechanical</u>

Heating, ventilating and fire protection equipment was provided as agreed upon by SWEC and by NSP. Ambient design air temperatures at the plant will be -14° F in the winter and 89° F in the summer.

2.0 SYSTEM DESCRIPTION

2.1 HYDRAULIC

2.1.1 Intake Screenhouse Equipment

Plant intake flow from the Mississippi River enters the intake screenhouse through eight 18.5 ft. by 11.2 ft. bay openings. The bottom of the inlet skimmer wall is at Elev. 667.0. Each bay is equipped with a raked trash rack and a traveling water screen with low pressure fish wash sprays and high pressure trash wash sprays.

The intake screenhouse also contains the following:

a. High and low pressure screenwash pumps and piping.

b. Traveling rake to clean trash racks.

c. Stop gates which will enable dewatering of 2 screen bays.

d. Bypass gates which will automatically open when the head loss across the traveling water screens exceeds 18 in. This could occur when trash loading is so high that clogging of the screens results.

e. Screenwash system pipeline strainers.

f. Overhead traveling crane to service all equipment within the structure and to handle screen storage racks.

g. Air compressors for service air and instrument air.

h. Fish and trash troughs to collect screenwash water.

2.1.1.1 Traveling Water Screens

Eight through flow traveling water screens equipped with fish buckets, high and low pressure sprays have been provided to remove debris and organisms from the intake water from the Mississippi River. Each screen is 10 ft. wide and extends from the operating deck (El. 685') to the floor (El. 648.5'). Screen panels are easily replaceable. A 0.5 mm mesh will be used during the period extending from April 16 through August 31, and a 3/8 inch (9.5 mm) mesh will be used the remainder of the year. The screens are capable of operation at several different speeds, as necessitated by trash loading. The screens are designed to withstand an 8 ft. head differential and to operate continuously at a 3.5 ft. differential. Screen panels will be stored in a building close to the screenhouse.

There are larval and fish screenwash systems on the front or ascending side with a fish trough, and a high pressure two header spray system on the back with a debris trough. The drive for each screen is provided by a 5 hp variable speed motor.

The traveling screen specification H-109A discusses the screens in detail.

2.1.1.2 Trash Racks and Rake

One inclined trash rack, consisting of mounted 3/8" by 3" steel bars with 1-1/2" clear spacing, has been installed in each bay. One conventional trash rake with hopper traverses all eight bays on rails embedded in the deck. Space has been provided for the future installation of eight stationary bar screens if the need arises.

An alarm system will sound in the screen house and in the plant control room if a water level differential of 6 inches across the trash rack occurs. The racks have been structurally designed to withstand 5 feet of differential head.

The trash rake can traverse the intake screenhouse at a speed of 30 feet per minute.

The trash rake specification H-110M discusses the rake in detail.

2.1.1.3 Screenwash Pumps

A total of eight screenwash pumps have been provided as follows:

No. of Pumps	Duty	Capacity*	Pressure
2	Fish Spray	150 GPM	20 psi
2	Larvae Spray	190 GPM	10 psi
2	Trash-Fine Mesh	120 GPM	50 psi
2	Trash-Coarse Mesh	250 GPM	100 psi

*Flows as listed are per screen

One pump for each spray duty has been provided for each of two banks of four screens.

The fine screen trash removal spray pumps are two speed machines. During periods of extremely high trash loading, these pumps can be operated at the higher speed and the discharge will be used to supplement the coarse screen spray through the fine mesh trash spray header.

The pumps are of the vertical wet-pit type and draw water from behind the stop gates at the downstream side of the intake screenhouse. Pump discharges are equipped with 1/8 in. mesh manual blowdown y-type strainers.

Distribution piping for the two screenwash systems was designed for maximum flexibility. The fish spray pumps and the coarse mesh screenwash pumps start automatically on a preset differential across the screens. The larvae spray pumps and the fine mesh screenwash pumps will be started manually and will operate continuously from April 16 to August 31.

The screenwash pump Specification P-226L discusses the pumps in detail.

2.1.1.4 Bypass Gates

The bypass gates are of the vertical lift gate type with rollers. The gates open automatically when the head differential across the traveling water screens reaches 18" or when the head differential across the intake screenhouse reaches 24". Either of these could occur if the screens experience severe clogging that cannot be cleaned by the screenwash sprays. After cleaning the clogged screens, the bypass gates close by manually activated controls located in the intake screenhouse. The gate operators are designed to lift the gates at a speed of 5 feet per minute. The gates, when fully open, have a total of 500 sq. ft. of clear area to pass the full flow of 1400 c.f.s. with a head loss not exceeding 4 inches. Unscreened water will flow on downstream to the screenhouse where debris will be removed.

The top of the gates are below low water elevation to ensure complete submergence for ice protection. The bottom of the gates rest on a 2.75 foot high sill to allow for silt accumulation.

Differential water level sensors are installed in each of the screen bays to measure head loss across the traveling water screens.

The bypass gates Specification H-107S discusses the gate in detail.

2.1.1.5 Stop Gates

The stop gates are steel-bulkhead type. There are four gates, to enable dewatering of two bays concurrently. Each gate consists of four sections provided with dogging devices to enable removal of these gates in sections. Gate sections will be placed and removed by the traveling crane. To remove a gate, head difference across the gate must be less than 6 inches. Gates are designed to withstand a differential head of 30 feet.

The stop log gates Specification H-106A discusses the gates in detail.

2.1.1.6 Traveling Crane

A traveling crane has been provided in the screenhouse to service all equipment contained therein. The crane is a 15 ton capacity overhead bridge traveling crane. Crane capacity is based upon the maximum anticipated equipment load. The crane is operated from the deck of the intake screenhouse by means of a suspended pendant.

2.1.1.7 Siltation

A program of sediment monitoring and dredging will be prepared to assure that sediment accumulation does not affect the traveling screen operation. The sediment monitoring program will be designed to measure the sediment build-up as frequently as required.

2.1.2 Discharge Structure

Flow enters the discharge structure through four 10 ft. by 11 ft. openings and proceeds through separate bays to four motor operated sluice gates (5 ft., 6 ft., 7 ft., and 8 ft. square), then to the river through four submerged pipes. Flow through the four submerged pipes ranges from 150 cfs to 1390 cfs. Discharge velocities in each pipe is in the approximate range of 8 fps to 10 fps. Differential head losses across the structure are approximately 2.0 ft. and 3.0 ft. respectively.

The discharge pipe arrangement consists of four concrete pipes, one each of 5 ft., 6 ft., 7 ft., and 8 ft. diameters. They are installed parallel to each other in order of ascending diameters with the 5 ft. pipe at the southerly or downstream end of the structure and the 8 ft. pipe at the northerly or upstream end.

The following table shows the discharge capacity of all the various pipe combinations in the discharge structure.

PIPES USED (Diam. in Feet)	DISCHARGE (C.F.S) AT VELOCITY SHOWN V=8 f.p.s.		V=10 f.p.s.
5	157		196
6	226	150	283
7	308	300	385
5&6	383		479
8	402	400	503
5&7	465		581
6&7	534		668
5&8	559		699
6&8	628		785
5,6&7	691		864
7&8	710		888
5,6&8	785		982
5,7&8	867	800	1084
6,7&8	936		1170
5,6,7&8	1093		1390*

* At a discharge of 1390 c.f.s. the velocity is 10.17 fps.

Outfall pipes are placed on flat grade with inverts at Elev. 659.8. Downstream of the pipe, a discharge basin slopes down at one vertical to four horizontal to Elev. 652.

Slope erosion protection consisting of 12 in. (D50) rip-rap has been provided on the westerly and southerly sides of the outfall basin between Elev. 652 and Elev. 658.

The sluice gates are designed to withstand 20 ft. of unseating head. The gates can be operated locally or remotely either fully opened or fully closed.

The details of the sluice gates are specified in Specification H-107S.

Stop gates are provided for gate maintenance. They are the same stop gates that are used and stored in the intake structure. Removal of the gates will require equal water levels on both upstream and downstream surfaces. Use of the stop gates will not allow dewatering of the bays but will cut off flow through a bay.

The details of the gates are specified in Specification H-106A.

A parking area has been provided at the south end of the dike, with two boat ramps, one for access to the area inside the dike, the other for access outside the dike.

Space has been provided in the parking area near the discharge structure to allow for future installation of dechlorination equipment.

A channel was cut through the island approximately 400 ft. downstream of the discharge structure to allow circulation of river water into the slough and to provide boat access to the main channel. An 8 inch discharge pipe through the south end of the dike was provided to deliver warm water from the discharge canal to the slough in the event that the dissolved oxygen level in the slough becomes undesirably low. The pipe is placed on flat grade with invert at Elev. 675.0. It is capped at both ends with no control valve provided.

In accordance with the Minnesota Department of Natural Resources (MDNR) criteria, a control gate located at the west dike was provided to flood and drain the backwater area, which will be used as a sanctuary for water fowl. Operation will be as directed by MDNR.

The same control gate will also be used to drain the backwater area back into the discharge canal. It will be necessary to lower the water level in the discharge canal to accomplish this. Operation guidelines will be developed later.

2.2 ENVIRONMENTAL

2.2.1 Fish Return System

The organisms and debris washed off the traveling water screens is collected in a common trough and returned to the river through a buried pipe approximately 2200 feet long. The pipe discharges into the Mississippi River at a point approximately 1500 feet south of the intake screenhouse.

Because of potential icing problems, a partial flow of warm water, taken from the deicing line, is maintained in the system when the screenwash pumps are not in operation.

2.2.2 Environmental Monitoring Laboratory

A sampling laboratory is located northwest of the intake screenhouse. The laboratory contains a sampling tank to collect organisms and debris from the screens. It houses a larval table and adult fish sampling tanks and also contains a water quality lab and new office space to replace the present facilities. Two full size pumps, each rated at 300 gpm, are located in the sampling laboratory. These pumps provide ambient river water to the lab for use in the collection and storing of samples. The design of the environmental monitoring laboratory is covered in specification 12911.09-SOOLB.

2.2.3 Deicing System

The de-icing pumphouse is located north of the discharge canal, immediately downstream of the distribution basin. A buried 3 ft. diameter concrete intake pipe supplies warm water to the pumphouse.

Two 50 percent capacity pumps supply the de-icing water to the intake screenhouse. The pumps are vertical, wet pit propeller type units rated to deliver about 6550 gpm each, against a total dynamic head of 16 feet. Pump motors are each rated at 40 horsepower. Each pump has a motor operated discharge butterfly valve. The discharge from the two pumps manifold into a 30 inch diameter line which carries the de-icing water to the intake screenhouse. Removable roof panels provide access to the pumps in case they need to be removed for servicing.

The 30 inch pipeline delivering de-icing water to the intake screenhouse is buried below the frostline. The pipeline is installed at a slope which provides for drainage of the line when not in use. Where low points in the pipeline could not be avoided, drains were provided at the low points. At the intake screenhouse, the deicing water pipeline expands from 30 in. to 42 in. and is routed to the bottom of the intake channel directly in front of the screenhouse base mat. Vertical risers, connected to the 42 in. diameter header pipe, are attached to the upstream face of the screenbay piers. The risers terminate at Elev. 667.5, which is 0.5 ft. above the bottom elevation of the upstream curtain wall.

The risers located between adjacent screenbays are 18 in. in diameter with 3 in. diameter horizontal pipes acting as discharge ports. The discharge ports are 3 ft. on centers, extending from Elev. 650.5 to Elev. 665.5. Each riser has 12 discharge ports, 6 directed toward each of the two adjacent bays.

The risers which are located on the outermost screen bay piers are 12 in. in diameter with six 3 in. horizontal discharge ports located at the same elevations as discussed above.

The total deicing flow to each screenbay is approximately 3.2 cfs.

Deicing water for the by-pass gates is routed to the downstream side of the gates by two 4 in. diameter pipes. The pipes deliver approximately 0.5 cfs per gate. All guides and rollers for the gates are on the downstream side and are subjected to the deicing water flow.

2.3 GEOTECHNICAL

2.3.1 Discharge Dike

On the island, the dikes are founded on silty clay at Elev. 671. All materials above Elev. 671 (typically muck) were excavated and spoiled. The dike which crosses the slough west of the discharge structure and the dike across the former discharge canal is founded on sand. All soils containing less than 50% sand beneath the dikes were excavated and spoiled. Soil beneath the west dike was excavated to a minimum depth of one foot and stockpiled for use as topsoil. In the vicinity of the backwater drain, soil beneath the dike was excavated to stable subgrade.

Excavation of soil to founding depth and placement of fill took place simultaneously to minimize swell and/or disturbance with consequent loss of strength of the island foundation soils.

Dike fill consists of material excavated from the intake and from spoil banks which were stockpiled southwest of the cooling towers. Dike fill consist of sands and gravel containing less than 12% fines when placed underwater and less than 20% fines when placed above water.

2.4 STRUCTURAL

The intake screenhouse is a box type structure founded mostly below grade and water surface. The foundation is a concrete mat founded on cut. The substructure is reinforced concrete.

The superstructure consists of structural steel framing with metal clad siding. Front and rear walls of the intake screenhouse substructure extend down into the water, acting as a seal against floating debris and outside air. Elevations of the bottoms of the front and rear skimmer walls are 667.0 and 670.50 respectively. Deck elevation of the intake screenhouse is 685.0 with motors and electrical equipment placed above the floor so as to minimize damage due to flooding.

The discharge structure consists of a remotely controlled gate structure and four buried discharge pipes. The gate structure is a reinforced concrete box structure founded on cut. The discharge pipes consist of interlocking reinforced concrete pipe founded on cut and buried with earthfill. Sheet piling is used to retain slopes upstream of the gate structure.

The de-icing pumphouse consists of an ungated concrete pumpwell with a metal superstructure. The pumphouse is founded on cut and backfill placed against the four sides of the pumpwell to existing grade. The intake pipe for the pumphouse consists of interlocking reinforced concrete pipe. The discharge pipe is welded steel. Both pipes are founded on cut and buried. See Deicing System, section 2.2.3.

2.5 ELECTRICAL

2.5.1 13.8 KV Power

Two 13.8 KV Power feeders provide power to the intake structure. One feed originates at the #10 Bank Transformer and the other at the CT1 Transformer in the switchyard. The loads are divided equally between these two sources. Disconnect devices are provided by NSP on each feeder at the switchyard end.

2.5.2 480 VAC Power

Each 13.8 KV Power feed energizes a 1000/1333 KVA (AA/FA), 13.8 KV-480V transformer which in turn powers a double ended 480 V switchgear section. A bus tie breaker has been provided so that either source can supply the entire screenhouse. Main breakers on each switchgear source are interlocked with the tie breaker to allow only two out of three breakers closed at any one time. Each switchgear section then feeds a motor control center. One 480 V feed from the intake screenhouse powers motor control centers at the de-icing pumphouse and at the discharge structure.

The motor control center horizontal bus is rated 600A and vertical bus rated 300A. The bus work is braced for 22,000 Amps symmetrical. A 2" x 1/4" copper ground bus is supplied in each MCC. The MCC requirements are detailed in Specification E-015Q. The switchgear and transformer requirements are given in Specification E-015N.

2.5.3 120 VAC Power

480/277-240/120V transformers and corresponding distribution panels are provided for lighting, control panel power, and other miscellaneous 120 VAC loads at the intake, discharge, and de-icing pumphouse. Lighting circuits are 277V single phase. Transformers and distribution panels are divided between buses.

2.5.4 Grounding

All mechanical equipment, cable tray, conduit, motors, and building steel is tied to the existing plant grounding system. Ground rods were added as required at the remote structures to maintain a resistance to ground of less than 1 ohm per IEEE Standard 142.

2.5.5 Instrumentation and Control

Instrumentation, control requirements, and operation for the specific system is given in the logic descriptions (Appendix B) and logic diagrams.

2.5.6 Lighting, 120 VAC Receptacles, and Welding Receptacles

The area lighting level in the intake structure and de-icing pumphouse is designed to be between 10 and 30 foot candles. Additional lighting is provided as required. Emergency egress lighting is provided in buildings.

The lighting level at the discharge structure is designed to be between 2-5 foot candles.

Convenience and welding receptacles are provided and located as required.

A bill of material for the lighting system, 120 VAC receptacles, and welding receptacles was prepared by SWEC for purchase by the Electrical Contractor.

2.5.7 Security

Security system requirements were determined by NSP.

2.5.8 Raceway

Power, control, and instrument cable installed from the turbine building to the intake structure and from the intake structure to the de-icing pumphouse and discharge structure is direct burial rated cable.

Cable tray installed in the intake screenhouse is aluminum. The cable tray in the plant itself is used for routing new cables when possible.

Cables installed in the turbine building use the existing cable tray system.

Raceway was specified by SWEC in the installation specification for purchase by the Electrical Contractor.

2.5.9 Wire and Cable

Specification E-024A details 600V control cable requirements.
Specification E-023A details 600V and 13.8KV power cable requirements.
Specification E-024P details 300V instrument cable requirements.

2.5.10 Miscellaneous

All electrical equipment at the intake screenhouse, deicing pumphouse and discharge structure is located above the 150 year flood elevation. All indoor electrical equipment enclosures are NEMA 1A or better. Outdoor enclosures are NEMA 4 or better. Indoor motors are open drip-proof. Outdoor motors are totally enclosed.

2.5.11 Cathodic Protection

Cathodic Protection is provided at the intake screenhouse and for direct buried conduit as required.

2.6 MECHANICAL

2.6.1 Ventilation

A ventilation system was provided for the intake scr変house in order to provide an indoor air temperature of 104°F when the outdoor air temperature is 89°F. The required air movement is 15,200 cfm. Air exhaust is provided by two power operated roof top ventilators. Air intake is provided by louvered openings in the west wall. All ventilation openings are provided with bird screens and are designed to prevent weather penetration.

2.6.2 Heating

A heating system in the intake screenhouse, is designed to maintain an operating temperature of 50°F when the outdoor air temperature is -14°F and the river temperature is 32°F. The system consists of eleven electric unit heaters rated at 30 KW each for a total installed capacity of 330 KW. Each unit heater has an individual adjustable thermostat located on an adjacent wall.

2.6.3 Fire Protection

Portable fire extinguishers are provided as necessary. The traveling water screen spray wash header has two fire hose connections with Elkhart model L-E, 95 gpm nozzles.

2.6.4 Service Air

A service air compresor system has been provided in the intake screenhouse. The compressor system is designed to provide 225 scfm at 110 psig. Compressed air is routed to 15 quick disconnect type air stations throughout the screenhouse for maintenance as required. The compressor system is skid mounted with a self contained liquid cooling system and air drying system.

2.6.5 Instrument Air

A duplex instrument air compressor system has been provided in the intake screenhouse to provide instrument air to the bubble tube instrument racks and to the eight screenwash three way air operated plug valves. The instrument air compressor system consists of two 18.5 acfm air cooled non lubricated compressors mounted on one skid. The compressor system is designed to provide 100 psig oil free air at -40°F dew point. Only one compressor is required for the instrument air load with the second compressor provided as backup.

2.7 QUALITY ASSURANCE

The screenhouse and all associated equipment are QA Type III. The discharge structure and all associated equipment are QA Type III. All equipment has the same design and quality assurance classifications unless otherwise rated.

2.8 CODES AND STANDARDS

The screenhouse and associated equipment was designed in accordance with the following codes and standards as indicated by the Project Analysis Report:

Screen Pumps	Manufacturers Standard
Traveling Water Screens	Manufacturers Standard
Trash Rack & Rake	Manufacturers Standard
Strainers	Manufacturers Standard
Bypass Gates	Manufacturers Standard
Stop Gates	Manufacturers Standard
Valves	USAS-B31.1-1967
	USAS-B16.5-1968
	MSS SP-61
Piping (Steel)	USAS B31.1-1967
Piping (Fiberglass)	ANSI B31-1980
Motors	NEMA MG-1-1972
Steel Structure	AISC - 1980
Concrete Structures	ACI 318-77
Electric Cable	IEEE 383-1974
Sluice Gates	Manufacturers Standard

3.0 SYSTEM OPERATION

3.1 System Arrangement

The system arrangement is as indicated on drawing number NF-92703 for the intake and NF-92704 for the discharge.

3.2 Description of Intake and Discharge Flows

3.2.1 Normal Operation

Discharge flow rates are limited during specified periods by provisions in the NPDES permit as listed below:

April	150 cfs
May	300 cfs
June 1-15	400 cfs
June 16-30	800 cfs

During these periods the intake flow rates cannot exceed the allowable discharge rates plus an allowance for evaporative and drift losses from the cooling towers.

During other periods of the year the intake flow rate may vary to provide maximum plant efficiency provided the thermal criteria listed in Section 1.1.3.5 is not exceeded.

3.2.2 Infrequent Operation

Higher intake flow rates than those permitted by the discharge provisions listed in Section 3.2.1 will be allowed in order to prevent condenser inlet temperatures from exceeding 85°F. The NPDES permit allows for these higher flow rates provided they are minimized to the extent practical. During these periods the discharge thermal criteria must still be met.

3.3 Two Unit Winter Startup

In the event that both plants must be shut down during winter months, the warm water source for de-icing will be lost. Both bypass gates in the intake screenhouse should be manually opened if not already open and it should be verified that at least one sluice gate is open. The bypass gates and sluice gate should be verified open at the onset of the outage and remain open for the duration of the outage to allow plant startup.

4.0 SYSTEM LIMITATIONS AND SETPOINTS

Maximum Operating Water Level	678 ft.
Normal Operating Water Level	673.5 ft
Minimum Operating Water Level	672.5 ft.
Average Net Screen Face Velocity	0.5 fps at 800 cfs. 0.88 fps at 1410 cfs.

4.1 EQUIPMENT

4.1.1 Screen Size

Larval Season	April 16 to Aug. 31	0.5 mm mesh
Remainder of Year	Sept. 1 to April 15	9.5 mm mesh

Speed

Differential Pressure In W.G. Across Screens	9.5 mm	0.5 mm
0"	0 fpm	3 fpm
4"	3 fpm	3 fpm
8"	20 fpm	20 fpm
10"	Alarm	Alarm
18"	Bypass Gate Open	Bypass Gate Open

Design Maximum Differential Pressure	8 ft. WG
Design Operating Differential Pressure	3.5 ft. WG

4.1.2 Trash Rack and Rake

Design Maximum Differential	5 ft. WG
Traversing Speed	30 fpm

4.1.3 Screen Wash Pumps

4.1.3.1 Coarse Screen Trash Removal Pumps

Number of pumps	2
HP	100
RPM	1800
Capacity (gpm per pump)	1000

4.1.3.2 Two Speed Fine Screen Trash Removal Pumps

Number of pumps	2
HP	33/75
RPM	1200/1800
Capacity (gpm per pump)	480/760

4.1.3.3 Coarse Screen Fish Removal Pumps

Number of pumps	2
HP	15
RPM	1800
Capacity (gpm per pump)	600

4.1.3.4	Fine Screen Larvae Removal Pumps	
	Number of pumps	2
	HP	20
	RPM	1800
	Capacity (gpm per pump)	760

4.1.4 Bypass Gates

Number of Gates	2
Head Loss at Max Flow	4 in. W.G.
Net Free Area	500 sq. Ft.
Maximum Flow	1410 cfs

4.1.5 De-Icing Water Supply Pumps

Number of pumps	2
HP	40
RPM	1200
Capacity (gpm per pump)	6550

5.0 SAFETY FEATURES

Safety features for the intake screenhouse, discharge structure and de-icing pumphouse were provided. These include, but are not limited to, handrails, fire extinguishers, non slip tread, and other equipment necessary to provide a safe working environment.

6.0 SYSTEM MAINTENANCE

6.1 MAINTENANCE APPROACH

Normal access to equipment for inspection and maintenance is provided by system design. Special features provided for maintenance are discussed in the following sections.

6.2 PREVENTIVE MAINTENANCE

Preventive maintenance of all components and controls for the intake structure is conducted following normal nuclear power plant practice and manufacturer's recommendations.

6.3 TESTING AND SURVEILLANCE

6.3.1 Screen Wash Pumps and De-icing Pumps

The screenwash pumps are tested monthly to verify operability. The de-icing pumps are tested monthly during winter months when not in use to verify operability. The test is performed during normal operation. The following parameters are recorded during the test:

1. Suction water elevation.

2. Discharge pressure.

3. Vibration amplitude.

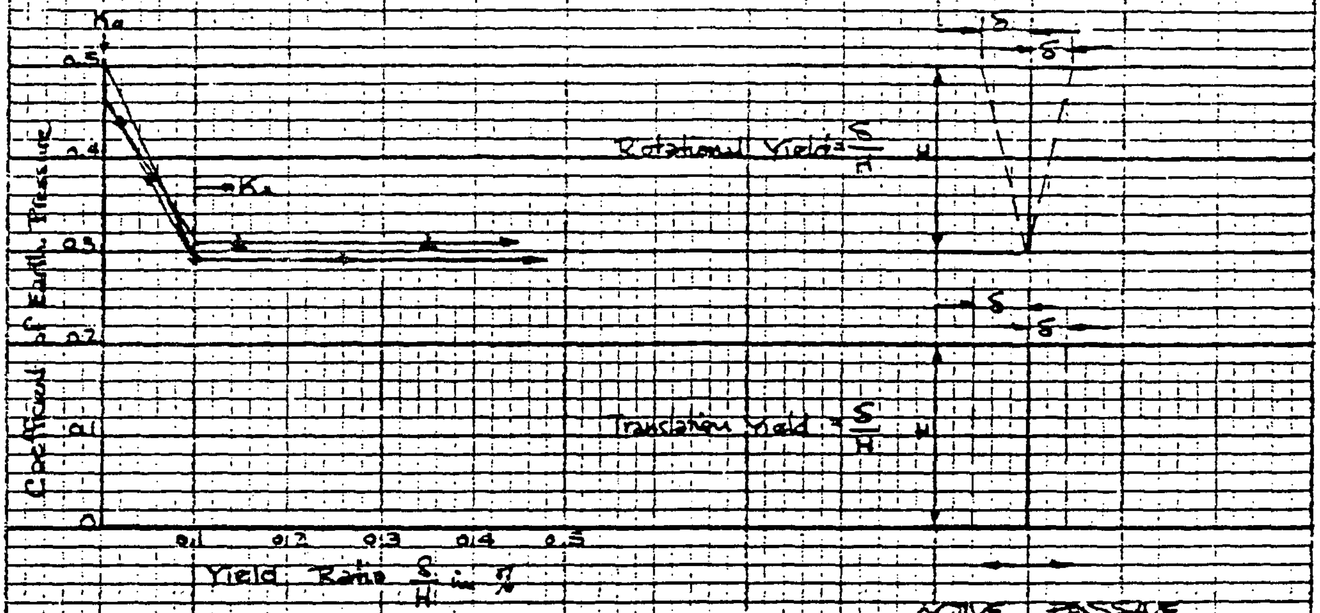
6.3.2 Valves

A. All valves except vent, drain, instrument, test valves and maintenance isolation valves are partially stroked once every three months, and fully stroked annually.

B. All check valves are tested annually.

6.4 INSERVICE INSPECTION

All components are visually examined while in operation every three months.

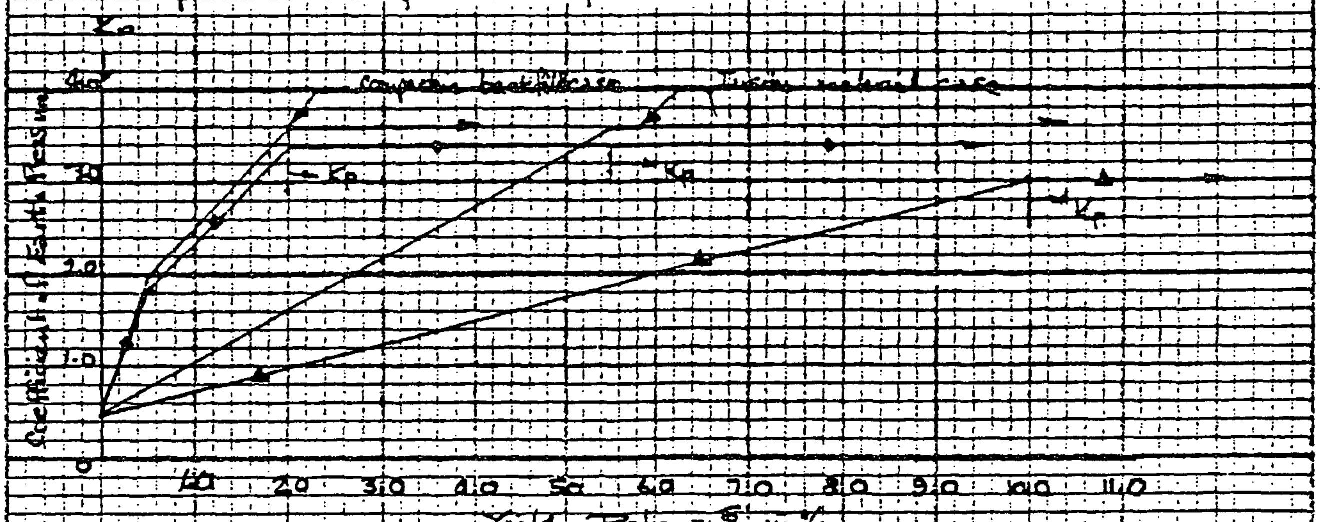


ACTIVE CASE

ACTIVE PASSIVE

= Intake & Deicing Pumphouse soils
= Discharge Sand above El. 671
= Discharge Sand below El. 671

Ka = coeff. of active Earth pressure
Ko = coeff. of earth pressure at rest
Kp = coeff. of passive earth pressure



PASSIVE CASE

FIGURE 1

Modify Intake & Discharge
PRAIRIE ISLAND UNITS 1 & 2
NORTHERN STATES POWER COMPANY

COEFFICIENTS OF EARTH PRESSURE
(Ref: S&W Geotechnical Guideline 6.15, Rev. 3)

NOTES:

1. ALL CONDUIT IS SHOWN DIAGRAMMATICALLY EXCEPT WHERE SPACE ALLOCATION HAS BEEN DESIGNATED. WHERE SPACE ALLOCATION HAS BEEN SHOWN THE CONDUIT SHALL BE RUN WITHIN THE DIMENSIONED LIMITS. CONDUIT, WHEN DIMENSIONED, SHALL BE INSTALLED AS INDICATED.

