XcelEnergy

PRAIRIE ISLAND NUCLEAR GENERATING PLANT

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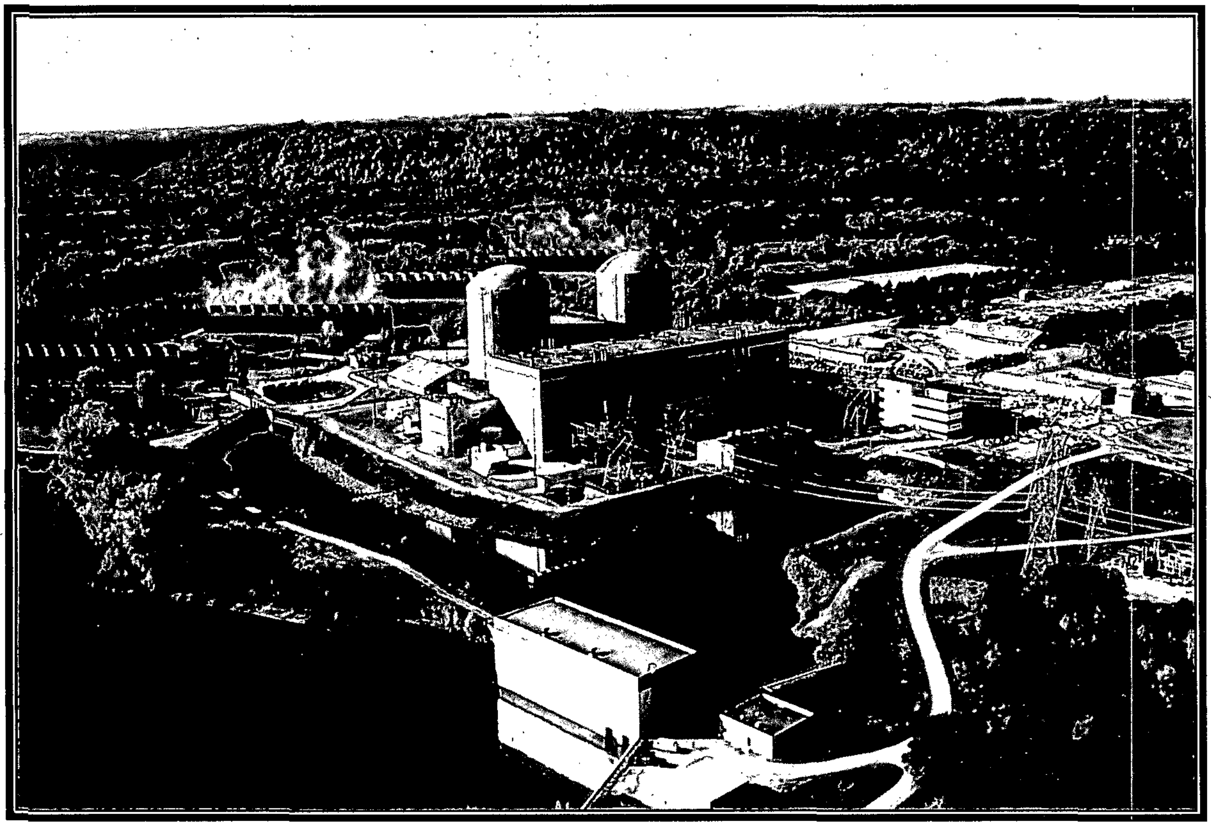

Documents Requested During NRC Environmental Review

Surface Water

Binder 2 of 3

Prairie Island Nuclear Generating Plant
NRC Document Request List

Item Number	Document
Liz Wexler	
63	Bodensteiner, J. 1991
64	ESWQD. 2000.
65	ESWQD. 2001.
66	ESWQD. 2002.
67	ESWQD. 2003.
68	ESWQD. 2004.
69	ESWQD. 2005.
71	HDR. 1978.
72	NSP. 1981a.
73	NSP. 1981b.
74	NSP. 1983.
75	Corr Binder: Letter from Matt Langan, MNDNR, Aug 10, 2007
76	Corr Binder: Letter from John Stine, MDH, April 10, 2008
77	Corr Binder: Letter from Gary Wege, USFWS, June 20, 2007
78	**Corr Binder: Letter from Terry Birkenstock, ACE, March 11 2008. If possible, include** attachment (2002 Clam Chronicle.pdf)
79	Corr Binder: Email from Tom Lovejoy, WDNR, Aug 31, 2007
80	Report regarding fish kill in 2000
82	**Letter to H. Krosch and D. Kriens from W. Jensen, Chlorination of Circ Water System** Fish Loss Report, October 14
83	NUS Corporation. 1976.
84	Stone and Webster. 1983.
85	**Xcel Energy, 2007, PINGP Environmental Monitoring and Ecological Studies Program** 2006 Annual Report.
86	**Xcel Energy, 2008, PINGP Environmental Monitoring and Ecological Studies Program** 2007 Annual Report.
87	NPDES Filing Cooling Data (Binder 14)
89	From Aquatic Review Binder: ESE. 1999.
91	DMR: 5/21/98
92	DMR: 6/19/98
93	DMR: 10/21/98
94	DMR: 5/21/99
95	DMR: 7/20/01
96	DMR 11/21/01
97	DMR: 8/21/03
98	DMR: 5/20/05
101	Entire 316(b) Binder (Comprehensive Demonstration Study)
102	Plume Modeling of Discharge Canal Discharge Sluice Gate flow into the river

SECTION 316(a) DEMONSTRATION
FOR THE PRAIRIE ISLAND NUCLEAR GENERATING PLANT
ON THE MISSISSIPPI RIVER NEAR
RED WING, MINNESOTA

NPDES PERMIT NO. MN0004006

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ENVIRONMENTAL REGULATORY
ACTIVITIES DEPARTMENT

NORTHERN STATES POWER COMPANY
MINNEAPOLIS, MINNESOTA

AUGUST 1978

PREPARED BY
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HDR ecosciences

TABLE OF CONTENTS

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

LIST OF FIGURES

LIST OF FIGURES (Con't)

LIST OF FIGURES (Con't)

LIST OF FIGURES (Con't)

LIST OF FIGURES (Con't)

LIST OF TABLES

LIST OF TABLES (Con't)

LIST OF TABLES (Con't)

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I EXECUTIVE SUMMARY

A. INTRODUCTION

Thermal discharges, including power plants such as PINGP, are regulated by state and federal laws. All dischargers to surface waters are required by the FWPCA Amendments of 1972 ("the Act,"P.L. 92-500) to obtain a National Pollution Discharge Elimination System (NPDES) permit from an authorized agency. In Minnesota, the Minnesota Pollution Control Agency (MPCA) has been designated as lead agency to the Environmental Protection Agency (EPA) and administers the law using the Act and MPCA Regulation WPC 36(u)(3).

For this 316(a) demonstration, a predictive Type 2 approach was selected for assessing future impacts of the PINGP thermal discharge upon indigenous biota. This involves selection of representative important species (RIS), including fish and invertebrates, and relies primarily on literature data for thermal tolerances and on thermal plume models to estimate potential impacts. Appropriate site-specific data were utilized to supplement the predictive approach.

B. ENVIRONMENTAL CHARACTERISTICS

PINGP is located on the west bank of the Mississippi River approximately 2.4 km (1.5 mi) upriver from Lock and Dam No. 3 (Figure I-1). The plant intake and discharge areas are separated from the main river channel by a series of small islands that delineate the outlet channels of Sturgeon Lake, a backwater lake connected to the river by numerous small channels. The river is 300 to 370 m (1,000 to 1,200 ft) wide near PINGP, and the banks of the main channel slope fairly steeply to the bottom. The Sturgeon Lake outlet area is quite shallow, and consequently, the intake and discharge areas have been dredged to a depth of about 3.1 m (10 ft). The thermal effluent flows approximately 610 m (2,000 ft) before entering the main channel of the river at Barney's Point.

River flows are regulated to maintain a minimum pool level for navigation during ice-free months (usually mid-March to early December). The annual average discharge rate at Prescott, Wisconsin, was 16,200 cfs for the period 1928 to 1976. River flows have seasonal fluctuations with a peak in April (weekly average of 44,000 cfs) and a low in December (weekly average of 7,000 cfs). The maximum rate recorded was 228,000 cfs on 18 April 1965, and the minimum was 2,100 cfs on 14 August 1936. River

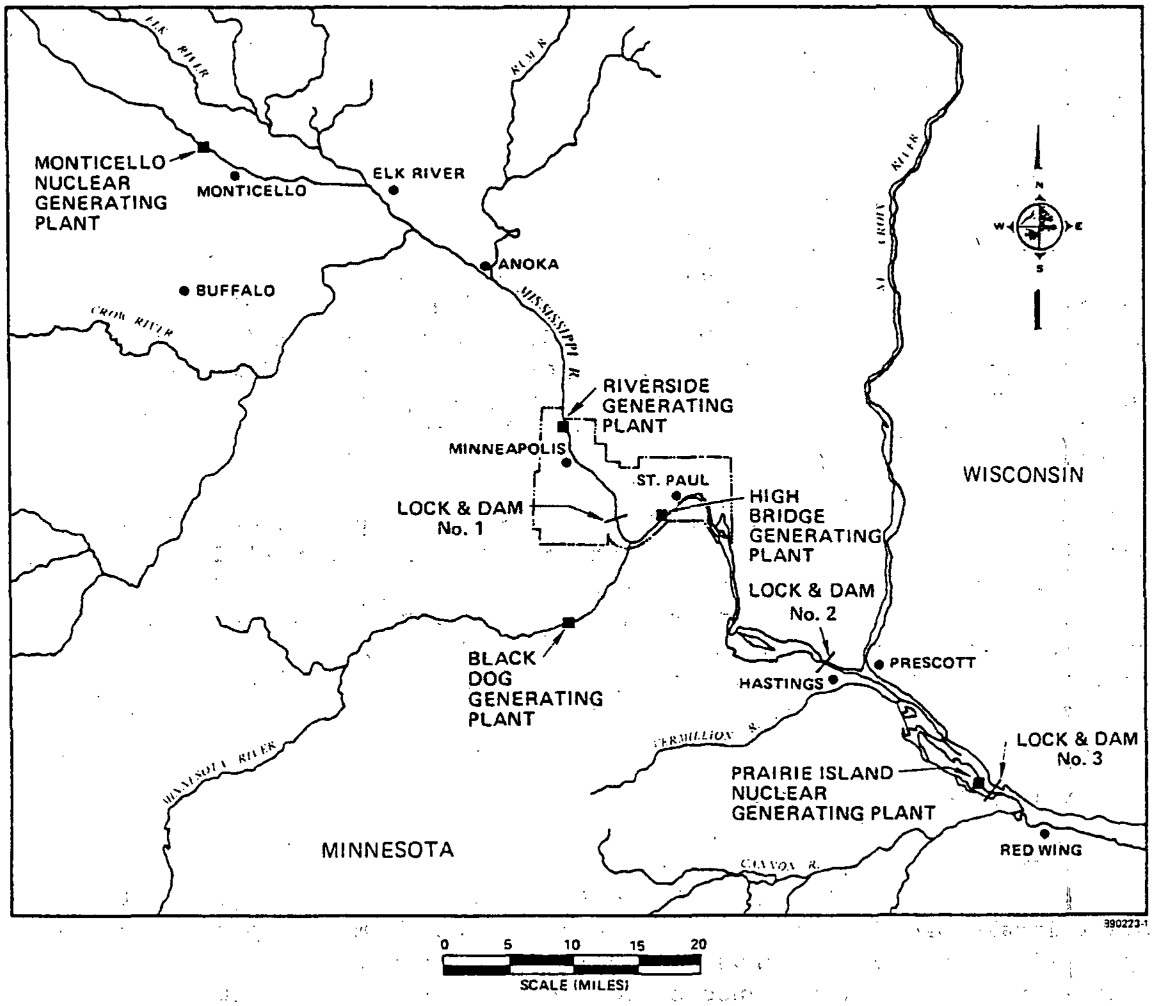
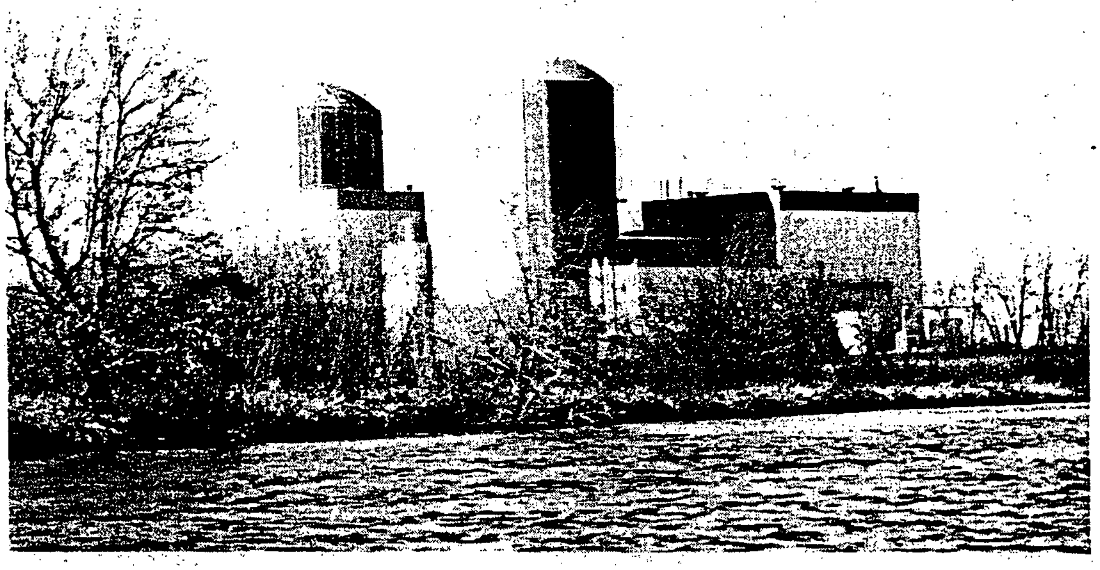


Figure I-1. Location of the Prairie Island Nuclear Generating Plant.



The Prairie Island Nuclear Generating Plant is located on the west bank of the Mississippi River approximately 2.4 km (1.5 mi) upriver from Lock and Dam No. 3. Heated effluent is discharged into the southern end of Sturgeon Lake, which is separated from the main river channel by a series of small islands, and enters the river at Barney's Point.

temperatures also have seasonal variations with a low of 0° C (32° F) in winter when the river freezes over and a high of 29° C (85° F) in summer. Intake temperature data from Northern States Power Company's Red Wing Generating Plant (RWGP) located 15 km (9.4 mi) downriver from PINGP were used to represent PINGP ambient river temperatures since long-term data were not available near the plant. Daily temperature fluctuations are low in the river [1.1° C (2° F)] but may be fairly high in backwater areas. In Sturgeon Lake, the average fluctuation was 2° to 3° C (3.5° to 5.4° F) with a maximum of 9.7° C (17.5° F) during ice-free months of 1974 through 1977.

Extensive water quality analyses have been conducted by NSP in the vicinity of PINGP since 1969 in addition to the U.S.G.S. measurements conducted at Lock and Dam No. 3 since 1969. Although dissolved oxygen (DO) levels never reach critically low levels, the high nutrient concentrations reflect the upriver discharge of domestic wastewater into the Mississippi River from the Minneapolis-St. Paul Metropolitan Sewage Treatment Plant. The Minnesota River also influences water quality in the vicinity of PINGP through addition of suspended sediments, dissolved solids, and other agriculturally related runoff. Elevated levels of potential toxicants such as ammonia, lead, mercury, and especially cyanide have been observed periodically at Lock and Dam No. 3, indicating that some biota may be pre-stressed before encountering the PINGP thermal plume. No significant non-thermal changes in water quality have been attributed to the operation of PINGP.

The Mississippi River near PINGP comprises numerous habitat types, thus creating a complex ecosystem. The river is fairly eutrophic near PINGP as a result of runoff from agriculture and wastewater discharges from the Metropolitan Sewage Treatment Plant. Biota in all trophic levels have been sampled in the vicinity of PINGP since 1969, and from this information a list of representative important species (RIS) was selected for assessing impacts in this demonstration. 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*. Sampling from 1973 through 1976 has indicated that gizzard shad, white bass, freshwater drum, and carp dominated the adult and juvenile fish populations near PINGP from late May through October. Abundances varied both seasonally and annually for the dominant species. Larval fish were present in the water column during spring and summer with peak densities occurring in July of 1974 and June of 1975. The most abundant species were white bass, emerald shiners, carp, and gizzard shad. Life histories, thermal tolerances, migrations and spawning areas, predator-prey interactions, and diseases and parasites were included in the discussion for the RIS.

Both commercial and recreational fishing occur in Pool No. 3. Catfish, carp, drum, and buffalo are the most valuable commercial species, and the harvest and catch per unit effort in Pool No. 3 increased from 1970 through 1974 while declining in Pool Nos. 4 and 4a. Based on creel census information from 1973 through 1976, recreational fishing pressure has remained lower in the vicinity of PINGP than in the tailwaters of Dam No. 3; however, fishing success was higher above the Dam. Walleye and white bass were the RIS most frequently caught near PINGP, while white bass dominated the catch in the PINGP discharge area during spring.

A high diversity of benthic macroinvertebrate, zooplankton, and primary producer populations exists near PINGP. Marked seasonal variations in organism abundance were common in all groups. Many of the macroinvertebrates are larval stages of terrestrial and aquatic insects that emerge from the water during summer, while 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 PINGP discharge canal or the main channel of the river. Life histories and thermal tolerance information for all biotic categories except macrophytes are also discussed.

Northern bald eagles and various waterfowl migrate through the Mississippi River Valley in spring and fall with some overwintering in areas of open water. The PINGP area does not appear to be an important eagle overwintering area although the discharge may enhance the number of mallards overwintering. Peregrine falcons, an endangered species, are being reintroduced in former nesting areas along Lake Pepin approximately 48 to 80 km (30 to 50 mi) downriver from PINGP.