2. WHERE EXPOSED CONDUIT CROSSES A VIBRATION JOINT OR WHERE CONDUIT EXPANSION PROVISION IS REQUIRED, A SHORT LENGTH OF FLEXIBLE CONDUIT SHALL BE INSTALLED.

3. CONCEALED OR BURIED CONDUIT SUBJECT TO FLOODING SHALL BE SLOPED TOWARD BOXES, HANDHOLES OR MANHOLES FOR DRAINAGE.

4. ALL CONDUIT LOCATED IN SCREENWELLS, UNDERGROUND TUNNELS, PITS AND OUTDOORS ON EXTERIOR WALLS SHALL BE MOUNTED SO THERE IS AT LEAST ONE-QUARTER INCH AIR SPACE BETWEEN THE CONDUIT AND THE SUPPORTING SURFACE.

5. WHERE UNGROUNDED CONDUCTORS ENTER A CONDUIT IN A CABINET, PULL BOX, JUNCTION BOX, OR AUXILIARY GUTTER, THE CONDUCTORS SHALL BE PROTECTED BY A SUBSTANTIAL BUSHING O-Z ELECTRICAL MFG CO TYPE "B" OR APPROVED EQUIVALENT, PROVIDING A SMOOTHLY ROUNDED INSULATING SURFACE, UNLESS THE CONDUCTORS ARE SEPARATED FROM THE CONDUIT FITTING BY SUBSTANTIAL INSULATING MATERIAL SECURELY FASTENED IN PLACE. WHERE CONDUIT BUSHINGS ARE CONSTRUCTED WHOLLY OF INSULATING MATERIAL, A LOCKNUT SHALL BE INSTALLED BOTH INSIDE AND OUTSIDE THE ENCLOSURE TO WHICH THE CONDUIT IS ATTACHED.

6. ALL CONDUIT CONNECTIONS TO ALL MOTORS, VIBRATING EQUIPMENT, BELT DRIVEN EQUIPMENT, PRESSURE AND LEVEL SWITCHES, THERMOCOUPLES, ETC, TO BE MADE WITH FLEXIBLE CONDUIT.

7. RIGID STEEL CONDUIT RUN IN EARTH AND NOT ENCASED IN CONCRETE SHALL HAVE A PVC JACKET, OR BE COATED WITH ASPHALTUM.

8. ALUMINUM CONDUIT SHALL NOT BE EMBEDDED IN CONCRETE.

9. WHERE CONDUIT CROSSES VIBRATION JOINTS IN SLAB, USE 18" LENGTH OF FLEXIBLE STEEL CONDUIT WRAPPED WITH $\frac{1}{2}$" OF OAKUM AND THREE THICKNESSES OF BURLAP, THOROUGHLY PAINTED WITH ASPHALTUM.

10. CONDUIT ENTERING SHEET STEEL OR ALUMINUM BOXES, WITHOUT HUBS, EXPOSED TO WATER OR RAIN, SHALL BE TERMINATED WITH A CONDUIT FITTING APPLETON ELECTRIC CO TYPE "HUB", THOMAS & BETTS CO BULLET HUB SERIES 370 OR APPROVED EQUAL.

POWER INDUSTRY GROUP		ELECTRICAL CONDUIT NOTES	5	REVISED NOTE
CHECKED	E.S.K. 7-6-60		ISSUE	DESCRIPTION
CORRECT	F.J.S 7-7-60			
APPROVED	[illegible] 7-7-60	STANDARD DESIGN DRAWING		STD-ME-1-3-5

NOTES:

1. ALL CONDUIT, WIRE AND ELECTRICAL EQUIPMENT TO BE INSTALLED IN ACCORDANCE WITH THE LATEST STANDARDS OF THE "NATIONAL ELECTRICAL CODE" AS ADOPTED BY THE NATIONAL FIRE PROTECTION ASSOCIATION, UNLESS OTHERWISE NOTED IN THESE STANDARDS.

*2. MARK NUMBERS REFER TO ITEMS IN BILL OF ELECTRICAL MATERIAL OR COMPUTER PRINTOUTS.

3. FOR CABLE NUMBERS REFER TO CABLE SCHEDULES OR COMPUTER PRINTOUTS.

*4. FOR ABBREVIATIONS REFER TO STONE & WEBSTER ENGRG CORP STD-MG-1000 SERIES.

*5. FOR LOCATION AND DATA FOR INSTRUMENT TRANSMITTERS, THERMOCOUPLES, PRESSURE SWITCHES, ETC, REFER TO EQUIPMENT LIST.

6. CENTER LINE OF ALL POWER RECEPTACLES AND PUSH BUTTON STATIONS TO BE 4'-0" ABOVE FLOOR ELEVATION UNLESS OTHERWISE NOTED.

7. THE TOP OF ALL CONTACTOR AND STARTER GROUPS SHALL BE 6'-0" ABOVE FLOOR ELEVATION UNLESS OTHERWISE NOTED. THE EXACT DETAILS OF ARRANGEMENT SHALL BE DETERMINED BY THE CONTRACTOR; HOWEVER, THE GENERAL ARRANGEMENT SHALL FOLLOW IN SO FAR AS PRACTICABLE THE ARRANGEMENT AS SHOWN ON WIRING DIAGRAMS.

8. CLEARANCE, IF REQUIRED FOR ALL STRUCTURAL MEMBERS, CONDUIT, TRAYS AND EQUIPMENT FOR THE ISOLATED PHASE BUS SHALL BE INDICATED ON THE DRAWING. CONDUIT FOR SECONDARIES OF GENERATOR CURRENT TRANSFORMER LEADS, BOTH PHASE AND NEUTRAL SIDES, SHALL BE INSULATED IN ACCORDANCE WITH MANUFACTURER'S DRAWINGS.

*Notes 2, 4, 5 are not applicable to Job 12911.09 (NSP E-78Y073)

POWER INDUSTRY GROUP		ELECTRICAL CONDUIT, TRAY & LIGHTING NOTES GENERAL	4	REDRAWN ADDED PROPRIETARY, DELETED & REVISED NOTES
CHECKED	E.S.K. 7/6/60		ISSUE	DESCRIPTION
CORRECT	H.A.T. 7/7/60			
APPROVED	C.W.M. 7/7/60	STANDARD DESIGN DRAWING	STD-ME-1-1-4	
ISSUE	(4) [illegible] (5)	(6) (7)		

NOTES:

1. ALL GROUNDING SHALL BE INSTALLED IN ACCORDANCE WITH THE LATEST STANDARDS OF THE "NATIONAL ELECTRICAL CODE" AS ADOPTED BY THE NATIONAL FIRE PROTECTION ASSOCIATION, UNLESS OTHERWISE NOTED IN THESE STANDARDS.
2. THE GROUNDING SYSTEM IS SHOWN DIAGRAMMATICALLY. EXACT LOCATION OF CABLE, GROUND RODS AND CONNECTIONS SHALL BE DETERMINED BY THE CONTRACTOR UNLESS OTHERWISE DETAILED.
3. CABLE SHALL BE SOFT DRAWN, STRANDED, BARE COPPER OF SIZE SPECIFIED ON DRAWING, UNLESS OTHERWISE NOTED.
4. IN SWITCHYARD CONTROL HOUSES WHICH ARE IN SWITCHYARDS OF 230KV OR ABOVE, ALL REINFORCING STEEL AND BUILDING STEEL SHOULD BE BONDED TOGETHER AND TIED INTO THE GROUND GRID.
5. WHERE GROUND CABLE IS TO BE EXTENDED IN THE FUTURE, COIL 5'-0" AND BURY SO THAT IT IS ACCESSIBLE.
6. * BUILDING STEEL SHALL BE GROUNDED AT BASEMENT ELEVATION BY CADWELDING OR THERMOWELDING ALTERNATE STRUCTURAL COLUMNS OF THE OUTSIDE BUILDING WALLS TO A COPPER GROUNDING LOOP.
7. GROUND CONNECTORS FOR ATTACHING THE GROUND CABLE TO MASONRY, ABSESTOS, METAL SURFACES OR EQUIPMENT SHALL BE BURNDY TYPE "GB" OR APPROVED EQUIVALENT.
8. ALL BOLTED JOINTS SHALL BE MADE UP FIRMLY. BOLTS, NUTS, AND WASHERS SHALL BE SILICON-BRONZE ALLOY FOR COPPER TO COPPER CONNECTIONS. FOR ALUMINUM TO ALUMINUM CONNECTIONS USE HIGH STRENGTH ALUMINUM OR STAINLESS STEEL HARDWARE. USE STAINLESS STEEL HARDWARE WHEN CONNECTING DISSIMILAR MATERIALS.
9. A GROUND SYSTEM SHOULD ALWAYS BE CONNECTED TO A CONTINUOUS METALLIC UNDERGROUND WATER PIPING SYSTEM, METAL WELL CASINGS OR SHEET STEEL PILING WHERE AVAILABLE, IN ADDITION TO DRIVING GROUND RODS INTO THE EARTH TO SUCH DEPTH AS MAY BE NECESSARY TO REACH PERMANENTLY MOIST SOIL. THIS ASSUMES THAT THE PILING OR PIPING SYSTEM DOES NOT REQUIRE CATHODIC PROTECTION.
10. WHERE GROUND CABLE IN CONCRETE CROSSES EXPANSION JOINTS, THE CABLE SHALL BE WRAPPED WITH BURLAP AND PAINTED WITH ASPHALTUM, OR WRAPPED WITH POLYETHYLENE. THE GROUND CABLE SHALL BE WRAPPED A DISTANCE OF 18 INCHES EITHER SIDE OF THE EXPANSION JOINT.
11. AT LEAST TWO TIES TO GROUND SHALL BE PROVIDED FOR THE GENERATOR, DISCONNECTING SWITCH STRUCTURES, CIRCUIT BREAKERS, MAIN AND STATION SERVICE TRANSFORMERS, AND SWITCHGEAR.
12. IN OUTDOOR INSTALLATIONS, STRANDED GROUNDING CONDUCTORS SHALL BE INSTALLED EITHER ENTIRELY EXPOSED ON THE SURFACE OF THE CONCRETE FOUNDATION MECHANICALLY PROTECTED, OR ENTIRELY WITHIN THE FOUNDATION USING A COPPER BAR OR GROUNDING INSERT TO MAKE THE TRANSITION THROUGH THE CONCRETE. THE STRANDED CONDUCTOR SHALL NOT BE INSTALLED SO THAT IT LEAVES THE CONCRETE AT AN EXPOSED OUTDOOR LOCATION.

* Note 6 not applicable to Job 12911.09 (NSP E-78Y073). Underground connections will be compression type.

POWER INDUSTRY GROUP		ELECTRICAL GROUNDING NOTES		
CHECKED	E.S.K. 7/6/60		6	REDRAWN, ADDED PROPRIETARY & REVISED NOTES
CORRECT	H.A.T. 7/7/60		ISSUE	DESCRIPTION
APPROVED	C.W.M. 7/7/60	STANDARD DESIGN DRAWING		STD-ME-2-1-6
ISSUE	(6)	(7) (8) (9)		

NOTES (CONT.):

* 13. CONNECTIONS BETWEEN THE GROUND CABLE AND CONNECTOR MAY BE MADE BY COMPRESSION, BOLTS OR ~~EXOTHERMIC PROCESS~~. CONNECTIONS BETWEEN THE CONNECTOR AND THE EQUIPMENT SHALL BE BY MEANS OF BOLTS. CONNECTIONS BETWEEN THE GROUND CABLE AND SUPPORTING STRUCTURE MAY BE WITH BOLTS IF A CONNECTOR IS USED OR EXOTHERMIC PROCESS IF THERE IS NO CONNECTOR. A TYPICAL BOLTED CONNECTOR WOULD BE BURNDY TYPE "MA" OR APPROVED EQUIVALENT.

14. ELECTRICAL EQUIPMENT, TRAYS, AND CONDUIT SHALL BE BONDED TOGETHER TO INSURE ELECTRICAL CONTINUITY. CABLE TRAYS SHALL BE GROUNDED VIA COPPER TO BUILDING STEEL ON EACH END AND NOT MORE THAN EVERY 100 FT. ALL CONDUIT FROM CABLE TRAYS TO ELECTRICAL EQUIPMENT SHALL BE BONDED TO THE TRAY. AT ELECTRICAL EQUIPMENT WHERE CONDUIT DROPS ARE NOT USED AND CABLE IS RUN FROM THE CABLE TRAYS INTO THE EQUIPMENT, THE CABLE TRAY SHALL BE BONDED TO THE EQUIPMENT. AT METAL-CLAD SWITCHGEAR, LOAD CENTERS AND MOTOR CONTROL CENTERS, THE BONDING JUMPER SHALL BE 2/0 CABLE.

15. ALL METALLIC STRUCTURES, MOTORS AT 2300V AND ABOVE, SWITCHGEAR, MOTOR CONTROL CENTERS, CONTROL AND RELAY BOARDS, LIGHTING CABINETS, CONTACTORS, CABLE TRAYS, AND CONDUIT SHALL BE PERMANENTLY AND EFFECTIVELY GROUNDED BY A GROUND CABLE CONNECTED TO THE GROUND GRID. OTHER EQUIPMENT MAY BE BOLTED TO SUPPORTING STRUCTURE OR CONNECTED TO THE STRUCTURE WITH A GROUND CABLE. ALL MOTORS LESS THAN 25 HP AT 575V OR LESS MAY BE GROUNDED THROUGH THE CONDUIT SYSTEM. EXPANSION JOINTS IN CONDUIT SHALL BE MADE ELECTRICALLY CONTINUOUS BY A BONDING JUMPER.

16. BURIED OR SUBMERGED EQUIPMENT SUCH AS TRAVELING SCREENS AND THEIR FOUNDATION BOLTS OR PIPING TO WHICH CATHODIC PROTECTION MAY BE APPLIED MUST NOT BE IN METALLIC CONTACT WITH REINFORCING RODS, METALLIC CONDUIT, GROUNDING CABLE OR OTHER PIPING. THEY SHOULD BE SEPARATED AS FAR APART AS CONDITIONS WILL PERMIT. INSULATING FLANGES, UNIONS OR COUPLINGS MAY BE REQUIRED IN THE PIPE RISERS JUST ABOVE GROUND ELEVATION.

17. ALL GROUNDING CABLE IN CATHODIC PROTECTION AREA SHALL HAVE INSULATION SUITABLE FOR DIRECT BURIAL IN EARTH.

18. FOR ELECTRICAL CONTINUITY OF METAL RACEWAY CONTAINING WIRES OPERATING ABOVE 250V, PROVIDE TWO LOCKNUTS, ONE INSIDE AND ONE OUTSIDE OF BOXES AND CABINETS.

19. ALL SHIELDED CABLE SHALL BE TERMINATED AND GROUNDED ACCORDING TO THE RECOMMENDATION AND INSTRUCTIONS GIVEN BY THE ENGINEER, UNLESS OTHERWISE SHOWN ON DRAWINGS.

20. ARMORED CABLES SHALL HAVE THE CABLE ARMOR GROUNDED IN ACCORDANCE WITH INSTRUCTIONS GIVEN BY THE ENGINEER.

* No Exothermic process connections shall be made on Job 12911.09 (NSP E-78Y073)

POWER INDUSTRY GROUP		ELECTRICAL GROUNDING NOTES	7	REDRAWN & REVISED NOTES
CHECKED	E.S.K. 7/6/60			
CORRECT	H.A.T 7/7/60		ISSUE	DESCRIPTION
APPROVED	C.W.M. 7/7/60	STANDARD DESIGN DRAWING	STD-ME-2-2-7	
ISSUE	(7)	(8) (9) (10)		

STONE & WEBSTER ENGINEERING CORPORATION — PAGE NO

INDUCTION MOTOR DATA — J.O. NO.

1	CLIENT	PROJECT
2	FURNISHED BY	DATE BY
3	MARK OR ITEM NO.	
4	PURCHASER'S REQUIREMENTS	DATA FURNISHED BY SELLER
5	SERVICE	MAKE
6	TYPE	FRAME NO.
7	NO OF UNITS	HORSEPOWER
8	MOUNTING	SERVICE FACTOR
9	ELEC. CHARACTERISTICS, V PH HZ	FULL LOAD RPM
10	SYNCH. SPEED, RPM	FULL LOAD AMP
11	HORSEPOWER	LOCKED ROTOR AMP
12	SERVICE FACTOR	STARTING TORQUE, % F.L.
13	ENCLOSURE	PULL-OUT TORQUE, % F.L.
14	INSULATION CLASS	EFF.-FULL LOAD, %
15	INSULATION TREATMENT	EFF.-3/4 LOAD, %
16	AMBIENT TEMP-C	EFF.-1/2 LOAD, %
17	STATOR TEMP RISE-C	P.F.-FULL LOAD, %
18	BEARING TYPE	P.F.-3/4 LOAD, %
19	BEARING TEMP RELAY	P.F.-1/2 LOAD, %
20	BEARING THERMOCOUPLE	P.F. AT STARTING, %
21	HALF COUPL. OR SHEAVE MTD BY	SHORT CIRCUIT A-C TIME CONSTANT, SEC.
22	ROTATION *	X/R RATIO
23	WK^2 OF DRIVEN EQUIP. ($LB\text{-}FT^2$)	SPACE HTRS., TOTAL WATTS
24	BRKWY. TORQ. DRVN. EQUIP.	RADIAL BEARING-TYPE
25	OVERSIZE COND. BOX	THRUST BEARING-TYPE
26	COND. BOX LOCATION *	BEARING SERVICE-HR
27	SPACE HEATERS, VOLTAGE, PHASE	NORMAL BRG. OPER. TEMP-C
28	SPLIT END BELLS	NET WEIGHT-LB
29	TERMINAL LUGS, TYPE	OIL COOL. SYS. REQ'D
30	STATOR HIGH TEMP DEVICE	BRG. OIL PRESS. RANGE, PSI
31	ADJUSTABLE SLIDE RAILS	BRG. OIL REQ'D EA. BRG. GPM
32	SOLEPLATES	NAME PLATE CODE LETTER
33	PROJECT ELEV., FT	PERMISSIBLE STARTS PER HR WITH:
34	SHAFT (HOLLOW, SOLID)	MOTOR AT AMBIENT TEMP.
35	COUPLING (SELF-RELEASE,	MOTOR AT RATED TOTAL TEMP.
36	SOLID, NONREVERSING,	TYPE SEALED INSUL. SYS.
37	ADJUSTABLE, FLEXIBLE)	DESCRIPTION OF INSUL. SYS.
38	DOWNTHRUST-CONTINUOUS	MAX. STALL TIME WITH L.R. AMPS, SEC.
39	UPTHRUST-CONTINUOUS	ACCEL. TIME, FULLY LOADED
40	UPTHRUST-MOMENTARY	WITH 100% V, SEC.
41	DOWNTHRUST-MOMENTARY	WITH 80% V, SEC.
42		WITH % V, SEC.
43	SIDE THRUST	
44	MAX REVERSE SPEED	
45	DRAIN PLUG AND VENT	
46	AIR INTAKE AND DISCHARGE SCREENS	
47	C.T. RATIO	WK^2 OF ROTOR, $LB\text{-}FT^2$
48	SURGE CAPACITORS	
49	ANTI-FRICT. BRG. SERVICE-HR	
50	MINIMUM STARTING VOLTAGE %	
51		
52	REMARKS:	REMARKS:
53	ALL PERFORMANCE DATA BASED ON NORMAL RATED	ALL PERFORMANCE DATA BASED ON NORMAL RATED
54	VOLTAGE AND FREQUENCY	VOLTAGE AND FREQUENCY
55	ITEMS 34-44 APPLY TO VERTICAL MOTORS ONLY	
56		
57		
58		
59		
60	* VIEWED FROM END OPPOSITE COUPLING END	

APPENDIX B
LOGIC DESCRIPTION

B 1.0 LOGIC SYSTEM DESIGN

B 1.1 System Arrangement

B 1.1.1 Intake Screenhouse

The intake screenhouse is served by eight traveling water screens, one traveling trash rake, two 50 percent-capacity coarse screen trash removal pumps, two (two-speed) 50 percent-capacity fine or coarse screen trash removal pumps, two 50 percent-capacity coarse screen fish removal pumps, two 50 percent-capacity larvae removal pumps, twelve differential level sensing points, one fish return line temperature sensor, two bypass gates, one overhead bridge crane, and one jib crane.

All pumps will have motor-driven butterfly valves on the discharge.

The screenhouse load will be supplied by two 13.8 KV feeders from the switchyard. (Transformers CT1 and 10 Bank.)

B 1.1.2 Deicing Pumphouse

The deicing system is comprised of two 50 percent-capacity deicing pumps, each with a motor-driven butterfly valve. These valves are interlocked to the pumps to prevent the pump from starting against a closed valve. One 480 volt feeder from the intake screenhouse will supply power to a local motor control center for the deice system.

B 1.1.3 Discharge Structure

The discharge structure is served by four motor-operated discharge gates, one discharge canal level sensor, and four temperature sensors. The control signal for the gates will originate from the plant "Main Control Board". One 480 volt feeder from the deicing pumphouse will supply power to a local motor control center for the gate drive motors.

B 1.2 Control and Instrumentation

B 1.2.1 Description of Operation

B 1.2.1.1 New Screenhouse

A. Traveling Screens

Each traveling water screen is driven by a variable speed A.C. motor giving a speed range from 3 to 20 fpm. Each traveling screen has two types of screen panels. The fine mesh screen panels are used from April 16 to August 31, and the coarse mesh screen panels are used during the rest of the year.

Locally mounted at each screen is a JOG-REMOTE selector switch and a JOG pushbutton. The REMOTE position will enable the OFF-INVERTER selector switch mounted on the screenhouse control board to function. The JOG position will enable a pushbutton to jog a screen for maintenance purposes. The jog speed is the 60 cycle speed of approximately 20 fpm. The OFF position will disable the respective screen. The INVERTER position will run the screen at the speed determined by the inverter frequency.

The mode of operation for each bank of four screens is controlled by a MANUAL-AUTO selector switch on the screenhouse control board. When the switch is in the MANUAL position, the four corresponding screens will run off the inverter at a speed manually selected on a potentiometer mounted on the control board. A START and STOP pushbutton for each bank of four screens will initiate the manual run sequence. In the AUTO position the bank of four screens will run at a speed required by the control system.

A signal from any one of four screen differential level sensors associated with a group of four traveling screens will start the operation of that group. If one or more of the traveling screens is not in the INVERTER position, the control input from the level sensor for that traveling screen will be disabled and the rest of the traveling screens will continue to operate as normal.

A two position switch (fine-coarse) for each set of four traveling screens is used to select the type of screen panels currently in service, either fine mesh screen panels or coarse mesh screen panels. In the FINE position, the screens will continually run at 3 fpm when the differential is 4 inches or less. In the COARSE position, the traveling screens and the fish and trash spray wash systems will not run as long as the differential is less than 4 inches. When any 1 screen within a group of 4 exceeds 4 inches differential for a period of two minutes, a signal will be initiated to start all four screens in that group at 3 fpm.

Operation at differentials 4 inches and above is the same for both fine and coarse mesh screens. If the differential increases above 4 inches for either type of screen the speed will automatically increase proportionally until reaching the maximum speed of 20 fpm at 8 inches of head differential.

The coarse screens will remain in this load follow mode until the differential drops below 3 inches for 20 minutes, then they will shut off. The fine screens will continue to run at 3 fpm below 4 inches of differential.

The screens will automatically rotate (with wash sprays) 1-1/3 revolutions if they have not operated in the last 8 hours. The speed will be the same as used during jogging.

At 10 inches differential of water, an alarm will be sounded on the annunciators at the plant "Main Control Board" and in the intake screenhouse.

In the event of an inverter failure the screens will be transferred to a 60 hertz backup power source that will run the screens at about 20 fpm.

B. Screen Wash Pumps

There are two identical screen wash pump systems, one system each for a group of four screens.

During the time period of April 16 to August 31 when the fine mesh screen panels are being used, one low pressure larvae removal spray pump and one low pressure trash removal spray pump will run continuously for each bank of four screens. The trash removal pumps are two speed pumps that should be in the slow speed position during this time.

A RUN-STOP/RESET and SLOW-FAST control switch is provided for each of these pumps at the screenhouse control board. In the RUN position the pumps will start and run. In the STOP/RESET position the pumps will stop.

During the balance of the year, when the coarse screen panels are used, separate high pressure fish and trash removal spray pumps will be used. Each of the coarse screen pumps are controlled by a MANUAL-OFF/RESET-AUTO control switch mounted in the control board. The MANUAL position will start and run the corresponding pump and the OFF/RESET position will stop the pump. In the AUTO position both the trash and fish removal spray wash systems will start once any of the screens in that bank of four are signaled to start. Prior to starting the screens, the coarse screen pumps will start and run for 2 minutes to fill the return lines, and will continue to run for 10 minutes after the screens stop to flush the return lines.

A motor-operated valve on the discharge of each pump will open as soon as the pumps are started. If the valve does not fully open within 15 seconds, an alarm will sound and the pump will stop. The RESET function of the STOP or OFF position allows the pumps to be restarted after a valve open failure. Each motor-operated discharge valve can also be opened or closed manually using a CLOSE-AUTO-OPEN control switch on the control board.

The fine screen larvae pump and coarse screen fish pump use a common pipe header to the screens for each system. The coarse screen fish pump is interlocked to the fine screen larvae discharge valve to prevent the pump from starting if the opposite discharge valve is open.

During heavy trash loading in the coarse screen mode of operation, a second trash removal spray header on each screen may be placed in operation. This may be done by opening the manual valve on the secondary trash removal header and manually starting the fine screen trash removal pumps in the fast speed.

C. Bypass Gates

Each of the two hydraulic bypass gates will be controlled by a AUTO-LOCAL control switch on each units control box. The LOCAL position enables the UP and DOWN pushbuttons to function on the hydraulic units.

In the AUTO position both gates will open in unison whenever the differential level across any one screen in the INVERTER mode within both groups of four screens exceeds 18 inches, the differential level across the entire screenhouse exceeds 24 inches, total deicing system failure, or all power to the new intake structure is lost.

Once open, the gates will latch in place. The gates must first release the automatic "dogging device" before they can be closed. In the event of a power failure, each gate accumulator will have sufficient capacity to automatically open the gate after a time delay of two minutes to eliminate spurious trips. If one of the two hydraulic pump units should fail, manual cross-tie valving can be opened to allow any one pump to be used singly on either gate.

D. Trash Rake

The intake screenhouse will be provided with one traveling trash rake which will run along a rail in the deck of the structure. The trash rake is manually controlled. A differential level sensor across the trash rack in each bay will alarm at 6 inches indicating that trash needs to be removed.

E. Overhead Crane

A 15 ton capacity traveling overhead bridge crane is available for servicing equipment in the intake screenhouse. It is manually controlled from a suspended pendant control box above the screenhouse deck.

F. Jib Crane

A jib crane is located and manually controlled on the north side of the intake screenhouse building to aid in the removal and emptying of the trash baskets.

B 1.2.1.2 Deicing System

Two manually started deicing pumps are available to keep the traveling screens from icing up during the winter months. Water will be supplied from the discharge of the plant and pumped to the screenhouse to submerged diffusers in front of each bay. Motor driven butterfly valves on the discharge of each pump will open before its associated pump can start. The pumps and valves can be started or opened at the screenhouse control board or locally at the pump.

B 1.2.1.3 Discharge Structure

The required flowrate and discharge velocity will be maintained by the control room operator opening an appropriate combination of the four sluice gates. Each gate will have a REMOTE-LOCAL and OPEN-CLOSE switch locally and an OPEN-CLOSE control switch in the "Main Control Room" that will enable the operator to either fully open or fully close the respective gate.

A calculated discharge flowrate and open/close gate position will be displayed along with the average temperature of the open discharge pipes on the "Main Control Board Mimic Bus".

B 1.2.2 Component Control Description

B 1.2.2.1 Intake Screenhouse

A. TRAVELING SCREENS - Typical of eight (Two groups of four)
(CT-067-111 through CT-067-118)
(Ref drawings NF-92780-1, NF-92780-2)

1. Each individual traveling screen will manually start from the control board in the intake screenhouse whenever all of the following conditions are satisfied:

   a. The screen bank selector switch (CS-91800-48, 49) is in the MANUAL position.
   (Speed range of 3 fpm to 20 fpm may be selected manually on a potentiometer mounted on the control board.)

   b. The individual screen selector switch (CS-91800-03 through CS-91800-10) is in the INVERTER position.

c. The screen bank START pushbutton (PB-91800-59, 60) is depressed.

d. The individual local screen selector switch (CS-91900-02 through 91907-02) is in the REMOTE position.

e. Motor circuit breaker closed.

f. Motor thermal overload reset.

2. Each individual traveling screen can be manually jogged from the screen location whenever all of the following conditions are satisfied:

a. The individual local screen selector switch (CS-91900-02 through CS-91907-02) is in the JOG position. (Speed during jog will be approximately 20 fpm.)

b. Jog button (PB-91900-01 through PB-91907-01) is depressed at the screen location.

c. The individual screen selector switch (CS-91800-03 through CS-91800-10) is in the INVERTER position.

d. Motor circuit breaker closed.

e. Motor thermal overload reset.

3. Each bank of four traveling screens will automatically start with coarse screens whenever all of the following conditions are satisfied:

a. The individual selector switch for each of the four screens in the bank (CS-91800-03 through CS-91800-10) is in the INVERTER position.

b. The screen bank selector switch (CS-91800-48, 49) is in the AUTOMATIC position.

c. Differential level across any one screen in the bank exceeds 4 inches for more than 2 minutes.

d. The screen selector switch (CS-91800-23, 24) is in the COARSE position. (September 1 to April 15.)

e. 2 minutes has elapsed after the spraywash pump start.

f. Header pressure of the screen fish removal system (PS-91602, PS-91603) must exceed 15 psig.

g. Header pressure on the screen trash removal system (PS-91600 or PS-91604, PS-91601 or PS-91605) must exceed 45 psig.

h. The individual local screen selector switch (CS-91900-02 through CS-91907-02) is in the REMOTE position.

i. Motor circuit breaker closed.

j. Motor thermal overload reset.