C. PLANT DESCRIPTION AND OPERATING PROCEDURE

The PINGP circulating water system may be operated in four basic modes: closed, partial recycle, helper, or open cycle. Closed cycle is normally used during the cooler parts of the year, and blowdown is held at approximately 150 cfs. When the temperature of the mixed, makeup and recycled water reaches 29.4° C (85° F) at the condenser, partial recycle is begun and increased as necessary to maintain the condenser inlet temperature at or below 29.4° C. In this mode, cooling towers are still used, but the blowdown and makeup water flows are increased. Helper cycle (no recycle) and open cycle operation are optional modes that have not been used in the past but could be used if needed.

The circulating water system is not chlorinated since the condenser tubes are cleaned mechanically (Amertap method). The cooling water system, however, is chlorinated to prevent biofouling of heat exchanger surfaces, and this water is discharged to the circulating water system. The volume of the cooling water is only 4 percent of the circulating water volume, and chlorine may be lost to the atmosphere in the recycle canal. Measurements of total residual chlorine at the discharge gates have shown the concentration to be less than 0.03 ppm.

PINGP is a base load facility and each of the two units is rated at 507 MWe in summer and 523 MWe in winter. Refueling of one unit occurs during winter while refueling of the other is usually in early spring. These refueling periods are generally 4 to 6 weeks long. Based on past operation, the probability of a forced trip (outage) occurring while the other unit is being refueled is 0.55, and the probability of simultaneous forced trips is 0.00035.

Operating modes should remain similar to those utilized in the past. During summer, however, full helper cycle is proposed from 16 June through 31 August to increase the efficiency of the plant. This would cause the temperature differential between ambient river water and blowdown to decrease, thus decreasing the maximum temperatures in the plume during summer.

D. THERMAL PLUME

The thermal plume was modeled for various typical and extreme environmental conditions for each month of the year (61 cases total). A two-dimensional (2-D) model was utilized for the near-field area bounded by the intake approach channel on the north, the river bank on the west, the islands on the east, and the entrance to the main river channel at Barney's Point on the south. For the main channel of the river from Barney's Point to Lock and Dam No. 3, a three-dimensional model (3-D) was utilized. The model descriptions and results are presented in Appendix I, including plots of surface isotherms for representative conditions. Historic typical and extreme cases were based on 1975 and 1976 operational and environmental information, while proposed extreme cases were a combination of 7-day, 10-year low river flow, high river ambient temperature, a maximum blowdown rate, a southerly wind, and a high wet bulb temperature which would result in poor cooling tower performance. The models were calibrated with data from the September 1974 and August 1975 field thermal surveys.

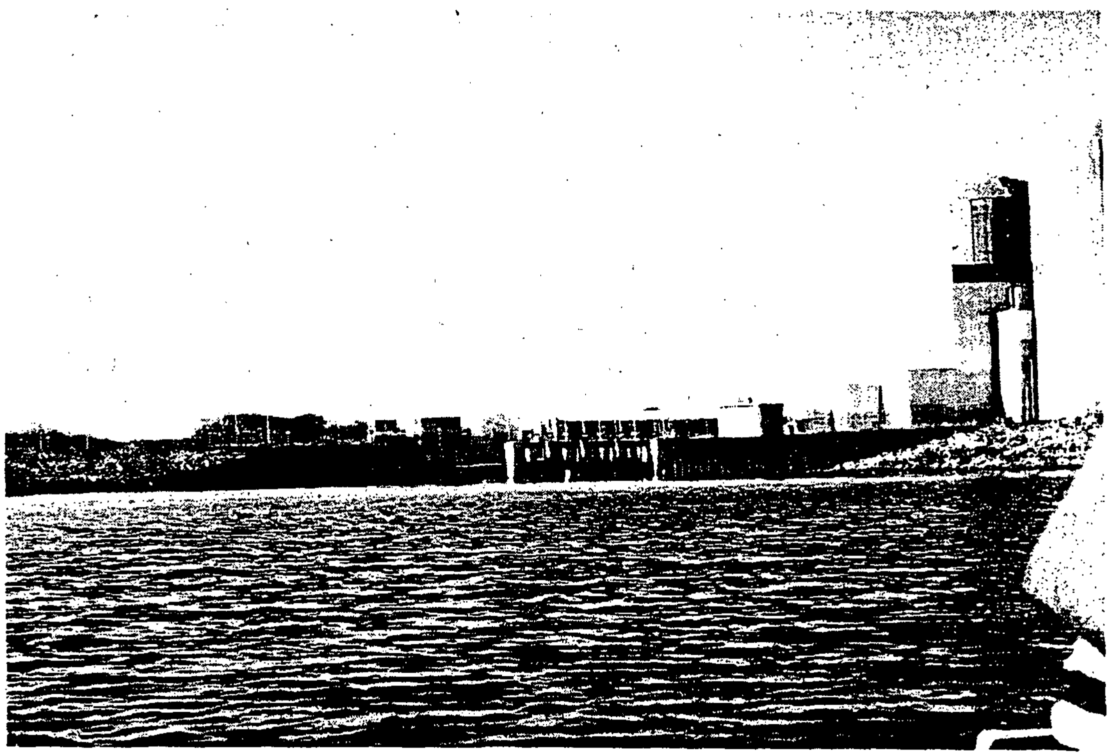
The thermal plume model results were compared with the proposed NPDES permit for PINGP, and 13 of 61 cases exceeded the proposed thermal limits. All but two of the cases that exceeded were for typical environment conditions in late fall and winter (October through March). These two cases, which were for proposed extreme conditions, exceeded the 30° C (86° F) maximum temperature criterion at Barney's Point by less than 1° C (1.8° F). One case was in July and the other in August. The proposed extreme cases, however, are one day events that occur with a probability of 0.000005 (1 hour every 278 years) per month. The criterion exceeded in the other 11 cases was the 2.8° C (5° F) ΔT limit at Barney's Point (edge of the mixing zone).

For future operation during typical environmental conditions of river flow, ambient river temperature, and blowdown rate, a variance to the proposed NPDES permit will be necessary to meet the thermal criteria without derating the plant. An extension of the mixing zone boundary 488 m (1,600 ft) downriver for October through March would be sufficient to maintain compliance with the proposed NPDES permit.

E. BIOLOGICAL IMPACTS OF THERMAL DISCHARGE

To predict the potential biological impacts of operating PINGP, both literature and field data were used along with the thermal plume model results. For fish, the predictive approach based on literature information and model results was emphasized with some supportive use of field data. For invertebrates and primary producers, however, an extensive reanalysis of the existing field data was performed since literature information was limited.

Based on preferred temperatures reported in the literature, all of the fish RIS would prefer to reside in some portion of the PINGP thermal plume when ambient water temperatures are low, and some species should avoid at least the warmer areas within the plume during summer. These predictions have been confirmed by field studies which indicated that white bass, carp, emerald shiner, walleye, and gizzard shad were definitely attracted to the discharge during winter and/or spring. Shorthead redhorse, white bass, carp, and gizzard shad showed a distinct avoidance of the warmest discharge areas during summer. Upper lethal temperatures were used to estimate the potential areas of exclusion for long-term use by adults during typical summer conditions. These areas were calculated to be less than 4.4 ha (10.9 A) for all of the RIS fish and would occur only in July and August.



The PINGP thermal discharge attracts fish during most of the year, although some species avoid the warmest portion of the plume in summer. Impacts to the representative important species (RIS) of fish and macroinvertebrates, however, are predicted to be minimal.

The thermal discharge could induce premature spawning in fish which reside in the plume during spring. Field studies have shown that carp, walleye, gizzard shad, and emerald shiner are the dominant species in the discharge area during spring; however, no premature spawning has been observed during the field surveys. The warmest areas of the plume may preclude successful spawning in a small area, either by exclusion of adults or through thermal stress to embryos. The maximum area of potential exclusion for typical environmental conditions is small [17 ha (42 A) for northern pike and less than 9 ha (22 A) for the other RIS], particularly when compared to the area of Sturgeon Lake [324 ha (800 A)] which has an abundance of suitable spawning habitat for most of the RIS. Furthermore, the estimated exclusion areas may include little or no suitable spawning habitat for some species, and the maximum area of exclusion for each species occurs during only a portion of the spawning period. Thus, the potential for impact would be considerably less than that estimated from exclusion area alone. Larval fish drifting from Sturgeon Lake through the discharge area will be subjected to elevated temperatures, but literature data for larval thermal tolerances do not indicate that stress would occur at PINGP.

Although the PINGP thermal discharge can affect various RIS life functions in the discharge area, no measurable effects are expected to occur in the fish populations of Pool No. 3. Potential premature spawning of carp and gizzard shad should have negligible effects since only a small proportion of their populations are calculated to be present in the discharge during spring. For walleye and emerald shiner, early spawning is also predicted to have minimal effects on river populations since it is unlikely that all of those in the discharge would spawn early, and even if they did, it is unlikely that all such spawning would be unsuccessful. Exclusion of adults from potential spawning areas in the immediate discharge area should have negligible effects on river populations since many other suitable spawning areas are present nearby (e.g., Sturgeon and North Lakes).

The potential for cold shock exists at PINGP during winter from either simultaneous shutdown of both units or an unscheduled trip while the other unit is down. Fish are attracted to the thermal plume in winter, temperatures exceeding the recommended maximum weekly average temperature for cold shock protection exist in the plume, and the probability of a forced trip occurring during refueling of the other unit is 0.55. The thermal plume is smaller, however, during one unit operation. The species most likely to be affected is gizzard shad since it is the dominant species present in winter and one of the most sensitive to cold shock. Potential mortality to gizzard shad is not expected to decrease river populations, however. This prolific species normally has large winter die-offs as ambient water temperatures approach 0° C (32° F), and the discharge and recycle canals may provide a temporary thermal refuge which would only delay such natural die-offs.

The PINGP discharge is not expected to affect any endangered species of fish nor inhibit any fish migrations. Predator-prey interactions as well as parasitism and diseases are likewise predicted to be negligibly affected. Fish population structure should not be changed although such changes are very difficult to measure and are generally indistinguishable from other influences, both natural and man-induced.

Sport fishing has not been in the past and should not be degraded as a result of the PINGP thermal discharge. Fishing success in recent years has been higher above Lock and Dam No. 3 than in the tailwaters of the Dam, although the fishing pressure and harvest have been lower. In the immediate discharge area, fishing success should be enhanced during all but the warmest periods in summer. Fishing pressure has been observed to be higher in the discharge during spring which indicates that some fishermen were taking advantage of the higher fish densities in the plume, and the catch at that time was primarily white bass.

Site-specific invertebrate and primary producer field data were reanalyzed primarily for the operational years of 1975 and 1976. Data for phytoplankton from 1973 and from the first 6 months of 1977 for macroinvertebrates were also utilized. Between station and between date sample variability were computed by ANOVA, Duncan's Multiple Range Test, and the Student t-Test. Power calculations were also used to establish the likelihood that actual differences between samples would be detected as significant by the above tests. In addition to the sample variance testing, multiple regressions were conducted in order to determine whether or not temperature was highly related to abundances of biota on a spatial basis (i.e., between intake and discharge stations).

From these reanalyses, impacts appear to be minimal or non-existent in most biotic categories. The following characteristics of biotic categories were found not to differ significantly between intake and discharge stations: phytoplankton species diversity or biovolume; periphyton density, species diversity, and phaeophytin a content; zooplankton species diversity and density; and macroinvertebrate (dredge and artificial substrate) density. The power of these statistical tests, however, is limited by the inability to discern differences between station values as a result of the low number of replicate samples taken at each station

The following characteristics of biotic categories were found to differ significantly between intake and discharge stations: phytoplankton primary productivity, periphyton chlorophyll a, and macroinvertebrate species diversity for dredge samples. The significant differences in phytoplankton chlorophyll a between intake and discharge samples probably resulted from plant entrainment damage, while the significant differences between intake and discharge for dredge macroinvertebrate species diversity could have resulted from differences in substrate and current rather than, or in addition to, thermal effects. A study of aquatic insect emergence rates showed that only the mayfly, *Caenis*, may have emerged slightly earlier from heated water stations than from ambient temperature stations. All other aquatic macroinvertebrates including one RIS (*Hydropsyche*) emerged at approximately equal rates and times from both heated and control stations. Variations in the distribution of aquatic macrophytes between years in the discharge canal have not been definitely related to the thermal plume, but appear to be more dependent upon fluctuations in water level, siltation, and currents.

Multiple regressions showed that although temperature was selected as the parameter most highly related ($R^2 = 0.35$) to zooplankton density (and its subgroups, rotifers and crustaceans) on an annual basis, seasonal relationships were low ($R^2 = 0.06$). This indicates that annual variation (between intake and discharge) was negligible. Temperature was not significantly related to phytoplankton or macroinvertebrate (both dredge and artificial substrate samples) densities. Periphyton was not tested for significant correlations with water temperature because of insufficient coincidental water quality data.

Predictive impacts for non-fisheries biota were determined by comparing the most relevant thermal bioassay information with the thermal plume model results for typical and proposed extreme environmental conditions. Four RIS macroinvertebrates were selected (*Hydropsyche, Macronemum, Pseudocloeon,* and *Stenonema*), all of which are aquatic insect larvae. Thermal tolerances for selected zooplankton, phytoplankton, and periphyton were also compared with thermal plume configurations for indications of potential drift mortality or exclusionary areas.

From this predictive analysis of comparing organism thermal tolerances with plume configurations, the following results were found: no drift mortalities are expected for phytoplankton, zooplankton, or macroinvertebrates. Most habitats in the discharge canal that are otherwise suitable for aquatic macroinvertebrates will not be rendered unsuitable as a result of high temperatures, except for small portions during proposed extreme environmental conditions. For instance, the area in the discharge canal equivalent to approximately one to six percent of Sturgeon Lake may be avoided by two macroinvertebrate RIS (*Hydropsyche* and *Macronemum*). This does not mean, however, that these two taxa will be killed or even excluded from the discharge areas during extreme conditions, but that they will be less common at higher temperatures in the discharge area than in control areas. Site-specific information for these two species during the unusually warm, low flow year of 1976 indicated, however, that they did not avoid the discharge canal.

Based on literature data, a two-week acceleration of the emergence schedules for most aquatic macroinvertebrates is predicted for the entire area of the discharge canal (equivalent to about 5.7 percent of Sturgeon Lake). These predictions, however, are not supported by site-specific study results conducted in 1974 (except possibly for *Caenis*). In an area comparable to less than 0.5 percent of Sturgeon Lake, a five-month acceleration of emergence schedules is predicted, although this has not been observed in the past to occur in the PINGP discharge canal. Other predictions indicate that warmer water areas of the discharge canal may favor more thermally tolerant taxa, but this area would be insignificant compared to the area of Sturgeon Lake. The thermal plume should not favor the encroachment or proliferation of nuisance organisms, such as blue-green algae; blooms of these phytoplankton have occurred seasonally long before PINGP became operational. Moreover, no federally protected flora or fauna will be impacted by the thermal discharge.

The operation of past and proposed discharge modes at PINGP, therefore, have not and should not inhibit the protection and propagation of a balanced, indigenous invertebrate and primary producer biota. The discharge plume will cause neither appreciable harm nor adverse levels of impact to non-fisheries biota. No drifting forms are expected to or have been observed to be damaged by passage through the plume. Even during extreme environmental conditions, the maximum area of avoidance as a result of heated water for certain RIS macroinvertebrates is small in relation to the total area available in the adjacent backwater habitat of Sturgeon Lake. Moreover, emergence schedules of aquatic macroinvertebrates are expected to be altered only slightly by the heated plume and only negligible losses are expected as a result of premature emergence. Finally, the occurrence and distribution of aquatic macrophytes near PINGP appears to be more influenced by fluctuations in water level, sedimentation, and current conditions than by temperature. Any losses of aquatic macrophytes that may result from the thermal discharge is small in comparison to the total distribution of macrophytes in Sturgeon Lake, as suitable habitat for these plants in the discharge canal is extremely limited.

F. CONCLUSIONS

It is concluded that the thermal discharge resulting from past operation of PINGP has not caused appreciable harm to any aquatic biota, and the protection and propagation of a balanced, indigenous biota has been maintained. During future operation in past or proposed modes, impacts are expected to remain similar to those in the past.

II INTRODUCTION

A. LEGAL REQUIREMENTS AND RATIONALE

The operation of all power plants in Minnesota is regulated by state and federal laws. The Federal Water Pollution Control Act Amendments of 1972 ("The Act" P.L. 92-500) require that municipalities and industries discharging into surface waters obtain a National Pollution Discharge Elimination System (NPDES) permit from an authorized agency. If the discharger can demonstrate that the required limitations are more stringent than necessary to assure the propagation of a balanced indigenous population within the water body receiving the discharge, then alternative effluent limitations may be in order.

Discharges from power plants in Minnesota fall primarily under the jurisdiction of the Minnesota Pollution Control Agency (MPCA) which has been designated as lead environmental regulatory agency for this state by the Environmental Protection Agency (EPA). The MPCA administers the law using both the Act and MPCA Regulation WPC 36(u)(3). The Minnesota guide for 316(a) demonstrations (MPCA, 1975) will be used as the primary source of information for developing this demonstration. The Interagency 316(a) Technical Guidance Manual (EPA, 1977) provides valuable ancillary information to the Minnesota Guide but will be considered tentative in view of its draft status and Edison Electric Institute and Utilities Water Act Group (1977) comments.

After conferring with MPCA and EPA personnel, a Type 2 demonstration was selected for assessing the impact of the PINGP discharge upon indigenous biota. This type of demonstration involves selection of Representative Important Species (RIS) for discussion of potential thermal impacts to the aquatic ecosystem. At PINGP, these include several fish and macroinvertebrate taxa. Other trophic levels including primary producers and zooplankton are considered also because of their potentially high biological value to the aquatic ecosystem near PINGP, but no RIS were selected. The predictive Type 2 demonstration relies primarily upon literature data for thermal tolerances of the RIS and other biota and modeling of the thermal plume in the receiving waters. In addition, some site-specific information will be utilized in this demonstration to supplement the predictions of whether or not the RIS and other biota are protected.

B. SCOPE AND ORGANIZATION

The requirements for this demonstration have been outlined by the MPCA and the EPA as discussed above. The demonstration begins with a description of the environmental characteristics of the aquatic habitat near PINGP. These characteristics include hydrology, water quality, and general aquatic biology of the Mississippi River and its associated backwater habitats. Life history descriptions and habitat preferences of 10 fish RIS (black crappie, walleye, channel catfish, carp, emerald shiner, gizzard shad, white sucker, shorthead redhorse, white bass, and northern pike) are provided as well as four macroinvertebrate RIS (two caddisflies, *Hydropsyche* and *Macronemum*; and two mayflies, *Stenonema* and *Pseudocloeon*). In addition, thermal tolerance data are summarized for RIS and other selected taxa from all trophic levels.

A description of the plant and its operating procedures follows the discussion of existing environmental characteristics. The circulating water system and its modes of operation are described along with a summary of chlorination procedures and other chemicals used. Next, plant performance is discussed in relation to coincidental environmental conditions such as river temperature and flow. The occurrence of plant outages and potential recirculation of discharge water are then presented.

Following the plant description is a section on the past and predicted characteristics of the thermal plume. Results of thermal surveys from 1974 through 1976 will be presented and discussed as well as results of the near- and far-field plume models for various typical and extreme conditions. Finally, the observed and the predicted plume will be compared with state temperature standards and the NPDES permit limitations.

Biological impacts of the thermal discharge are discussed in the next section. Predicted impacts to the RIS are analyzed in order to assess whether or not the propagation of these species is protected in spite of the PINGP discharge. In addition, biota for which no RIS were selected are also considered with respect to impacts of the thermal discharge. These biota include zooplankton, primary producers (phytoplankton, periphyton, and aquatic macrophytes), and other biota (waterfowl and eagles).

Finally, the conclusions of the impact analyses including a discussion of whether appreciable harm or an adverse level of impact has or will occur are addressed. A complete list of all literature cited is provided as well as a number of appendices. These include: Appendix A.—Data Catalog; Appendix B.—Details of Non-fisheries Statistical Analyses; Appendix C.—Cross-Reference to State and Federal Regulations; Appendix D.—Cross-Reference to Regulatory Agency Requests; Appendix E.—Glossary; Appendix F.—Conversion Tables (Metric to English); Appendix G.—Agency Communication (Federal, State, and Local); Appendix H.—Unpublished or Obscure Reference Material; Appendix I.—

Thermal Discharge Analysis; Appendix J.—Regulatory Agencies Questions and Answers; Appendix K.—Species Lists; Appendix L.—Statistical Analysis: Discharge Electrofishing Study; Appendix M.—Joint Frequency Tables: River Flow-Blowdown Rate; Appendix N.—Thermal Surveys at PINGP.

C. ACKNOWLEDGMENTS

A number of NSP personnel have been instrumental in providing the voluminous information required to compile this 316(a) demonstration. The efforts and guidance of Mr. Larry Grotbeck, Mr. Richard McGinnis, and Mr. Lee Eberley are greatly appreciated. Also providing helpful information regarding plant operation, history, and design were Mr. Alex Simich, Mr. Don Brown, and numerous others at NSP. Drs. George Yeh and Y. Y. Shen of Stone and Webster Engineering Corporation compiled the predictive modeling for the thermal plume and assisted in the development of the demonstration since its inception. Dr. J. S. Rao of the Mathematics Department at the University of California at Santa Barbara assisted in statistical analysis, and Dr. Charles Hanson of the University of California at Davis provided valuable comments in reviewing the manuscript.

Mr. Larry Olson of the MPCA in addition to Mr. Gary Milburn and Mr. Vacys Saulys of EPA Region V in Chicago provided guidance and assistance in developing the demonstration outline and selecting the RIS. At the Minnesota Department of Natural Resources, Mr. Howard Krosch, Mr. Joe Geis, and Mr. Scott Gustafson generously provided data at our request and continually responded to our information queries. Various personnel from the Corps of Engineers Office in St Paul provided valuable input into the data collection process regarding river flows, operation of the lock and dam system, and barge traffic. Dr. McConville of St. Mary's College expressed interest in the demonstration, and recommended a number of unpublished theses and published articles that were useful in interpreting many of the field survey data results. Drs. Kathleen and Alan Baker of the University of New Hampshire supplemented information provided in the annual reports regarding primary producers, such as phytoplankton and periphyton. Personnel at the U.S. Fish and Wildlife Service office in Minneapolis and Dr. Harrison Tordoff at the Bell Museum of Natural History relayed information concerning waterfowl and eagles near PINGP, and personnel from the Metropolitan Sewage Treatment Plant in St Paul provided effluent water quality summaries defining nutrient and toxicant loads that may impact biota in the vicinity of PINGP.

III ENVIRONMENTAL CHARACTERISTICS

A. HYDROLOGY

1. River Basin Characteristics. The principal surface waters in the vicinity of the site are the Mississippi, Cannon, St. Croix, and Vermillion rivers, as well as several connected river lakes such as Sturgeon and North lakes. Water levels in the Mississippi River and Sturgeon Lake are controlled by Lock and Dam No. 3 which is located approximately 2.4 km (1.5 mi) downstream from the site. The Vermillion and Cannon rivers enter the main stream of the Mississippi below the dam, while the St. Croix River joins the Mississippi River channel about 20.8 km (13 mi) above the plant site. The location of these streams are shown in Figure III-1. The USGS gauging station closest to PINGP is at Prescott (14 river miles upstream), and water quality is measured at Lock and Dam Nos. 2 and 3.

The stretch from Lock and Dam No. 3 (796.7 river miles above the confluence of the Ohio and the Mississippi Rivers) to Lock and Dam No. 2 near Prescott is called Pool No. 3 of the Upper Mississippi River navigation system. This includes the portion of the St. Croix River extending upriver to Stillwater. Normal pool elevation is 674.5 ft above mean sea level (1929 Datum). At normal level, Pool No. 3 (excluding the St. Croix) covers approximately 7,264 ha (17,950 acres), and the total drainage area of the river at Lock and Dam No. 3 is 120,700 km^2 (46,600 mi^2) including 19,814 km^2 (7,650 mi^2) contributed by the St. Croix River. A schematic longitudinal section diagram from Lock and Dam No. 1 to No. 4 is shown in Figure III-2.

The primary control point (Corps of Engineers, 1974) for Pool No. 3 water level is situated at Prescott and is called Control Point No. 3. At low river flows (≤ 14,000 cfs), a constant pool elevation of 674.5 ft msl (Corps of Engineers uses 1912 Datum adjustment of 675 ft msl) is maintained at Prescott by controlling headwater and discharge from Dam No. 3. At 14,000 cfs, the headwater elevation would be 673.5 ft msl which is the maximum allowable drawdown for the pool (see Figures III-3 and III-4). The operating curve for discharges of less than 14,000 cfs (Stefan and Anderson, 1977) is described as:

$$h = 674.5 - 5.1 \times 10^{-9} Q^{2.0} \text{ for } 0 < Q < 14,000 \text{ cfs},$$

where h is the headwater elevation (ft msl) measured at Dam No. 3 and Q is the discharge at Dam No. 3.

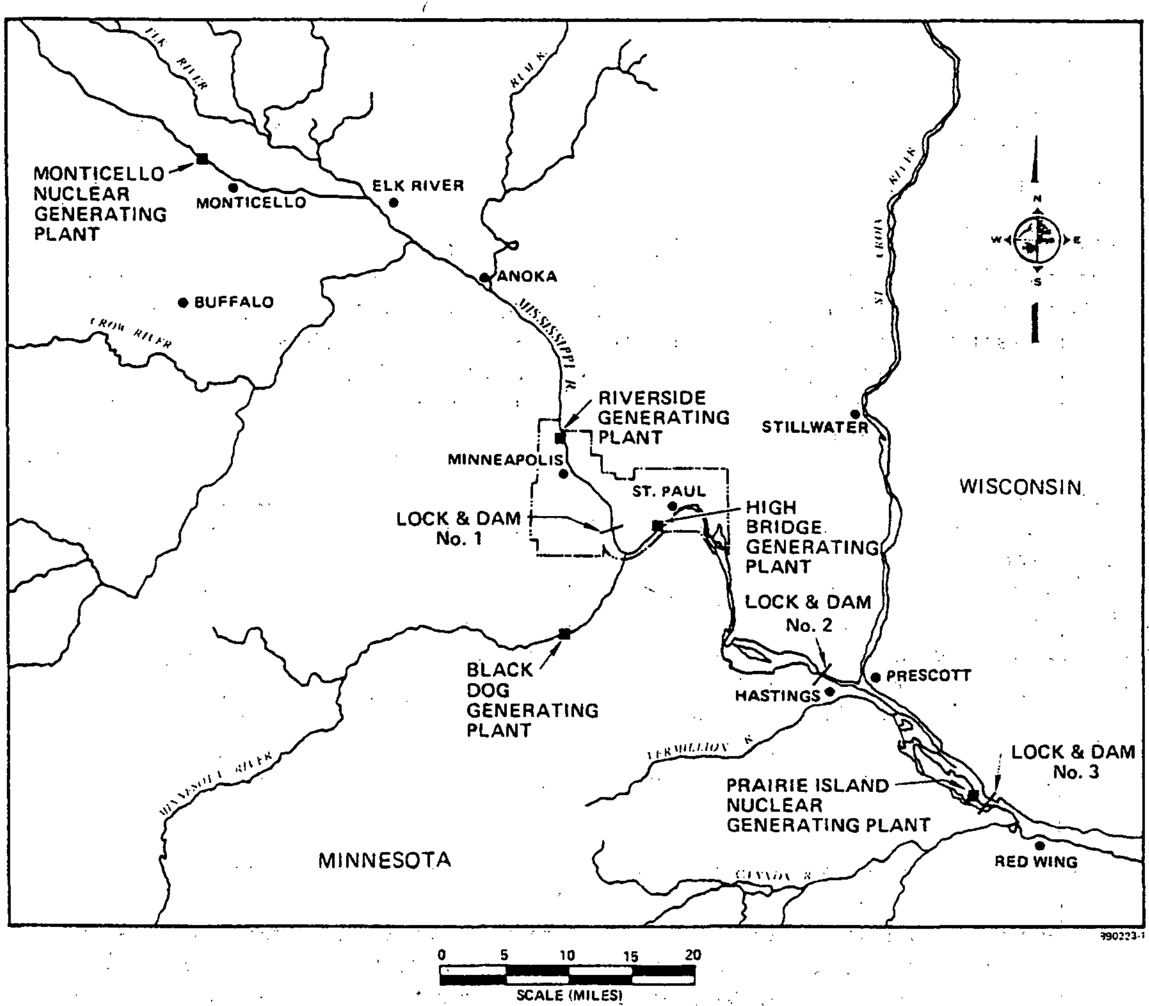


Figure III-1. Location of major streams and gauging stations.

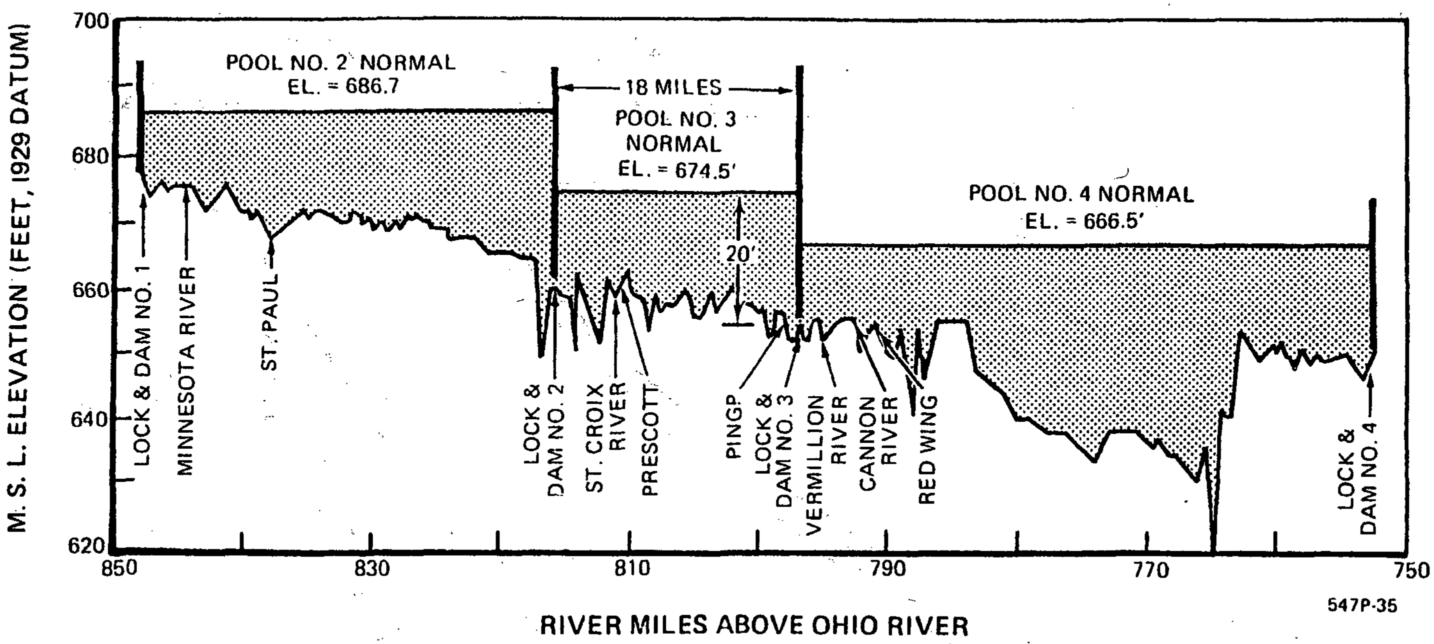


Figure III-2. Longitudinal section of the Mississippi River from Dam No. 1 to Dam No. 4 showing the relative locations of Pool No. 3 and PINGP (adapted from AEC, 1973).

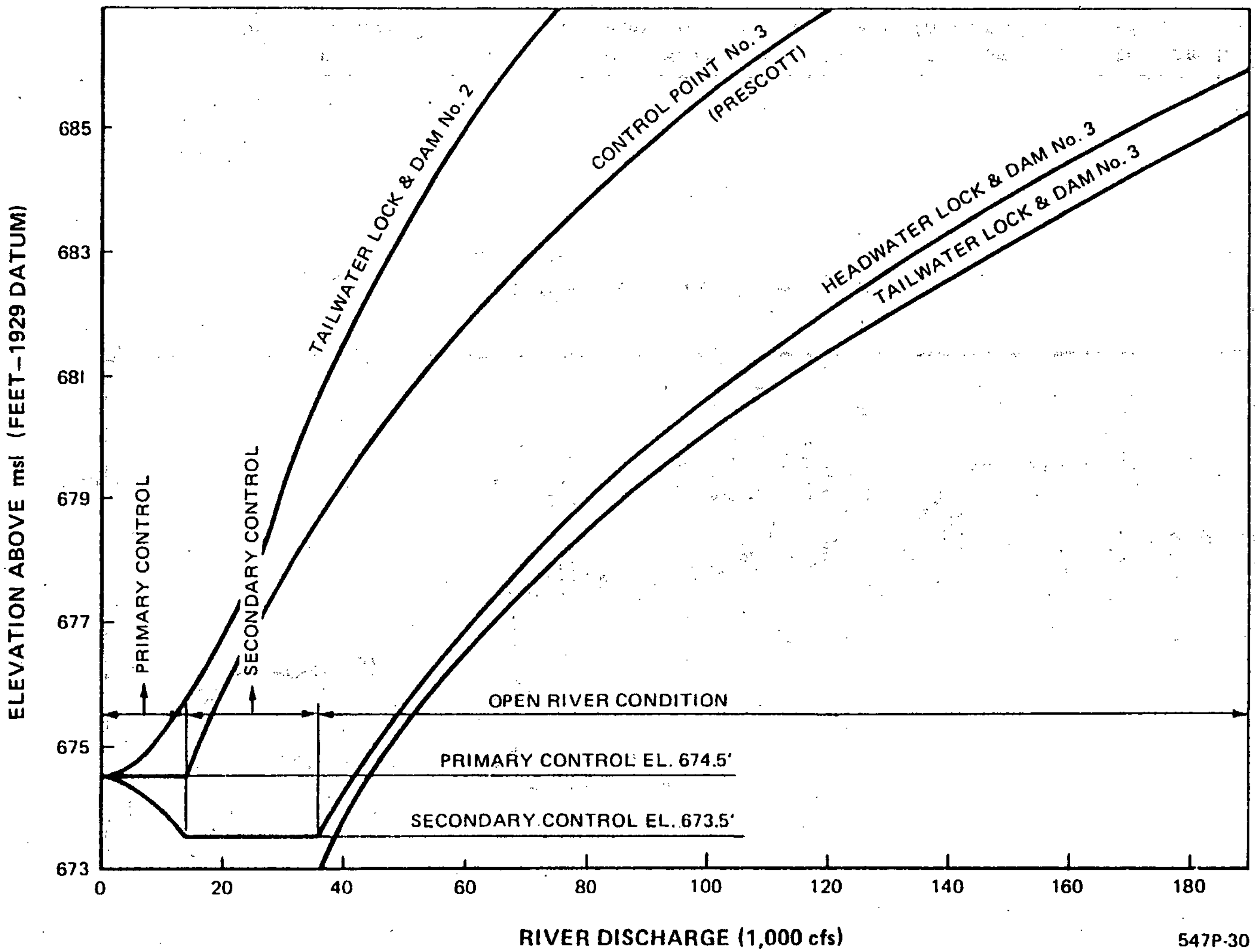


Figure III-3. Stage-discharge diagram for Pool No. 3 (adapted from Corps of Engineers, 1974).