4. Each bank of four traveling screens will <u>continuously run at minimum speed with fine screens</u> whenever all of the following conditions are satisfied:

   a. The individual selector switch for each of the four screens in the bank (CS-91800-03 through CS-91800-10) is in the INVERTER position.

   b. The screen bank selector switch (CS-91800-48, 49) is in the AUTOMATIC position.

   c. The screen selector switch (CS-91800-23, 24) is in the FINE position. (April 16 to August 31.)

   d. Screen differential less than 4 inches.

   e. Header pressure of the screen larvae removal system (PS-91602, PS-91603) must exceed 15 psig.

   f. Header pressure on the screen trash removal system (PS-91604, PS-91605) must exceed 45 psig.

   g. The individual local screen selector switch (CS-91900-02 through CS-91907-02) is in the REMOTE position.

   h. Motor circuit breaker closed.

   i. Motor thermal overload reset.

5. Each traveling screen will <u>automatically start and run for 1-1/3 revolutions</u> at approximately 20 fpm whenever <u>all</u> of the following conditions are satisfied.

   a. The screen bank selector switch (CS-91800-48, 49) is in the AUTOMATIC position.

   b. 8 hours has passed since the screen has been run.

c. The individual selector switch for each of the four screens in the bank (CS-91800-03 through CS-91800-10) is in the INVERTER position.

d. The individual local screen selector switch (CS-91900-02 through CS-91907-02) is in the REMOTE position.

e. The screen mesh selector switch (CS-91800-23, 24) is in the COARSE position.

f. 2 minutes has elapsed after the spraywash pump start.

g. Header pressure of the screen fish (PS-91602, PS-91603) removal system must exceed 15 psig.

h. Header pressure on the screen trash removal system (PS-91600, PS-91601) must exceed 45 psig.

i. Motor circuit breaker closed.

j. Motor thermal overload reset.

6. Each individual traveling screen <u>will stop</u> whenever <u>any</u> of the following conditions are satisfied:

a. The individual selector switch (CS-91800-03 through CS-91800-10) is in the OFF position.

b. The screen bank STOP pushbutton (PB-91800-61, 62) is depressed.

c. The screen selector switch (CS-91800-23, 24) is in the COARSE position, the individual screen selector switch (CS-91800-03 through CS-91800-10) is in the INVERTER position, the screen bank selector switch (CS-91800-48, 49) is in the AUTOMATIC position, and the differential level (DPT-91700 through DPT-91707) across all the screens within a bank of 4 that are in the INVERTER position, drop below 3 inches for more than 20 minutes.

d. Header pressure on the screen fish removal system (PS-91602, PS-91603) drops below 10 psig.

e. Header pressure on the screen trash removal system (PS-91600 and PS-91604, PS-91601 and PS-91605) drops below 40 psig.

f. Motor circuit breaker open.

g. Motor thermal overload.

B. Coarse Screen Fish Removal Pump - Typical for two (Ref. drawing NF-92780-4)

1. The coarse screen fish removal pump (CS-045-1033, 1034) will manually start from the control board in the intake screenhouse whenever all of the following conditions are satisfied:

   a. The pump selector switch (CS-91800-12, 14) is in the MANUAL position.

   b. Motor circuit breaker closed.

   c. Motor thermal overload reset.

2. The coarse screen fish removal pump will automatically start whenever all the following conditions are satisfied:

   a. The pump selector switch (CS-91800-12, 14) is in the AUTOMATIC position.

   b. The fine screen larvae removal pump discharge valve (MV-91208, 9) is closed.

   c. Differential level (DP-91704 through DP-91707, DP-91713 through DP-91716) across any of 4 traveling screens in the corresponding bank exceeds 4 inches for 2 minutes, or the screens have not been run for 8 hours. (Note: The individual screen selector switch (CS-91800-03 through CS-91800-10) must be in the INVERTER position before differential level can be considered for that screen.)

   d. Screen mode selector switch (CS-91800-23, 24) is in the COARSE position.

   e. Motor circuit breaker closed.

   f. Motor thermal overload reset.

3. The coarse screen fish removal pump will stop whenever any of the following conditions are satisfied:

   a. The pump selector switch (CS-91800-12, 14) is in the OFF/RESET position.

   b. Ten (10) minutes has elapsed since the corresponding bank of screens automatically stopped.

   c. The screen operation mode selector switch (CS-91800-23, 24) is in the FINE position.

d. 15 seconds has elapsed since the pump has started and the discharge valve has not opened. (Note: The pump can now only be restarted in the AUTOMATIC position by first manually placing the appropriate selector switch in the OFF/RESET position and then returning it to the AUTOMATIC position.)

e. Motor circuit breaker open.

f. Motor thermal overload.

C. Coarse Screen Trash Removal Pump - Typical for two (Ref. drawing NF-92780-3)

1. The coarse screen trash removal pump (CT-045-1023, 1024) will manually start from the control board in the intake screenhouse whenever all of the following conditions are satisfied:

   a. The pump selector switch (CS-91800-11, 13) is in the MANUAL position.

   b. Motor circuit breaker closed.

   c. Motor thermal overload reset.

2. The coarse screen trash removal pump will automatically start whenever all the following conditions are satisfied:

   a. The pump selector switch is in the AUTOMATIC position.

   b. Differential level (DP-91704 through DP-91707, DP-91713 through DP-91716) across any of 4 traveling screens in the corresponding bank exceeds 4 inches for 2 minutes, or the screens have not been run for 8 hours. (Note: The individual screen selector switch (CS-91800-03 through CS-91800-10) must be in the INVERTER position before differential level can be considered for that screen.)

   c. Screen mode selector switch (CS-91800-23, 24) is in the COARSE position.

   d. Motor circuit breaker closed.

   e. Motor thermal overload reset.

3. The coarse screen trash removal pump will <u>stop</u> whenever <u>any</u> of the following conditions are satisfied:

   a. The pump selector switch (CS-91800-11, 13) is in the OFF/RESET position.

   b. Ten (10) minutes has elapsed since the corresponding bank of screens automatically stopped.

   c. Screen operation mode selector switch (CS-91800-23, 24) is in the FINE position.

   d. 15 seconds has elapsed since the pump started and the discharge valve has not opened. (Note: The pump can now only be restarted in the AUTOMATIC position by first manually placing the appropriate selector switch in the OFF/RESET position and then returning it to the AUTOMATIC position.)

   e. Motor circuit breaker open.

   f. Motor thermal overload.

D. <u>Fine Screen Larvae Removal Pump</u> - Typical for Two (Ref. drawing NF-92780-4)

1. The fine screen larvae removal pump (CT-045-1031, 1032) will <u>manually start</u> from the control board in the intake screenhouse whenever <u>all</u> of the following conditions are satisfied:

   a. The pump selector switch (CS-91800-27, 32) is in the RUN position.

   b. Motor circuit breaker closed.

   c. Motor thermal overload reset.

2. The fine screen larvae removal pump will <u>manually stop</u> whenever <u>any</u> of the following conditions are satisfied:

   a. The pump selector switch is in the STOP/RESET position.

   b. 15 seconds has elapsed since the pump started and the discharge valve has not opened. (Note: The pump can only be restarted by first manually placing the appropriate selector switch in the STOP/RESET position and then returning it to the RUN position.)

   c. Motor circuit breaker open.

   d. Motor thermal overload.

E. <u>Fine Screen Trash Removal Pump</u> - Typical for Two
(Re. drawing NF-92780-3)

1. The fine screen trash removal pump (CT-045-1021, 1022) will <u>manually start</u> from the control board in the intake screenhouse whenever <u>all</u> of the following conditions are satisfied.

   a. The pump selector switch (CS-91800-25, 30) is in the RUN position.

   b. The speed selector switch (CS-91800-26, 31) is either in the FAST or SLOW position.

   c. Motor circuit breaker closed.

   d. Motor thermal overload reset.

2. The fine screen trash removal pump will <u>stop</u> whenever <u>any</u> of the following conditions are satisfied:

   a. The pump selector switch (CS-91800-25, 30) is in the STOP/RESET position.

   b. 15 seconds has elapsed since the pump has started and the discharge valve has not opened. (Note: The pump can only be restarted by first manually placing the appropriate selector switch in the STOP/RESET position and then returning it to the RUN position.)

   c. Motor circuit breaker open.

   d. Motor thermal overload.

F. <u>Coarse Screen Fish and Trash Removal Pump Discharge Valves</u> - Typical of four (MV-91202 through MV-91205).
(Ref. drawings NF-92780-3 and NF-92780-4)

1. The discharge valves for the coarse screen trash and fish removal pumps will <u>manually open</u> from the control board in the intake screenhouse whenever <u>all</u> of the following conditions are satisfied.

   a. The valve selector switch (CS-91800-16, 17, 21, 22) is in the OPEN position.

   b. Motor circuit breaker closed.

   c. Motor thermal overload reset.

2. The coarse screen trash and fish removal pumps discharge valves will <u>manually close</u> from the control board in the intake screenhouse whenever <u>all</u> of the following conditions are satisfied.

   a. The valve selector switch (CS-91800-16, 17, 21, 22) is in the CLOSE position.

   b. Motor circuit breaker closed.

   c. Motor thermal overload reset.

3. The coarse screen trash and fish removal pump discharge valves will <u>automatically open</u> from the control board in the intake screenhouse whenever <u>all</u> of the following conditions are satisfied.

   a. The valve selector switch (CS-91800-16, 17, 21, 22) is in the AUTO position.

   b. The corresponding trash or fish removal pump starts.

   c. Motor circuit breaker closed.

   d. The motor thermal overload reset.

4. The coarse screen trash and fish removal pumps discharge valves will <u>Automatically close</u> from the control board in the intake screenhouse whenever <u>all</u> of the following conditions are satisfied.

   a. The valve selector switch (CS-91800-16, 17, 21, 22) is in the AUTO position.

   b. The corresponding trash or fish removal pump stops.

   c. Motor circuit breaker closed.

   d. Motor thermal overload reset.

G. <u>Fine Screen Trash Removal Pump Discharge Valve</u> - Typical of two (MV-91200, MV-91201)
(Ref. drawing NF-92780-3)

1. The fine screen trash removal pump discharge valve will <u>manually open</u> from the control board in the intake screenhouse whenever <u>all</u> of the following conditions are satisfied.

   a. The valve selector switch (CS-91800-15, 20) is in the OPEN position.

   b. Motor circuit breaker closed.

   c. Motor thermal overload reset.

2. The fine screen trash removal pump discharge valve will manually close from the control board in the intake screenhouse whenever all of the following conditions are satisfied.

    a. The valve selector switch (CS-91800-15, 20) is in the CLOSE position.

    b. Motor circuit breaker closed.

    c. Motor thermal overload reset.

3. The fine screen trash removal pump discharge valve will automatically open from the control board in the intake screenhouse whenever all of the following conditions are satisfied.

    a. The valve selector switch (CS-91800-15, 20) is in the AUTO position.

    b. The fine screen trash removal pump has started.

    c. Motor circuit breaker closed.

    d. Motor thermal overload reset.

4. The fine screen trash removal pump discharge valve will automatically close from the control board in the intake screenhouse whenever all of the following conditions are satisfied.

    a. The valve selector switch (CS-91800-15, 20) is in the AUTO postion.

    b. The fine screen trash removal pump stops.

    c. Motor circuit breaker closed.

    d. Motor thermal overload reset.

H. Fine Screen Larvae Removal Pump Discharge Valve - Typical of two (MV-91208, MV-91209)
(Ref. drawing NF-92780-4)

1. The fine screen larvae removal pump discharge valve will manually open from the control board in the intake screenhouse whenever all of the following conditions are satisfied.

    a. The valve selector switch (CS-91800-57, 58) is in the OPEN position.

    b. Motor circuit breaker closed.

    c. Motor thermal overload reset.

2. The fine screen larvae removal pump discharge valve will manually close from the control board in the intake screenhouse whenever all of the following conditions are satisfied.

   a. The valve selector switch (CS-91800-57, 58) is in the CLOSE position.

   b. Motor circuit breaker closed.

   c. Motor thermal overload reset.

3. The fine screen larvae removal pump discharge valve will automatically open from the control board in the intake screenhouse whenever all of the following conditions are satisfied.

   a. The valve selector switch (CS-91800-57, 58) is in the AUTO position.

   b. The fine screen larvae removal pump has started.

   c. Motor circuit breaker closed.

   d. Motor thermal overload reset.

4. The fine screen larvae removal pump discharge valve will automatically close from the control board in the intake screenhouse whenever all of the following conditions are satisfied.

   a. The valve selector switch (CS-91800-57, 58) is in the AUTO position.

   b. The fine screen larvae removal pump has stopped.

   c. Motor circuit breaker closed.

   d. Motor thermal overload reset.

I. Bypass Gates - Typical for two (CT-062-301, 302) (Ref. drawing NF-92780-5)

1. Either bypass gate will manually open from the local control box in the intake screenhouse whenever all of the following conditions are satisfied:

   a. Local control box selector switch is in the LOCAL position.

   b. UP pushbutton is depressed on the local control box.

   c. Hydraulic accumulator is charged.

2. Either bypass gate will manually close from the local control box in the intake screenhouse whenever all of the following conditions are satisfied:

   a. The local control box selector switch is in the LOCAL position.

   b. The local DOWN pushbutton is depressed (this will also release the "dogging device").

   c. Hydraulic accumulator is charged.

3. Both bypass gates (2) will automatically open and lock in place in unison whenever all of the following conditions are satisfied:

   a. Local control box selector switch in the AUTO position.

   b. Hydraulic accumulator is charged.

   c. And any one of the following conditions exist.

      i) differential level across the screenhouse exceeds 24", or

      ii) differential level across at least one screen within both groups of 4 screens exceeds 18", or

      (Note: The individual screen selector switch (CS-91800-03 through 10) must be in the INVERTER position before differential level can be measured across that screen.)

      iii) total deicing system failure

      iv) Loss of control power to either hydraulic system will cause the individual bypass gate to lock open.

4. If an auto open signal is initiated and after a time delay of 3 minutes both gates have not opened, the accumulators will automatically be used to open the gates.

B 1.2.2.2 Deicing System

A. Deicing Pump - Typical for two (CT-045-1041, 1042)
(Ref. drawing NF-92781)

1. The deicing pump will manually start from the control board in the intake screenhouse whenever all of the following conditions are satisfied:

   a. Control board pump selector switch (CS-91800-28, 29) is momentarily in the RUN position.

   b. Deice pump discharge valve MV-91206 or MV-92107 have previously been manually opened.

   c. Motor circuit breaker is closed.

   d. Motor thermal overload reset.

2. The deicing pump will manually start from the deicing pumphouse whenever all of the following conditions are satisfied:

   a. The local pump selector switch (CS-91908, CS-91909) is momentarily in the RUN position.

   b. Deice pump discharge valve MV-91206 or MV-92107 have previously been manually opened.

   c. Motor circuit breaker is closed.

   d. Motor thermal overload reset.

3. The deicing pump will stop whenever any of the following conditions are satisfied:

   a. Control board pump selector switch (CS-91800-28, 29) is momentarily in the STOP position.

   b. Local pump selector switch (CS-91908, CS-91909) is momentarily in the STOP position.

   c. Deice pump discharge valves (MV-91206, MV-91207) is closed.

   d. Motor circuit breaker is open.

   e. Motor thermal overload.

B. Deicing Pump Discharge Valves - Typical for two (MV-91206, MV-91207)
(Ref. drawing NF-92781)

1. The deicing pump discharge valve will manually open from the control board in the intake screenhouse whenever all of the following conditions are satisfied.

    a. Control board valve selector switch (CS-91800-18, 19) in the OPEN position.

    b. Motor circuit breaker is closed.

    c. Motor thermal overload is reset.

2. The deicing pump discharge valve will manually close from the control board in the intake screenhouse whenever all of the following conditions are satisfied.

    a. Control board valve selector switch (CS-91800-18, 19) is in the CLOSE position.

    b. Motor circuit breaker is closed.

    c. Motor thermal overload is reset.

3. The deicing pump discharge valve will manually open from the deice building whenever all of the following conditions are satisfied.

    a. The local valve selector switch (CS-91910, 11) is in the OPEN position.

    b. Motor circuit breaker is closed.

    c. Motor thermal overload is reset.

4. The deicing pump discharge valve will manually close from the deice building whenever all of the following conditions are satisfied.

    a. The local valve selector switch (CD-91910, 11) is in the CLOSE position.

    c. Motor circuit breaker is closed.

    d. Motor thermal overload is reset.

B 1.2.2.3 Discharge Structure

A. Sluice Gate - Typical for four (CT-062-391 thru 394)
(Ref. drawing NF-92782)

1. The sluice gate will manually open from the plant "Main Control Board" whenever all of the following conditions are satisfied:

   a. Control room selector switch (49060 thru 49063) is in the OPEN position.

   b. Local selector switch (91924, 91926, 91928, 19130) is in the REMOTE position.

   c. Motor electrical fault reset.

   d. Motor thermal overload reset.

2. The sluice gate will manually close from the plant "Main Control Board" whenever all of the following conditions are satisfied:

   a. Control room selector switch (49060 thru 49063) is in the CLOSE position.

   b. Local selector switch (91924, 91926, 91928, 91930) is in the REMOTE position.

   c. Motor electrical fault reset.

   d. Motor thermal overload reset.

3. The sluice gate will manually open at the discharge structure whenever all of the following conditions are satisfied:

   a. Local selector switch (91924, 91926, 91928, 91930) is in the LOCAL position.

   b. Local selector switch (91925, 91927, 91929, 91931) is in the OPEN position.

   c. Motor electrical fault reset.

   d. Motor thermal overload reset.

4. The sluice gate will manually close at the discharge structure whenever all of the following conditions are satisfied:

   a. Local selector switch (91924, 91926, 91928, 91930) is in the LOCAL position.

b. Local selector switch (91925, 91927, 91929, 91931) is in the CLOSE position.

c. Motor electrical fault reset.

d. Motor thermal overload reset.

B 1.3 Annunciators

B 1.3.1 Intake Screenhouse

Annunciators are provided on the intake screenhouse control board as follows:

A. 8 each - Screen 121 thru 128 differential greater than or equal to 10 inches.

B. 8 each - Trash rack, Bay 1 thru 8 differential greater than or equal to 6 inches.

C. 1 each - Screenhouse building differential greater than or equal to 24 inches (either of two sensors).

D. 3 each - Lo instrument air pressure (instrument transmitter rack 001, instrument transmitter rack 002, compressor receiver.)

E. 1 each - Hi DP - Instrument air dryer.

F. 1 each - Screen fish-larvae wash system failure (any one of four pumps).

G. 1 each - Screen trash wash system failure (any one of four pumps).

H. 1 each - Deice system failure

I. 1 each - Lo fish return line temperature (one sensor near fish return discharge).

J. 1 each - Bypass gates open.

K. 1 each - Bypass gate trouble.

L. 2 each - Air receiver - Hi water level (instrument air, service air) - Future.

M. 1 each - Programmable controller failure. (Primary CPU.)

N. 2 each - INVERTER 91801-A or B fault.

O. 1 each - Screenhouse load center trouble.

P. 1 each - Envir Lab Basement

Q. 1 each - Lock and Dam #3 Equipment Problem

B 1.3.2 Main Control Room

Annunciators using existing spare windows are provided on the plant "Main Control Board" as follows:

A. Screen differential greater than or equal to 10 inches.

B. Screenhouse differential greater than or equal to 24 inches.

C. Bypass gates open.

D. General alarm - screenhouse.

E. Bypass gate trouble.

B 1.4 Indicators

B 1.4.1 Screenhouse Control Board Indication
The following variables will be displayed on the intake screenhouse control board.

A. 2 - Building differential level (one from each of two sensors).

B. 8 - Screen differential level (one from each of eight sensors).

C. 8 - Trash rack differential level (one from each of eight sensors).

D. 1 - Fish return line discharge temperature.

E. 2 - Screen speed (one for each bank of 4 screens).

B 1.4.2 "Mimic Bus Insert" Indication
The following variables will be added to the display in the plant control room.

A. Intake river temperature.

B. Traveling water screen RUN/STOP.

C. Bypass gate OPEN/CLOSE.

D. Deice pumps RUN/STOP.

E. Deice pump discharge valve OPEN/CLOSE.

F. Average - discharge temperature.

G. Discharge flow rate.

H. Discharge canal level.

Note: These signals are in addition to signals already included in the control room.

B 1.5 Instrumentation I/O for screenhouse programmable controller (PC)

B 1.5.1 Analog Input

A. Trash Rack Differential Pressure

Instrument: 8 each - Foxboro Model 823, 2-wire, differential pressure transmitter, span set at 0-25 inches water equals 4-20 madc output to PC.

B. Traveling Screen Differential Pressure

Instrument: 8 each - Foxboro Model 823, 2-wire, differential pressure transmitter, span set at 0-25 inches water equals 4-20 madc output to PC.

C. Screenhouse Differentail Pressure

Instrument: 2 each - Foxboro Model 823, 2-wire, differential pressure transmitter, span set at 0-25 inches water equals 4-20 madc output to PC.

D. Screenhouse Intake Level

Instrument: 1 each - Drexelbrook admittance level probe and transmitter, 2 wire, span set at 0-13 feet equals 4-20 madc output to PC.

E. Discharge Canal Level

Instrument: 1 each - Drexelbrook admittance level probe and transmitter, 2 wire, span set at 0-13 feet equals 4-20 madc output to PC.

F. Discharge Temperature

Instrument: 4 each - Action Pak model TP621N - 052 - Type T Thermocouple transmitter, span set at 0-180 degree F equals 4-20 madc output to PC.

G. Fish Return Line Temperature

Instrument: 1 each - Action Pak model TP621N - 052 - Type T Thermocouple transmitter, span set at 0-180 degree F equals 4-20 madc output to PC.

B 1.5.2 Digital Input (120 Volt)

A. Discharge Gate (Open or Close)

4 each - 1 open limit switch (normally open) per discharge gate, 4 discharge gates total, contact closure indicates gate not closed.

B. Screen Drive Inverter Fault

2 each - 1 normally closed contact per each inverter drive, 2 inverter drives total, contact closure indicator inverter fault.

B 1.5.3 Analog Output (4-20 madc)

A. Screen Drive Inverter Signal

2 each - 4 to 8 inches water differential pressure across any one of four screens in the INVERTER mode will cause a corresponding output of 4-20 madc to the appropriate screen drive inverter.

B. Screenhouse Intake Level - Mimic

1 each - PC input change of 4-20 madc (0-13 ft. span) will cause a corresponding output of 4-20 madc to the main plant Mimic Bus Insert.

C. Discharge Canal Level - Mimic

1 each - PC input change of 4-20 madc (0-13 ft. span) will cause a corresponding output of 4-20 madc to the main plant Mimic Bus Insert.

D. Plant Discharge Flow - Mimic

1 each - PC output of 4 to 20 madc to correspond to 0-1500 cfs by using the following calculation:

$$Q_T=(K_5\ I_5 + K_6\ I_6 + K_7\ I_7 + K_8\ I_8)\ [h_{DIS}-h_{INT}]$$

Xcel Energy Prairie Island Nuclear Generating Plant

Technology Installation and Operation Plan (TI&O Plan)

Submitted in Accordance with the NPDES Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities

NPDES Permit MN0004006

October 25, 2006

Prepared by:

Xcel Energy
Environmental Services

TABLE OF CONTENTS

1.0 Introduction

1.1 Purpose

On July 9th, 2004 the EPA published an amendment to rule 316(b) of the Clean Water Act (CWA) in the Federal Register (from hereafter referred to as "the Rule"). The purpose of the amendment is to establish the best technology available for minimizing adverse environmental impact associated with the use of cooling water intake structures. The Technology Installation and Operation Plan (TIO Plan) is one component of the Comprehensive Demonstration Study (CDS), which is being submitted by our facility to comply with 40CFR 125.95(b)(4)(ii).

1.2 Compliance Alternative 2

The Rule states five alternatives for a facility to choose from in order to be in compliance. Xcel Energy chose compliance alternative 2 (40 CFR 125.94(a)(2)) for Prairie Island Nuclear Generating Plant (PINGP), as discussed in the "Proposal For Information Collection (PIC)." Briefly, compliance alternative 2 requires Xcel Energy to demonstrate that existing design and construction technologies, operational measures, and/or restoration measures at PINGP meet the impingement and entrainment performance standards.

1.3 TIO Plan Description

The TIO Plan is intended to describe the operational measures that are currently used at PINGP. Included in this Plan are operational measures used that are intended to minimize impingement and entrainment at the facility. Operational measures are documented with procedures and preventative maintenance (PM) plans. This Plan will list and describe operational and maintenance procedures that are used for the intake technology at PINGP to address meeting the impingement and entrainment national performance standards (40CFR 125.94(b)). It should be noted that a schedule for the installation and maintenance of any new design and construction activities will not be included, since PINGP's intake technologies are already meeting the performance standards and no new technologies need to be installed.

2.0 Prairie Island Nuclear Generating Plant Information

2.1 Location

PINGP is located on the Mississippi River in Goodhue County (township 113N, range 15W) near Red Wing, Minnesota. The site is located within the city limits of the City of Red Wing, Minnesota on the west bank of the Mississippi River. The plant site is located about 26 miles SE of the Twin Cities Metropolitan Area. The total area of the site is approximately 578 acres.

The principal surface waters in the vicinity of PINGP are: the Mississippi River, Sturgeon Lake, the Vermillion River, and the Cannon River. Lock and Dam Number 3, which is located approximately one and one-half miles downstream of the plant, controls the levels of the Mississippi River and Sturgeon Lake.

2.2 Generation

PINGP has two units, identified as units 1 and 2. Each unit employs a 2-loop pressurized water reactor. Full commercial operation began on December 16, 1973 for Unit 1 and on December 21, 1974 for Unit 2. Both units are licensed with the Nuclear Regulatory Commission (NRC) for operation at 1650 MWt per reactor, which is equivalent to a gross electrical output of 575 MWe. Northern States Power (NSP), d/b/a Xcel Energy, owns the facility, while Nuclear Management Company (NMC) operates the facility.

2.3 Cooling System Description

Water is withdrawn from the Mississippi River for condenser/circulation water system and cooling water systems. The condenser/circulating water system provides high volume cooling water flow for the turbine-condenser steam cycle whenever a unit is operating. The cooling water system also supplies other plant equipment, such as pumps, motors, and heat exchangers.

PINGP's cooling water system is capable of operating as a once-through system, a closed-loop system, or a helper system. River water enters the plant through the intake screenhouse and the plant screenhouse. Circulating waters discharged to the river are controlled by sluice gates and recycle gates. When cooling towers are in operation, some of the plant waste heat is transferred to the air and the remainder is transferred to the river. During the period the towers are out of service, the waste heat is transferred to the river or recycled back to the intake canal to temper the incoming cold water.

2.4 Intake Description

Plant intake flow from the Mississippi River enters the intake screenhouse through eight 18.5 foot high by 11.2 foot wide bay openings. The bottom of the inlet skimmer wall is at elevation 667.0 feet. Each bay is equipped with a raked trash rack and a traveling water screen with low-pressure fish wash sprays and high-pressure trash wash sprays. Bypass gates are available to maintain a continuous flow in the event that flow through the screens is reduced due to high debris loading. The bypass gates are a vertical lift gate type with rollers. The gates open automatically when the head differential across the traveling water screens reaches 18 inches or when the head differential across the intake screen house reaches 24 inches.

Each screen is 10 foot wide and extends from the operating deck (elevation 685 feet) to the floor (elevation 648.5 feet). Screen panels are replaceable. During the period of April 1 through August 31 (the spawning season), fine mesh screens (0.5 mm) are used to minimize the number of fish eggs and larval entrained. For the remainder of the year, coarse mesh screens (3/8-inch or 9.5 mm) are in service. The screens are capable of operation at several different speeds, as necessitated by debris loading.

During fine mesh screen operation, the screens run continuously. When the head differential is 4 inches or less, the screens continuously travel at 3 fpm during fine mesh operation. Coarse screen operation is intermittent, meaning that the spray wash systems (both fish and debris) do not operate when the differential level is less than 4 inches. These screens will, however, automatically rotate, with sprays operating, 1-1/3 revolutions if 8 hours pass without screen operation. For both fine and coarse screen operation, if the differential level exceeds 4 inches, screen speed increases proportionally up to a maximum of 20 fpm at 8 inches differential level.

The traveling water screens are equipped with fish lift buckets to remove organisms from the intake water. Aquatic organisms impinged on the screens, or carried in the attached buckets, travel with the screen during rinsing and are washed into a fish collection trough. Removal of the fish and organisms is accomplished on the upward travel side with a low-pressure (10 psi) inside spray when fine mesh is used and with a low-pressure (20 psi) outside spray when coarse mesh is used. Debris is removed by a backside interior high-pressure (50 psi for fine mesh and 100 psi for coarse mesh) spray system. The organisms and debris washed off the traveling water screens collect in a common trough and return to the river through a buried pipe approximately 2200 feet long. The pipe discharges into the Mississippi River at a point approximately 1500 feet south of the intake screen house.

3.0 Operational and Maintenance Procedures

Operational and maintenance procedures are classified into four categories based on the type of work being done. The four types of procedures are mechanical PMs, instrument and control (I & C) PMs, surveillance procedures, and testing procedures. Procedures for all work types that are relevant to the intake screenhouse are identified and described in this section and summarized in Table 1.

3.1 Surveillance Procedure (SP)

Surveillance Procedures are procedures that direct the actual operation of equipment or valve lineup to verify proper flows or pressures. SPs are typically conducted to verify required testing criteria/codes or meet Technical Specification requirements. PINGP implements three SP's that are pertinent to the intake screenhouse or appropriation of water. SP's are listed in Table 1 and described in the following text.

SP 1333

Surveillance Procedure 1333 is implemented for verification of the NPDES permit requirements. The intent of SP 1333 is to maintain NPDES permit compliance. This SP is performed throughout the year on fixed dates as stated in the NPDES permit and outlined in the SP. Operational measures directed by SP 1333 include:

- Ensure installation and operability of fine mesh traveling screens.
- Operation of cooling towers.
- Verification of fine mesh larvae spray header pressure.
- Verification of plant discharge flow less than 300 cfs (April and May).
- Verification of plant discharge flow less than 400 cfs (June 1 to 15).
- Verification of plant discharge flow less than 800 cfs (June 16 to 30).
- Maintenance of 5°F or less ΔT across the plant.
- Installation of coarse mesh screens.