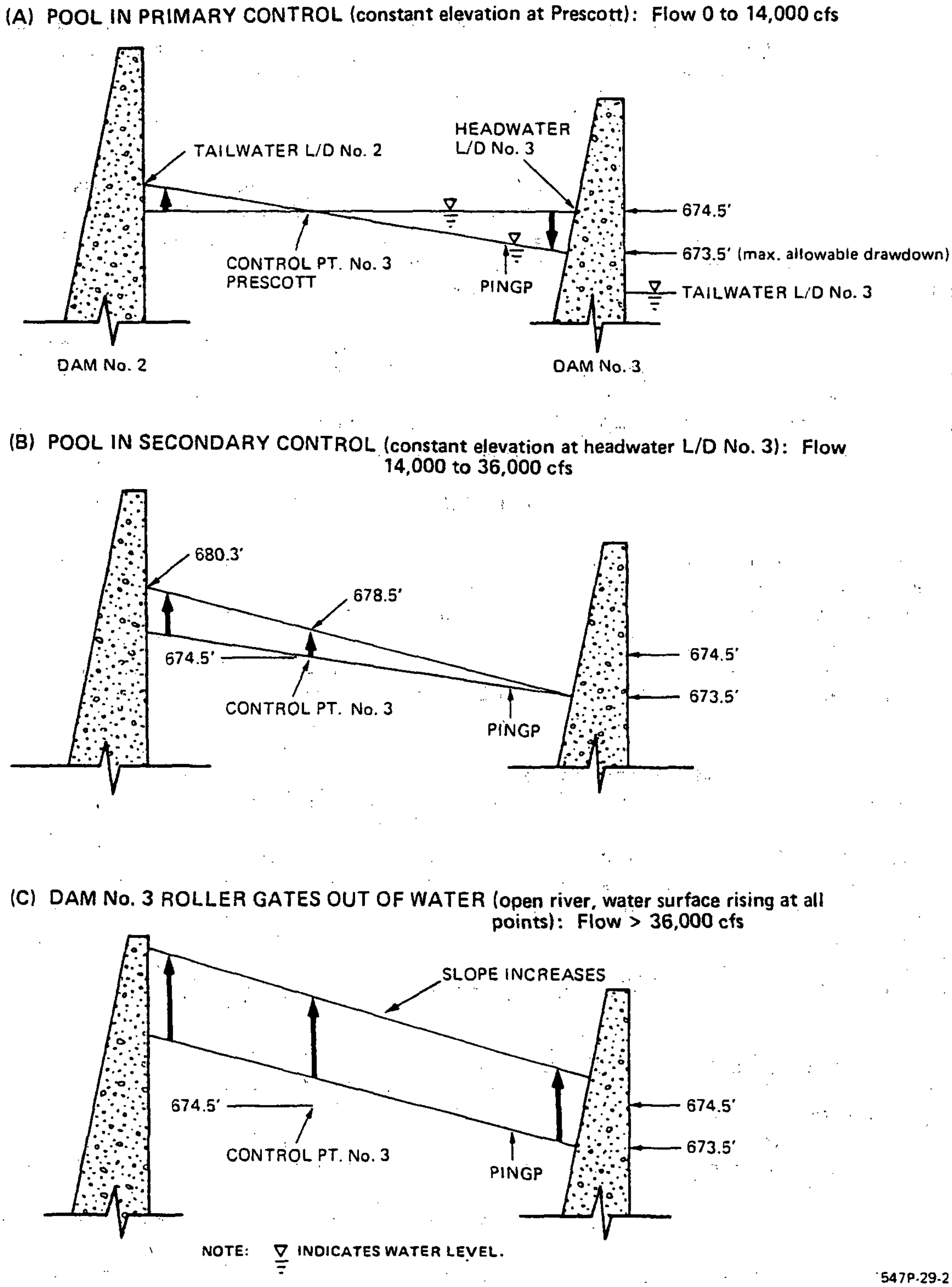


Figure III-4. Schematic diagram of how water level in Pool No. 3 is controlled.

After the headwater elevation reaches 673.5 ft msl, the discharge control is shifted to the secondary control which requires that the headwater at Dam No. 3 be kept the same until the discharge reaches 36,000 cfs or

$$h = 673.5 \text{ for } 14{,}000 < Q < 36{,}000 \text{ cfs.}$$

During secondary control, the discharge is calibrated against the water surface elevation measured at Control Point No. 3 (Figure III-3). At this control stage, the headwater at Dam No. 3 would be kept constant while the Control Point No. 3 elevation is allowed to rise due to the inflow from Dam No. 2 and the St. Croix River (Figure III-4).

After the river discharge reaches 36,000 cfs, all the roller gates at Dam No. 3 are raised to the maximum height (above the water surface), and the dam no longer regulates the flow of the river (i.e., the open river condition prevails). The empirical head discharge equation for this condition is described as (Stefan and Anderson, 1977):

$$h = 673.5 + 2.5 \times 10^{-9} (Q - 36{,}000)^{0.77} \text{ for } Q > 36{,}000 \text{ cfs.}$$

When the river flow decreases, the gates at Dam No. 3 are returned to the water and secondary control is in effect until the stage at Control Point No. 3 is reduced to 674.5 ft msl, at a discharge of 14,000 cfs. If discharge continues to drop, primary control would then take place to hold the pool level constant (674.5 ft msl) at Control Point No. 3 and to allow the headwater at Dam No. 2 to rise while that at Dam No. 3 decreases to 673.5 ft. According to the discharge records at Prescott over the past 49 years, the river is in primary control about 70 percent of the time. The river is in secondary control approximately 20 percent of the time and the open river condition prevails for 10 percent of the time.

A 2.7 m (9 ft) deep navigation channel is maintained by the Corps of Engineers between Minneapolis and the mouth of the Missouri River to facilitate transport of commodities by barge. In 1976, 6,050 lockages were recorded for Lock No. 3 of which 2,377 were commercial (Corps of Engineers, 1977). On the St. Croix River, a 2.7 m (9 ft) channel extends from the confluence with the Mississippi River to Stillwater, Minnesota.

2. <u>Characteristics of the PINGP Vicinity</u>. The PINGP site is a lowland terrace associated with the Mississippi River floodplain. The site is separated from the other lowlands by the Vermillion River and various small lakes on the west and the south, and by the Mississippi River and North and Sturgeon Lakes on the east and north. The topography is almost flat except for the low bluffs to the north. The hummocky nature of the terrain and the sandy soils on the site results in little significant surface drainage.

In the immediate vicinity of the plant site, the surface elevation ranges from 206 to 215 m (675 to 706 ft) above mean sea level. A typical cross section of the floodplain is shown in Figure III-5. The normal elevation of

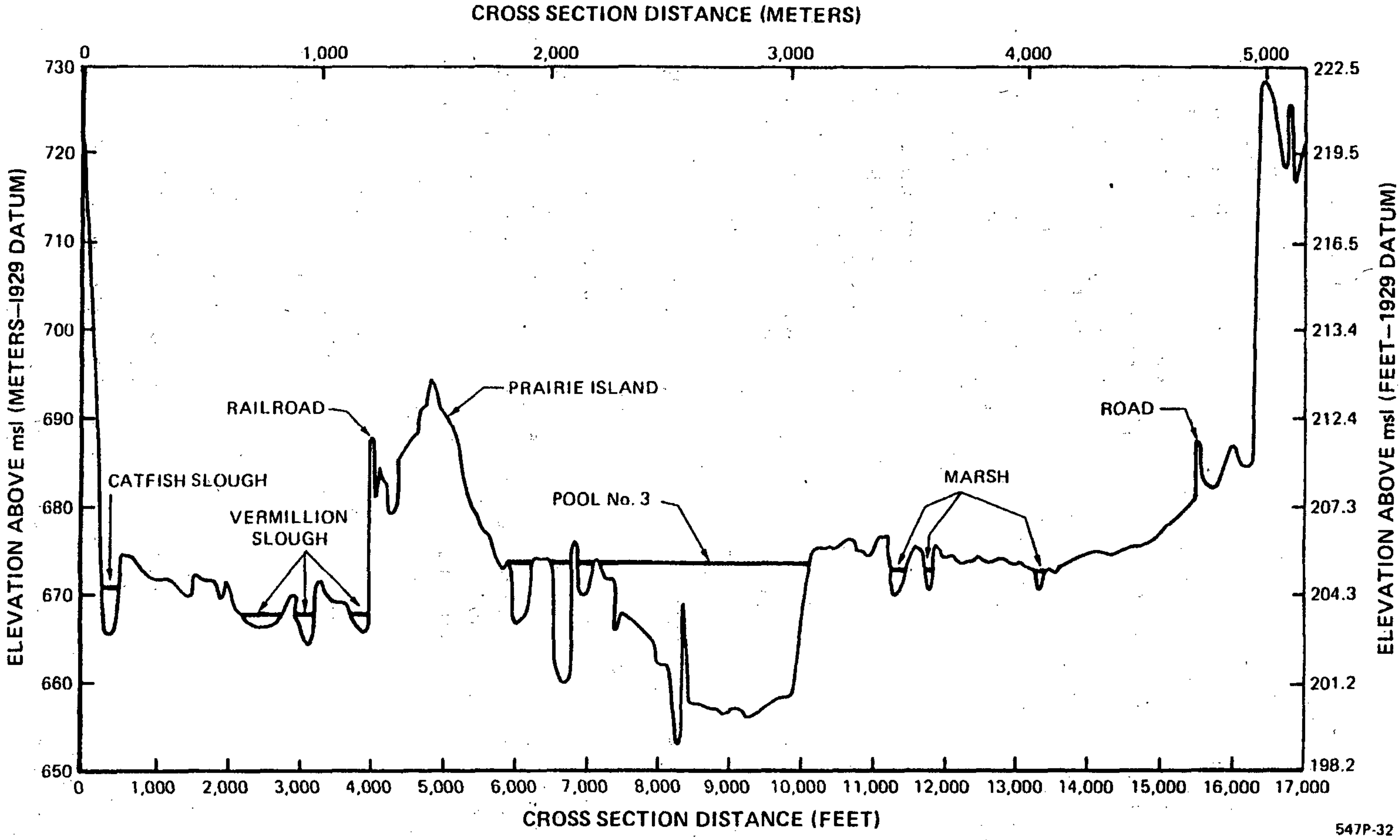


Figure III-5. Typical Mississippi Valley cross section near PINGP (AEC, 1973).

Pool No. 3 (at Prescott) is 674.5 ft msl, and the maximum recorded flood level at Prescott was 692.61 ft msl on 18 April 1965. Due to the high permeability of the sandy alluvial soils underlying Prairie Island, the groundwater table is shallow and responds quickly to changes in river stage. The groundwater level almost coincides with the river surface, ranging from 673 to 674 ft. The general regional groundwater flow is from the higher, partially glaciated bedrock areas toward the Mississippi River and its tributaries. Since Pool No. 3 is elevated by Lock and Dam No. 3, the pool surface is usually higher than the Vermillion River and its backwater lakes, which enter downstream of Lock and Dam No. 3. Consequently, the groundwater table at Prairie Island slopes southwestward to charge the Vermillion River.

In Pool No. 3, there are two major backwater lakes connected to the river by numerous small channels and river runs. These two lakes are North Lake and Sturgeon Lake (Figure III-6).

Sturgeon Lake, from which almost all the plant intake water is withdrawn, is one of the largest backwater lakes in the area. Water in the lake comes primarily from the Mississippi River through numerous coulees and reaches and through channels from North Lake. A small amount of the inflow is through groundwater seepage; however, this is believed to be insignificant compared to surface inflows (Stefan and Anderson, 1977). The depth of Sturgeon Lake varies from 1.2 to 4.6 m (4 to 15 ft). Like many other backwater lakes in the area, it is probably the result of Pleistocene glaciation.

The hydraulics of North Lake, Sturgeon Lake, and the Mississippi River near PINGP has been studied by Stefan and Anderson (1977). They divided the river/lake region into two network systems: Sturgeon Lake and the downstream area (see Figures III-7 and III-8). The Sturgeon Lake system consists of Sturgeon, North, and Brewer lakes; six river sections in the Mississippi River; and 13 river runs between the three lakes and the river. The downstream system consists of a section of the Mississippi River near PINGP; plant intake and discharge channels, and channels among the small islands in lower Sturgeon Lake.

The hydraulic networks were analyzed by applying the laws of conservations of mass and energy. Conservation of mass requires that the sum of all flows into and out of a channel junction be zero; however, this does not include water loss or exchange through seepage, evaporation, or evapotranspiration. Sturgeon Lake and North Lake were not treated as channels since the velocity in them is too low as a result of their large cross-sectional areas. Conservation of energy requires that the total head losses in parallel channels be the same and head losses in channels in series be additive. Head losses are from channel bed shear stresses and from wind shear stresses on the water surface. Twelve continuity equations (conservation of mass) and nine energy equations (conservation of energy) are necessary to compute the flow rates for the 21 channels specified in Figure III-7. The details of the mathematical model can be found in Stefan and Anderson's report. The solution of this set of

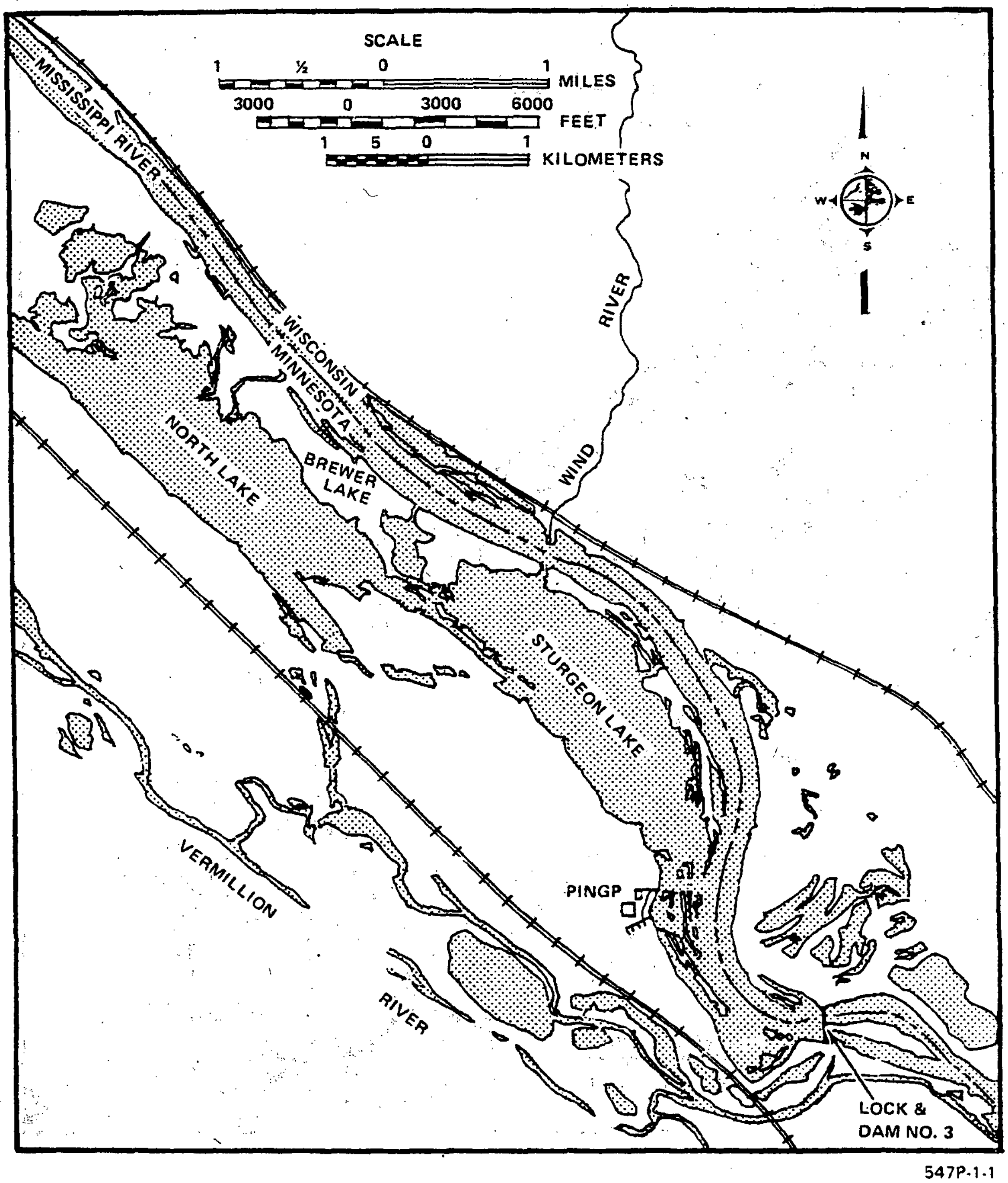


Figure III-6. Major water bodies in the vicinity of the PINGP.