SP 1260

Surveillance Procedure 1260 is implemented to ensure the accuracy and operability of the Discharge Canal flow instrumentation, and fulfills the H4, ODCM calibration requirement. The discharge flow rate is determined by measuring the level at the intake screenhouse and discharge canal. The difference between the levels (ΔH) and position of the sluice gates determine discharge flow. This SP is performed on an 18-month interval.

SP 1707

Surveillance Procedure 1707 is implemented to test the river temperature monitoring system. The test verifies the accuracy and operability of the river temperature monitoring system as required per NPDES Permit #MN0004006.

PINGP monitors the river water temperature at seven locations by remote monitoring stations and a central receiving station. The remote stations measure the water temperature at the following locations: Two at Sturgeon Lake (upstream), one on the Mississippi River at Diamond Bluff (upstream), at piers 1, 2, and 3 of Lock and Dam No. 3 (downstream), and at the intake screenhouse. At each location there is at least one dual element Type T thermocouple measuring the temperature providing a voltage input to one of the remote monitoring stations. Each of these remote monitoring stations sample the river temperature on a scheduled frequency and transmits the data to a central receiver at the plant. Each temperature monitoring point is compared to an RTD probe measurement made at the temperature element. This SP is performed yearly.

3.2 Preventative Maintenance

Preventative Maintenance (PM) is the classification of work that includes predictive (condition-based) and periodic/planned (time-based) actions taken to maintain a piece of equipment within design operating conditions and to extend its life. Further, PM is used to assure that safety related, security related, 10CFR71 related, and fire protection related equipment is maintained to operate within normal limits or will function to place the plant in a safe condition if normal limits are exceeded. Plant maintenance personnel perform the maintenance in accordance with plant procedures, vendor manuals, and vendor instructions.

3.2.1 Mechanical

PINGP has seven mechanical PM procedures that are used in the intake screenhouse. The PM numbers, descriptions, and frequencies used at PINGP are listed in Table 1 and summarized in this section.

PM 3512-2 and PM 3512-3

The primary purpose of PMs 3512-2 and 3512-3 is to change the screen mesh size from fine to coarse (or coarse to fine) as required by PINGP's NPDES/SDS permit guidelines. PM 3512-2 is initiated for Bank 1 screen change out and PM 3512-3 is initiated for Bank 2 screen change out. The secondary purposes of these PMs are to inspect/repair or replace certain parts of the equipment that may be worn or loose. Some of these items, like the tray to boot seal, function to prevent flow of aquatic organisms past the screens and into the plant intake. Thus, the inspections/repairs are a necessity for minimizing entrainment of fish.

PMs 3512-2 and 3512-3 are usually scheduled 2-3 weeks prior to the dates given in the NPDES/SDS permit (April 1st and August 31st of each year). The frequency of each of these PMs, consequently, is sixth months (once every 180 days).

PM 3512-4-121 and PM 3512-4-122

The purpose of these two PMs is to perform inspections of the 121 and 122 Bypass Gate Hydraulic Systems. The PM consists of changing filters, checking oil level, and looking for oil leakage. These two PMs are performed annually.

PM 3512-5

The purpose of this PM is to take measurements of the carrier chain roller radial clearance of the intake screen house vertical traveling screens. These measurements enable plant personnel to predict when to take a traveling screen out of service for chain adjustment and/or parts replacement. PM 3512-5 is conducted 2 times per year, generally co-incidental with the screen change over PMs.

PM 3512-8

The purpose of PM 3512-8 is to inspect and record the condition of both the intake screenhouse and plant screenhouse bar racks with the use of a diver. In addition, the diver inspects the river/canal area into the plant screenhouse and outlet of the intake screenhouse for debris/sand build-up. This PM is conducted once every five years.

PM 3512-9 and PM 3512-10

The purpose of these PMs is for a diver to perform an inspection of the wheels, shafts, nuts, bolts, piston attachment to the emergency bypass gate and surrounding area of the bay. Also, as directed by the System Engineer, clean mud from the eight horizontal plates on the backside of the gates and blow mud from the gate (floor level) a distance of 6 feet. These two PMs are performed annually.

PM 3512-15

The purpose of this procedure is to perform a top to bottom inspection and repair of the intake traveling screen assembly. This procedure requires dewatering the corresponding bay to perform repairs to the foot-shaft assembly. Maintenance activities include: lubricating/greasing components, repairing traveling chain, inspecting foot and head shaft assemblies, recording adjustment measurements, and installing screens. This PM is performed as needed for inspection and repair.

PM 4500-7

The primary purpose of this PM is to make sure the trash racks, fish trough, and entrance to the fish return pipeline are clean of debris. A secondary purpose is to grease the screens regularly to prevent bearing failure and to watch for fluid leaks and listen for equipment sounds that are abnormal to the operation of the screenhouse. The frequency of this PM is daily, with some of the weekly and monthly tasks done as the visual conditions dictate.

3.2.2 Instrument and Control (I&C)

Instrument and control preventative maintenance is directed at the instruments associated with the intake traveling screens, bypass gates, and air systems. There are four I&C PM procedures relevant to the intake screenhouse. The numbers, descriptions, and frequencies of the four I&C PMs are listed in Table 1 and summarized below.

IC 0CT-8

The purpose of this PM is for the calibration of the intake traveling screen supply pressure. This PM has a frequency of once every 36 months.

ICPM 0-005

The purpose of this PM is to calibrate instruments on bypass gates 121 and 122. Instruments calibrated include intake structure building differential pressure transmitters, oil level switches, and oil pressure switches. This PM has a frequency of once every 24 months.

ICPM 0-010

The purpose of this PM is to calibrate instruments used for the intake screenhouse screenwash. Instruments calibrated include differential pressure transmitters, pressure switches, and fish return temperature monitoring loop. This PM is performed on a 24-month interval.

ICPM 0-014

The purpose of this procedure is to ensure proper calibration of the service and instrument air compressors in the intake screenhouse. This PM is performed on a 36-month interval.

3.4 Testing Procedure (TP)

Testing procedures verify that all interfaces with existing plant equipment and systems operate as intended and all critical performance parameters are achieved. This testing may require specific plant operational modes to adequately test all conditions. PINGP has two TPs that are pertinent to the intake screenhouse and/or maintaining 316(b) compliance.

TP 1690

Testing Procedure 1690 is intended to detect any major changes of sediment buildup in front of the Intake. During summer months, the approach canal and intake canal are depth sounded to detect any drastic sediment changes. An increase of sediment buildup could affect plant operation or intake screenhouse equipment. The frequency of this TP is once during the summer months.

TP 2537

The purpose of Testing Procedure 2537 is to cycle the Intake Screenhouse Bypass Gate's Emergency Open Solenoid Valve. The solenoid valve changes position on loss of power, allowing the accumulators to open their respective bypass gate. TP 2537 consists of failing the power to each bypass gate, by using a manual bypass valve positioned to divert oil flow from the bypass gate to the oil reservoir. In addition, the valve will allow the hydraulic pumps to operate, increasing the "duty cycle time" of the system, and enabling the filtration system to clean the hydraulic oil. It should be noted that this procedure does not open the bypass gates. The frequency of this TP is once every seven days (weekly).

4.0 Assessing Efficacy of Intake Technologies

In 1983, a new screenhouse was constructed at the PINGP. There are presently two complete screening facilities operating at PINGP. The old, or original, traveling screens and screenhouse (plant screenhouse) were designed to prevent debris, fish, and other organisms from entering the plant via the cooling water intake. The new screenhouse and screens (intake screenhouse), completed in 1983, were designed and located to exclude fish from the warm circulating water system. In order to determine the efficacy of PINGP's cooling water intake structure, a review of historical data and reports will be used.

During November 1983 through March 1984 impingement samples were collected from coarse mesh screens at the intake screenhouse. Total number of fish impinged was estimated by expanding the numbers collected during weekly samples over an entire month. In addition, fish collected were recorded as live or dead, live fish were held in aquaria for up to 96 hours. To determine the efficiency of the screen wash in removing fish on the front side of the coarse mesh screens, a dip net was used to collect material washed off the backside of screens. The results of the samples indicate the front spray wash system was nearly 80 percent effective in removing fish.

During sample years 1984 to 1989, sample collection of fish impinged on the fine mesh screens started in April and continued through August. Samples were collected 2 to 3 days a week by diverting 25 percent of the screen wash water into larval collection tanks in the basement of the environmental lab.

Three types of samples were collected to provide various data. Sample types included abundance, initial survival, and latent survival. Initial survival samples were collected at night or early morning to determine night density of fish and eggs and initial survival of fish impinged on the fine mesh screens. Initial samples underwent a "first and second" sort. The first sort was designed to remove live and dead fish, with emphasis placed on removing all live fish in a time efficient manner. The second sort was designed to assure removal of all remaining fish and eggs. Abundance samples were collected during early to midmorning to estimate day density of fish and eggs impinged on the fine mesh screens. Latent survival samples were collected to determine the latent survival of fish impinged on the fine mesh screens. Fish collected for latent survival estimates were held for 48 or 96 hours and checked at selected time increments. Number of live and dead fish were recorded during each time interval.

During 1984, back wash samples from fine mesh screens were also collected. Back wash samples were collected while an abundance sample was collected. This sample was collected using a 0.5 mm mesh ichthyoplankton drift net placed in the high pressure trash removal return trough. Comparing data from the abundance and back wash samples was utilized to determine the efficiency of the low pressure front wash in removing fish impinged on the fine mesh screens. Twenty-four pairs of samples compared indicated that the front spray wash removal system was more than 98 percent efficient in removing fish from the front side of the fine mesh screens.

During the months of April, May, and June operational measures to reduce intake flow are in place per the NPDES permit to minimize potential impacts to larval fish and eggs at the intake. Operations at PINGP reflect this design with current operational measures as follows:

April 15 to 30: 300 cfs (194 mgd) if the flow in the river is at or above 15,000 cfs
150 cfs (97 mgd) if the flow in the river is below 15,000 cfs
May 1 to 31: 300 cfs (194 mgd)
June 1 to 15: 400 cfs (259 mgd)
June 16 to 30: 800 cfs (517.5 mgd)

Through screen velocities during the period of April 15 to June 15 range from 0.29 ft/sec to 0.38 ft/sec. These through screen velocities during this sensitive larvae period are less than the 0.5 ft/sec performance standard for impingement mortality as stated in the 316(b) Phase II rule document. The remaining periods of the year flow is limited to the design intake flow of 1410 cfs.

Impingement studies were conducted from 1992 to 2005 to evaluate the effects of increased water appropriation, from 150 to 300 cubic feet per second (cfs) during April, on impingement of larval fish on 0.5 mm fine mesh traveling screens at PINGP. From 2002 to 2005, permit approved blowdown (discharge) reduction to 300 cfs or less was initiated on April 15th rather than on April 1st. Prior to 1992, the cooling water intake system operated with fine-mesh screens from April 16 through August 31, in accordance with plant's NPDES Permit. Since 1992, for study purposes, the plant has implemented fine-mesh screen operation on April 1 to accommodate sampling during the month of April for years 1992 through 2005. Data for this evaluation were collected by pre-dawn and daylight sampling of larval fish and fish eggs from the screenwash water. Estimated impingement values during April for all years were low and represented by relatively few taxa/life stage combinations.

Stone and Webster (1977) conducted studies for alternative intake designs to reduce entrainment mortality at PINGP. One objective was to determine criteria for screen mesh size that is fine enough to screen a large percentage of eggs and larval stages of species considered to be important. Based on this study, it was determined that 0.5 mesh screen would be required to adequately screen those organisms from the water entering the intake canal. Examination of the larval data indicated that 0.5 mm mesh should screen a wide range of eggs and larvae found in the vicinity of PINGP.

Impingement estimates calculated for 1985 through 1988 are considered to be a realistic approximation of the number of larval fish and eggs which would have been entrained through PINGP in the absence of the fine mesh screens. Entrainment studies in 1975 estimated that nearly 70 million larvae and eggs were entrained at PINGP. Impingement estimates from fine mesh screens for 1985 through 1988 were similar with estimated number of larvae and eggs impinged ranging from 42 million to 77 million. Species composition of entrainment and impingement samples is also similar with freshwater drum, cyprinids, and gizzard shad representing a large percentage of samples.

5.0 Conclusion

PINGP's current NPDES permit regulates the continued operational and maintenance measures in place for the intake screenhouse. The NPDES permit directs river water withdrawal rates, operation of the intake screenhouse and fish return system and requirement of fine mesh screens to minimize entrainment of larval fish and eggs (Appendix A).

During the period April 1 through August 31, PINGP is required to operate the intake vertical traveling screens in continuous mode and using fine-mesh (0.5 mm) screen material in order to minimize entrainment of larval fish, fish eggs, and other aquatic organisms. In addition, intake flows are limited from April 15 through June 30 in order to minimize the impingement of fish and fish larvae. During the remaining months (September through March) when entrainment of larval fish and eggs is not expected standard 3/8-inch mesh screens are installed. The fish handling and return system is in service during both time periods. Surveillance procedures at PINGP are utilized to verify that required operational measures are implemented. Preventative maintenance procedures are used to assure that intake screenhouse equipment is maintained and operates within required limits.

Based on survival studies, sampling induced mortality studies, and operational measures, PINGP meets the impingement standards set forth by the 316(b) rule. Survival of juvenile and larger fish sampled from fine mesh screens is 71.5 percent. In addition, studies to determine sampling induced mortality determined that nearly 10 percent of mortality to juvenile fish (15 percent mortality for all life stages) is caused by the sampling method. With sampling mortality factored in, over 80 percent survivorship is expected from PINGP fine mesh screens. If operational measures are factored in, it can be assumed that overall fish survivorship of the community is increased since fewer fish overall are being impinged. During the peak larval density period (May and June), PINGP intake flows are limited to 20 to 30 percent of design flow. The assumption can be made that during these months only one-third of the fish that would have been impinged (if operating at design flow) are being impinged resulting in increased overall survivorship.

Due to the use of 0.5 mm (fine) mesh screens at the intake screenhouse from April through August entrainment standards are met at Prairie Island. It has been documented from larval studies conducted at PINGP that 0.5 mm mesh screens collect eggs and larvae of all fish expected to be encountered in the naturally occurring drift from the Mississippi River community within the vicinity of the plant.

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TABLES

Table 1. Summary of Procedures for all Work Types Relevant to the Intake Screenhouse.

Task ID	Title	Frequency	Group	Description
PM 3512-2	BANK 1 INTAKE TRAVELING SCREEN FINE/COARSE MODE AND SCREEN CHANGES	6 MONTH FREQ 180 DAY INTERVAL	MECH	Changes the Bank 1 intake traveling screens and Bank 1 mode from Coarse to Fine or Fine to Coarse
PM 3512-3	BANK 2 INTAKE TRAVELING SCREEN FINE/COARSE MODE AND SCREEN CHANGES	6 MONTH FREQ 180 DAY INTERVAL	MECH	Changes the Bank 2 intake traveling screens and Bank 2 mode from Coarse to Fine or Fine to Coarse
PM 3512-4-121	121 INTAKE SCREENHOUSE BYPASS GATE ANNUAL INSPECTION	ANNUAL	MECH	Perform annual inspection of 121 bypass gate hydraulic system
PM 3512-4-122	122 INTAKE SCREENHOUSE BYPASS GATE ANNUAL INSPECTION	ANNUAL	MECH	Perform annual inspection of 122 bypass gate hydraulic system
PM 3512-5	INTAKE TRAVELING SCREENS SPRING AND FALL ELECTRICAL AND MECHANICAL MEASUREMENTS	BI-MONTHLY 61 DAY INTERVAL	MECH	Perform inspection, maintenance, and adjustment of intake traveling screens
PM 3512-8	FIVE YEAR UNDERWATER INSPECTION OF SCREENHOUSE INLET(S)	5 YEAR	ENG	Inspect and record the condition of intake screenhouse inlet and outlet for debris/sand build-up
PM 3512-9	121 INTAKE SCREENHOUSE BYPASS GATE INSPECTION	ANNUAL	MECH	Perform an underwater inspection of the 121 intake screenhouse bypass gate
PM 3512-10	122 INTAKE SCREENHOUSE BYPASS GATE INSPECTION	ANNUAL	MECH	Perform an underwater inspection of the 122 intake screenhouse bypass gate
PM 3512-15	INTAKE TRAVELING SCREEN TOP TO BOTTOM INSPECTION AND REPAIR	AS NEEDED	MECH	Perform a top to bottom inspection and repair of the intake traveling screen
PM 4500-7	INTAKE SCREENHOUSE WEEKLY TASKS	WEEKLY	MECH	Perform periodic (daily/weekly) tasks as described in procedure
IC 0CT-8	INTAKE TRAVELING SCREEN SUPPLY PRESSURE INDICATORS	3 YEAR	IC	Perform calibration of instruments listed in IC OCT-8
ICPM 0-005	121 &122 BYPASS GATES INSTRUMENT CALIBRATION	24 MONTH INTERVAL	IC	Calibrate instruments associated with bypass gates
ICPM 0-010	INTAKE SCREENHOUSE SCREENWASH INSTRUMENTS CALIBRATION	24 MONTH INTERVAL	IC	Calibrate instruments associated with screenwash functions
ICPM 0-014	INTAKE SCREENHOUSE SERVICE & INSTRUMENT AIR COMPRESSER INSTRUMENT CALIBRATION	36 MONTH INTERVAL	IC	Calibration of service and instrument air compressors
SP 1260	DISCHARGE CANAL FLOW INSTRUMENTS CALIBRATION	18 MONTH	OPS	Verifies accuracy and operability of discharge canal flow instrumentation
SP 1333	VERIFICATION OF NPDES PERMIT REQUIREMENTS	FIXED DATE	OPS	Verifies seasonal changes to plant operations to meet permit requirements
SP 1707	RIVER TEMPERATURE MONITORING SYSTEM YEARLY TEST	ANNUAL	OPS	Verifies accuracy and operability of river temperature monitoring system
TP 2537	INTAKE SCREENHOUSE BYPASS GATE EMERGENCY OPEN SOLENOID VALVE CHECK	WEEKLY	OPS	Cycles intake screenhouse bypass gate emergency open solenoid valve
TP 1690	APPROACH, INTAKE, RECYCLE AND OLD DISCHARGE CANAL DEPTH SOUNDING	ANNUAL	ENG	Depth soundings to detect any major changes in build-up of sand/silt

APPENDIX A—PINGP NPDES Permit

Minnesota Pollution Control Agency

CERTIFIED MAIL NO: 7004 2510 0000 2117 5535
RETURN RECEIPT REQUESTED

Mr. Patrick Flowers
Manager, Water Quality Solid Waste
Northern States Power d/b/a Xcel Energy
414 Nicollet Mall
Minneapolis, MN 55401-1993

RE: Major Modification National Pollutant Discharge Elimination System/State Disposal System Permit No. MN 0004006
Xcel Prairie Island Nuclear Generating Plant
Welch, Minnesota

Dear Mr. Flowers:

Enclosed is a copy of the reissued final modified National Pollutant Discharge Elimination System (NPDES)/State Disposal System (SDS) permit for the Prairie Island Nuclear Generating Plant. This permit supersedes an earlier NPDES permit that was issued on September 23, 2005, and modified on January 26, 2006. All written comments received during the public notice period were considered.

It is the responsibility of the Permittee to maintain compliance with all of the terms and conditions of this permit. Please carefully review the entire permit.

We would like to draw your attention to the following:

Limits and Monitoring Requirements:
An additional requirement to monitor and report the total calendar month flow at surface discharge station SD 001 during the months of April, May, and June has been added. The previous permit required that this value be reported only for the months July through March. The modified permit requires year round monitoring and reporting for total calendar month flow at SD 001.

Dredged Material Management Requirements:
The modified permit includes requirements related to the storage, treatment, disposal and/or reuse of dredged material generated at Prairie Island Nuclear Generating Plant. The modified permit does not authorize or regulate the dredging activity itself. Prior to conducting dredging

activities in the bed of public waters the Xcel Energy is required to contact the Minnesota Department of Natural Resources, the U.S. Army Corps of Engineers, the appropriate Soil and water Conservation District, county and/or local unit of government.

If you have any questions regarding any of the terms and conditions of the permit, please contact Katrina Kessler of our staff at 651-296-7376.

Sincerely,

Jeff Stollenwerk
Supervisor
Land and Water Quality Permits Section
Industrial Division

KK:lmg

Enclosures: Final Permit

cc: Jim Bodensteiner, Xcel Energy, Minneapolis (w/enclosures)
Brent Kuhl, Xcel Energy, Minneapolis (w/enclosures)
Jeanne Tobias, Xcel Energy, Prairie Island Plant (w/enclosures)
George Azevedo, Environmental Protection Agency, Chicago (w/enclosure)

STATE OF MINNESOTA
Minnesota Pollution Control Agency

Industrial Division

National Pollutant Discharge Elimination System (NPDES) and State Disposal System (SDS) Permit MN0004006

PERMITTEE: Northern States Power Company d/b/a Xcel Energy

FACILITY NAME: Prairie Island Nuclear Generating Plant

RECEIVING WATERS: Mississippi River

CITY/TOWNSHIP: Welch **COUNTY: Goodhue**

MODIFICATION DATE: 6/30/2006 **EXPIRATION DATE: August 31, 2010**

The state of Minnesota, on behalf of its citizens through the Minnesota Pollution Control Agency (MPCA), authorizes the Permittee to discharge from this facility to the receiving waters named above, in accordance with the requirements of this permit.

The goal of this permit is to protect water quality according to Minnesota and U.S. statutes and rules, including Minn. Stat. chs. 115 and 116, Minn. R. chs. 7001, 7050 and 7060, and the U.S. Clean Water Act.

This permit is effective on the modification date identified above, and supersedes the previous permit that was issued for this facility on September 23, 2005, and modified on January 26, 2006.

This permit expires at midnight on the expiration date identified above.

Signature: ______________________________
Michael (Mike) J. Tibbetts, Manager *For* The Minnesota Pollution Control Agency
Land and Water Quality Permits Section
Industrial Division

If you have questions on this permit, including the specific permit requirements, permit reporting or permit compliance status, please contact:

Minnesota Pollution Control Agency
Industrial Division
520 Lafayette Road North
St. Paul, MN 55155-4194
Telephone: (651) 296-7376
Fax: (651) 296-8717
Telephone Device for Deaf (TTY): (651) 282-5332

Table of Contents

Required Submittals

316(b) Required Submittals*:

Source water physical data required by 316(b) Phase II ....October 28, 2006
Cooling water intake structure data..October 28, 2006
Cooling water system data...October 28, 2006
Proposal for Information Collection ....October 28, 2006
Comprehensive Demonstration Study..October 28, 2006
Results of IM &E Study..October 28, 2006
Design Construction Technology Plant..October 28, 2006
Technology Installation and Operation Plan ....October 28, 2006
Verification Monitoring Plan...October 28, 2006

**The Permittee has tentatively selected Compliance Alternative (2) of 40 CFR 125.94 (a) to meet the impingement and entrainment reduction requirements. Alternative (2) requires that the Permittee demonstrate that existing design and construction technologies, operational measures, and/or restoration measures meet the impingement mortality and entrainment performance standards.*

Other Submittals:

Storm water pollution prevention plan...........180 days after permit issuance
DMRs ....21 days after the end of each calendar month following permit issuance
Application of permit reissuance ....180 days before permit expiration

Permitted Facility Description

This facility is a two unit nuclear fueled electric-generating plant. Both units use a pressurized water reactor system design with a maximum Nuclear Regulatory Commission (NRC) licensed power level of 1650 megawatts thermal per unit, which is equivalent to a combined maximum generating capacity of approximately 1100 megawatts electric for the facility. The treatment and disposal systems at the plant consist of a chemical treatment system, a reverse osmosis system, a radioactive waste (radwaste) treatment system, an intake screening system, and cooling towers. Water is withdrawn from wells for plant process uses, and from the river for condenser/circulating water system and cooling water systems. The condenser/circulating water system provides high volume cooling water flow for the turbine-condenser steam cycle whenever a unit is operating and also allows for excess heat rejection when a nuclear unit is at thermal power with the generator off-line. The cooling water system supplies other plant equipment, such as pumps, motors, and heat exchangers and is normally operated at all times.

The plant discharges condenser/circulating water and cooling water to the Mississippi River via the condenser/circulating water system discharge canal through surface discharge SD 001. During the winter months, a portion of the warm water from the discharge canal is returned to the intake screenhouse via a de-icing line to prevent ice build-up on the bar racks and traveling screens. The plant discharges steam generator blowdown through surface discharge SD 002. Radwaste treatment system effluent is discharged through surface discharge SD 003. The reverse osmosis (RO) system effluent is discharged through surface discharge SD 004. The unit 1 and unit 2 turbine building sumps, which are comprised of noncontact cooling water, condensate traps and drains, roof and floor drains, unit 1 and 2 condensate blowdown and the heating system blowdown, are discharged through surface discharges SD 005 and SD 006. Miscellaneous plant floor drains are discharged through surface discharge SD 010. All of the above surface discharges (SD) are ultimately discharged to the river via the circulating water system discharge canal, SD 001.

The plant intake screen backwash is discharged via SD 012. The fish return system which collects impinged fish, aquatic organisms, and debris off the vertical traveling screens is also discharged via SD 012. SD 012 discharges directly to the river.

The plant has two internal waste streams, the Unit 1 and Unit 2 cooling water systems. These systems are treated routinely with bromine and/or chlorine to control biofouling organisms and, when being treated, are designated as waste streams WS 001 and WS 002. Bromine and/or chlorine residuals are limited in accordance with this permit. Since WS 001 and WS 002 are comprised of cooling water system flow(s) at the time of treatment, these internal waste streams are also discharged to the river via the circulating water system at SD 001.

The plant also has an on land treatment and disposal system, typically referred to as the "land-lock drainage system." The land-lock drainage system is used for periodic disposal and treatment of turbine building sump discharges when the total suspended solids and oil and grease residual of the sump water is such that it exceeds applicable discharge limitations. The system consists of an approximately 500 ft long, 10 ft wide drainage trench which allows for treatment/filtration of collected water through a semi-permeable clay liner system. Reconstructed in 1998, the drainage trench does not discharge to surface waters, and accumulated water either evaporates or seeps away. Turbine building sump discharges to the land-lock drainage system are primarily composed of river water/sediment and solids.

The plant uses a number of chemical additives for various purposes within the plant systems and piping and may discharge residual concentrations of these additives via the surface discharges. The concentrations of any additives used that may contribute to a discharge have been reviewed and approved by the MPCA (reference NPDES Limits Matrix dated November 1, 2004) and are restricted accordingly. Any new chemical additive usage or increase in dosages used requires approval by the MPCA in accordance with Chapter 7 of this permit.

The plant is limited in the amount of heat it may discharge to the river. The thermal limitations regulating the plant cooling water discharge are described in Chapter 5 part 2 Applicable Effluent Limitations – Thermal Limitations. The plant's heat discharge or thermal load to the river is limited by mixed river temperature immediately below Lock and Dam No. 3, downstream of the plant. Cooling tower operation is sometimes required to meet the thermal limitations. To determine the ambient river water temperature, assess the plant's thermal input, and assure compliance with applicable thermal limitations, temperature monitoring is conducted at SD 001 (condenser/circulating water and cooling water discharge canal outfall), at the plant intake (SW 002), at the main river channel (SW 003-upstream river point), at a point(s) in Sturgeon Lake (SW 004-upstream river point), and immediately downstream of Lock and Dam No. 3 by three separate temperature probes (SW 001).

The plant is also regulated by the amount of river water that may be used for condenser and equipment cooling. The design of the various plant cooling systems does not allow for direct measurement or river intake flow but does allow for calculation of discharge flow SD 001 based on sluice gate positions and canal water elevation. River water withdrawal rates are controlled indirectly by imposing limitations on discharge flow at SD 001, which approximates intake flow. The discharge flows are limited from April 15 through June 30 in order to minimize the impingement of fish and fish larvae, as stated in Chapter 1, Part 5.1. The plant must operate the intake screening system throughout the year as required in Chapter 5, Parts 4.1 and 4.2 to assure impinged fish are returned to the river via the fish return system. In addition, during the period April 1 through August 31, the plant is required to operate the intake vertical traveling screens using the fine mesh screen material in order to minimize entrainment of larval fish, fish eggs, and other aquatic organisms.

Sanitary wastewater generated at the plant is treated using the plant's septic system or trucked to Red Wing WWTP or Prairie Island Community Water Treatment Plant.