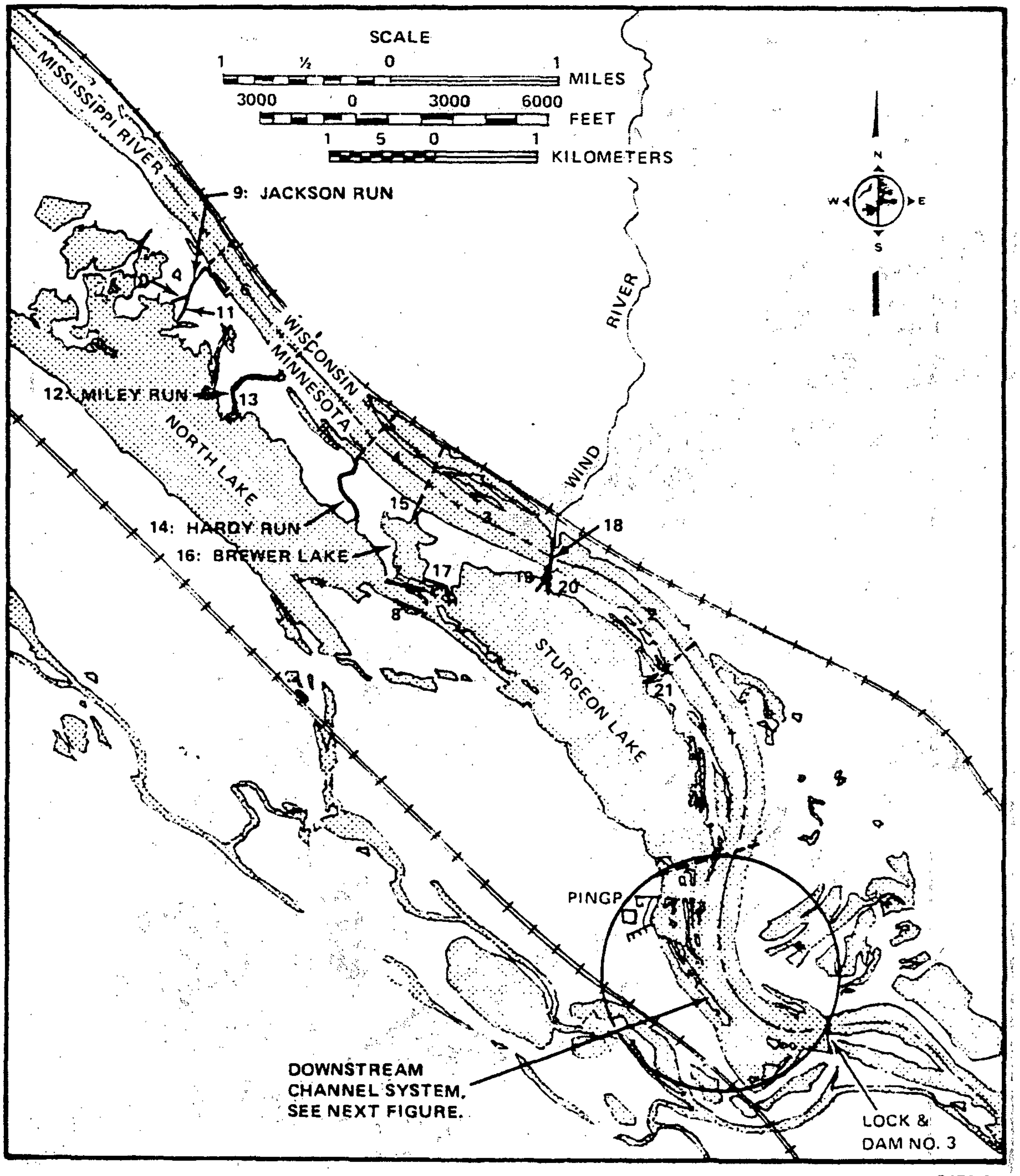


Figure III-7. Sturgeon Lake channel system for the hydraulic network calculations (from Stefan and Anderson, 1977).

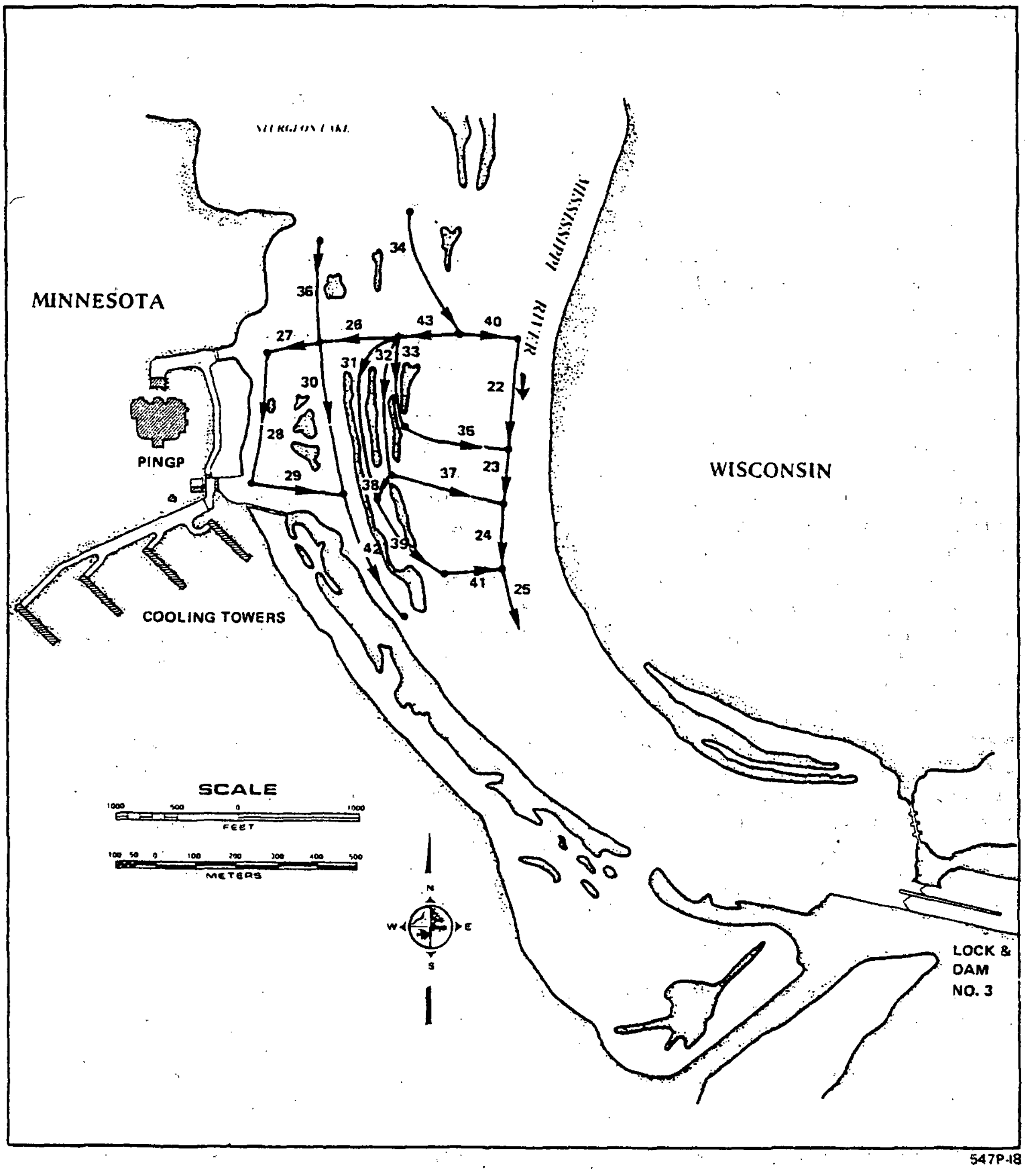


Figure III-8. Downstream channel system for the hydraulic network calculations (from Stefan and Anderson, 1977).

equations serves as the input to the downstream channel system analysis. For every river discharge and wind velocity, the outflows from Channel 1 and Sturgeon Lake are used as inflows for the downstream channel system, i.e., in Channels 34, 36, and 1.

Similar sets of continuity equations and energy equations are constructed for the 22 channels in the downstream channel system. The computed flow rates for Channels 36, 26, 27, 28, 30, and 42 are in turn used for the thermal plume analysis described in Section V.

The results of the computation of the downstream channel system were calibrated against limited field measurements conducted by the U.S. Geological Survey and J. Gorman, Inc., of Minneapolis, and the results are presented in Table III-1 for Sturgeon Lake and Channel 42. As shown by the data, the predicted flow rate in Sturgeon Lake fell within 5 percent of the measured values when the river flow was less than 40,000 cfs. During flood conditions (> 60,000 cfs), however, the calculated value was 19 percent below the measured one. Thus, the trend is toward a flow deficit for the computed flow rate in Sturgeon Lake as the total river flow goes up. Since the primary emphasis in this study was on low river flows, the error at higher flows is of little significance. Predicted flows through Channel 42 for the three measurements were 7 percent below, 17 percent above, and 94 percent below the measured values. The large error in the latter case could be caused by a variety of reasons, including the sensitivity of Channel 42 to winds from the west to northwest and possible strong stratification during low river flows (2,890 cfs). Field instrumentational errors could also be a cause, particularly during the low flow conditions, since most of the velocities in Channel 42 were less than the threshold value of the flow meter. Counter flows (or recirculating flows) could easily be overlooked. In general, the hydraulic network model developed by Stefan and Anderson is considered to reasonably predict the flow rates in Sturgeon Lake and Channel 42 as a function of total river discharge. The Sturgeon Lake discharge versus the Mississippi River discharge with no wind is shown in Figure III-9. From this figure, it is calculated that between 19 and 32 percent of the total river flow at Lock and Dam No. 3 passes through Sturgeon Lake (Channels 34 and 36). The Channel 42 flow, with no wind, can also be approximated by the equation $Q_{42} = 0.14\ Q_r^{0.96}$ from the results of Stefan and Anderson's model.

3. River Morphometry Near PINGP. The Mississippi River in the vicinity of PINGP is 300 to 370 m (1,000 to 1,200 ft) wide, and the bathymetry is shown in Figure III-10. The river banks slope fairly steeply to the river bottom, and the navigation channel has required minimal dredging since 1935 (Cin, 20 October 1977).

Sturgeon Lake is a very shallow lake and its important morphometric parameters are summarized as follows:

- Maximum length: 5.0 km (3.1 mi)
- Maximum effective length: 3.5 km (2.2 mi)

Table III-1. Comparison of the computed discharges in Sturgeon Lake and Channel 42 with the field measurements.

Date	Q_{River} (cfs)	$Q_{Sturg. L.}$ (cfs)	Q_{42} (cfs)	Wind Speed (mph)	Wind Direc.	Q_p Intake (cfs)	Q_p Discharge (cfs)	Source	$Q_{Stur. L.}$	Q_{42}
3/26/73	62,000	18,820	-	8.6	70°	0	0	JG[1]	15,270	6,150
5/02/74	40,400	10,900	-	18.9	180°	185	150	U.S.G.S.[2]	10,020	3,930
5/09/74	32,360	7,430	-	8.0	125°	185	150	U.S.G.S.	7,140	3,110
7/01/74	21,880	4,590	-	14.7	225°	185	150	U.S.G.S.	4,740	2,060
11/26/74	10,400	-	960	17.7	145°	185	150	JG	1,640	890
8/01/75	13,500	2,700	1,150	12.9	200°	1,095	1,060	JG	2,580	1,340
10/13/76	2,890	-	1,070	18.0	295°	245	210	JG	1,150	70
	MEASURED								COMPUTED	

[1] J. Gorman, Inc., Minneapolis, Minnesota, 1973.

[2] U.S. Geological Survey, Water Resources Data for Minnesota, 1974.

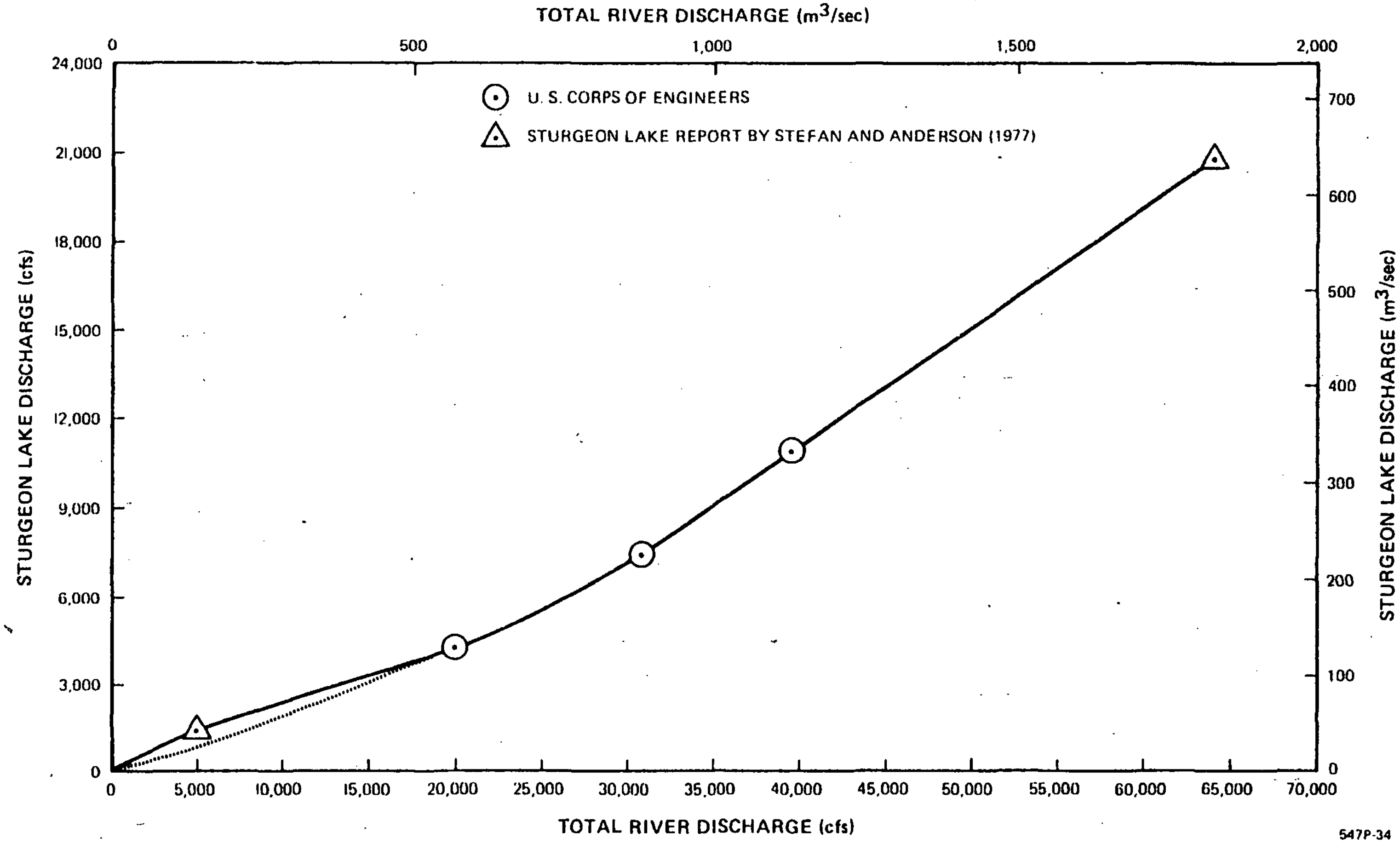


Figure III-9. Sturgeon Lake discharge versus total river discharge (Stefan, 1973).

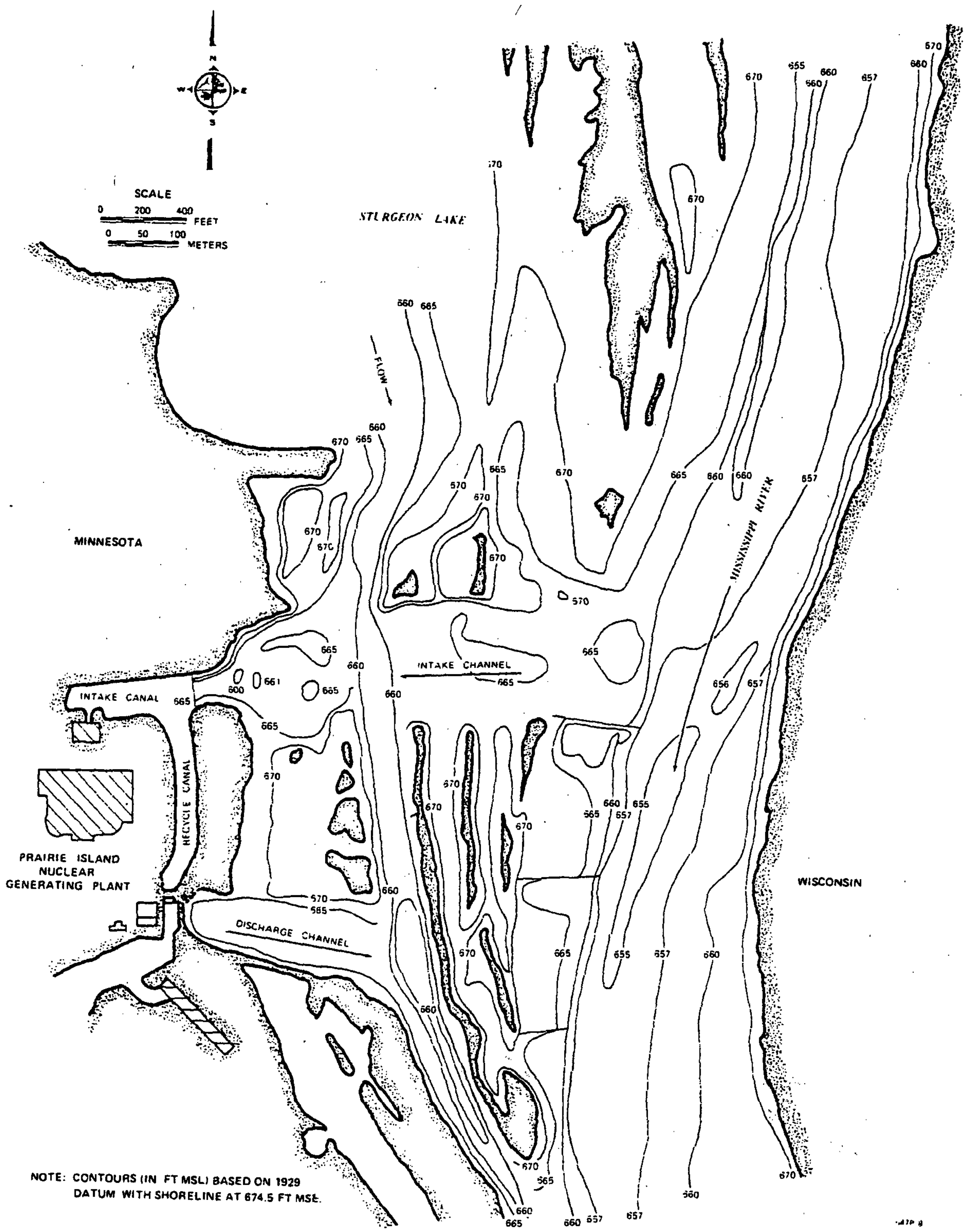


Figure III-10. Bathymetry of Sturgeon Lake and the Mississippi River near PINGP (diagram dated 14 December 1976).