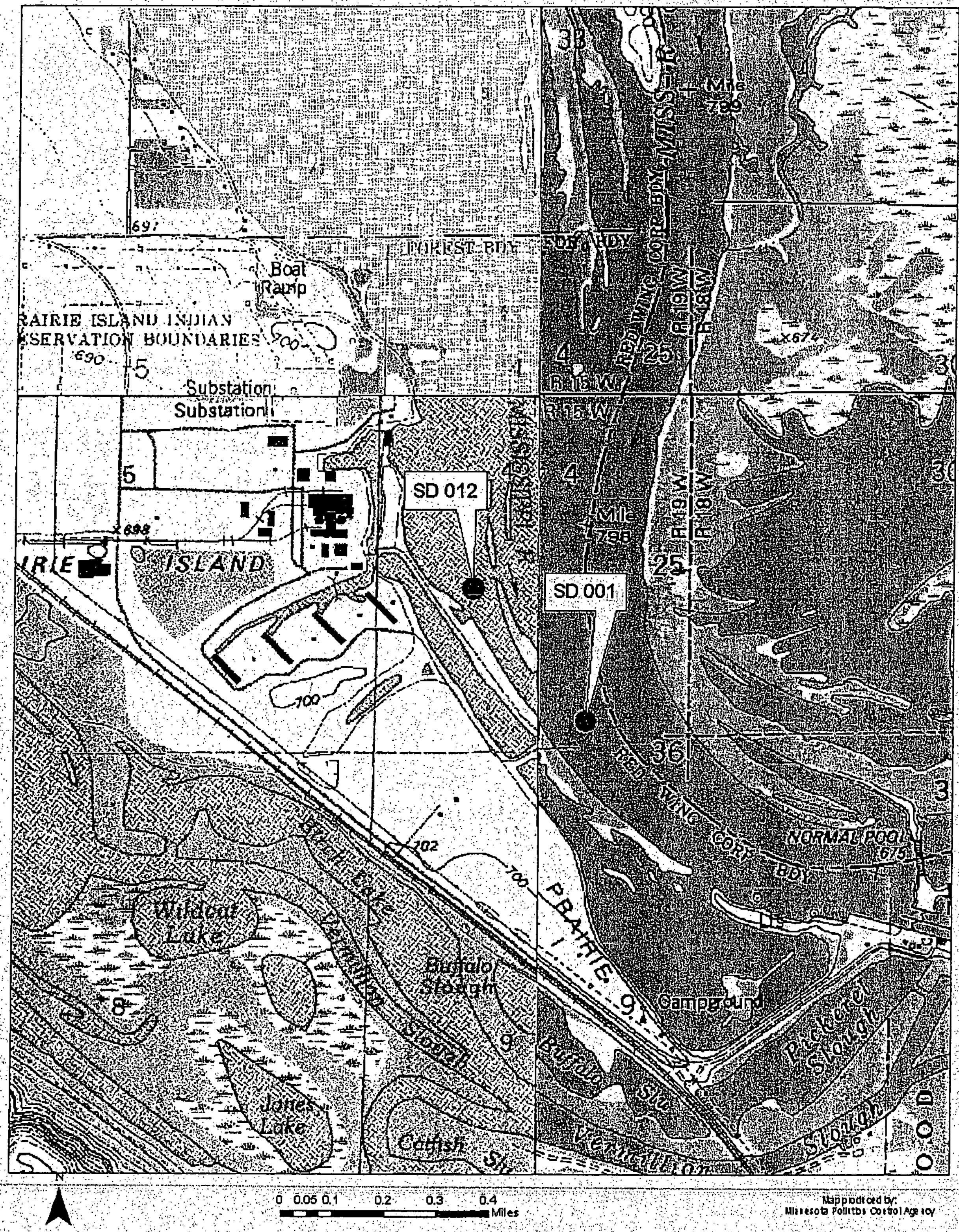
The surface discharge (SD) and internal waste stream (WS) discharges from the plant are described in the following table, with approximate flows in million gallons per day (MGD):

DISCHARGE	WASTEWATER SYSTEM	MAXIMUM FLOW	AVERAGE FLOW
SD 001	Condenser/Circulating Water and Cooling Water	864	503
SD 002	Steam Generator Blowdown	0.576	0.012
SD 003	Radioactive Waste Effluent	0.230	0.002
SD 004	Reverse Osmosis Effluent	0.244 [1]	0.051 [1]
SD 005	Unit 1 Turbine Building Sump	0.360	0.030
SD 006	Unit 2 Turbine Building Sump	0.360	0.030
SD 010	Miscellaneous Plant Floor Drains	0.015	0.001
SD 012	Intake Screen Backwash and Fish Return	3.2	2.0
WS 001 WS 002	Combined Unit 1 and Unit 2 Cooling Water (when subject to oxidation)	69	25

Note: [1] Flows are based on available data for 3 months of system operation in 2005

The location of the facility and the selected monitoring stations is shown on the map below.

Topographic Map of Permitted Facility



The Permittee shall comply with the limits and monitoring requirements as specified below.

SD 001: Condenser Circ Water & Cooling Water Sys (Applicable only during discharge)

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Chlorine Rate	Monitor Only	kg/day	Daily Maximum	Jan-Dec	Calculation	1 x Day	2
Flow	Monitor Only	MG	Calendar Month Total	Jan-Dec	Measurement	1 x Day	1
Flow	Monitor Only	mgd	Daily Average	Jul-Mar	Measurement	1 x Day	1
Flow	97	mgd	Daily Average	Apr	Measurement	1 x Day	13
Flow	194	mgd	Daily Average Intervention	Apr	Measurement	1 x Day	12
Flow	194	mgd	Daily Average Intervention	May	Measurement	1 x Day	4
Flow	259	mgd	Daily Average	Jun	Measurement	1 x Day	15
Flow	517.5	mgd	Daily Average Intervention	Jun	Measurement	1 x Day	14
Oxidants, Total Residual (Bromine), Continuous	0.001	mg/L	Daily Maximum	Jan-Dec	Calculation	1 x Day	
Oxidants, Total Residual (Bromine), Intermittent	0.05	mg/L	Instantaneous Maximum	Jan-Dec	Grab	1 x Day	
Oxidants, Total Residual (Chlorine), ...inuous	0.04	mg/L	Daily Maximum	Jan-Dec	Calculation	1 x Day	
...nts, Total Residual (Chlorine), Intermittent	0.2	mg/L	Instantaneous Maximum	Jan-Dec	Grab	1 x Day	
pH	9.0	SU	Calendar Month Maximum	Jan-Dec	Grab	1 x Week	17
pH	6.0	SU	Calendar Month Minimum	Jan-Dec	Grab	1 x Week	17
Plant Capacity Factor, Percent of Capacity	Monitor Only	%	Calendar Month Average	Jan-Dec	Measurement	1 x Day	
Temperature, Water	Monitor Only	Deg F	Single Value	Jan-Dec	Measurement, Continuous	1 x Day	7

SD 002: Steam Generator Blowdown Discharge

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Flow	Monitor Only	mgd	Calendar Month Average	Jan-Dec	Estimate	1 x Month	
Flow	Monitor Only	MG	Calendar Month Total	Jan-Dec	Estimate	1 x Month	
Solids, Total Suspended (TSS)	65.3	kg/day	Calendar Quarter Average	Jan-Dec	Grab	1 x Quarter	
Solids, Total Suspended (TSS)	30	mg/L	Calendar Quarter Average	Jan-Dec	Grab	1 x Quarter	
Solids, Total Suspended (TSS)	217.0	kg/day	Daily Maximum	Jan-Dec	Grab	1 x Quarter	
Solids, Total Suspended (TSS)	100	mg/L	Daily Maximum	Jan-Dec	Grab	1 x Quarter	

The Permittee shall comply with the limits and monitoring requirements as specified below.

SD 003: Radwaste Treatment Effluent

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Flow	Monitor Only	mgd	Calendar Month Average	Jan-Dec	Estimate	1 x Month	
Flow	Monitor Only	MG	Calendar Month Total	Jan-Dec	Estimate	1 x Month	
Solids, Total Suspended (TSS)	26.0	kg/day	Calendar Quarter Average	Jan-Dec	Grab	1 x Quarter	
Solids, Total Suspended (TSS)	30	mg/L	Calendar Quarter Average	Jan-Dec	Grab	1 x Quarter	
Solids, Total Suspended (TSS)	86.9	kg/day	Daily Maximum	Jan-Dec	Grab	1 x Quarter	
Solids, Total Suspended (TSS)	100	mg/L	Daily Maximum	Jan-Dec	Grab	1 x Quarter	

SD 004: Reverse Osmosis Effluent

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Flow	Monitor Only	mgd	Calendar Month Average	Jan-Dec	Estimate	1 x Month	
Flow	Monitor Only	MG	Calendar Month Total	Jan-Dec	Estimate	1 x Month	

SD 005: Unit 1 Turbine Bldg Sump Dschg

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Flow	Monitor Only	mgd	Calendar Month Average	Jan-Dec	Estimate	1 x Month	
Flow	Monitor Only	MG	Calendar Month Total	Jan-Dec	Estimate	1 x Month	
Oil & Grease, Total Recoverable (Hexane Extraction)	10	mg/L	Calendar Month Average	Jan-Dec	Grab	1 x Month	
Oil & Grease, Total Recoverable (Hexane Extraction)	15	mg/L	Daily Maximum	Jan-Dec	Grab	1 x Month	
Solids, Total Suspended (TSS)	30	mg/L	Calendar Month Average	Jan-Dec	Grab	1 x Month	16
Solids, Total Suspended (TSS)	100	mg/L	Daily Maximum	Jan-Dec	Grab	1 x Month	16

SD 006: Unit 2 Turbine Bldg Sump Dschg

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Flow	Monitor Only	mgd	Calendar Month Average	Jan-Dec	Estimate	1 x Month	
Flow	Monitor Only	MG	Calendar Month Total	Jan-Dec	Estimate	1 x Month	
Oil & Grease, Total Recoverable (Hexane Extraction)	10	mg/L	Calendar Month Average	Jan-Dec	Grab	1 x Month	
Oil & Grease, Total Recoverable (Hexane Extraction)	15	mg/L	Daily Maximum	Jan-Dec	Grab	1 x Month	
Solids, Total Suspended (TSS)	30	mg/L	Calendar Month Average	Jan-Dec	Grab	1 x Month	16

The Permittee shall comply with the limits and monitoring requirements as specified below.

SD 006: Unit 2 Turbine Bldg Sump Dschg

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Solids, Total Suspended (TSS)	100	mg/L	Daily Maximum	Jan-Dec	Grab	1 x Month	16

SD 010: Misc Plant Floor Drains Discharge

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Flow	Monitor Only	mgd	Calendar Quarter Average	Jan-Dec	Estimate	1 x Quarter	
Flow	Monitor Only	MG	Calendar Quarter Total	Jan-Dec	Estimate	1 x Quarter	
Oil & Grease, Total Recoverable (Hexane Extraction)	10	mg/L	Calendar Quarter Average	Jan-Dec	Grab	1 x Quarter	
Oil & Grease, Total Recoverable (Hexane Extraction)	15	mg/L	Daily Maximum	Jan-Dec	Grab	1 x Quarter	
Solids, Total Suspended (TSS)	30	mg/L	Calendar Quarter Average	Jan-Dec	Grab	1 x Quarter	16
Solids, Total Suspended (TSS)	100	mg/L	Daily Maximum	Jan-Dec	Grab	1 x Quarter	16

SD 012: Intake Screen Backwash + Fish Retn

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Flow	Monitor Only	mgd	Calendar Month Average	Jan-Dec	Estimate	1 x Month	
Flow	Monitor Only	MG	Calendar Month Total	Jan-Dec	Estimate	1 x Month	3

SW 001: Mississippi River Below Lock & Dam #3

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Temperature Difference Between Sample & Reference Point	5	Deg F	Monthly Average of Daily Maximum	Apr-Oct	Measurement, Continuous	1 x Day	9
Temperature, Water	86	Deg F	Daily Average	Jan-Dec	Measurement, Continuous	1 x Day	8
Temperature, Water	43	Deg F	Daily Average Intervention	Nov-Mar	Measurement, Continuous	1 x Day	5
Temperature, Water	43	Deg F	Daily Average Intervention	Apr-Oct	Measurement, Continuous	1 x Day	10

SW 002: Plant Intake Channel

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Temperature, Water	Monitor Only	Deg F	Single Value	Jan-Dec	Measurement, Continuous	1 x Day	8

The Permittee shall comply with the limits and monitoring requirements as specified below:

SW 003: Main River Channel Upstream Pt.

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Temperature, Water	Monitor Only	Deg F	Single Value	Jan-Dec	Measurement, Continuous	1 x Day	8

SW 004: Sturgeon Lake - Upstream Pt.

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Temperature, Water	Monitor Only	Deg F	Single Value	Jan-Dec	Measurement, Continuous	1 x Day	8

WS 001: Unit 1Cooling Water Discharge

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Flow	Monitor Only	mgd	Calendar Month Average	Jan-Dec	Measurement, Continuous	1 x Day	6
Flow	Monitor Only	MG	Calendar Month Total	Jan-Dec	Measurement, Continuous	1 x Day	6
Oxidants, Total Residual	2.0	mg/L	Daily Maximum	Jan-Dec	Grab	1 x Day	11

WS 002: Unit 2 Cooling Water Discharge

Parameter	Limit	Units	Limit Type	Effective Period	Sample Type	Frequency	Notes
Flow	Monitor Only	mgd	Calendar Month Average	Jan-Dec	Measurement, Continuous	1 x Day	6
Flow	Monitor Only	MG	Calendar Month Total	Jan-Dec	Measurement, Continuous	1 x Day	6
Oxidants, Total Residual	2.0	mg/L	Daily Maximum	Jan-Dec	Grab	1 x Day	11

The Permittee shall comply with the limits and monitoring requirements as specified below.

Notes:
1 -- Determined using flow curve and sluice gate position, see Chapter 9, Part 1.28.
2 -- During intermittent treatment, the discharge of total residual oxidants shall be limited to a total of 2 hours per 24 hour period. The Permittee shall monitor the amount and time of oxidant application and shall report it monthly.
3 -- Large debris collected at the trash racks shall be disposed of so as to prevent it from entering waters of the state
4 -- May exceed this flow limit if needed to keep from exceeding 85 degree F condenser inlet temperature operating limit provided that flow is minimized and cooling towers are operating to the maximum extent possible.
5 -- Once the temperature in the receiving water falls below 43 degrees F for five consecutive days the discharge shall not raise the temperature of the receiving water above 43 degrees for an extended period of time. If the temperature in the river is greater than 43 degrees F for two consecutive days the Permittee shall notify the MPCA. This limits applies until the ambient river temperature increases to 43 degrees F or above for 5 consecutive days or until April 1, whichever occurs first. The Permittee shall submit the daily maximum, daily average, and daily minimum temperature collected at each of the three monitoring probes located on the dividing piers at Lock and Dam No. 3 with the monthly DMR.
6 -- See Chapter 3 for data collection and reporting.
7 -- See Thermal Limitations in Chapter 5.
8 -- See applicable sections in Chapter 2 and 5 for thermal limitations and data collection requirements.
9 -- Starting April 1 the discharge shall not raise the temperature of the receiving water greater than 5 degrees F above the ambient water temperature based on the monthly averages of maximum daily temperatures at the three monitoring probes (reference point) located on the piers dividing Lock and Dam No. 3. This limit applies until such a point when the daily average temperature of the receiving water is less than 43 degrees F for 5 consecutive days.
10 -- Starting April 1 the discharge shall not raise the temperature of the receiving water greater than 5 degrees F above the ambient water temperature. This limit applies until such a point when the daily average temperature of the receiving water is less than 43 degrees F for 5 consecutive days. The Permittee shall submit the daily maximum, daily average, and daily minimum temperature for each of the three monitoring probes located on the dividing piers at Lock and Dam No. 3 with the monthly DMR.
11 -- The Permittee shall monitor SD 001 for total residual oxidant and be subject to the limitations as described in the Limits and Monitoring requirements for SD 001.
12 -- This limit applies from April 15 -30 when the flow in the receiving water is greater than or equal to 15, 000 cfs. May exceed this flow limit if needed to keep from exceeding the 85 degree F condenser inlet temperature operating limit provided that flow is minimized and cooling towers are operating to maximum extent possible.
13 -- This limit applies from April 15 -30 when the flow in the receiving water is less than 15, 000 cfs. May exceed this flow limit if needed to keep from exceeding the 85 degree F condenser inlet temperature operating limit provided that flow is minimized and cooling towers are operating to maximum extent possible.
14 -- This limit applies from June 16 - 30. May exceed this flow limit if needed to keep from exceeding 85 degree F condenser inlet temperature operating limit provided that flow is minimized and cooling towers are operating to the maximum extent possible.
15 -- This limits applies from June 1- 15. May exceed this flow limit if needed to keep from exceeding 85 degree F condenser inlet temperature operating limit provided that flow is minimized and cooling towers are operating to the maximum extent possible.
16 -- Where the background level of natural origin is reasonably definable and normally is higher than the specified limits for total suspended solids (average and maximum), the natural level may be used as the limit.
17 -- pH limit is not subject to averaging and shall be met at all times.

hapter 1. Surface Discharge Stations

1. Sampling Location

1.1 Samples taken in compliance with monitoring requirements specified for surface discharge SD 001 shall be taken at a point representative of the discharge. Samples taken in compliance with monitoring requirements for outfalls 002, 003, 004, 010, and 012 shall be taken at a point representative of the discharge prior to mixing with other waste streams. Samples taken in compliance with monitoring requirements for outfalls 005 and 006 shall be taken at a point representative of the discharge prior to mixing with other waste streams, and samples shall be taken at each outfall.

2. Surface Discharges

2.1 Oil or other substances shall not be discharged in amounts that create a visible color film.

2.2 There shall be no discharge of floating solids or visible foam, except that which occurs naturally in the river, in other than trace amounts.

2.3 The Permittee shall install and maintain outlet protection measures at the discharge stations to prevent erosion if necessary.

3. Discharge Monitoring Reports

3.1 The Permittee shall submit monitoring results for discharges in accordance with the limits and monitoring requirements for this station. If no discharge occurred during the reporting period, the Permittee shall check the "No Discharge" box on the Discharge Monitoring Report (DMR).

equirements for Specific Stations

4.1 SD 001: Submit a monthly DMR monthly by 21 days after the end of each calendar month following permit issuance.

4.2 SD 002: Submit a monthly DMR monthly by 21 days after the end of each calendar month following permit issuance.

4.3 SD 003: Submit a monthly DMR monthly by 21 days after the end of each calendar month following permit issuance.

4.4 SD 004: Submit a monthly DMR monthly by 21 days after the end of each calendar month following permit issuance.

4.5 SD 005: Submit a monthly DMR monthly by 21 days after the end of each calendar month following permit issuance.

4.6 SD 006: Submit a monthly DMR monthly by 21 days after the end of each calendar month following permit issuance.

4.7 SD 010: Submit a quarterly DMR quarterly by 21 days after the end of each calendar quarter following permit issuance.

4.8 SD 012: Submit a monthly DMR monthly by 21 days after the end of each calendar month following permit issuance.

5. Special Requirements

Discharge Operations

Chapter 1. Surface Discharge Stations

5. Special Requirements

5.1 The plant cooling water discharge flows in million gallons per day (mgd) shall be limited as follows during the specified periods:

April 15 - 30:	194 mgd if the flow in the river is at or above 15,000 cfs
	97 mgd if the flow in the river is below 15,000 cfs
May 1 - 31:	194 mgd
June 1 -15:	259 mgd
June 16-30:	517.5 mgd

5.2 The plant may discharge water at SD 001 at higher flow rates during the specified period if needed to prevent condenser inlet temperatures from exceeding 85 degree F provided that such higher flows are minimized to the extent practical, and all cooling towers are opearted to the maximum practical extent.

316(b) Demonstration
Source Water Physical Data, Cooling Water Intake Structure Data, Cooling Water System Data

5.3 The Permittee shall submit the source water physical data, cooling water intake structure data, and cooling water system data in accordance with the NPDES Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities, published July 9, 2004 in the Federal Register pursuant to 316(b) of the Clean Water Act, 40CFR Parts 9, 122, 123, 124, and 125.

The data shall be submitted by October 28, 2006.

316(b) Proposal for Information Collection and Comprehensive Demonstration Study Requirements

5.4 The Permittee has tentatively selected Compliance Alternative (2) of 40CFR 125.94 (a) to meet the impingement and entrainment reduction requirements. Alternative (2) requires that the Permittee demonstrate that existing design and construction technologies, operational measures, and/or restoration measures meet the impingement mortality and entrainment performance standards.

5.5 The Permittee shall submit a Proposal for Information Collection in accordance with the NPDES Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities by October 28, 2006.

5.6 The Permittee shall submit a comprehensive demonstration (CDS) study in accordance with 316(b) of the Clean Water Act, 40CFR Parts 9, 122, 123, 124, and 125. The 316(b) demonstration study elements, further described below, shall be implemented to assure that the location, design, construction, and capacity of the cooling water intake structure at the plant reflect the best technology available (BTA) for minimizing adverse environmental impact.

The 316(b) CDS shall demonstrate that the implementation and/or operation of technology and operational measures will reduce cooling water intake impingement mortality of all life stages of fish and shellfish by 80 to 95 and percent and will reduce entrainement by 60 to 90 percent from the baseline calculation, based on the 316(b) performance requirements for a freshwater river.

The Permittee shall submit the CDS by October 28, 2006.

316(b) Demonstration Impingement Mortality and Entrainment (IM&E) Characterization Study (baseline development)

hapter 1. Surface Discharge Stations

5. Special Requirements

5.7 The Permittee shall submit the results of an Implingement Mortality and Entrainment Characterization Study (IM&E Study). The study shall provide information to support the development of a calculation baseline for evaluating impingement mortality and entrainment consistent with the 316(b) rule. The Permittee may update the study upon request to, and approval by, the MPCA.

All field sampling shall be conducted under present normal plant operating conditions, screen rotation, and plant flows. Documentation shall be maintained of plant operations during sampling. All species impinged shall be identified, with weight and length measurements taken to the extent feasible. Data from historical studies may be included in the calculation of baseline impingement and entrainment if deemed relevant and appropriate.

5.8 The IM&E Study shall include the following in accordance with the 316(b) requirements:

a. Taxonomic identifications of all life stages of fish, shellfish, and any species protected under Federal, State, or Tribal Law (including threatened or endangered species) that are in the vicinity of the cooling water intake structure and are susceptible of impingement and entrainment.

b. A characterization of all life stages of fish, shellfish, and any species protected under Federal, State, and Tribal Law (including threatened or endangered species) identified pursuant to paragraph a. above, including a description of the abundance and temporal and spatial characteristics in the vicinity of the cooling water intake structure(s), based on sufficient data to characterize annual, seasonal, and diel variations in impingement mortality and entrainment (e.g. related to climate and weather differences, spawning, feeding, and water column migration). These may include historical data that are representative of the current operation and biological conditions at the site.

c. Documentation of the current impingement mortality of all life stages of fish, shellfish, and any species protected under Federal, State, or Tribal Law (including threatened or endangered species) identified pursuant to paragraph a. above and an estimate of impingement mortality and entrainment to be used as a baseline.

5.9 The Permittee shall submit the results of the IM&E study, by October 28, 2006. The submittal shall describe the calculated baseline for impingement mortality and entrainment and verify the calculated baseline based on the total acquired impingement and entrainment data.

316(b) Demonstration
Design and Construction Technology Plan

5.10 The Permittee shall submit a Design and Construction Technology Plan (DCT Plan) to the MPCA for review and approval. The DCT Plan shall describe the technologies and/or operational measures in place and/or selected to meet the impingement and entrainment performance requirements in the 316(b) Rule, 125.94.

5.11 The DCT Plan shall include the following information in accordance with 316(b) Rule requirements:

a. A narrative description of the design and operation of all design and construction technologies and/or operational measures (existing and proposed), including fish handling and return systems, that are in place or will be used to meet the requirements to reduce impingement mortality and entrainment of those species expected to be most susceptible, and information that demonstrates the efficacy of the technologies and/or operational measures for those species. A complete narative description is contained in the NPDES permit application.

b. Calculations of the reduction in impingement mortality and entrainment of all life stages of fish and shellfish that would be achieved by the technologies and/or operational measures selected, based on the IM&E study. The total reduction in mortality must be assessed against the calculation baseline.

c. Design and engineering drawings, and calculation results and descriptions, prepared by a qualified professional to support the descriptions required by paragraph a. above.

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5. Special Requirements

5.12 The DCT Plan shall be submitted to the MPCA for review and approval by October 28, 2006.

316(b) Demonstration
Technology Installation and Operation Plan

5.13 A Technology Installation and Operation Plan (TIO Plan) shall be submiited for MPCA review and approval. The TIO Plan shall includes the following in accordance with 316(b) Rule requirements:

a. A schedule for the maintenance of any new design and construction technologies. The technology installation shall be reasonably scheduled to ensure that impacts to energy reliability and supply are minimized.

b. List of operational and other parameters to be monitored, and the locations and frequency for monitoring.

c. List of activities to be undertaken to ensure to the degree practicable the efficacy of installed design and construction technologies and operational measures, and the schedule for implementation.

d. A schedule and methodology for assessing the efficacy of any installed design and construction technologies and operational measures in meeting applicable performance standards or site specific requirements, including an adaptive management plan for revising design and construction technologies, operational measures, operation and maintenance requirements, and/or monitoring requirements if the assessment indicates that applicable performance standards (impingement mortality and entrianment reductions) are not being met.

5.14 The TIO Plan shall be submitted to the MPCA for review and approval by October 28, 2006. The Permittee shall meet the terms of the TIO Plan in accordance with MPCA approval of the TIO Plan, including any revisions to the adaptive management plan component of the TIO Plan that may be necessary should applicable performance standards (impingement mortality and entrainment reductions) not be met.

316(b) Demonstration
Verification Monitoring Plan

5.15 The Permittee shall submit a Verification Monitoring Plan (VM Plan) to the MPCA for review and approval. The VM Plan shall describe the monitoring to be conducted over a period of 2 years designed to verify that the full-scale performance of the proposed or already implemented technologies and/or operational measures are successful in meeting the performance standards (applicable impingement mortality and entrainment reductions). The VM Plan shall provide the following:

a. Description of the frequency and duration of monitoring, the parameters to be monitored, and the basis for determining the parameters and the frequency and duration of monitoring. The parameters selected and duration and frequency of monitoring shall be consistent with any methodology for assessing success in meeting applicable performance standards in the TIO Plan. The method for assessment of success shall be specified including the averaging period for determining the percent reduction in impingement mortality.

b. A proposal on how naturally moribound fish and shellfish that enter the cooling water intake structure would be identified and taken into account in assessing success in meeting the performance standard.

c. A description of the information to be included in a subsequent biennial status report to the MPCA.

5.16 The VM Plan shall be submitted to the MPCA by October 28, 2006.

Chapter 1. Surface Discharge Stations

5. Special Requirements

5.17 Verfication monitoring in accordance with the VM Plan shall be conducted for a period of 2 years to demonstrate whether the design and construction technology and/or operational measures meet the applicable performance standard (impingement mortality and entrainment reduction). A final report on verification monitoring shall be submitted to the MPCA within 120 days of completion of verification monitoring. The MPCA may approve a change to the plan at any time. The plan elements and procedures shall be followed as described in the latest approved version of the plan. The Permittee may make changes to the studies and plan upon request to, and approval by, the MPCA.

316(b) Demonstration
Records

5.18 The Permittee shall maintain records of significant data used to develop the IEM, TIO Plan, VM Plan; records regarding compliance with the requirements of the 316(b) Rule; and any compliance monitoring data for a period of at least 5 years from permit issuance.

316(b) Demonstration
Biennial Status Report

5.19 The Permittee shall submit a biennial status report beginning July 1, 2011 to the MPCA. The biennial status report shall summarize monitoring data and other information relevant to performance of the installed technology and/or operation measures. Other information shall include summaries of significant operation and maintenance records and summaries of adaptive management activities, or other information relevant to determining compliance with the facility's TIO Plan.

Chapter 2. Surface Water Stations

1. Sampling Location

1.1 Temperature monitoring for SW Station 001 shall be taken by 3 separate probes located immediately downstream of Lock and Dam No. 3 on three piers dividing the four gated sections of the dam. Individual temperature (maximum, average, and minimum) data from each probe shall be collected and submitted. Compliance with the 5 degree F maximum allowable increase at SW 001 shall be based on the monthly average of the daily maximum temperature at the three probes. Temperature monitoring for SW Station 002 shall be taken at a point in the intake channel representative of river water temperature unaffected by the plant thermal discharge. Temperature monitoring for SW Station 003 shall be taken in the main river channel at a point unaffected by the plant thermal discharge. Temperature monitoring for SW Station 004 shall be taken in Sturgeon Lake at one or more points unaffected by the plant for thermal discharge.

2. Discharge Monitoring Reports

2.1 The Permittee shall submit monitoring results in accordance with the limits and monitoring requirements for this station. If flow conditions are such that no sample could be acquired, the Permittee shall check the "No Flow" box and note the conditions on the Discharge Monitoring Report (DMR).

2.2 For parameters required to be monitored continuously, portions of the monitoring data will occasionally be lost when equipment is out of service for repairs or while performing routine instrument calibrations and maintenance. In such cases, loss of one hour or less of data in a calendar day need not be reported unless the Permittee has reason to believe that resulting values reported on the DMR are not representative of actual conditions.

3. Requirements for Specific Stations

3.1 SW 001: Submit a monthly DMR monthly by 21 days after the end of each calendar month following permit issuance.

Chapter 2. Surface Water Stations

3. Requirements for Specific Stations

3.2 SW 002: Submit a monthly DMR monthly by 21 days after the end of each calendar month following permit issuance.

3.3 SW 003: Submit a monthly DMR monthly by 21 days after the end of each calendar month following permit issuance.

3.4 SW 004: Submit a monthly DMR monthly by 21 days after the end of each calendar month following permit issuance.

4. Special Requirements

Exceedance of Permit Thermal Limitations Under Energy Emergencies

4.1 The thermal limitations of this permit may be exceeded for a limited period under extreme conditions of electrical energy emergencies. Exceedance of the thermal limitations may occur only during electrical energy emergencies. For purposes of this permit an "electrical energy emergency" is defined as the time period when Northern States Power Company's, d/b/a Xcel Energy (Permittee or Xcel Energy), generating system is in System Conditioning Operating Code Red, or when in System Code Orange (danger) if degradation to Code Red appears likely absent corrective action.

4.2 System Code Red (emergency) occurs when the energy supply is subject to, but not limited to, partial power interruptions, curtailment of energy supply to controlled customers and peak controlled customers, power interruption to commercial customers, and reduction of peak voltage. It represents a situation where all electrical reserves have been exhausted, the electrical grid is unstable, and electrical demand has exceeded electrical supply. Code Red is also commonly referred to as a "brown-out". A Code Red may also lead to interruption to retail customers and power interruption, commonly referred to as a rotating "black-out".

System Code Orange (danger) occurs when the entire electrical system is vulnerable to instability due a single failure, such as a potential transmission fault, loss of a generating unit, or other technical failure. It represents a situation where electric power demand is currently being met but utility equipment is being operated at or near maximum dependable capacity and remaining energy reserves are extremely low or non existent. Under Code Orange energy controlled customers and energy peak customers are being curtailed, external energy is unavailable, and loss of an Xcel electrical generating unit or external purchase would result in Xcel being unable to meet required NERC (North American Electric Reliability Council) operating requirements.