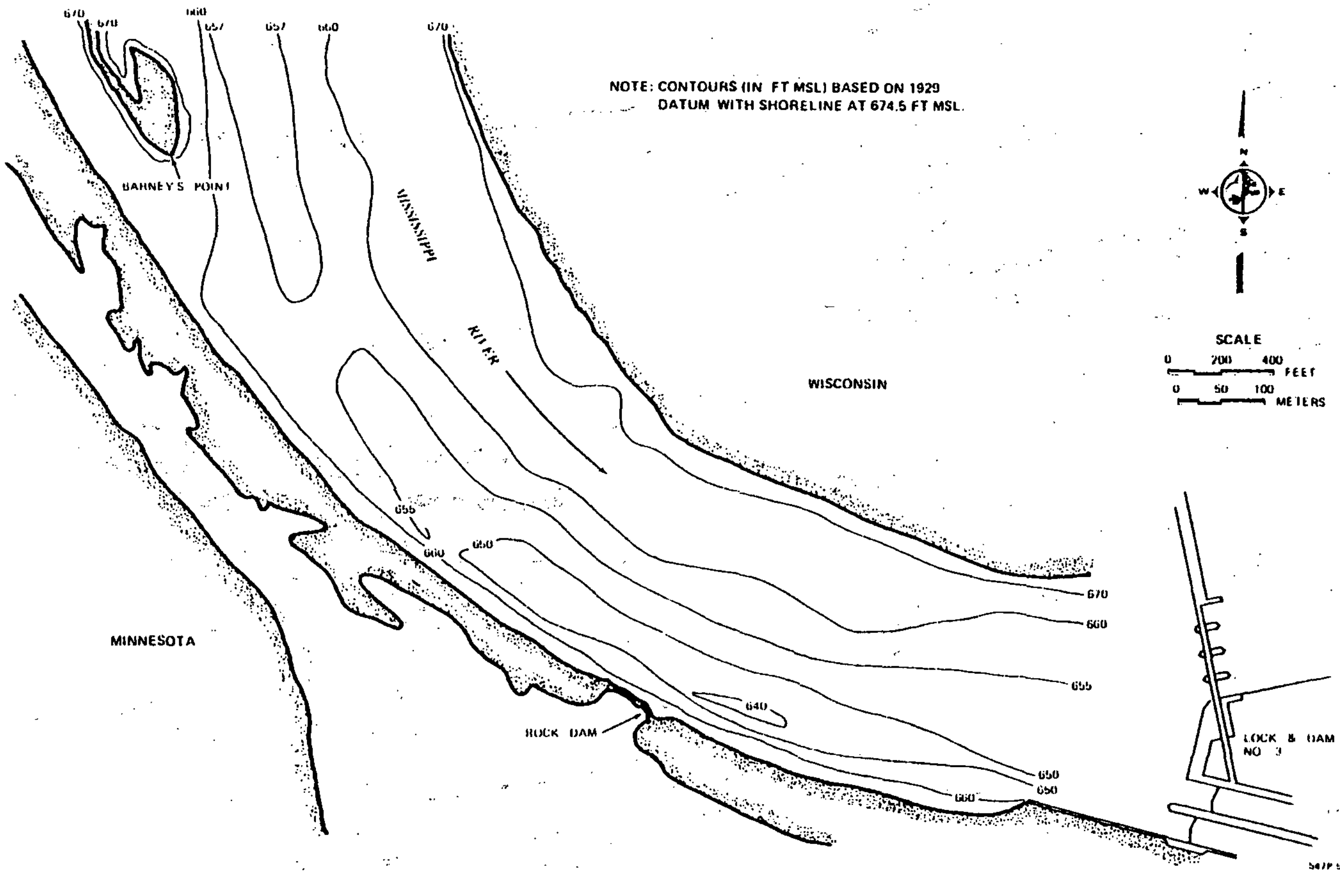


Figure III-10. (Continued)

- Maximum width: 2.8 km (1.75 mi)
- Direction of major axes: SE-NW
- Surface area: 323.8 hectares (800 acres)
- Mean width: 0.8 km (0.5 mi)
- Volume: 6.7×10^6 m^3 (2.37×10^8 ft^3)
- Maximum depth (based on water surface elevation of 674.5 ft msl): 6 m (20 ft)
- Average depth (based on water surface elevation of 674.5 ft msl): 2.07 m (6.79 ft)
- Shoreline: 17.3 km (10.7 mi)
- Range of retention time of water: 3.8 hr to 42.6 hr (corresponding to river flows of 1,868 m^3/sec and 226.4 m^3/sec)

Near its southern end, numerous small islands occur, and this is where the PINGP intake and discharge are located. In 1970, the approach channel (Class I structure) for the plant intake water supply was dredged to a bottom elevation of 664.5 ft msl (3.1 m deep at normal pool level) and a width of 183 m (600 ft). The discharge canal (Class III structure) was dredged to a bottom elevation of 664.5 ft msl also, and the width increases from 30.5 m (100 ft) at the discharge gates to 122 m (400 ft) at a distance of 213 m (700 ft). The canal dikes were compacted fill and are constructed to appear as a natural channel. A survey of the channels in 1976 by J. Gorman, Inc., indicated no substantial sediment deposit.

4. Discharge Rates. There are two major gauging stations on the Mississippi River near the plant site: at Prescott, Wisconsin, and at Winona, Minnesota. Prescott is about 24 km (15 mi) above the plant (811.4 river miles above the Ohio River), and the drainage areas is estimated to be 116,032 km^2 (44,800 mi^2). The St. Croix River enters the Mississippi River at Prescott, and there are no other major tributaries between Prescott and the plant site. Winona is about 135.5 km (84.2 mi) downstream from the plant site (725.7 river miles above the Ohio River), and the total drainage area there is about 153,328 km^2 (59,200 mi^2). Because of the proximity of the Prescott station, flowrates from there are used throughout this demonstration.

Prescott has a continuous discharge record since June 1928 (49 years). The average discharge for the first 48 years (up to 1976) was 16,200 cfs. The instantaneous maximum flowrate ever recorded was 228,000 cfs on 18 April 1965, while the minimum daily flow was 2,100 cfs, observed on 14 August 1936*. The average monthly and weekly river flows are shown in Figure III-11.

*On 13 July 1940, a record minimum flow of 1,380 cfs was observed. This was probably the result of an operator error at Dam No. 2 (see Preliminary Safety Report for PINGP).

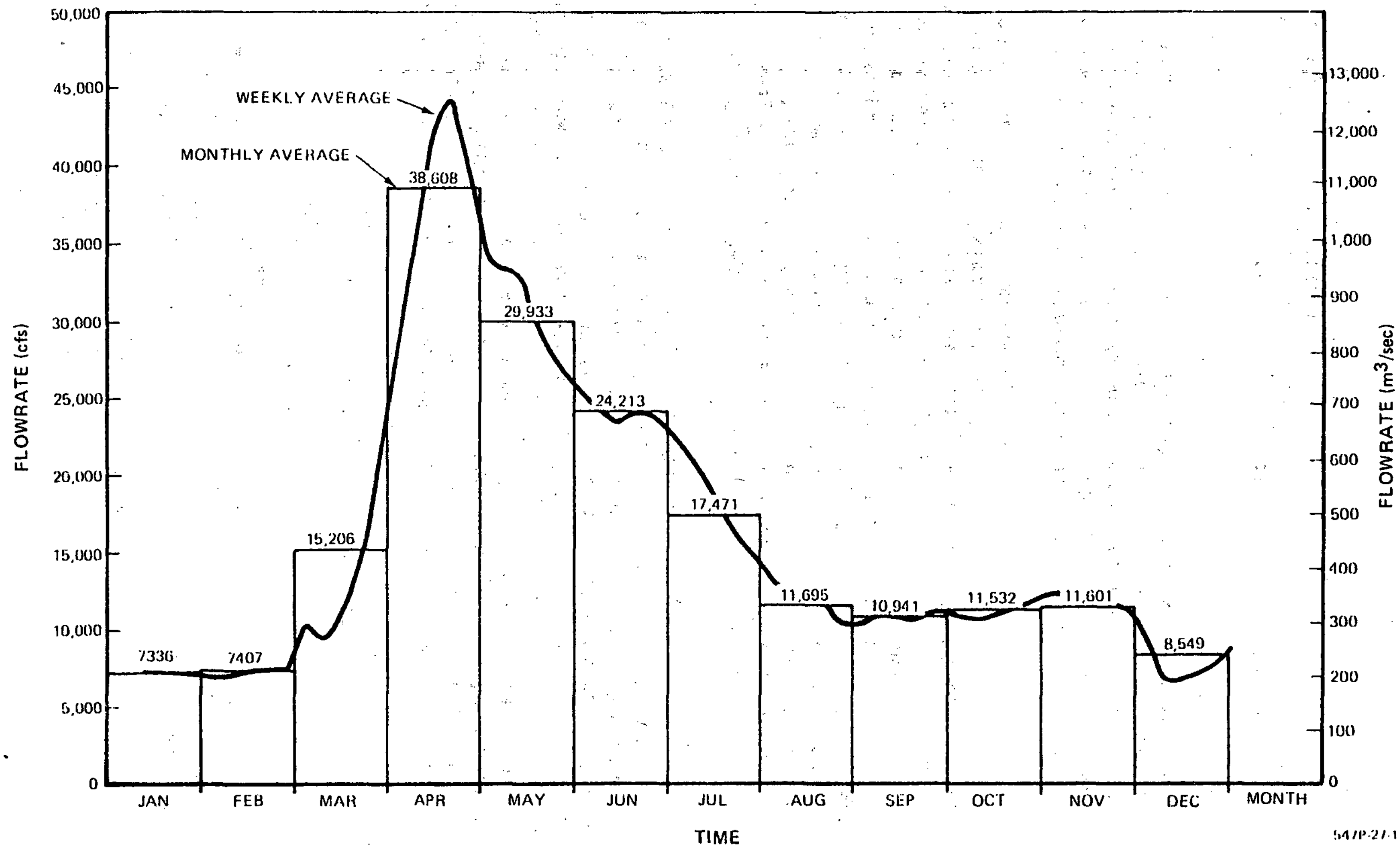


Figure III-11. Average monthly and weekly Mississippi River flows at Prescott, Wisconsin based on USGS data from June 1928 through September 1976.

It can be seen that the discharge usually peaks in April due to snowmelt runoff and levels off from September to February when the river is charged mostly by groundwater. Figure III-12 shows the calculated 7-day, 10-year recurrence flows for each month. A standard log-Pearson Type III distribution was used in computing these numbers. Also shown on the figure is the percentage of time in each month when the 7-day, 10-year low flow was not exceeded. These values ranged from 2.2 to 8.4 percent and will be used in Section IV to estimate the probabilities of the joint-event occurrences.

B. WATER QUALITY OF THE MISSISSIPPI RIVER

1. Temperature. Ambient river temperature data in the vinicity of PINGP provide necessary input for the thermal plume model (see Section V) as well as a reference for spawning and thermal tolerance information discussed in Section III C. The following discussion assesses the available data to determine the most adequate record.

The stations at which water temperature has been recorded regularly include the resistance temperature detector (RTD) station at the intake canal of PINGP, a temperature recording station in Sturgeon Lake maintained by the Minnesota Department of Natural Resources (MDNR station), a station at Lock and Dam No. 3, several stations utilized for water quality sampling in the ecological monitoring program, and the intake temperature station at NSP's Red Wing Generating Plant (RWGP).

The RTD intake station at PINGP is located on the river side of the intake canal barrier wall. Temperature sensors are vertically spaced at 0.6 m (2 ft) intervals on two pilings for a total of 10 sensors. All RTD readings are averaged by the plant computer and recorded hourly on the plant log. These recorded values enter the plant environmental event log only when discharge flow is adjusted. Even though the RTD data represent a continuous record, they cannot be considered representative of river temperature for several reasons. First, the period of record is too short since data are only available from February 1975 to present. Second, possible instrumentation problems exist which would make the data unreliable. And third, during high blowdown rates and southerly winds, intake temperature readings may be above ambient river temperature due to upriver movement of heated effluent.

The MDNR station is on the river (northwest) side of Sturgeon Lake (Figure III-13) at a depth of 0.8 to 0.9 m (2.5 to 3 ft). The station is located in shallow water since the rest of the lake averages 2.1 m (6.8 ft) in depth. Temperatures were recorded on strip charts during the ice-free months of 1975 through 1977. Due to lack of calibration and maintenance records, these data will be used only to indicate diurnal fluctuations in temperature. The observed diurnal fluctuations were fairly large,

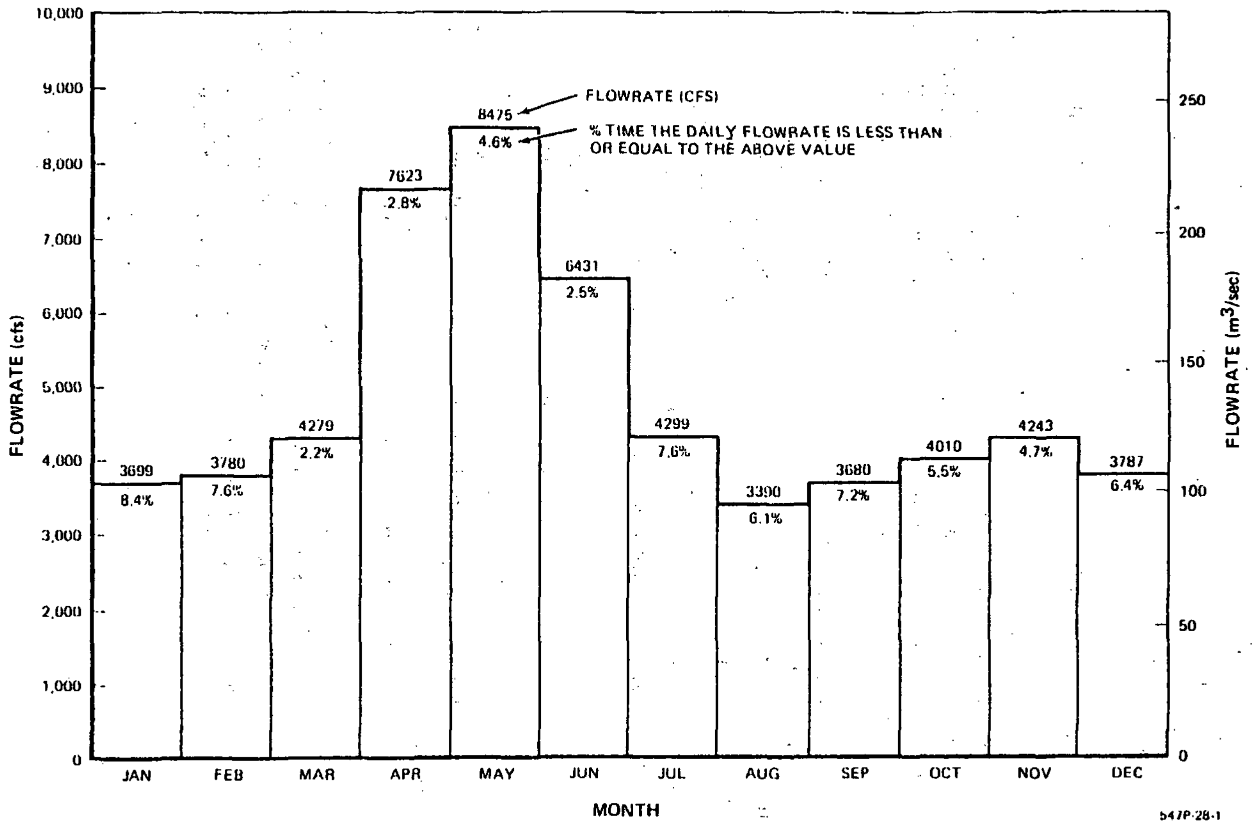


Figure III-12. Monthly 7-day, 10-year low flows for the Mississippi River at Prescott, Wisconsin, and the percentage of time the daily flowrate is less than or equal to the 7-day, 10-year flows. Based on USGS data for June 1928 through September 1976.

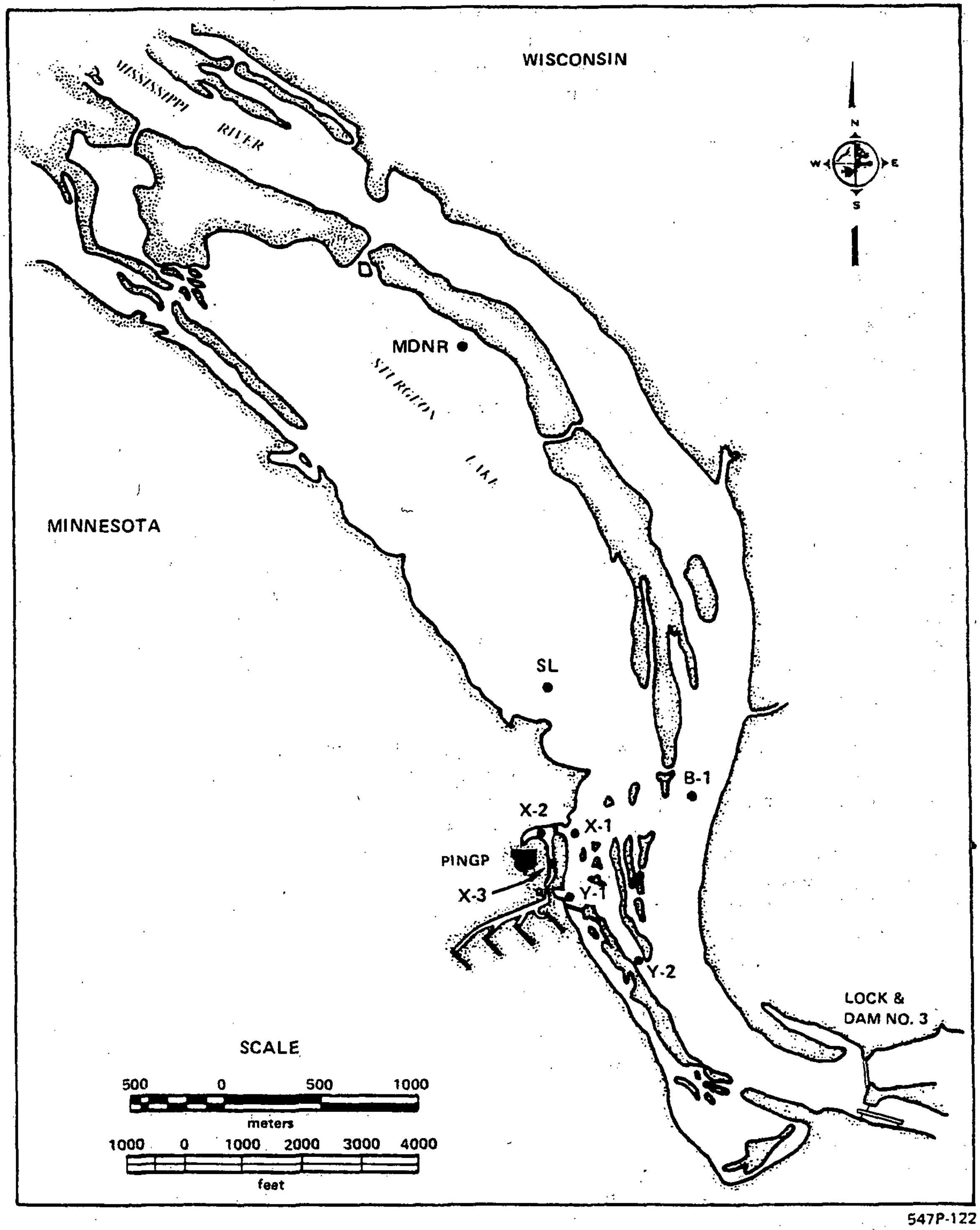


Figure III-13. Location of the Minnesota Department of Natural Resources (MDNR) temperature recording station and the locations of water quality stations where temperature is routinely monitored.

averaging 2° to 3° C (3.5° to 5.4° F) with a maximum of 9.7° C (17.5° F). Vertical temperature stratification is not expected to be significant at this station because of its shallow depth; however, no records are available to substantiate this assumption.

Daily maximum and minimum river temperatures have been recorded at Lock and Dam No. 3 since 6 August 1969. Two temperature probes are used at this station: a primary probe located approximately 1.2 m (4 ft) below normal pool elevation on the upstream face of the dam, and a secondary sensor located on the downstream face of the dam which is used only when the primary probe malfunctions. Measurements were taken first by the Minneapolis-St. Paul Sanitary District, then by the Federal Water Pollution Control Administration, and presently by the U.S. Geological Survey. Since Lock and Dam No. 3 is located only 1.6 km (1 mi) downriver from the PINGP discharge, temperatures may have been periodically influenced by thermal discharges from the plant. Thus, only the four years of pre-operational data may be used (the first unit of PINGP came on-line in December 1973), and this period of record is probably insufficient to define long-term temperature trends.

In addition to the PINGP intake, Lock and Dam No. 3, and MDNR records, temperatures were measured at several NSP water quality stations shown in Figure III-13 from 1972 through 1976. Surface, mid-depth, and bottom temperatures were taken once or twice a month with a thermister. Temperatures measured near the intake are probably most representative of PINGP intake water temperatures; however, because of infrequent measurements (twice a month maximum) these data are of limited value.

Temperature measurements at RWGP intake located 15 km (9.4 mi) downriver from PINGP have been taken manually since 1950. RWGP is a 28 MWe (summer rating) natural gas/coal-fired plant that utilizes once-through cooling. The plant initially operated as a base load facility, but became a peaking plant in 1974. It operates approximately 16 hours a day during weekdays, and intake temperatures are recorded hourly during operation from thermocouples located on the discharge side of the circulating water pumps. These thermocouples were calibrated on 29 March 1978 and the temperature readouts were found to be within 0.3° C (0.5° F) of a mercury thermometer (McGinnis, Zimmel, and Martin, 1978). Despite the lack of previous calibration, the RWGP data are expected to be within 0.6° C (1.0° F) of the true temperatures given the general accuracy of bimetal (thermocouple) measurements.

Owing to the small heat rejection and circulating water flows from RWGP and the downriver location of the discharge, the intake temperatures are assumed to be free of thermal recirculation. Slightly higher than ambient readings of less than 1.1° C (2° F), however, might be expected during winter deicing operations. RWGP intake temperature is also considered to be unaffected by the PINGP thermal discharge since thorough mixing and dilution of the PINGP plume with ambient river water is accomplished by passage through Lock and Dam No. 3. Immediately downriver from Lock and

Dam No. 3, river temperature rise should be less than 1.1° C (2° F) 90 percent of the time (see Section IV B.1). Residual heat passing through Lock and Dam No. 3 should readily dissipate before reaching RWGP, 11.6 km (7 mi) downriver.

To test the validity of RWGP data, temperatures taken during the PINGP water quality monitoring studies were compared with RWGP temperatures for the same date. Surface, mid-depth, and bottom temperatures at Station X-1 (Figure III-13) were averaged*, and the daily maximum at RWGP on the same day was subtracted to obtain a ΔT_a. The positive and the negative ΔT_a's were then averaged separately for each year. Data presented in Table III-2 indicate that temperatures were similar at both locations for the sample dates compared. The small differences observed may be the result of differences in the time of day when measurements were taken, flows, flow ratios, and wind. The RWGP data represent daily maxima which generally occur in mid-morning to late afternoon. Table III-3 shows the diurnal temperature fluctuations calculated from daily maxima and minima recorded at Lock and Dam No. 3. During the warm months (April through August) the average ΔT_a is less than the diurnal temperature fluctuation. Thus, it can be concluded that RWGP temperatures are generally an acceptable representation of average river temperatures.

Table III-2. Summary of the mean temperature differences (ΔT) between ecological monitoring stations and the Red Wing Generating Plant intake.

YEAR	ANNUAL AVERAGE TEMPERATURE DIFFERENCE (C)	
	+[1]	-[2]
1972	1.0	0.95
1973	0.9	0.47
1974	0.49	0.65
1975	0.60	0.86
1976	0.56	0.85
Mean	0.71 (~1.3° F)	0.76 (~1.4° F)

[1]PINGP field temperatures above RWGP intake temperatures.

[2]RWGP intake temperatures above PINGP field temperatures.

*This takes into account heat recirculation and stratification.

Table III-3. Average diurnal river temperature fluctuation measured at Lock and Dam No. 3 (U.S.G.S., 1969-1976)[1].

MONTH	JAN	FEB	MAR	APR	MAY	JUNE
Diurnal Temperature Difference in °C (°F)	0.17 (0.3)	0.30 (0.54)	0.64 (1.2)	1.17 (2.1)	1.37 (2.5)	1.04 (1.9)
MONTH	JULY	AUG	SEPT	OCT	NOV	DEC
Diurnal Temperature Difference in °C (°F)	1.16 (2.1)	0.4 (0.7)	0.68 (1.2)	0.58 (1.0)	0.5 (0.9)	0.18 (0.3)

[1]The record is based on the maximum and minimum daily temperatures taken at Lock and Dam No. 3.

A graphical presentation of weekly mean river temperature for the period 1959 through 1974 is shown in Figure III-14. The river surface remains frozen in winter months until late February, and temperatures gradually increase in spring. After reaching a peak of about 24° C (76° F) in late July, temperatures decline until late December when the river surface again freezes. A maximum temperature at RWGP of 29° C (85° F) occurred on 2 August 1977.

Weekly averages of daily minima, means, and maxima for the period 1959 through 1974 are given in Appendix Table A-1, and monthly averages are shown in Appendix Table A-2. Weekly and monthly average river flows are also included in these two tables for reference. Combining flow and temperature shows that, in general, both river flow and temperature rise until late May when spring runoff reaches its peak. Then, river flow starts to decrease gradually while water temperature keeps rising as a result of increases in air temperature and warmer inflows from tributaries. After late August, both river flow and temperature decrease because of low rainfall and declining solar angle. In winter months, river flow is mainly supplied by groundwater, and temperatures remain near freezing. The tables also show that the difference between daily maximum and minimum temperatures for any given period is less than 1.1° C (2° F).

Appendix Table A-3 shows the monthly and annual cumulative distribution of daily maximum temperatures. The range of temperature variations indicates that large fluctuations exist during spring and fall, and minimum fluctuations are observed in winter. The annual cumulative distribution (last column of Appendix Table A-3) is plotted on Figure III-15, and it can be seen that the river remains frozen almost 25 percent of the time.

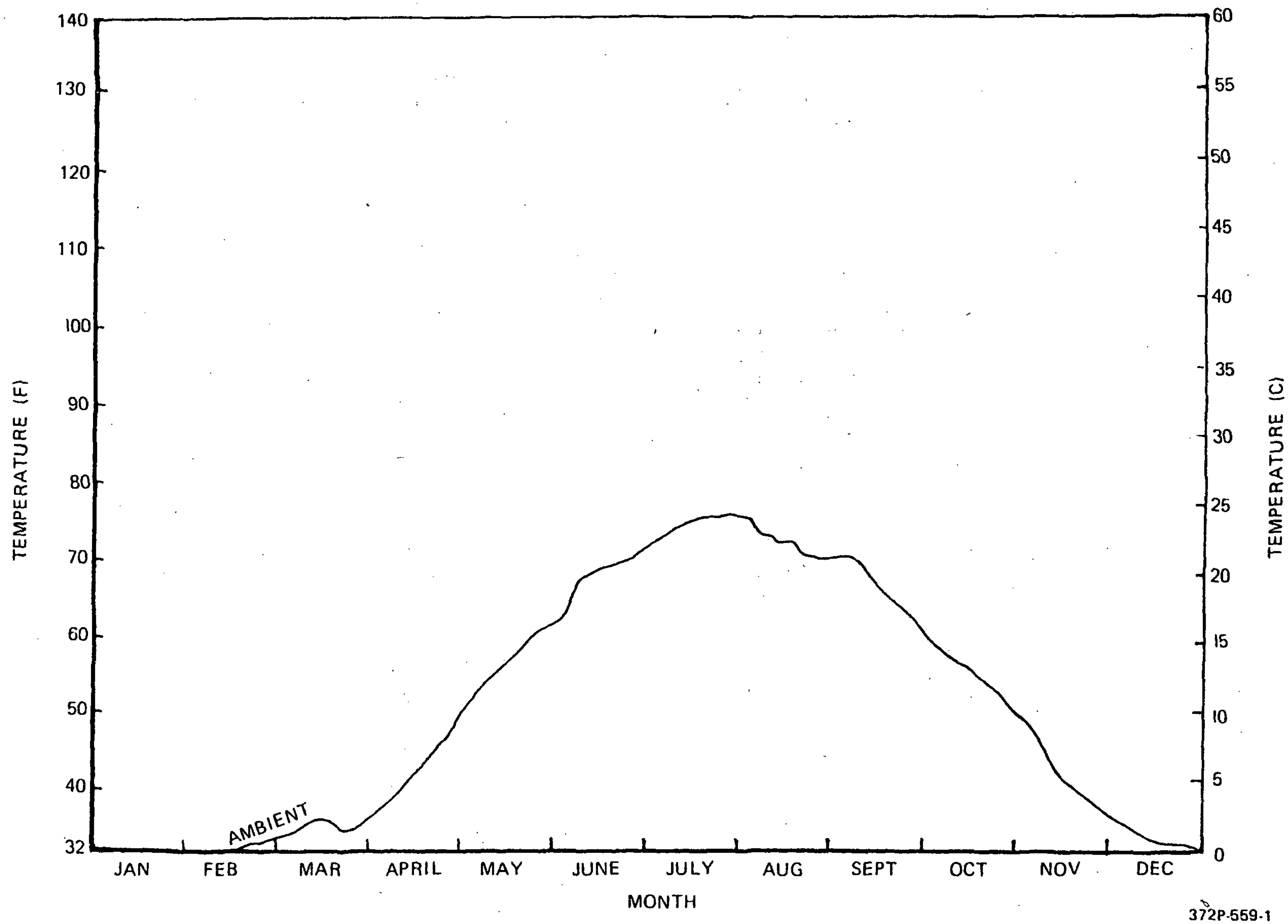


Figure III-14. Weekly average river temperature at Red Wing (from the RWGP log, 1959-1974).

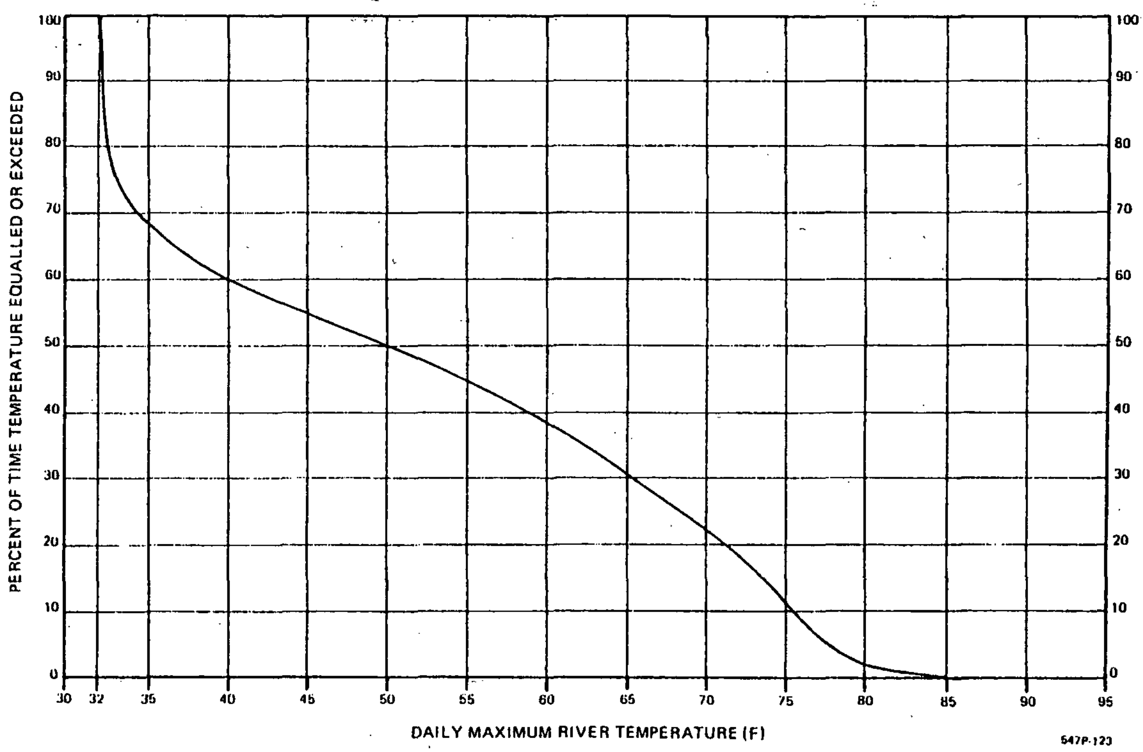


Figure III-15. Cumulative frequency of occurrence of daily maximum river temperatures at RWGP (from RWGP log).

2. Water Quality in the Vicinity of PINGP.

a. GENERAL BACKGROUND INFORMATION. The segment of the Mississippi River immediately upriver from Lock and Dam No. 3 near PINGP is more of a lacustrine than a riverine habitat, characterized by low turbidity throughout most of the year. The water is moderately hard and slightly eutrophic (Tables III-4 and III-5). Measurements of trace metals (Table III-5) indicate that levels may be elevated above normal background conditions at times. In addition, toxicants such as phenols and cyanide have been measured at relatively high levels in this section of the river.

The Metropolitan Wastewater Treatment Plant (MWTP), located approximately 61 km (38 mi) upstream from PINGP, contributes a substantial amount of the nutrient and toxicant load in the Mississippi River as far downstream as PINGP. The MWTP was constructed in 1938, and provided primary treatment only. In 1966, secondary treatment was added to a designed capacity of 218 million gallons a day (mgd), and additional facilities for activated sludge treatment were constructed in 1972. At present, construction is also underway to further expand the plant which will result in enhanced effluent quality in future years. Appendix Table A-4 summarizes the effluent quality in 1975 and 1976. Besides the gradual decrease in volume, it is also apparent that effluent quality has been improving (and is expected to improve in future years), thus further minimizing the influence of this domestic sewage upon water quality conditions in the Mississippi River. The enhanced levels of metals and other toxicants at Lock and Dam No. 3 may be a result of the MWTP discharge, although agricultural sources may also be a source of some constituents (Omernick, 1977). BOD levels measured at Lock and Dam No. 3 since 1969 usually appear to be well below the average dissolved oxygen levels, which may explain the consistently high dissolved oxygen levels measured at Lock and Dam No. 3 (Table III-5) and near PINGP.

b. EFFECTS OF PINGP EFFLUENT. Average, maximum, and minimum dissolved oxygen levels have been measured at seven water quality stations in the vicinity of PINGP from 1973 to present, and the concentrations usually averaged well above the minimum levels necessary for most aquatic life (i.e., minimum levels rarely dropping below 5 mg/l). In most instances, mean, maximum, and minimum oxygen concentrations were higher in surface samples than in those near the bottom, although in some instances (see Figure III-16), dissolved oxygen inversion occurred. At Station 12 (see Figure III-17 for location), a more measureable oxygen inversion was noted at Stations 21 and 25, located in the PINGP discharge. This may have been the result of less oxygen saturated thermal effluent floating above the colder, more oxygen laden ambient river waters. It should be noted, however, that an oxygen inversion was observed at Station 25 in 1973, also, when the plant was not operational. This indicates that dissolved oxygen inversions may periodically occur naturally in this area. During operational years (1974 to 1977), it appears that the dissolved oxygen content of water passing through the plant decreased slightly (compare Stations 12 and 18 in Figure III-16), probably as a result of

Table III-4. Minimum, maximum, and mean concentrations of water quality parameters in subsurface samples collected from 21 June 1970 through 13 September 1977 (from NUS, 1976; Eberley, 1977; NSP, unpublished)[1].