4.3 Thermal limitation exceedances may occur only under the following conditions:

1. Thermal limitation exceedances will only be considered under an electrical energy emergency. Xcel Energy shall base decisions regarding thermal limitation exceedances on engineering and operational measures necessary to maintain stable regional energy supplies and protect critical generation and transmission equipment. Xcel Energy shall take all reasonable corrective actions available to avoid thermal limitation exceedances.

2. Thermal limitation exceedances are allowable only after Xcel Energy has exhausted all other reasonable alternatives or determined them to be inadequate. These alternatives include, but are not limited to, use of all available Xcel Energy power generation including Xcel Energy oil burning facilities and reserves, energy purchases, demand side management measures, curtailment of non-essential auxiliary load, and public appeals for voluntary energy conservation measures. Energy costs, either incurred at Xcel Energy generating facilities or through energy purchased, shall not be a factor in exhausting these alternatives.

3. Xcel Energy shall restore operations to return to compliance with permit thermal limitations as soon as possible upon termination of the electrical energy emergency, that is, upon return to a stable system Code Orange (danger) or better system code. The duration of thermal limitation exceedances shall be minimized.

hapter 2. Surface Water Stations

4. Special Requirements

4.4

4. Xcel Energy shall limit the severity of thermal limitation exceedances to the extent possible. Xcel Energy shall maintain any existing cooling tower systems and other cooling systems used to remove heat from cooling water to be discharged, so that these cooling systems are completely available during energy emergencies.

5. Xcel Energy shall attempt to notify the MPCA in advance of its intent to exercise this provision to exceed the permit thermal limitations under an electrical energy emergency. If Xcel Energy is unable to provide advance notification, due to sudden problems caused by storms, unplanned loss of critical generation or transmission, or similar circumstances causing conditions to rapidly deteriorate, Xcel Energy shall notify MPCA staff as soon as possible after the initial response actions are completed. If the event occurs after normal business hours or a weekend Xcel Energy shall notify the State Duty Officer and provide follow up notification to MPCA the next business day.

6. Xcel Energy shall institute monitoring for any environmental impacts during exceedances of the thermal limitations. Specifically Xcel Energy shall institute periodic biological observations of the zone of influence of the thermal discharge on the receiving water and any plant discharge canal, to monitor for signs of dead or distressed fish and other aquatic life. Any dead or distressed fish observed shall be tabulated and recorded by Xcel Energy staff and reported within one day, or the next business day if on a weekend, to the MPCA and the Minnesota Department of Natural Resources (MDNR).
Xcel Energy shall submit a monitoring plan for biological observations during electrical energy emergencies, within 30 days after issuance of this permit.

4.5

7. Xcel Energy shall comply with the Minnesota Department of Natural Resources (MDNR) requirements concerning any costs or charges levied by the MDNR for fish or other aquatic organisms lost due to any thermal limitation exceedances.

8. Unless otherwise specified by the MPCA, during an electrical energy emergency Xcel Energy shall provide a daily summary of the status of plant operations, the nature and extent of any permit deviations or exceedances of the thermal limitations, any mitigating actions being taken, and any observed environmental impacts. The daily summaries shall be provided by telephone and e-mail message to the MPCA during business days. Daily summaries during the weekend shall be provided by e-mail message.

Chapter 2. Surface Water Stations

4. Special Requirements

4.6

9. Xcel Energy shall provide a written summary of any thermal limitation exceedances pursuant to an electrical energy emergency within 30 days of termination of the energy emergency. The summary shall address at a minimum:

a. The specific cause of the electrical energy emergency and information describing the conditions leading to the energy emergency which may include, but are not limited to, weather conditions and power demands.

b. The system code that Xcel Energy was operating under and all steps that Xcel took to lower energy demand and/or increase energy output in order to prevent a thermal limitation exceedance. These steps include, but are not limited to, items such as operation of peaking and oil burning plants, internal load reduction measures, energy purchases, public appeals for voluntary energy reduction, implementation of curtailment of service to interruptible customers, power interruption to commercial customers, etc.

c. A statement confirming that the electrical energy emergency leading to exceedances of thermal limitations was unintentional and that there was no known, viable engineering alternative for deviation from the plantt s permitted thermal limitations. A similar statement confirming that the electrical energy emergency leading to exceedances of thermal limitations resulted from factors beyond Xcel Energy's control and did not result from operator error, improperly designed facilities, lack of preventative maintenance, or increases in production beyond the design capacity of the treatment facility (cooling equipment).

4.7

d. A written summary of the technical aspects of the facility that are involved with cooling and maintaining compliance with thermal limitations.

e. Information on any alternatives to a thermal limitation exceedance and impacts that would likely have occurred if power generation was reduced in order to avoid a thermal limitation exceedance. Such impacts may include public health and safety, public security issues, damage to generating plants, disruption of commercial and industrial processes, and related potential impacts.

f. If it is determined that the thermal limitation exceedance was the result of inadequate design, operations or maintenance, the actions Xcel Energy will take to avoid a future thermal limitation exceedance.

apter 2. Surface Water Stations

4. Special Requirements

4.8 This provision is meant to provide for limited and infrequent short-term exceedances of the permit thermal limitations solely under extreme and relatively unique circumstances (such as an unusual heat wave). This provision does not preclude the MPCA from subsequently requiring Xcel Energy to resolve any recurring thermal limitation exceedances through installation of additional cooling equipment, or other measures to remove excess heat, in the event that thermal exceedances become relatively frequent or are the result of inadequate design under normal (non-emergency) conditions.

This provision does not preclude the MPCA from taking any enforcement action pursuant to thermal limitation exceedances if the above conditions are not followed.

Chapter 3. Waste Stream Stations

1. Sampling Location

1.1 Samples for Station WS 001 and WS 002 shall be taken at each internal wastestream, units 1 and 2, cooling water discharge or at another point representative of the discharge prior to mixing with circulating water or any other waters.

1.2 The Permittee shall submit monitoring results for discharges in accordance with the limits and monitoring requirements for this station. If no discharge occurred during the reporting period, the Permittee shall check the "No Discharge" box on the Discharge Monitoring Report (DMR).

1.3 For parameters required to be monitored continuously, portions of the monitoring data will occasionally be lost when equipment is out of service for repairs or while performing routine instrument calibrations and maintenance. In such cases, loss of one hour or less of data in a calendar day need not be reported unless the Permittee has reason to believe that resulting values reported on the DMR are not representative of actual conditions.

2. Requirements for Specific Stations

2.1 WS 001: Submit a monthly DMR monthly by 21 days after the end of each calendar month following permit issuance.

2.2 WS 002: Submit a monthly DMR monthly by 21 days after the end of each calendar month following permit issuance.

3. Special Requirements

3.1 If the need arises to raise the halogen level above 2.0 mg/l for WS 001 and WS 002, units 1 and 2 plant cooling water, a calculation shall be performed using the actual condenser/circulating water and cooling water flow halogen demand determined at that time. This information shall be submitted with the other monitoring data required in the monthly DMR.

3.2 A calculation shall be performed using the actual cooling water flow rate, condenser/circulating water flow rate and the halogen demand of 0.5 mg/l. The calculation consists of the ratio of total cooling water flow rate to the condenser/circulating water flow rate multiplied by the highest measured cooling water halogen level, minus the condenser/circulating water demand (0.5 ppm). The value should be a negative value showing that all the halogen was used prior to discharge to the river.

Chapter 4. Industrial Process Wastewater

1. Prohibited Discharges

1.1 The Permittee shall prevent the routing of pollutants from the facility to a municipal wastewater treatment system in any manner unless authorized by the pretreatment standards of the MPCA and the municipal authority.

1.2 The Permittee shall not transport pollutants to a municipal wastewater treatment system that will interfere with the operation of the treatment system or cause pass-through violations of effluent limits or water quality standards.

1.3 This permit does not authorize the discharge of sewage, wash water, scrubber water, spills, oil, hazardous substances, or equipment/vehicle cleaning and maintenance wastewaters to ditches, wetlands or other surface waters of the state except as permitted in the NPDES permit, for site treatment systems.

2. Hydrotest Discharges

2.1 The Permittee shall notify the MPCA prior to discharging hydrostatic test waters. The Permittee shall provide information necessary to evaluate the potential impact of this discharge and to ensure compliance with this permit. This information shall include:

a. the proposed discharge dates;

b. the name and location of receiving waters, including city or township, county, and township/range location;

c. an evaluation of the impact of the discharge on the receiving waters in relation to the water quality standards;

d. a map identifying discharge location(s) and monitoring point(s);

e. the estimated average and maximum discharge rates;

f. the estimated total flow volume of discharge;

g. the water supply for the test water, with a copy of the appropriate Minnesota Department of Natural Resources (DNR) water appropriation permit;

h. water quality data for the water supply;

i. proposed treatment method(s) before discharge; and

j. methods to be used to prevent scouring and erosion due to the discharge.

2.2 The above notificaiton procedure does not apply to routine hydrostatic tests of plant equipment provided all of the following conditions are met:

a. The test is conducted using the equipment's normal process water.

b. The hydrostatic discharge is through the designated outfall for that equipment when in normal operation (as identified in this permit).

c. The water meets all applicable discharge criteria for that outfall, including volume and rate.

d. There are no residual chemicals or contaminants present of a type or at levels beyone those already reviewed and approved as acceptable by the MPCA staff for that outfall.

3. Polychlorinated Biphenyls (PCBs)

3.1 PCBs, including but not limited to those used in electrical transformers and capacitors, shall not be discharged or released to the environment.

apter 4. Industrial Process Wastewater

4. Application for Permit Reissuance

4.1 The permit application shall include priority pollutant analytical data as part of the application for reissuance of this permit. These analyses shall be done on individual samples taken during the two year period before the reissuance application is submitted.

Chapter 5. Dredged Material Management

1. Authorization

1.1 This permit is intended to regulate the storage, disposal and/or reuse of dredged material.

1.2 This permit authorizes the Permittee to store, dispose, and/or reuse dredged material in accordance with the provisions of this permit.

1.3 This permit does not authorize or otherwise regulate dredging activity. However, dredging activity is subject to the water quality standards specified in Minnesota Rules chs. 7050 and 7060.

Initiation of dredge activities shall not commence until the Permittee has obtained all federal, state and/or local approvals that may be required for a particular project, including but not limited to state permits regulating activities in the bed of public waters as defined in Minn. Stat. sec. 105 from the Minnesota Department of Natural Resources (DNR), federal permits for dredged or fill material from the U.S. Army Corps of Engineers, and local permits from the appropriate Soil and Water Conservation District, county or local unit of government (LUG).

1.4 Compliance with the terms and conditions of this permit releases the Permittee from the requirement to obtain a separate permit for construction and/or industrial activities at the storage, disposal and/or reuse site that would otherwise require the Permittee to obtain a construction and/or industrial storm water permit in accordance with the Clean Water Act and Agency rules, except where the use or reuse of dredged material is occurring at a location separate from other activity covered by this permit.

2. Sampling and Analyses

2.1 Characterization of sediment from the proposed dredge site must be completed prior to the initiation of dredging activity. Results of sediment characterization must be compiled and submitted to the MPCA prior to the start of dredging. Characterization shall consist of at least a grain size analysis and, if applicable, baseline and additional sediment analysis per Tables 3 and 4 of Appendix 1.

2.2 Grain Size Analysis

The Permittee shall complete a sieve grain size analysis using ASTM Method C-136 for the gradation analysis and ASTM Method D-2487 for classification. The minimum number of samples required for the analysis shall be determined using table 1 in Appendix 1. If the sieve analysis obtained is greater than 95 percent sands then the material is acceptable for Tier 1 or 2 use and additional analytical sampling is not required.

2.3 Baseline Sediment Analysis

Dredged material not excluded from additional analysis (as determined by the grain size analysis), must be analyzed for the constituents listed in Table 2 of Appendix 1.

2.4 Additional Analysis

If it is established through a review of past activities at the site that there is a reasonable likelihood for a pollutant to be present in sediment at a dredge site, the dredged material must be analyzed for additional analyte(s) in accordance with Table 3 and Table 4 in Appendix 1.

Chapter 5. Dredged Material Management

3. Rehandling, Off-Loading and Transportation of Dredged Material

3.1 Dredged materials shall be managed in a manner so as to minimize the amount of material returned by spillage, erosion or other discharge to waters of the state during rehandling, off-loading and/or transportation activities.

3.2 Areas for the rehandling and/or off-loading of dredged material shall be sloped away from surface water or otherwise controlled.

3.3 Dredged material hauled on federal, state, or local highways, roads, or streets must be hauled in such a way as to prevent dredged material from leaking, spilling, or otherwise being deposited in the right-of-way. Dredged material deposited on a public roadway must be immediately removed and properly disposed.

3.4 Tracked soil and/or dredged material shall be removed from impervious surfaces that do not drain back to the dredged material storage, disposal and/or reuse facility within 24 hours of discovery, and placed in the storage, disposal and/or reuse facility site.

4. Storage, Disposal and/or Reuse of Dredged Material

4.1 Authorization. Prior to the use of a new (different from already disclosed) site for the storage, disposal, and/or reuse of dredged material, the Permittee shall obtain written MPCA approval for such use.

4.2 General. Any site used for the storage, disposal and/or reuse of a dredged material shall be operated and maintained by the Permittee to control runoff, including stormwater, from the facility to prevent the exceedance of water quality standards specified in Minnesota Rules, chs. 7050 and 7060.

4.3 The Permittee may dispose of dredged material at a permitted solid waste landfill, through on-site disposal, or through reuse for a beneficial purpose, as follows:
a. Temporary storage and/or treatment of dredged material at the dredge project site. Temporary storage of dredged material is subject to the requirements of part 3.4 of this chapter.
b. Disposal of dredged material at the dredge project site. Disposal of dredged material is subject to parts 3.5 through 3.36 of this chapter.
c. Reuse of dredged material for beneficial purposes. Reuse of dredged material is subject to parts 3.37 through 3.39 of this chapter.

A. Temporary Storage and/or Treatment of Dredged Material

4.4 All of the following requirements apply to the temporary storage and/or treatment of dredged material:
a. Temporary storage shall not exceed 1 year. Storage or accumulation of dredged material for more than 1 year constitutes disposal, and is subject to the disposal facility requirements of parts 3.5 through 3.36 of this chapter.
b. Dredged materials shall be managed in a manner so as to minimize the amount of material returned by spillage, erosion or other discharge to waters of the state. Best management practices for the management of dredged materials are outlined in the MPCA fact sheet, "Best Management Practices for the Management of Dredged Material".
c. If dikes, berms or silt fences have been constructed to contain temporary stockpiles of dredged material, they shall not be removed until all material has been removed from the stockpile.

B. Disposal of Dredged Material

4.5 Notification. Notification of a new or existing dredge disposal facility shall be submitted for MPCA review and approval.

4.6 Disposal facilities shall be constructed/operated in accordance with local requirements, including the requirement to obtain a permit, license, or other governmental approval to initiate construction.

apter 5. Dredged Material Management

4. Storage, Disposal and/or Reuse of Dredged Material

4.7 Initial Site Plan. An initial site plan shall be prepared and submitted for MPCA review and approval. The initial site plan shall consist of volume calculations for the final permitted capacity and a map of the facility. The map of the facility shall include the permitted boundaries, dimensions, site contours (at contour intervals of two feet or less), soil boring locations with surface elevations and present and planned pertinent features, including but not limited to roads, screening, buffer zone, fencing, gate, shelter and equipment buildings, and surface water diversion and drainage. The initial site plan must be signed by a land surveyor registered in Minnesota or a professional engineer registered in Minnesota.

4.8 Delineation and Identification of Permitted Waste Boundary. The perimeter or outer limit of a dredged material disposal facility shall be indicated by permanent posts or signage. In addition, a permanent sign, identifying the operation and showing the permit number of the site, shall be posted at the dredged material disposal facility.

Site Selection and Use

4.9 Locational Prohibitions. All of the following locational standards apply to any facility for the disposal of dredged material:
a. The disposal facility must be located entirely above the high water table.
b. The disposal facility must not be located within a shoreland or wild and scenic river land use district governed by Minn. R. chapters 6105 and 6120.
c. The disposal facility must not be located within a wetland, unless the Permittee has obtained all federal, state and/or local approvals that may be required for a particular project.
d. The disposal area shall not be located in an area which is unsuitable because of topography, geology, hydrology, or soils.

4.10 Separation Distances. A minimum separation distance of 50 feet must be maintained between the boundaries of the disposal facility and the site property line.

Design Requirements

4.11 The following design standards apply to a facility used for the disposal of dredged materials:
a. An earthen containment dike, or other MPCA approved embankment and/or other sediment control measure(s), shall be established around the perimeter of the dredged material disposal facility (permitted waste boundary).
b. Site preparation shall allow for orderly development of the site. Initial site preparations shall include clearing and grubbing, topsoil stripping and stockpiling, fill excavation, if appropriate, drainage control structures, and other design features necessary to construct and operate the facility.
c. Surface water runoff shall be diverted around dredged materials disposal facilities to prevent erosion, and protect the structural integrity of exterior embankments from failure.
d. Slopes and drainageways shall be designed to prevent erosion. Slopes longer than 200 feet shall be interrupted with drainageways.
e. Final slopes for the fill area shall be a minimum two percent and a maximum 20 percent, and shall be consistent with the planned ultimate use for the site.
g. Final cover shall consist of at least 18 inches of soil with the top 12 inches capable of sustaining vegetative growth.
h. For a system that will impound water (e.g. hydraulic dredging) with a constructed dike over 6 feet in height, or that impound more than 15 acre-feet of water, the system is subject to Minn. R. parts 6115.0300 through 6115.0520 [state Dam Safety Program]. Contact state Dam Safety Program staff at (651) 296-0521 for more information.

Chapter 5. Dredged Material Management

4. Storage, Disposal and/or Reuse of Dredged Material

4.12 Site Stabilization. The Permittee shall stabilize the dredged material disposal facility before any disposal in the facility is allowed, as follows:
a. The exterior slope of all permanent dikes or berms shall be no steeper than 3 to 1 (horizontal to vertical). The exterior slopes of all permanent dikes or berms must be seeded and a soil fixative (e.g. mulch, blanket) applied within 72 hours of the completion of any grading work on the slopes.
b. If grading work is completed too late in the growing season to seed or plant the desired species, then the Permittee must propagate an annual cover crop that can be dormant seeded or planted and must apply a soil fixative to the site. At the very minimum, the Permittee must apply a soil fixative to the exterior slopes of all permanent dikes or berms prior to the first snowfall.
c. Silt fences, if used, must be properly installed. The silt fences shall be tall enough and installed at a sufficient distance from the base of the permanent dikes/berms or temporary stockpiles to create a reasonable secondary containment area.

4.13 Operational Plan. An Operational Plan of the site and immediately adjacent area shall be developed and implemented, and shall show progressive development of trench and/or area fills and any phase construction. The scale of the development plan shall not be greater than 200 feet per inch.

4.14 Facilities for the disposal of dredged material shall be designed by a professional engineer registered in the state of Minnesota, and in accordance with the criteria in parts 3.13 and 3.14 of this chapter. The Permittee shall construct the facility in accordance with these design plans and specifications under the direct supervision of a professional engineer registered in the state of Minnesota.

4.15 Certification Required. Prior to use of a facility for the disposal of dredged material under this part, the Permittee shall obtain and submit written certification from an engineer licensed in Minnesota stating that the disposal facility meets the requirements of parts 3.13 and 3.14 of this chapter, and has been constructed in accordance with the design plans and specifications.

Site Management, Limitations, and Restrictions

4.16 New or Expanded Facilities. All of the following requirements apply to the construction of new or expanded facilities used for the disposal of dredged material:
a. The Permittee shall plan for and implement construction practices that minimize erosion and maintain dike integrity.
b. Erosion control measures shall be established on all downgradient perimeters prior to the initiation of any upgradient land-disturbing construction activities.
c. Surface runoff must be directed around and away from the storage and/or disposal facility site, until the site is stabilized, usually by assuring that vegetative cover is well-established.
d. Sediment control practices shall be designed and implemented to minimize sediment from entering surface waters. The timing of the installation of sediment control practices may be adjusted to accommodate short-term activities such as equipment access. Any short-term activity must be completed as quickly as possible and the sediment control practices must be installed immediately after the activity is completed. However, sediment control practices must be installed before the next precipitation event even if the activity is not complete.
e. All erosion and sediment control measures shall remain in place until final stabilization has been established. Permanent cover or final stabilization methods are used to prevent erosion, such as the placement of rip rap, sodding, or permanent seeding or planting. Permanent seeding and planting must have a uniform perennial vegetation cover of at least 70 percent density to constitute final stabilization.

apter 5. Dredged Material Management

4. Storage, Disposal and/or Reuse of Dredged Material

4.17 Management of Disposal Facilities. The following standards apply to a facility used for the disposal of dredged material:

a. Each fill phase shall be outlined with grade stakes, and staked for proper grading and filling.
b. All trenches or fill areas shall be staked with permanent markers.
c. A permanent benchmark shall be installed on-site and show its location on the facility as-built plan.
d. Run-on and run-off of stormwater shall be controlled. The owner or operator must implement management practices designed to control run-on and run-off of stormwater from the disposal facility.
e. Vegetative cover shall be established within 120 days of reaching the final permitted capacity of the dredged material disposal facility, or within 120 days of the inactivation or completion of a phase of the facility thereof.
f. If the disposal facility contains any particulate matter that may be subject to wind dispersion, the owner or operator shall cover or otherwise manage the dredged material to control wind dispersion.
g. Nuisance conditions resulting from the disposal of dredged material shall be controlled and managed by the facility owner or operator.
h. Cover slopes shall be surveyed and staked during placement.

Inspection and Maintenance

4.18 Periodic Site Inspections. The Permittee shall inspect the disposal facility to ensure integrity of the erosion control measures, system stability and dredged material containment. At a minimum, the facility shall be inspected:

a. prior to the initial placement of any dredged material in the facility; and,
b. within 24 hours of each significant storm event and/or the subsidence of flood events; or,
c. at least once per month if a and/or b, above, are not occurring.

Inspections may be less frequent once a project is complete assuming all material has been transported to an off-site permitted facility or reused in accordance with this permit and is vegetated.

4.19 Recordkeeping. The Permittee shall record the date of each inspection, any problem identified with the facility, and the action(s) taken to correct any identified problem. The Permittee shall keep these inspection records on site and available to MPCA staff upon request.

4.20 Nonfunctioning erosion and sediment control measures shall be repaired, replaced or supplemented with functioning erosion and/or sediment control measures within three days of discovery.

4.21 Dikes and berms constructed to contain hydraulically dredged material and the attendant liquid must be maintained free of all types of animal burrows. Animal burrows should be backfilled with compacted material within three days of discovery.

4.22 Where dredging and disposal have been suspended due to frozen ground conditions, the inspections and maintenance shall begin as soon as weather conditions warrant, or prior to resuming dredged material placement in the disposal facility, whichever occurs first.

Sediment Removal and Disposal

4.23 Dredged material shall be removed from disposal facilities in a manner so as to not damage the integrity and effectiveness of the containment structure or area.

4.24 Dredged material removed from a storage, disposal, and/or reuse facility shall be managed in accordance with this chapter.

4.25 Recordkeeping. The Permittee shall record the dates, the volume of dredged material removed from the disposal facility, and the method and location of the disposition (disposal or reuse) of such materials. This information shall be submitted with the annual 'Dredged Material Report', as specified in the 'Annual Report' part of this chapter.

Closure and Post-Closure Requirements

Chapter 5. Dredged Material Management

4. Storage, Disposal and/or Reuse of Dredged Material

4.26 The Permittee must cease to dispose of dredged materials and immediately close the dredged material disposal facility when:
a. the Permittee declares the dredged material disposal facility closed;
b. all fill areas reach final permitted capacity;
c. an agency permit held by the facility expires, and renewal of the permit is not applied for, or is applied for and denied;
d. an agency permit for the facility is revoked; and/or,
e. an agency order to cease operations is issued.

4.27 Closure Plan. The Permittee shall prepare and submit a 'Closure Plan' for the final closure of a dredged material disposal facility for MPCA review and approval.

4.28 The 'Closure Plan' shall identify the steps needed to close the entire site at the end of its operating life. The closure plan shall include the following elements:
a. A description of how and when the entire facility will be closed. The description shall include the estimated year of closure and a schedule for completing each fill phase.
b. An estimate of the maximum quantity of dredged material in storage at any time during the life of the facility.
c. A cost estimate including an itemized breakdown for closure of each fill phase and the total cost associated with closure activities at dredged material disposal facilities.

4.29 A copy of the approved 'Closure Plan' and all revisions to the plan shall be kept at the facility until closure is completed and certified. At the time of closure, the agency will issue a closure document in accordance with Minn. R. part 7001.3055.

4.30 Amendment of Plan. The Permittee may amend the 'Closure Plan' (plan) any time during the life of the facility. The Permittee shall amend the plan whenever changes in the operating plan or facility design affect the closure procedures needed, and whenever the expected year of closure changes. Required amendments shall be completed within 60 days of any change or event that affects the closure plan.

4.31 Notification of Final Facility Closure. The Permittee shall notify the commissioner at least 90 days before final facility closure activities are to begin, except if the permit for the facility has been revoked.

4.32 Closure Performance Standard. The Permittee must close the dredged material disposal facility in a manner that eliminates, minimizes, or controls the escape of pollutants to ground water or surface waters, to soils, or to the atmosphere during the postclosure period.

4.33 Completion of Closure Activities. Within 30 days after receiving the last shipment of dredged material for disposal, the Permittee must begin the final closure activities outlined in the approved 'Closure Plan' for the dredged material disposal facility. Closure activities must be completed according to the approved 'Closure Plan'. The commissioner may approve a longer period if the owner or operator demonstrates that the closure activities will take longer due to adverse weather or other factors not in the control of the Permittee.

4.34 Closure Procedures.
a. Complete the appropriate activities outlined in the approved 'Closure Plan'.
b. Complete final closure activities consisting of submitting to the county recorder and the commissioner a detailed description of the waste types accepted at the facility and what the facility was used for, together with a survey plat of the site. The plat must be prepared and certified by a land surveyor registered in Minnesota. The landowner must record a notation on the deed to the property or on some other instrument normally examined during a title search, that will in perpetuity notify any potential purchaser of the property of any special conditions or limitations for use of the site, as set out in the 'Closure Plan' and closure document.

●pter 5. Dredged Material Management

4. Storage, Disposal and/or Reuse of Dredged Material

4.35 Certification of Closure. When final facility closure is completed, the Permittee shall submit to the commissioner certification by the Permittee and an engineer registered in Minnesota that the facility has been closed in accordance with this chapter.

The certification shall contain the following elements:
a. a completed and signed 'Site Closure Record';
b. documentation of closure, such as pictures, showing the construction techniques used during closure; and,
c. a copy of the notation carrying the recorder's seal which has been filed with the county recorder.

4.36 Post-Closure Care. After final closure, the Permittee shall comply with the following requirements:
a. restrict access to the facility by use of gates, fencing, or other means to prevent further disposal at the site, unless the site's final use allows access;
b. maintain the integrity and effectiveness of the final cover, including making repairs to the final cover system as necessary to correct the effects of settling, subsidence, gas and leachate migration, erosion, root penetration, burrowing animals, or other events;
c. prevent run-on and run-off from eroding or otherwise damaging the final cover;
d. protect and maintain surveyed benchmarks

C. Beneficial Use or Re-Use of Dredged Material

4.37 Prior to the use or reuse of a dredged material, the Permittee shall determine the appropriate "suitable reuse category" of the dredged material to be used or reused, as described below.

●.38 Suitable Reuse Categories. The suitable reuse category of a dredged material is based on the analyzed characteristics of the dredged material (sampled prior to dredging or in a spoil pile after dreding) and appropriately applied Soil Reference Values (SRVs), which are listed in Table 2 of Appendix 1 to this permit.

For the purposes of this permit, dredged material intended for the beneficial use or reuse is categorized into three tiers: Tier 1, Tier 2, and Tier 3. If the sieve analysis obtained by a #200 sieve is greater than 95 percent sands then the material is acceptable for Tier 1 or 2 use and additional analytical sampling is not required.

a. Tier 1 material is authorized to be used or reused at/on sites with a residential property use category. Tier 1 material is characterized by a contaminant level that is at or below all respective analyte concentrations listed in the Tier 1 SRV column for any contaminant that can be reasonably expected to be present in the dredged material.
b. Tier 2 material is authorized to be used or reused on/at sites with an industrial or recreational use category. Tier 2 material is characterized by a contaminant level that is at or below all respective analyte concentrations listed in the Tier 2 SRV column for any contaminant that can be reasonably expected to be present in the dredged material.
c. Tier 3 material is NOT authorized to be used or reused under this permit. Tier 3 material is characterized by a contaminant level that is greater than any respective analyte concentrations listed in the Tier 2 SRV column for any contaminant that can be reasonably expected to be present in the dredged material.

4.39 Storage Prior to Reuse. Storage of dredged material prior to reuse or use is subject to the temporary storage requirements of this chapter, or the disposal requirements of this chapter, as applicable.

Chapter 5. Dredged Material Management

5. Annual Report

5.1 The annual 'Dredged Material Report' shall be on a form provided by the Commissioner, or another MPCA approved form, and shall include the following elements:
a. Dates of dredging;
b. Volume of material placed into storage or disposal facility;
c. Any incidents, such as spills, unauthorized discharge and/or other permit violations which may have occurred;
d. Water level records for the disposal facilities of hydraulic dredging projects;
e. Such information as the MPCA may reasonably require of the Permittee pursuant to Minn. R. 7001 and Minn. Stat. chap. 115 and 116 as amended;
f. For disposal facilities, the dates of 'Periodic Site Inspections' required by this chapter, and the status of erosion control measures at the disposal facility;
g. For disposal facilities, the dates, the volume of dredged material removed from the disposal facility, and the method and location of the disposition (disposal or reuse) of such materials.
h. For facilities that used or reused dredged material during the previous calendar year, the following information shall also be provided:
i. A written description of the use or reuse of the dredged material;
ii. A written determination of the use category and appropriate Soil Reference Values (SRVs); and,
iii. The results of an evaluation of the level of contaminants in the dredged material proposed for reuse for the respective SRVs.

6. Definitions

6.1 "Beach Nourishment" means the disposal of dredged material on the beaches or in the water waterward starting at or above the Ordinary High Water Level (OHWL) for the purpose of adding to, replenishing, or preventing the erosion of, beach material.

6.2 "Beneficial Re-use" means the re-use of dredged material, after the material has been dewatered, in projects such as, but not limited to: road base, building base or pad, etc.

6.3 "Carriage, or Conveyance, Water" means the water portion of a slurry of water and dredged material.

6.4 "Carriage Water Return Flow" means the carriage water which is returned to a receiving water after separation of the dredged material from the carriage water in a disposal, rehandling or treatment facility.

6.5 "Design capacity" means the total volume of compacted dredged materials, along with any topsoil, intermittent, intermediate, and/or final cover, as calculated from final contour and cross-sectional plan sheets that define the areal and vertical extent of the fill area.

6.6 "Discharges of Dredged Material" means any addition of dredged material into waters of the state and includes discharges of water from dredged material disposal operations including beach nourishment, upland, or confined disposal which return to waters of state. Material resuspended during normal dredging operations is considered "de minimis" and is not a dredged material discharge.

6.7 "Disposal Facility" means a structure, site or area for the disposal of dredged material.

6.8 "Dredged Material" means any material removed from the bed of any waterway by dredging.

6.9 "Dredging" means any part of the process of the removal of material from the beds of waterways; transport of the material to a disposal, rehandling or treatment facility; treatment of the material; discharge of carriage or interstitial water; and disposal of the material.

6.10 "Erosion Control" means methods employed to prevent erosion. Examples include: soil stabilization practices, horizontal slope grading, temporary or permanent cover, and construction phasing. (look for SW definition)

6.11 "Final Stabilization" means that all soil disturbing activities at the site have been completed, and that a uniform perennial vegetative cover (a density of 70 percent cover for unpaved areas and areas not covered by permanent structures) has been established or equivalent permanent stabilization measures have been employed. Examples of vegetative cover practices can be found in Supplemental Specifications to the 1988 Standard Specifications for Construction (Minnesota Department of Transportation, 1991).

apter 5. Dredged Material Management

6. Definitions

6.12 "Flood Event" means that the surface elevation of a waterbody has risen to a level that causes the inundation or submersion of areas normally above the Ordinary High Water Level.

6.13 "Impoundment" means a natural or artificial body of water or sludge confined by a dam, dike, floodgate, or other barrier.

6.14 "Interstitial, or Pore, Water" means water contained in the interstices or voids of soil or rock in the dredged material.

6.15 "Ordinary High-Water Level (OHWL)" means the boundary of waterbasins, watercourses, public waters, and public waters wetlands, and shall be an elevation delineating the highest water level which has been maintained for a sufficient period of time to leave evidence upon the landscape, commonly that point where the natural vegetation Cs from predominantly aquatic to predominantly terrestrial. For watercourses, the ordinary high water level is the elevation of the top of the bank of the channel. For reservoirs and flowages, the ordinary high water level is the operating elevation of the normal summer pool. (Minn. Stat. chap. 103G.005 Subd. 14 and MN Rule 6120.2500 Subp. 11.)

6.16 "Rehandling Facility" means a temporary storage site or facility used during the transportation of dredged material to a treatment or disposal facility.

6.17 "Significant Storm Event" means a storm event that is greater than 1.0 inches in magnitude and that occurs at least 72 hours from the previously measurable (greater than 1.0 inch rainfall) storm event. The 72-hour storm event interval may be waived where:

a. the preceding measurable storm event did not result in a measurable discharge from the facility; or,

b. the Permittee documents that less than a 72-hour interval is representative for local storm events during the season when sampling is being conducted.

6.18 "Stabilized" means staked sod, riprap, wood fiber blanket, or other material that prevents erosion from occurring has covered the exposed ground surface. Grass seed is not stabilization.

6.19 "Storage Facility" means a structure, site or area for the holding of dredged material for more than 48 hours in quantities equal to or greater than ten cubic yards. Storage for more than 1 year constitutes disposal.

6.20 "Unconfined Disposal" means the deposition of dredged material, in water, on the bed of a waterway.

6.21 "Upland Disposal" means the disposal of dredged materials landward from the ordinary high-water level of a waterway or waterbody.

Chapter 6. Steam Electric

1. Authorization

1.1 The Permittee is authorized to discharge condenser/circulating water and noncontact cooling water in accordance with and in compliance with the effluent limitations, restrictions, and conditions contained elsewhere in this permit.

1.2 The Permittee holds a Minnesota Department of Natural Resources Permit 80-5081, which requires the facility to maintain the wetland (duck pond) adjacent to the discharge canal.

1.3 The Permittee is not prohibited from a discharge of condenser/circulating water and cooling water for use as a de-icing agent at the intake structure should the need arise.

2. Applicable Effluent Limitations - Thermal Limitation

2.1 The thermal waste streams shall not impact the safety and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the Mississippi River.

Chapter 6. Steam Electric

2. Applicable Effluent Limitations - Thermal Limitation

2.2 In accordance with the Federal Water Pollution Control Act, this permit may be re-opened to insert a more restrictive thermal limit or the requirement to conduct a 316(a) study if it has been shown that the thermal component(s) of the surface water discharges affect the safety and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the Mississippi River.

2.3 For the purposes of this permit, the fall trigger point is defined as the point at which the daily average upstream ambient river temperature falls below 43 degrees F for five consecutive days.

During the period April 1 through the fall thermal point the Permittee shall operate the cooling towers and associated equipment, to the extent necessary, in such a way that the cooling water discharge satisfies the following conditions:

1) Does not raise the temperature of the receiving water immediately below Lock and Dam No. 3 by more than 5 degrees F above ambient based on upstream monitoring data and the monthly averages of maximum daily temperatures at the three monitoring probes located on the piers dividing the four gated sections of the dam.

2) In no case shall it exceed a daily average temperature of 86 degrees F.

3) If the daily average ambient river temperature reaches 78 degrees F for two consecutive days, the Permittee shall operate all cooling towers to the maximum extent practicable. For single unit operations, this requirement is satisfied by operation of two of the four cooling towers.

2.4 During the effective period (beginning on the fall trigger point and ending March 31), or earlier as described below, plant thermal discharges shall be limited by ambient river temperature as follows:

Once the daily average ambient river temperature falls below 43 degrees F for five consecutive days, the Permittee shall not raise the temperature of the receiving water immediately below Lock and Dam No. 3 (SW 001) above 43 degree F for an extended period of time. While operating under this restriction, if the daily average temperature in the receiving water measured at SW 001 (measured using three probes on the piers dividing the four gated sections of the dam) equals or exceeds 43 degrees F for two consecutive days, the Permittee shall notify the Commissioner and the Minnesota Department of Natural Resources. Following such notification the Commission may require the Permittee to operate the cooling towers or take alternative action as necessary until such time that the 43 degree F criteria can be consistently met.

2.5 The spring trigger point is defined as the point in time that the daily average ambient river temperature increases to 43 degrees F or above for five consecutive days, or April 1, whichever occurs first.

The Permittee shall operate in the above manner (Section 2.4) throughout the winter and into spring until the spring trigger point. Once the spring 43 degree F daily average ambient river temperature trigger or the April 1 date trigger has been reached, plant thermal limits default back to the requirements of Section 2.3 until the following fall thermal trigger point. If the temperature trigger results in a partial month of operation under Section 2.3 conditions/requirements, compliance with the Delta T of 5 degrees F shall be based on the monthly average of the maximum daily ambient temperatures on days after the trigger is reached.

From April 1, or earlier as described above, through the fall thermal trigger point the requirements of Section 2.3 apply.

2.6 Abrupt temperature changes in the discharge due to changes in cooling tower operational modes or generator unit tripouts shall be minimized to the maximum extent practical to reduce the potential for thermal shock in the receiving water (Mississippi River). The Permittee shall be responsible for fish kills in the receiving water (Mississippi River) and the recirculating water system due to thermal shock and chemical treatments.

2.7 The ambient river water temperature shall be defined as the temperature of the river at a point unaffected by the plant or any other thermal discharge and shall be representative of the main river channel temperature and Sturgeon Lake outlet temperature.

apter 6. Steam Electric

2. Applicable Effluent Limitations - Thermal Limitation

2.8 The Permittee shall monitor the temperature of the receiving water immediately below Lock and Dam No. 3 continuously (using three probes on the piers dividing the four gated sections of the gates), and this data shall be reported along with the monthly discharge monitoring reports. The Permittee shall maintain the site temperature monitoring system for outfall SD 001.

2.9 The Permittee shall conduct temperature monitoring for stations including the combined effluent from the condenser/circulating water system and cooling water system (SD001), upstream locations Strugeon Lake 1, Sturgeon Lake 2, Diamond Bluff (main channel), the screenhouse inlet temperature (intake channel), and the three separate temperature probes located at Lock and Dam No. 3 (on the piers dividing the four gated sections of the dam). The minimum, maximum, and average temperatures shall be recorded daily at these stations and reported with the monthly discharge monitoring reports.

The Permittee shall maintain the site temperature monitoring system encompassing ambient river temperature, Lock and Dam No. 3, intake, and outfall SD 001. Eliminations or reductions in portions of the system may be allowed as the information is compiled. The Permittee may evaluate the reliability and/or representativeness of the monitoring system and its various stations. Any relocations in the system, and reductions or eliminations of monitoring requirements are subject o MPCA review and approval.

2.10 If monitoring equipment for Sturgeon Lake 1, Sturgeon Lake 2, or Diamond Bluff (main channel) is out of service, then intake temperature monitoring may be utilized as the back up for ambient river water temperature determination. If either Sturgeon Lake 1 or Surgeon Lake 2 is out of service, the remaining station(s) may be utilized as the backup for Sturgeon Lake temperature inputs to determine ambient river water temperature. The Sturgeon Lake 1 and Sturgeon Lake 2 temperature monitoring equipment may be removed from service in the fall after the daily average ambient river temperature is below 43 degrees F for two consecutive days. The Sturgeon Lake 1 and Sturgeon Lake 2 temperature monitoring equipment shall be reinstalled in the spring, once the potential for damage from ice and floating debris is minimal. It shall be installed prior to, or as soon after April 1 as practical.

3. Chlorination

3.1 Chlorine/bromine may be used only in the cooling water system, except chlorine or bromine may be used in the condenser/circulating cooling water system periodically to treat for parasitic amoeba or zebra mussels provided the circulating cooling water is dechlorinated prior to discharge.

The Permittee shall monitor the amount and time of bromine/chlorine application and shall report it monthly on the DMRs

3.2 During intermittent bromination the discharge of total residual oxidant (bromine/chlorine used) at SD 001, shall be limited to a total of 2 hours per 24 hour period and to an instantaneous maximum concentration of 0.05 mg/l. During continuous chlorination the discharge of total residual oxidant shall be limited to an instantaneous maximum concentration of 0.2 mg/l. The Permittee shall also monitor the amount and time of chlorine and or bromine application and shall report it monthly along with the other monitoring reports.

At times, plant configuration can result in shutdown of a unit's cooling water pump (WS 001 or WS 002) for a short period of time with continuous chlorine/bromine injection in progress. During this time, chlorine/bromine injection would continue via the normal injection path but could back flow through the idle cooling water pump suction and be drawn into the condenser/circulating water system. Any chlorine/bromine would be subsequently discharged to SD 001, the normal discharge for both the cooling water and condenser/circulating water systems. In this off-normal plant configuration, chlorine/bromine injection may continue at the normal rate provided SD 001 discharge limits are not exceeded. Any plant operation in this off-normal configuration shall be documented on the monthly DMR.

Chapter 6. Steam Electric

3. Chlorination

3.3 The discharge of total residual oxidants at SD001, bromine/chlorine used, shall be limited during intermittent bromination/chlorination to a total or two hours per 24-hour period from the facility. The Permittee shall also monitor the amount and time of chlorine and/or bromine application and shall report it monthly along with the other monitoring reports.

4. Intake Screens

4.1 The Permittee may operate with up to 3/8 inch mesh screens during the period September 1 through March 31. During the April 1 through August 31 period, the Permittee shall use the 0.5 mm fine mesh screens, or alternate minimum larger sized screens upon approval by the MPCA.

4.2 The intake screening system shall be maintained to provide for continuous fine mesh screen operation during the sensitive period April 1 through August 31 in order to minimize mortality of fish and other organisms. Operation shall include maintaining design screen wash pressures and operation of all intake screens to minimize fish impingement/entrainment and mortality. Maintenance of the intake screen system shall be scheduled and completed during the less sensitive impingement/entrainment period of September 1 through March 31. This restriction applies only to routine planned maintenance that 1) requires the intake screening system (or a portion of the system) to be taken out of service, and that 2) could reasonably be scheduled and completed outside of the time period of concern (March 31-September 1) without adversely affecting personnel safety or equipment reliability.

The Permittee shall minimize the amount of time that intake screenhouse emergency bypass gates are open. The emergency bypass gates may be opened when necessary to meet Nuclear Regulatory Commission reactor safety and testing requirements or to allow for urgently required maintenance or repairs. If the bypass gates are open for more than 24 hours in a calendar month the dates and circumstances shall be reported in the next DMR.

4.3 Water used to rinse the intake screens shall be free of chlorine and chemical additives.

4.4 Large debris collected at the trash racks shall be disposed of so as to prevent it from entering waters of the state.

4.5 The Permittee shall be responsible for fish kills in the receiving water and the recirculating water system due to thermal shock and chemical treatments.

4.6 The permit may be reopened and modified based on ecological monitoring and studies by the Minnesota Department of Natural Resources, the Wisconsin Department of Natural Resources, Northern States Power, and the MPCA.

4.7 The Permittee shall submit a monitoring plan to maintain ecological monitoring consistent with the Annual Environmental reports to the Commissioner for approval within 45 days of the effective date of this permit. The monitoring plan shall include the impingement study discussed in part 4.6 above. The Commissioner shall consult with the Minnesota Department of Natural Resources in review and approval of the ecological monitoring plan.

4.8 The Permittee shall submit an Annual Environmental report to the Commissioner by July 1 of each year summarizing the previous years' data collection.

4.9 The Commissioner shall consult with the Minnesota Department of Natural Resources in review and approval of the ecological monitoring submittals described in section 4.7 and 4.8 of this chapter.

Chapter 7. Stormwater

1. Authorization

1.1 This chapter authorizes the Permittee to discharge storm water associated with industrial activity in accordance with the terms and conditions of this chapter.

apter 7. Stormwater

2. Stormwater Pollution Prevention Plan

2.1 The Permittee shall submit a copy of the Storm Water Pollution Prevention Plan (SWPPP) to the MPCA 180 days after the permit is issued. Subsequent revisions to the SWPPP during the permit terms can be retained at the facility.

2.2 The Stormwater Pollution Prevention Plan shall include a description of appropriate Best Management Practices for protection of surface and ground water quality at the facility, and a schedule for implementing the practices. The Plan shall also include the procedures to be followed by designated staff employed by the Permittee to implement the plan.

2.3 The Permittee shall comply with its Stormwater Pollution Prevention Plan.

2.4 The Permittee shall develop and implement a Storm Water Pollution Prevention Plan to address the specific conditions at the industrial facility. The goal of the Plan is to eliminate or minimize contact of storm water with significant materials that should be treated before it is discharged.

3. Temporary Protection and Permanent Cover

3.1 The Permittee shall provide and maintain temporary protection or permanent cover for the exposed areas at the facility.

3.2 Temporary protection methods are used to prevent erosion on a short-term basis, such as the placement of mulching straw, wood fiber blankets, wood chips, erosion control netting, or temporary seeding.

3.3 Permanent cover or final stabilization methods are used to prevent erosion, such as the placement of riprap, sodding, or permanent seeding or planting. Permanent seeding and planting must have a uniform perennial vegetation cover of at least 70 percent density to constitute final stabilization.

4. Inspection and Maintenance

4.1 The Permittee shall ensure that temporary protection and permanent cover for the exposed areas at the site are maintained.

4.2 Site inspections shall be conducted at least once every two months during non-frozen conditions. Inspections shall be conducted by appropriately trained personnel at the facility site per the facility's Storm Water Pollution Prevention Plan (SWPPP). The purpose of inspections is to 1) determine whether structural and non-structural BMPs require maintenance or changes, and 2) evaluate the completeness and accuracy of the SWPPP. At least one inspection during a reporting period shall be conducted while storm water is discharging from the facility.

4.3 Inspections shall be documented and a copy of all documentation shall remain on the permitted site and be available upon request. Indicate the date and time of the inspection as well as the name of the inspector on the inspection form.

4.4 The following compliance items will be inspected, and documented where appropriate:

a. evaluate the facility to determine that the SWPPP accurately reflects site conditions;

b. evaluate the facility to determine whether new exposed materials have been added to the site since completion of the SWPPP, and document any new significant materials;

c. during the inspection conducted during the runoff event, observe the runoff to determine if it is discolored or otherwise visibly contaminated, and document observations; and,

d. determine if the non-structural and structural BMPs as indicated in the SWPPP are installed and functioning properly.

4.5 If the findings of a site inspection indicate that BMPs are not meeting the objectives of the SWPPP corrective actions must be initiated within 30 days and the BMPs restored to full operation as soon as field conditions allow.

Chapter 7. Stormwater

4. Inspection and Maintenance

4.6 The Permittee shall minimize vehicle tracking of gravel, soil or mud.

5. Sedimentation Basin Design and Construction

5.1 Inlet(s) and outlet(s) shall be designed to prevent short circuiting and the discharge of floating debris.

5.2 The inlet(s) shall be placed at an elevation at least above one-half of the basin design hydraulic storage volume.

5.3 The outlet(s) shall consist of a perforated riser pipe wrapped with filter fabric and covered with crushed gravel. The perforated riser pipe shall be designed to allow complete drawdown of the basin(s).

5.4 Permanent erosion control, such as riprap, splash pads or gabions shall be installed at the outlet(s) to prevent downstream erosion.

5.5 The basins shall be designed to allow for regular removal of accumulated sediment by a backhoe or other suitable equipment.

5.6 New sedimentation basins shall be designed by a registered professional engineer, and installed under the direct supervision of a registered professional engineer.

5.7 Basins shall provide at least 1800 cubic feet, per acre drained, of hydraulic storage volume below the top of the outlet riser pipe.

6. Application of Chemical Dust Suppressants

6.1 If a material applied is mixed with water or another solvent before application, the chemical analysis shall be done on the aqueous or other mixture that is representative of the solution applied. This analysis shall be conducted during the same calendar year of application. This analysis shall include the parameters that may be determined by U.S. Environmental Protection Agency (EPA) Methods 624 and 625 which are described in 40 CFR Part 136.

6.2 The Chemical Dust Suppressant Annual Report shall include:

a. a record of the dates, methods, locations and amounts by volume of application at the facility;

b. whether the product was applied in the preceding year; and

c. the results of a chemical analysis of the materials applied each year.

6.3 In areas that runoff to the surface receiving water identified on Page 1 of this permit (Mississippi River), chemical dust suppressants, if used, shall not be applied within 100 feet of the Mississippi River. These materials also shall not be applied within 100 feet of ditches that conduct surface flow to the Mississippi River.

6.4 If chemical dust suppressants are applied, the Permittee shall submit a Chemical Dust Suppressant Annual Report due March 31 of each calendar year following the application of a chemical dust suppressant.

Chapter 8. Chemical Additives

1. General Requirements

1.1 The Permittee shall receive prior written approval from the MPCA before increasing the use of a chemical additive authorized by this permit, or using a chemical additive not authorized by this permit. "Chemical additive" includes processing reagents, water treatment products, cooling water additives, freeze conditioning agents, chemical dust suppressants, detergents and solvent cleaners used for equipment and maintenance cleaning, among other materials.

1.2 The Permittee shall request approval for an increased or new use of a chemical additive 60 days before the proposed increased or new use.

apter 8. Chemical Additives

1. General Requirements

1.3 This written request shall include the following information for the proposed additive:

a. Material Safety Data Sheet.

b. A complete product use and instruction label.

c. The commercial and chemical names of all ingredients.

d. Aquatic toxicity and human health or mammalian toxicity data including a carcinogenic, mutagenic or teratogenic concern or rating.

e. Environmental fate information including, but not limited to, persistence, half-life, intermediate breakdown products, and bioaccumulation data.

f. The proposed method, concentration, and average and maximum rates of use.

g. If applicable, the number of cycles before wastewater bleedoff.

h. If applicable, the ratio of makeup flow to discharge flow.

1.4 This permit may be modified to restrict the use or discharge of a chemical additive.

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1. General Permit Requirements

Definitions

1.1 "Calendar Month Average" is calculated by adding all daily values measured during a calendar month and dividing by the number of daily values measured during that month. The "Calendar Month Average" limit is an upper limit.

1.2 "Calendar Month Maximum" is the highest value of single samples taken throughout the month. The "Calendar Month Maximum" is an upper limit.

1.3 "Calendar Month Minimum" is the lowest value of single samples taken throughout the month. The "Calendar Month Minimum" is a lower limit.

1.4 "Calendar Month Total" is calculated by adding all daily values measured during a calendar month. It is usually expressed in mass or volume units. The "Calendar Month Total" is an upper limit.

1.5 "Daily Maximum" means the maximum allowable discharge of pollutant during a calendar day. Where daily maximum limitations are expressed in units of mass, the daily discharge is the total mass discharged over the course of the day. Where daily maximum limitations are expressed in terms of a concentration, the daily discharge is the arithmetic average measurement of the pollutant concentration derived from all measurements taken that day. The "Daily Maximum" is an upper limit.

1.6 "Grab" sample type is an individual sample collected from one location at one point in time.

1.7 "Instantaneous Maximum" is the highest value recorded when continuous monitoring is used or when the reporting frequency is not specifically defined. The "Instantaneous Maximum" limit is an upper limit. The highest value recorded is reported.

1.8 "Single Value" in the context of this permit is in reference to temperature limitations described under thermal limitations, where applicable, or to a temperature monitoring requirement.

Chapter 9. Total Facility Requirements

1. General Permit Requirements

1.9 "Stormwater" means stormwater runoff, snow melt runoff, and surface runoff and drainage.

General Conditions

1.10 Incorporation by Reference. The following applicable federal and state laws are incorporated by reference in this permit, are applicable to the Permittee, and are enforceable parts of this permit: 40 CFR pts. 122.41, 122.42, 136, 403 and 503; Minn. R. pts. 7001, 7041, 7045, 7050, 7060, and 7080; and Minn. Stat. Sec. 115 and 116.

1.11 Permittee Responsibility. The Permittee shall perform the actions or conduct the activity authorized by the permit in compliance with the conditions of the permit and, if required, in accordance with the plans and specifications approved by the Agency. (Minn. R. 7001.0150, subp. 3, item E)

1.12 Toxic Discharges Prohibited. Whether or not this permit includes effluent limitations for toxic pollutants, the Permittee shall not discharge a toxic pollutant except according to Code of Federal Regulations, Title 40, sections 400 to 460 and Minnesota Rules, parts 7050.0100 to 7050.0220 and 7052.0010 to 7052.0110 (applicable to toxic pollutants in the Lake Superior Basin) and any other applicable MPCA rules. (Minn. R. 7001.1090, subp.1, item A)

1.13 Nuisance Conditions Prohibited. The Permittee's discharge shall not cause any nuisance conditions including, but not limited to: floating solids, scum and visible oil film, acutely toxic conditions to aquatic life, or other adverse impact on the receiving water. (Minn. R. 7050.0210 subp. 2)

1.14 Property Rights. This permit does not convey a property right or an exclusive privilege. (Minn. R. 7001.0150, subp. 3, item C)

1.15 Liability Exemption. In issuing this permit, the state and the MPCA assume no responsibility for damage to persons, property, or the environment caused by the activities of the Permittee in the conduct of its actions, including those activities authorized, directed, or undertaken under this permit. To the extent the state and the MPCA may be liable for the activities of its employees, that liability is explicitly limited to that provided in the Tort Claims Act. (Minn. R. 7001.0150, subp. 3, item O)

1.16 The MPCA's issuance of this permit does not obligate the MPCA to enforce local laws, rules, or plans beyond what is authorized by Minnesota Statutes. (Minn. R. 7001.0150, subp.3, item D)

1.17 Liabilities. The MPCA's issuance of this permit does not release the Permittee from any liability, penalty or duty imposed by Minnesota or federal statutes or rules or local ordinances, except the obligation to obtain the permit. (Minn. R. 7001.0150, subp.3, item A)

1.18 The issuance of this permit does not prevent the future adoption by the MPCA of pollution control rules, standards, or orders more stringent than those now in existence and does not prevent the enforcement of these rules, standards, or orders against the Permittee. (Minn. R. 7001.0150, subp.3, item B)

1.19 Severability. The provisions of this permit are severable, and if any provisions of this permit, or the application of any provision of this permit to any circumstance, is held invalid, the application of such provision to other circumstances and the remainder of this permit shall not be affected thereby.

1.20 Compliance with Other Rules and Statutes. The Permittee shall comply with all applicable air quality, solid waste, and hazardous waste statutes and rules in the operation and maintenance of the facility.

1.21 Inspection and Entry. When authorized by Minn. Stat. Sec. 115.04; 115B.17, subd. 4; and 116.091, and upon presentation of proper credentials, the agency, or an authorized employee or agent of the agency, shall be allowed by the Permittee to enter at reasonable times upon the property of the Permittee to examine and copy books, papers, records, or memoranda pertaining to the construction, modification, or operation of the facility covered by the permit or pertaining to the activity covered by the permit; and to conduct surveys and investigations, including sampling or monitoring, pertaining to the construction, modification, or operation of the facility covered by the permit or pertaining to the activity covered by the permit. (Minn. R. 7001.0150, subp.3, item I)

apter 9. Total Facility Requirements

1. General Permit Requirements

1.22 Control Users. The Permittee shall regulate the users of its wastewater treatment facility so as to prevent the introduction of pollutants or materials that may result in the inhibition or disruption of the conveyance system, treatment facility or processes, or disposal system that would contribute to the violation of the conditions of this permit or any federal, state or local law or regulation.

Sampling

1.23 Representative Sampling. Samples and measurements required by this permit shall be conducted as specified in this permit and representative of the discharge or monitored activity. (40 CFR 122.41 (j)(1))

1.24 Additional Sampling. If the Permittee monitors more frequently than required, the results and the frequency of monitoring shall be reported on the Discharge Monitoring Report (DMR) or another MPCA-approved form for that reporting period. (Minn. R. 7001.1090, subp. 1, item E)

1.25 Certified Laboratory. A laboratory certified by the Minnesota Department of Health shall conduct analyses required by this permit. Analyses of dissolved oxygen, pH, temperature and total residual oxidants (chlorine, bromine) do not need to be completed by a certified laboratory but shall comply with manufacturers specifications for equipment calibration and use. (Minn. Stat. Sec. 144.97 through 144.98 and Minn. R. 4740.2010 through 4740.2040)

1.26 Sample Preservation and Procedure. Sample preservation and test procedures for the analysis of pollutants shall conform to 40 CFR Part 136 and Minn. R. 7041.3200.

1.27 Equipment Calibration. All monitoring and analytical instruments used to monitor as required by this permit shall be calibrated and maintained at a frequency necessary to ensure accuracy. Flow monitoring equipment should be calibrated at least twice annually. For facilities with lift stations/pumps, calibration shall be completed at least twice annually. The Permittee shall maintain written records of all calibrations and maintenance for at least three years. (Minn. R. 7001.0150, subp. 2, items B and C)

1.28 Unless otherwise approved, instruments used to measure metered flows shall be accurate within plus or minus 10 percent of the true flow values. Flow for non-metered systems (e.g., screenwash return) shall be estimated using methods such as pump discharge curves and run times. SD 001 discharge flow shall be determined by comparing discharge canal sluice gate position and canal water elevation to the applicable engineering flow curves.

1.29 Maintain Records. The Permittee shall keep the records required by this permit for at least three years, including any calculations, original recordings from automatic monitoring instruments, and laboratory sheets. The Permittee shall extend these record retention periods upon request of the MPCA. The Permittee shall maintain records for each sample and measurement. The records shall include the following information (Minn. R. 7001.0150, subp. 2, item C):

a. The exact place, date, and time of the sample or measurement;

b. The date of analysis;

c. The name of the person who performed the sample collection, measurement, analysis, or calculation; and

d. The analytical techniques, procedures and methods used; and

e. the results of the analysis. (Minn. R. 7001.0150, subp. 2, item C)

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1.30 Completing Reports. The Permittee shall submit the results of the required sampling and monitoring activities on the forms provided, specified, or approved by the MPCA. The information shall be recorded in the specified areas on those forms and in the units specified. (Minn. R. 7001.1090, subp. 1, item D; Minn. R. 7001.0150, subp. 2, item B)

Required forms may include:

Discharge Monitoring Reports (DMRs)
The results of the monitoring and sampling required in this permit shall be recorded on the (grey and white) DMRs which, if required, will be provided by the MPCA. If no discharge occurred during the reporting period, the Permittee shall check the "No Discharge" box on the DMR. Note: Every open, white box must be filled-in on the DMR, unless no discharge occurred during the reporting period.

Supplemental Report Form (SRFs)
Individual values for each sample and measurement must be recorded on the SRF which, if required, will be provided by the MPCA. SRFs shall be submitted with the appropriate DMRs. You may design and use your own SRF, however it must be approved by the MPCA. Note: Required Summary information MUST also be recorded on the DMR. Summary information that is submitted ONLY on the SRF does not comply with the reporting requirements.

Other Reports and Forms
Other reports and information required by this permit shall be recorded on a form supplied or approved by the MPCA and submitted by the date specified in the permit. (Minn. R. 7001.1090, subp. 1, item D and Minn. R. 7001.0150, subp. 2, item B)

1.31 Submitting Reports. DMRs and SRFs shall be submitted to:

MPCA
Attn: Discharge Monitoring Reports
520 Lafayette Road North
St. Paul, Minnesota 55155-4194.

DMRs and SRFs shall be submitted or postmarked by the 21st day of the month following the sampling period or as otherwise specified in this permit. A DMR shall be submitted for each required station even if no discharge occurred during the reporting period. (Minn. R. 7001.0150, subps. 2.B and 3.H)

Other reports required by this permit shall be submitted or postmarked by the date specified in the permit to:

MPCA
Attn: WQ Submittals Center
520 Lafayette Road North
St. Paul, Minnesota 55155-4194

1.32 Incomplete or Incorrect Reports. The Permittee shall immediately submit an amended report or DMR to the MPCA upon discovery by the Permittee or notification by the MPCA that it has submitted an incomplete or incorrect report or DMR. The amended report or DMR shall contain the missing or corrected data along with a cover letter explaining the circumstances of the incomplete or incorrect report. (Minn. R. 7001.0150 subp. 3, item G)

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1. General Permit Requirements

1.33 Required Signatures. All DMRs, forms, reports, and other documents submitted to the MPCA shall be signed by the Permittee or the duly authorized representative of the Permittee. Minn. R. 7001.0150, subp. 2, item D. The person or persons that sign the DMRs, forms, reports or other documents must certify that he or she understands and complies with the certification requirements of Minn. R. 7001.0070 and 7001.0540, including the penalties for submitting false information. Technical documents, such as design drawings and specifications and engineering studies required to be submitted as part of a permit application or by permit conditions, must be certified by a registered professional engineer. (Minn. R. 7001.0540)

1.34 Detection Level. The Permittee shall report monitoring results below the reporting limit (RL) of a particular instrument as "<" the value of the RL. For example, if an instrument has a RL of 0.1 mg/L and a parameter is not detected at a value of 0.1 mg/L or greater, the concentration shall be reported as "<0.1 mg/L". "Non-detected ", "undetected ", "below detection limit ", and "zero" are unacceptable reporting results, and are permit reporting violations. (Minn. R. 7001.0150, subp. 2, item B)

1.35 Records. The Permittee shall, when requested by the Agency, submit within a reasonable time the information and reports that are relevant to the control of pollution regarding the construction, modification, or operation of the facility covered by the permit or regarding the conduct of the activity covered by the permit. (Minn. R. 7001.0150, subp. 3, item H)

1.36 Confidential Information. Except for data determined to be confidential according to Minn. Stat. Sec. 116.075, subd. 2, all reports required by this permit shall be available for public inspection. Effluent data shall not be considered confidential. To request the Agency maintain data as confidential, the Permittee must follow Minn. R. 7000.1300.

Noncompliance and Enforcement

1.37 Subject to Enforcement Action and Penalties. Noncompliance with a term or condition of this permit subjects the Permittee to penalties provided by federal and state law set forth in section 309 of the Clean Water Act; United States Code, title 33, section 1319, as amended; and in Minn. Stat. Sec. 115.071 and 116.072, including monetary penalties, imprisonment, or both. (Minn. R. 7001.1090, subp. 1, item B)

1.38 Criminal Activity. The Permittee may not knowingly make a false statement, representation, or certification in a record or other document submitted to the Agency. A person who falsifies a report or document submitted to the Agency, or tampers with, or knowingly renders inaccurate a monitoring device or method required to be maintained under this permit is subject to criminal and civil penalties provided by federal and state law. (Minn. R. 7001.0150, subp.3, item G., 7001.1090, subps. 1, items G and H and Minn. Stat. Sec. 609.671)

1.39 Noncompliance Defense. It shall not be a defense for the Permittee in an enforcement action that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of this permit. (40 CFR 122.41(c))

1.40 Effluent Violations. If sampling by the Permittee indicates a violation of any discharge limitation specified in this permit, the Permittee shall immediately make every effort to verify the violation by collecting additional samples, if appropriate, investigate the cause of the violation, and take action to prevent future violations. Violations that are determined to pose a threat to human health or a drinking water supply, or represent a significant risk to the environment shall be immediately reported to the Minnesota Department of Public Safety Duty Officer at 1(800)422-0798 (toll free) or (651)649-5451 (metro area). In addition, you may also contact the MPCA during business hours. Otherwise the violations and the results of any additional sampling shall be recorded on the next appropriate DMR or report.

.41 Unauthorized Releases of Wastewater Prohibited. Except for conditions specifically described in Minn. R. 7001.1090, subp. 1, items J and K, all unauthorized bypasses, overflows, discharges, spills, or other releases of wastewater or materials to the environment, whether intentional or not, are prohibited. However, the MPCA will consider the Permittee's compliance with permit requirements, frequency of release, quantity, type, location, and other relevant factors when determining appropriate action. (40 CFR 122.41 and Minn. Stat. Sec 115.061)

Chapter 9. Total Facility Requirements

1. General Permit Requirements

1.42 Upset Defense. In the event of temporary noncompliance by the Permittee with an applicable effluent limitation resulting from an upset at the Permittee's facility due to factors beyond the control of the Permittee, the Permittee has an affirmative defense to an enforcement action brought by the Agency as a result of the noncompliance if the Permittee demonstrates by a preponderance of competent evidence:

a. The specific cause of the upset;

b. That the upset was unintentional;

c. That the upset resulted from factors beyond the reasonable control of the Permittee and did not result from operational error, improperly designed treatment facilities, inadequate treatment facilities, lack of preventative maintenance, or increases in production which are beyond the design capability of the treatment facilities;

d. That at the time of the upset the facility was being properly operated;

e. That the Permittee properly notified the Commissioner of the upset in accordance with Minn. R. 7001.1090, subp. 1, item I; and

f. That the Permittee implemented the remedial measures required by Minn. R. 7001.0150, subp. 3, item J.

Operation and Maintenance

1.43 The Permittee shall at all times properly operate and maintain the facilities and systems of treatment and control, and the appurtenances related to them which are installed or used by the Permittee to achieve compliance with the conditions of the permit. Proper operation and maintenance includes effective performance, adequate funding, adequate operator staffing and training, and adequate laboratory and process controls, including appropriate quality assurance procedures. The Permittee shall install and maintain appropriate backup or auxiliary facilities if they are necessary to achieve compliance with the conditions of the permit and, for all permits other than hazardous waste facility permits, if these backup or auxiliary facilities are technically and economically feasible Minn. R. 7001.0150. subp. 3, item F.

1.44 In the event of a reduction or loss of effective treatment of wastewater at the facility, the Permittee shall control production or curtail its discharges to the extent necessary to maintain compliance with the terms and conditions of this permit. The Permittee shall continue this control or curtailment until the wastewater treatment facility has been restored or until an alternative method of treatment is provided. (Minn. R. 7001.1090, subp. 1, item C)

1.45 Solids Management. The Permittee shall properly store, transport, and dispose of biosolids, septage, sediments, residual solids, filter backwash, screenings, oil, grease, and other substances so that pollutants do not enter surface waters or ground waters of the state. Solids should be disposed of in accordance with local, state and federal requirements. (40 CFR 503 and Minn. R. 7041 and applicable federal and state solid waste rules)

1.46 Intake traveling screen rinse water and contents will be returned to the river uninterrupted for the protection of fish and other aquatic organisms.

1.47 Scheduled Maintenance. The Permittee shall schedule maintenance of the treatment works during non-critical water quality periods to prevent degradation of water quality, except where emergency maintenance is required to prevent a condition that would be detrimental to water quality or human health. (Minn. R. 7001.0150. subp. 3, item F and Minn. R. 7001.0150. subp. 2, item B)

1.48 Control Tests. In-plant control tests shall be conducted at a frequency adequate to ensure compliance with the conditions of this permit. (Minn. R. 7001.0150. subp. 3, item F and Minn. R. 7001.0150. subp. 2, item B)

Changes to the Facility or Permit

apter 9. Total Facility Requirements

1. General Permit Requirements

1.49 Permit Modifications. No person required by statute or rule to obtain a permit may construct, install, modify, or operate the facility to be permitted, nor shall a person commence an activity for which a permit is required by statute or rule until the Agency has issued a written permit for the facility or activity. (Minn. R. 7001.0030)

Permittees that propose to make a change to the facility or discharge that requires a permit modification must follow Minn. R. 7001.0190. If the Permittee cannot determine whether a permit modification is needed, the Permittee must contact the MPCA prior to any action. It is recommended that the application for permit modification be submitted to the MPCA at least 180 days prior to the planned change.

1.50 Report Changes. The Permittee shall immediately report to the MPCA (Minn. R. 7001.0150, subp. 3, item M.):

a. Any substantial changes in operational procedures;

b. Activities which alter the nature or frequency of the discharge; and

c. Material factors affecting compliance with the conditions of this permit. (Minn. R. 7001.0150, subp. 3, item M.)

1.51 MPCA Initiated Permit Modification, Suspension, or Revocation. The MPCA may modify or revoke and reissue this permit pursuant to Minn. R. 7001.0170. The MPCA may revoke without reissuance this permit pursuant to Minn. R. 7001.0180.

1.52 Permit Transfer. The permit is not transferable to any person without the express written approval of the Agency after compliance with the requirements of Minn. R. 7001.0190. A person to whom the permit has been transferred shall comply with the conditions of the permit. (Minn. R., 7001.0150, subp. 3, item N)

1.53 Permit Reissuance. If the Permittee desires to continue permit coverage beyond the date of permit expiration, the Permittee shall submit an application for reissuance at least 180 days before permit expiration. If the Permittee does not intend to continue the activities authorized by this permit after the expiration date of this permit, the Permittee shall notify the MPCA in writing at least 180 days before permit expiration.

If the Permittee has submitted a timely application for permit reissuance, the Permittee may continue to conduct the activities authorized by this permit, in compliance with the requirements of this permit, until the MPCA takes final action on the application, unless the MPCA determines any of the following (Minn. R. 7001.0040 and 7001.0160):

a. The Permittee is not in substantial compliance with the requirements of this permit, or with a stipulation agreement or compliance schedule designed to bring the Permittee into compliance with this permit;

b. The MPCA, as a result of an action or failure to act by the Permittee, has been unable to take final action on the application on or before the expiration date of the permit;

c. The Permittee has submitted an application with major deficiencies or has failed to properly supplement the application in a timely manner after being informed of deficiencies. (Minn. R. 7001.0040 and 7001.0160)

Appendix 1:

Table 1. Minimum number of samples for sediment evaluation

VOLUME PLANNED FOR REMOVAL in CUBIC YARDS	NUMBER OF CORE SAMPLE SITES
0-30,000	3
30,000-100,000	5
100,000-500,000	6
500,000-1,000,000	8
>1,000,000	>8

Table 2. Baseline Sediment Parameter List

Parameter	Analytical Method	Method Detection Limit (mg/kg, dry weight unless noted)	Tier 1 Soil Reference Value (SRV) (mg/kg, dry weight unless noted)	Tier 2 Soil Reference Value (SRV) (mg/kg, dry weight unless noted)
Inorganics – Metals				
Arsenic	SW-846 3050B/6010B EPA 6010 or 7060	0.42	5	20
Cadmium	SW-846 3050B/6010B EPA 7131	0.02	25	160
Chromium III	SW-846 3050B/6010B EPA 6010 or 7191	0.058	44,000	100,000
Chromium VI	SW-846 3050B/6010B EPA 6010 or 7191	0.058	87	650
Copper	SW-846 3050B/6010B EPA 6010 or 7211	0.1	11	9,000
Lead	SW-846 3050B/6010B EPA 6010 or 7421	0.22	300	700
Mercury	SW-846 7471A EPA 7471	0.02	0.5	1.5
Nickel	SW-846 3050B/6010B EPA 6010	0.36	560	2,500
Selenium	SW-846 3050B/6010B	0.43	160	1,250
Zinc	SW-846 3050B/6010B EPA 6010 or 7951	0.35	8,700	70,000
Inorganics – Nutrients				
Total Phosphorus	EPA 365.2/365.3	50		
Nitrate + Nitrite				
Ammonia-Nitrogen				
Total Kjeldahl Nitrogen				
Organics				
PCBs (Total)	SW-846 8081 EPA 8081, 3540B, 3541	0.02	1.2	8
Total Organic Carbon	SW 846 8081 SW846-EPA 9060	0.2%		
Physical Tests				
Sieve and Hydrometer Analysis	ASTM D-422			
Moisture Content	ASTM D-2216			

Table 3. Additional Sediment Parameter List

Parameter	Analytical Method	Method Detection Limit *(mg/kg, dry weight unless noted)*	Tier 1 Soil Reference Value (SRV) *(mg/kg, dry weight unless noted)*	Tier 2 Soil Reference Value (SRV) *(mg/kg, dry weight unless noted)*
Inorganics – Metals				
Barium	SW-846 3050B/6010B	0.049	1,200	11,000
Cyanide	SW-846 9012A	0.5	62	5,000
Manganese	SW-846 3050B/6010B	0.39	3,600	8,100
Inorganics – Nutrients				
Oil & Grease	SW-846 9070			
Organics				
Aldrin	SW-846 8081 EPA 8081, 354440B, 3541	0.00044	1	2
Chlordane	SW-846 8081 EPA 8081, 354440B, 3541	0.01	13	74
Endrin	SW-846 8081 EPA 8081, 354440B, 3541	0.00073	8	56
Dieldrin	SW-846 8081 EPA 8081, 354440B, 3541	0.00091	0.8	2
Heptachlor	SW-846 8081 EPA 8081, 354440B, 3541	0.00077	2	3.5
Lindane (Gamma BHC)	SW-846 8081 EPA 8081, 354440B, 3541	0.00029	9	15
DDT	SW-846 8081 EPA 8081, 354440B, 3541	0.00063	15	88
DDD	SW-846 8081 EPA 8081, 354440B, 3541	0.0002	56	125
DDE	SW-846 8081 EPA 8081, 354440B, 3541	0.0002	40	90
Toxaphene	SW-846 8081	0.003	13	28
2,3,7,8-dioxin, 2,3,7,8-furan and 15 2,3,7,8-substituted dioxin and furan congeners	EPA 8290	1-10 pg/g	0.00002	0.00003
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	EPA 8310	176 ug/kg	10	28
Pyrene	EPA 8310	195 ug/kg	890	5,800
Fluorene	EPA 8310	77.4 ug/kg	850	4,120
Acenapthene	EPA 8310	6.7 ug/kg	1,200	5,200
Anthracene	EPA 8310	57.2 ug/kg	7,880	45,400
Fluoranthene	EPA 8310	423 ug/kg	1,080	6,800
Benzo (a) pyrene (BAP)/BAP equivalent	EPA 8310	150 ug/kg	2	4
Benzo (a) anthracene	EPA 8310	108 ug/kg	The results for these analytes should be added together and treated as the BAP equivalent, which is compared against the soil reference value for Benzo (a) pyrene, above.	
Benzo (e) pyrene	EPA 8310	150 ug/kg		
Benzo (b) fluoranthene	EPA 8310	240 ug/kg		
Benzo (ghi) perylene	EPA 8310	170 ug/kg		
Benzo (k) fluoranthene	EPA 8310	240 ug/kg		

Chrysene		EPA 8310	166 ug/kg		
Dibenzo(ah)anthracene		EPA 8310	33 ug/kg		
Indeno (1,2,3-cd) pyrene		EPA 8310	200 ug/kg		
Physical Tests					
Atterburg Limits (Liquid Limit and Plastic Limit)	ASTM D4318				
Specific Gravity	ASTM D-854				

Table 4. Contaminants and Source Industries. Adapted from Inland Testing Manual (EPA/Corps, 1998)

	Acenapthene	Aldrin	Ammonia	Aniline	Arsenic	Benzo(a)anthracene	Benzo(a)pyrene	Cadmium	Chlordane	Chromium	Copper	Cyanide	DDE	DDT	Dieldrin	Endrin	Ethyl Parathion	Fluoranthene	Heptachlor	Hexachlorobenzene	Hexachlorocyclopentadiene	Lead	Mercury	2-Methylnaphthalene	Nickel	Oil and Grease	Organotin / Tin	PCB	Phenanthrene	Phosphorus	Pyrene	Selenium	Tetrachlorodibenzodioxin (TCDD)	Tetrachlorodibenzofuran (TCDF)	Toxaphene	Zinc
Aluminum Die-casting								■		■															■	■		■								
Ammunitions											■																			■						■
Anti-fouling Paints											■											■	■				■									
Automotive					■		■	■		■	■															■		■								■
Batteries																					■	■														
Boat Manufacturing / Boat Repair						■	■	■		■	■							■					■			■	■	■	■		■	■				■
Boat Refueling						■	■											■								■			■		■					
Chemical Manufacturing			■					■		■													■	■		■						■			■	
Coal Gasification (MGP)	■					■	■					■						■						■		■			■		■					
Commercial Farming	■	■	■											■	■															■					■	
Corrosion Metallurgy										■	■	■										■			■											■
Dairy			■																											■						
Detergents / Surfactants																														■						■
Dye	■			■																																
Electrical								■			■											■	■		■			■				■				■
Explosives			■								■																									
Fish and Wildlife Consumption Advisory																							■					■								
Fruits and Vegetables			■																											■						
Leather / Tanning										■																										
Meat Products			■																																	
Metal Finishing / Refining				■	■		■	■		■	■	■									■	■			■	■										■
Metallurgical Processes					■																				■	■										■
Nitric Acid Manufacturing			■																																	
Oxide Manufacturing										■	■																									■
Pesticides / Fertilizers	■	■	■												■	■	■		■	■										■					■	
Petroleum Refining			■																			■										■	■	■		
Phosphate Mining																														■						
Photographic					■					■																				■		■				
Pigments / Inks			■	■																		■	■									■				
Plastics	■																					■														
Printing Plates																														■						■
Pulp and Paper Mills																							■		■	■							■	■		
Rubber																																■				■
Steam Power				■	■		■	■		■	■											■			■											
Steel / Iron			■	■	■	■	■					■										■				■		■	■	■	■					■
Sulferic Acid			■	■																																
Textiles			■				■																													
Utilities																							■						■	■		■				■
Valuable Mineral Mining												■										■														■
Waste Water Treatment Plants			■						■	■	■											■	■		■	■		■		■	■					■

Xcel Energy Prairie Island Nuclear Generating Plant

Verification Monitoring Plan

Submitted in Accordance with the NPDES Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities

NPDES Permit MN0004006

October 25, 2006

Prepared by:

Xcel Energy
Environmental Services

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1.0 Introduction

On July 9th, 2004 the EPA published an amendment to rule 316(b) of the Clean Water Act (CWA) in the Federal Register (from hereafter referred to as "the Rule"). The purpose of the amendment is to establish the best technology available for minimizing adverse environmental impact associated with the use of cooling water intake structures. The Verification Monitoring Plan (VM Plan) is one component of the Comprehensive Demonstration Study (CDS), which is being submitted by our facility to comply with 40CFR 125.95(b)(4)(ii).

As stated in the Rule, the VM plan is to contain, at a minimum, two years of monitoring to verify the full-scale performance of the proposed or already implemented technologies and/or operational measures. The verification study is to begin once the design and construction technologies and/or operational measures are installed.

In addition, the VM plan must provide: (1) Description of the frequency and duration of monitoring, the parameters to be monitored, and the basis for determining the parameters and the frequency and duration for monitoring; (2) A proposal on how naturally moribund fish and shellfish that enter the cooling water intake structure would be identified and taken into account in assessing success in meeting the performance standards; (3) A description of the information to be included in a bi-annual status report.

2.0 Summary of Verification Monitoring

In 1983, a new screenhouse was constructed at the Prairie Island Nuclear Generating Plant (PINGP). There are presently two complete screening facilities operating at PINGP. The old, or original, traveling screens and screenhouse (plant screenhouse) were designed to prevent debris, fish, and other organisms from entering the plant via the cooling water intake. The new screenhouse and screens (intake screenhouse), completed in 1983, were designed and located to exclude fish from the warm circulating water system. Xcel Energy has conducted verification monitoring and related studies to verify the performance of intake screenhouse technologies at PINGP from 1983 through 2005.

2.1 Impingement

During November 1983 through March 1984 impingement samples were collected from coarse mesh screens at the intake screenhouse. Total number of fish impinged was estimated by expanding the numbers collected during weekly samples over an entire month. In addition, fish collected were recorded as live or dead, live fish were held in aquaria for up to 96 hours. To determine the efficiency of the screen wash in removing fish on the front side of the coarse mesh screens, a dip net was used to collect material washed off the backside of screens. The results of the samples indicate the front spray wash system was nearly 80 percent effective in removing fish.

During sample years 1984 to 1989, sample collection of fish impinged on the fine mesh screens started in April and continued through August. Samples were collected 2 to 3 days a week by diverting 25 percent of the screen wash water into collection tanks in the basement of the environmental lab. Three types of samples were collected to provide various data. Sample types included abundance, initial survival, and latent survival. Following a designated sampling duration, all fish and any debris were rinsed into two collection baskets located in the collection area of the tank. These baskets were then removed from the tank, the contents transferred to four-liter beakers, and transported to the fish handling and sorting area for further processing.

Initial survival samples were collected at night or early morning to determine night density of fish and eggs and initial survival of fish impinged on the fine mesh screens. Initial samples underwent a "first and second" sort. The first sort was designed to remove live and dead fish, with emphasis placed on removing all live fish in a time efficient manner. The second sort was designed to assure removal of all remaining fish and eggs. Abundance samples were collected during early to midmorning to estimate day density of fish and eggs impinged on the fine mesh screens. After the sample was collected, all fish, eggs, and debris were preserved in 10 percent buffered formalin solution containing rose bengal stain and were sorted after the stain had an opportunity to penetrate all organisms.

Latent survival samples were collected to determine the latent survival of fish impinged on the fine mesh screens. Samples were collected during early morning. After the sample was collected, aliquots were placed in Pyrex baking dishes and sorted over a light table. Only live fish were removed and placed in 250 ml wide mouth jars or six gallon aquaria containing filtered river water. Jars and aquaria were kept in acrylic plastic water baths receiving a constant supply of river water. This allowed fish to be maintained at ambient temperatures throughout the holding period. Fish collected for latent survival estimates were held for 48 or 96 hours and checked at selected time increments. Number of live and dead fish were recorded during each time interval.

During 1984, back wash samples from fine mesh screens were also collected. Back wash samples were collected while an abundance sample was collected. This sample was collected using a 0.5 mm mesh ichthyoplankton drift net placed in the high pressure trash removal return trough. Comparing data from the abundance and back wash samples was utilized to determine the efficiency of the low pressure front wash in removing fish impinged on the fine mesh screens. Twenty-four pairs of samples compared indicated that the front spray wash removal system was more than 98 percent efficient in removing fish from the front side of the fine mesh screens.

Fish and egg densities were calculated on a day and night basis using data from abundance and initial survival samples, respectively. Estimates of the number of fish and fish eggs impinged on the fine mesh screens were calculated by averaging data from initial and abundance samples. These values were expanded to weekly and yearly impingement estimates. All fish and eggs collected were identified to the lowest practical taxon by life stage and developmental phase. Life stages included egg, larvae, juvenile, and adult. Estimates of the number of fish and eggs impinged on the fine mesh screens were calculated by averaging data from the initial and abundance samples. These values were expanded to weekly and yearly impingement estimates.

Identification Methodology

All fish and eggs collected were identified to the lowest practical taxon by life stage and developmental phase. Life stages included egg, larvae, juvenile, and adult. Terminology and criteria are similar to those described by Auer (1982). The larval stage was divided into two developmental phases, prolarvae and postlarvae, which corresponded to Auer's terms yolk-sac larvae and larvae.

Terminology and criteria:

- Prolarvae—phase of development from moment of hatching to complete absorption of yolk.
- Postlarvae—phase of development from complete absorption of yolk to development of the full compliment of adult fin rays and absorption of fanfold.
- Juveniles—phase of development from complete fin ray development and fanfold absorption to sexual maturity.

All fish eggs removed from samples were enumerated, but only freshwater drum eggs were identified. Others were recorded as "unidentified fish eggs". No differentiation was made between live and dead eggs. Egg data were included only in density and total impingement estimates.

Total lengths of representative specimens were recorded to refine length ranges as established in previous years, for developmental phases off each taxon.

Identification aids included published and unpublished literature, recent manuals (Auer, 1982 and Holland, 1983), reference specimens from previous studies, and dissecting microscopes with bright field/dark field bases and polarizing filters.

Sampling Mortality

Extreme low river flows and excessive debris conditions occurred during impingement sampling in 1988. It became apparent that sampling induced mortality was having a pronounced impact on initial survival estimates. Large amounts of zooplankton and phytoplankton appeared to be causing increased mortality of fish in the sampling tank and was substantially increasing sorting time (NSP, 1989). To address this concern, the larval survivorship study was adapted in 1989 and 1990 by introducing test fish into the sample collection system. To differentiate from naturally occurring larval fish in the samples, test fish were marked with a biological stain. The resultant survival of test fish was used to assess sampling induced mortality.

The effects of debris loading were studied to determine the relationship to survival of larval fish collected. Studies conducted in 1989 and 1990 document that high debris in the collection system caused introduced test fish to suffer increased mortality and indicated survivorship of larval fish collected from the vertical traveling screens was underestimated. It was also determined that survival estimates are dependent on the hardiness of species and developmental stage of the fish (NSP, 1989).

Results of studies conducted in 1989 and 1990 indicate that sampling induced mortality caused by excessive debris in samples ranged from approximately 3 to 44 percent mortality depending upon sample period and test fish species. Overall, test fish survival was 85 percent, suggesting that the sampling method may account for 15 percent mortality of all fish sampled from fine mesh screens and up to 10 percent mortality of juvenile fish (NSP, 1989).

Related Studies

Impingement studies from 1992 to 2005 were conducted to evaluate the effects of increased water appropriation from 150 to 300 cubic feet per second (cfs) during April on impingement of larval fish on 0.5 mm fine mesh traveling screens at PINGP. From 2002 to 2005, permit approved blowdown (discharge) reduction to 300 cfs or less was initiated on April 15th rather than on April 1st. Prior to 1992, the cooling water intake system operated with fine-mesh screens from April 16 through August 31, in accordance with plant's NPDES Permit. Since 1992, for study purposes, the plant has implemented fine-mesh screen operation on April 1 to accommodate sampling during the month of April for years 1992 through 2005. Data for this evaluation were collected by pre-dawn and daylight sampling of larval fish and fish eggs from the screenwash water. Estimated impingement values during April for all years were low and represented by relatively few taxa/life stage combinations.

2.2 Entrainment

Based on studies conducted at PINGP (see IM&E Study), it was determined that 0.5 mesh screen would adequately screen eggs and larval stages of fish from the water entering the intake canal. Impingement estimates calculated for 1985 through 1988 are considered to be a realistic approximation of the number of larval fish and eggs which would have been entrained through PINGP in the absence of the fine mesh screens. Entrainment studies in 1975 estimated that nearly 70 million larvae and eggs were entrained at PINGP. Impingement estimates from fine mesh screens for 1985 through 1988 were similar with estimated number of larvae and eggs impinged ranging from 42 million to 77 million. Species composition of entrainment and impingement samples is also similar with freshwater drum, cyprinids, and gizzard shad representing a large percentage of samples.

2.3 Operational Measures and River Flow

During the months of April, May, and June operational measures to reduce intake flow are in place per the NPDES permit to minimize potential impacts to larval fish and eggs at the intake. Operations at PINGP reflect this design with current operational measures as follows:

April 15 to 30:	300 cfs (194 mgd) if the flow in the river is at or above 15,000 cfs
	150 cfs (97 mgd) if the flow in the river is below 15,000 cfs
May 1 to 31:	300 cfs (194 mgd)
June 1 to 15:	400 cfs (259 mgd)
June 16 to 30:	800 cfs (517.5 mgd)

Through screen velocities during the period of April 15 to June 15 range from 0.29 ft/sec to 0.38 ft/sec. These through screen velocities during this sensitive larvae period are less than the 0.5 ft/sec performance standard for impingement mortality as stated in the 316(b) Phase II rule document. The remaining periods of the year flow is limited to the design intake flow of 1410 cfs.

The Mississippi River is the source-water body for circulating and cooling water systems at PINGP. Xcel Energy provides water temperature and flow data in the PINGP Annual Report. The report presents daily plant operating hours, river inlet temperatures, site discharge temperatures and flows (blowdown). Also presented in the report are daily and monthly average Mississippi River flows, as provided by U.S. Army Corps of Engineers at Lock and Dam 3. Other monthly averages reported include PINGP intake flows, and the percentage of Mississippi River water entering the plant.

2.4 Electrofishing Surveys

Xcel Energy has conducted electrofishing surveys on the Mississippi River in the vicinity of PINGP since 1973. The ongoing study provides more than 30 years of data on the fish populations in the river.

To fulfill part of the continuing environmental monitoring requirements of PINGP, the Mississippi River fisheries population is sampled by electrofishing near Red Wing, Minnesota, May through October. The study area extends from 3.6 miles upstream of the plant (River mile 802) to 10.8 miles downstream of the plant (River mile 787.5). The objective of the study is to monitor and assess the status of the fishery in the vicinity of the PINGP (NSP, 1994). Parameters analyzed and compared to previous years include species composition, length-weight regressions, percent contribution (fish/hr), length-frequency distributions, and catch per unit effort (CPUE) for selected species.

Sampling is conducted monthly, May through October, within four established sectors of the study area. The runs within each sector are similar to previous years sampling to ensure a similar set of relative data indices for yearly comparison. Parameters used to describe the fisheries include species composition, length-weight regressions, percent contribution, length-frequency distributions, and catch per unit effort (CPUE). It is assumed that population dynamics and spatial distribution is represented by CPUE.

3.0 Proposed Monitoring Plan

Based on intake screen impingement and entrainment verification studies and related studies conducted since the construction of the intake screenhouse in 1983, Xcel Energy is not proposing any additional impingement or entrainment sampling at PINGP. Xcel Energy will continue to conduct electrofishing surveys as outlined in the Ecological Monitoring Plan submitted in accordance with NPDES permit MN0004006 Chapter 6, Section 4.7. In addition, Xcel Energy will continue to report water temperature and flow data consistent with past Annual Environmental Reports. The PINGP Annual Environmental Report will also be considered as the 316(b) bi-annual status report.

4.0 References

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Holland, L.E. and M.L. Huston (ed.). 1983. A Compilation of Available Literature on the Larvae of Fish Common to the Upper Mississippi River. Prepared for U.S. Army Corps of Engineers, Rock Island, IL. 364 pp.

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