PARAMETER	CONCENTRATION (mg/l UNLESS OTHERWISE NOTED)		
	MINIMUM	MAXIMUM	MEAN
Solids, Total	168	443	269
Solids, Dissolved	134	367	243
Solids, Suspended	1.4	85	27
Hardness, Total (as $CaCO_3$)	110	268	182
Hardness, Calcium (as $CaCO_3$)	76	180	117
Hardness, Magnesium (as $CaCO_3$)	34	100	65
Alkalinity, Total (as $CaCO_3$)	86	232	154
Alkalinity, Phenolphthalein (as $CaCO_3$)	0	24	3.3
Ammonia Nitrogen (N)	0	2.4	0.45
Carbonate[2] (CO_3)	0	29	3.1
Bicarbonate[2] (HCO_3)	103	235	176
Chloride (Cl)	2	32.9	14.8
Nitrate Nitrogen[3] (N)	<0.01	4.2	0.87
Sulfate (SO_4)	10	110	38
Phosphorus, Soluble[3] (P)	0.005	0.550	0.14
Silica (SiO_2)	0.1	16.2	8.1
Calcium[2] (Ca)	30.4	72	47
Magnesium[2] (Mg)	8.3	24	16
Sodium, (Na).	3.9	28.5	13
Iron, Total[3] (Fe)	0.0	2.36	0.57
Color[3] (APHA units)	15	100	50
Turbidity (JTU)	1	52	12
Conductivity (μmhos/cm)	230	572	393
pH	7.4	9.4	8.2
Biochemical Oxygen Demand	1.1	9.45	3.5

[1]Prior to plant operation (1970-1973) samples were collected at the location of the intake and after 1973 the samples were collected in the main channel of the river just upstream from the intake.

[2]Minimum, maximum, and mean calculated for the period of June 1970 to September 1977.

[3]Minimum, maximum, and mean calculated for the period of January 1970 to September 1977.

Table III-5. Selected water quality for the Mississippi River at Lock and Dam No. 3, 1969 to 1976 (U.S.G.S., 1967-1976).

WATER QUALITY PARAMETER	1969			1970			1971			1972			1973			1974			1975			1976		
	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN
DO, mg/l	12.0	6.6	8.71[1]	14.2	6.5	9.07[2]	12.2	6.2	9.45[3]	12.8	6.1	9.83[4]	12.2	6.8	10.38[4]	13.0	6.1	9.81[2]	12.7	6.5	9.43[5]	12	7.6	9.79[6]
CO_2, mg/l										8.5	7.6	8.05[7]	8.0	1.1	4.38[5]	11.0	0.6	3.91[5]	34	2.0	7.74[6]			
BOD, mg/l	5.4	2.6	3.82[8]	4.8	2.0	3.14[2]	4.6	1.1	2.75[3]	4.5	1.4	2.64[4]	7.8	1.4	3.52[4]	11	2.4	4.33[2]	3.5	1.2	2.43[5]	7.2	2.4	4.86[6]
Phenols, µg/l													10	0	3.25[5]	7	0	3.5[5]	10	0	5.17[5]	10	0	4.67[6]
Dissolved NH_4 (N), mg/l	0.6	0.4	0.49[10]	1.0	0.11	0.55[4]	0.85	0.31	0.58[11]	0.95	0.13	0.41[12]	0.86	0.34	0.56[8]	1.85	0.02	0.55[5]	1.1	0	0.40[6]			
Σ Dissolved A, µg/l												0[13]	0	0	0[7]			1[13]			2[13]			2[13]
Dissolved Cu, µg/l												23[13]	23	7	15[7]			4[13]			13[13]			2[13]
Σ Pb, µg/l												5[13]	100	<50	25[7]			<100[13]			700[13]			< 100[13]
Σ Hg, µg/l												0[13]	0.1	0	0.05[7]			0[13]			2.3[13]			0[13]
Dissolved Zn, µg/l												30[13]	140	30	0.85[7]			10[13]			30[13]			0[13]
CN, mg/l												0[13]	.01	0	0.005[7]			0[13]			0			11[13]
Dissolved NO_3 and NO_2 (N), mg/l							3.8	0.36	1.53[1]	12	0.30	1.81[12]	3.05	0.37	1.54[5]	3.04	0.35	1.10[5]	4.67	0.24	1.14[5]	1.7	0.04	0.52[6]
Dissolved PO_4, mg/l	0.44	0.28	0.34	0.43	0.06	0.26[4]	0.26	0.16	0.20[14]	0.22	0.02	0.14[9]	0.40	0.05	0.15[5]	0.25	0.05	0.15[5]	0.25	0.07	0.14[5]	0.17	0.06	0.10[6]

[1] Five monthly values.
[2] Eleven monthly values.
[3] Nine monthly values, one bimonthly value.
[4] Ten monthly values, two bimonthly values.
[5] Twelve monthly values.
[6] Nine monthly values.
[7] Two monthly values.
[8] Four monthly values.
[9] Seven monthly values, four bimonthly values.
[10] Three monthly values.
[11] Eight monthly values.
[12] Nine monthly values, seven bimonthly values.
[13] One monthly value.
[14] Six monthly values.

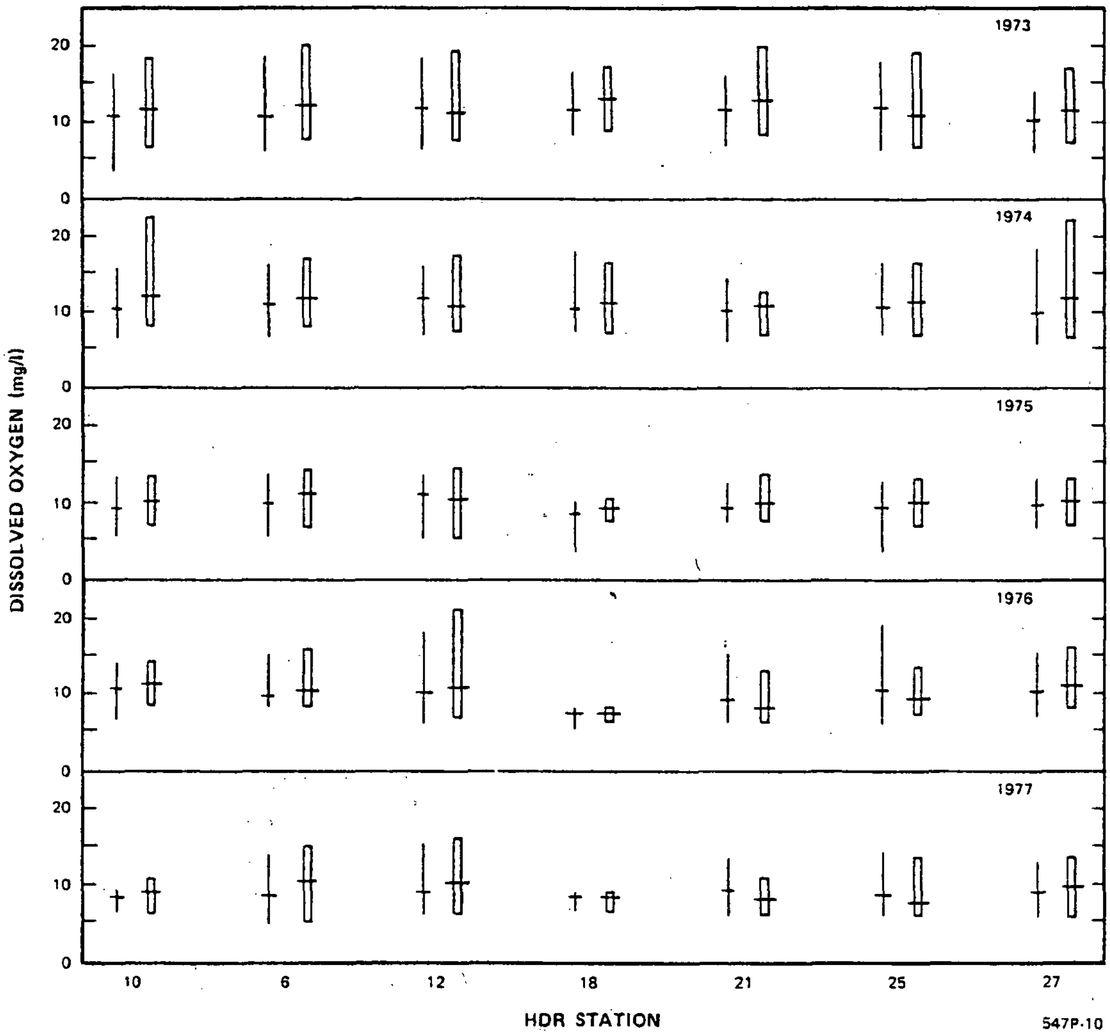
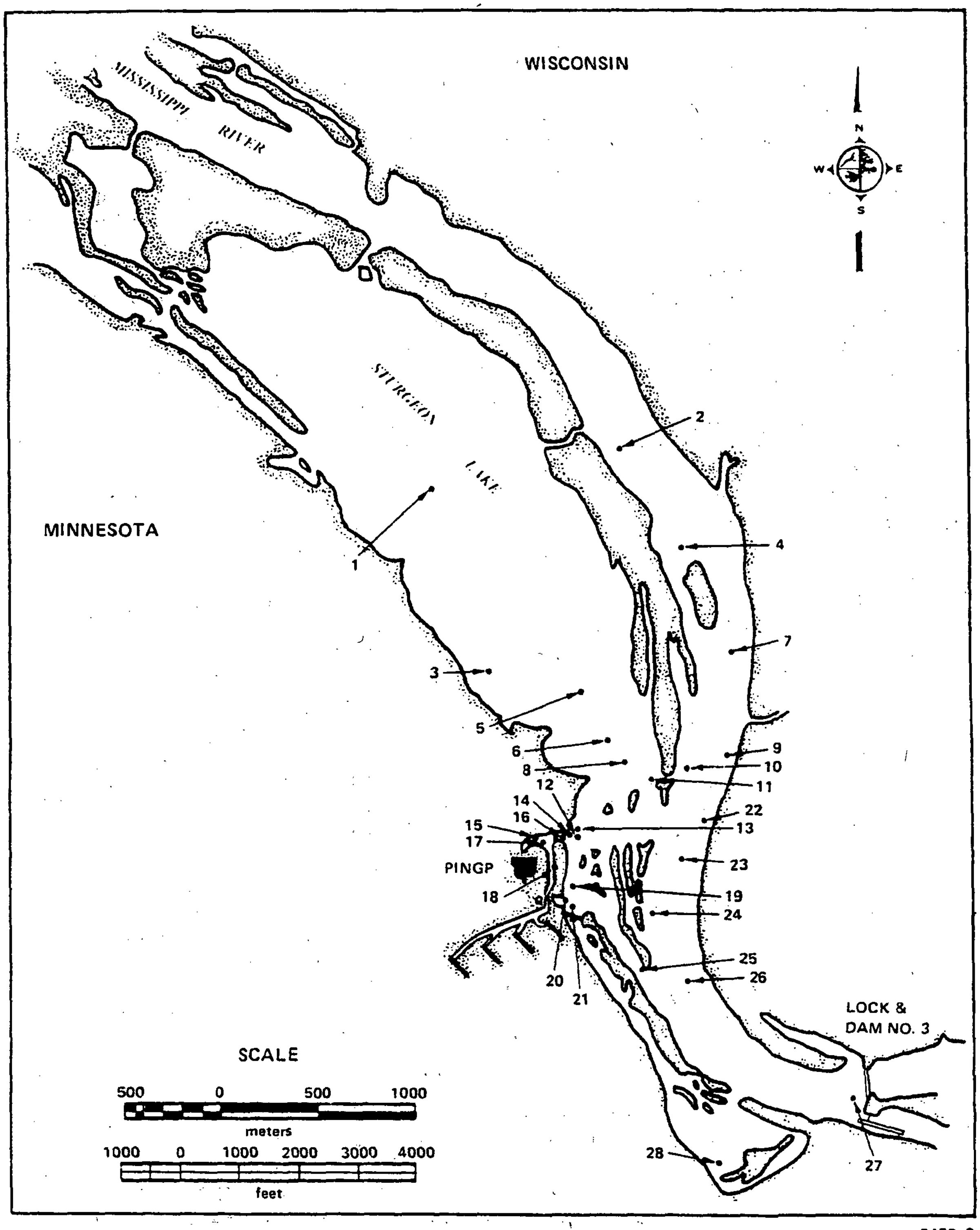


Figure III-16. Maximum, minimum, and average dissolved oxygen levels for selected stations in the vicinity of PINGP, 1973-1977. Open bars indicate range of surface DO, vertical lines indicate range of bottom DO, and horizontal lines indicate mean levels of DO (Dieterman, 1974-75; Schmidt, 1977; NSP, unpublished).



547P-6

Figure III-17. Sampling locations for water quality, phyto-plankton, periphyton, zooplankton, and macro-invertebrates.

increased water temperature, and therefore, lower oxygen saturation. Upon discharge from the plant, however, the dissolved oxygen levels quickly reached those of the receiving waters; thus, the effect of plant operation upon receiving water dissolved oxygen appeared to be temporary and minimal.

In order to determine quantitatively what effect PINGP exerts upon various water quality parameters, an analysis of variance was performed by Schmidt (1977) on data from two pairs of stations upriver and two pairs of stations downriver for 1975 and 1976. A comparison was also made between top and bottom samples collected at the same stations (Table III-6). Significant differences between up- and downriver stations might indicate a plant effect; between surface and bottom samples, a vertical stratification effect; between months, a temporal effect. The basic expected plant effect would be temperature controlled parameters such as dissolved oxygen. Enhanced temperature might also indirectly alter nutrient levels by enhancing primary production. Plant effluents may also increase dissolved solids and conductivity in the immediate vicinity of the discharge as a result of evaporation of cooling water during the closed and helper cycle modes of operation. Plant operation might also disrupt sediment related density stratification as a result of turbulence in the discharge water. In general, depth stratification exclusive of plant effect may be expected for sediment related parameters (due to density) and dissolved oxygen (due to depletion, production, and re-aeration), which in turn may indirectly cause variations between top and bottom pH, alkalinity, and nutrient levels. No measureable effect, however, is expected as a result of plant operation upon river water alkalinity and pH. Temporal variation in water quality parameters, in addition, is expected to occur mainly because of variations in river flow, temperature, allocthonous (originating outside the river) and autocthonous (originating in the river) inputs over time. Interaction between temporal and spatial (vertical and horizontal) values for all parameters may also result in significant variation, whether or not such significant variation was shown to occur without interaction.

In both 1975 and 1976, water quality parameters varied significantly at the $\alpha \leq 0.05$ level over time, that is, from month to month. Sediment related parameters, such as nonfilterable residue and turbidity, varied significantly between top and bottom samples at all stations compared. Plant impact on dissolved oxygen, conductivity, and ammonia nitrogen was also noted in both 1975 and 1976. According to Schmidt (1977), the cause for the difference in upriver and downriver ammonia nitrogen levels is unknown, while that for dissolved oxygen was probably a result of erroneous measurement. He also stated that increased conductivity readings downriver from the plant may be the result of the PINGP discharge since evaporation in the cooling towers increases the dissolved solids of the blowdown. Conductivity readings, however, were not corrected for temperature variations, which also may account for consistently higher levels measured in the discharge (Eberley, personal communication). Data for one station upstream and one downstream from PINGP are presented in Table III-7 (see Figure III-17 for locations). Eberley (1977), using a Student's *t*-Test on both years (1975 and 1976) combined, found no significant ($\alpha = 0.05$ level) differences

Table III-6. Summary of ANOVA for water quality data comparisons for two stations (HDR Stations 10 and 11) upriver and two stations (HDR Stations 25 and 27) downriver from PINGP measured at the top and bottom of the water column for 1975 and 1976 (from Schmidt, 1977).

WATER QUALITY PARAMETER	VARIATIONS SIGNIFICANT AT $\alpha \leq 0.05$											
	BETWEEN MONTHS		ABOVE VS BELOW PLANT		ABOVE AND BELOW PLANT BY MONTH		BETWEEN DEPTHS		BETWEEN DEPTHS BY MONTH		ABOVE AND BELOW PLANT BY DEPTH	
	1975	1976	1975	1976	1975	1976	1975	1976	1975	1976	1975	1976
Phenolphthalein alkalinity	x	x								x[1]		
Methyl-orange alkalinity	x	x										
Dissolved orthophosphate (P)	x	x										
Total dissolved phosphorus (P)	x	x										
Filterable Residue (TDS)	x	x										
Non-filterable residue (TSS)	x	x					x[2]	x[2]				
Ammonia nitrogen (N)	x	x	x[1]									
Nitrite nitrogen (N)	x	x										
Nitrate nitrogen (N)	x	x										
pH	x	x										
Conductivity	x	x		x[3]								
Dissolved Oxygen	x	x	x[4]									
Turbidity	x	x					x[2]	x[2]				

[1]Unknown explanation for significant variation.

[2]Variation due to natural density stratification.

[3]Variation possibly resulting from PINGP effluents; conductivity measurements were not corrected for temperature, which may account for a significant difference between upriver and downriver stations in 1976.

[4]Variation possibly resulting from erroneous chemical measurement.

Table III-7. Mean values for chemical parameters measured at the Prairie Island Nuclear Generating Plant during 1975 and 1976 (Eberley, 1977).

PARAMETERS AND UNITS		UPSTREAM (STATION 10)		DOWNSTREAM (STATION 25)	
		1975	1976	1975	1976
Solids-mg/l	Total	236.00	246.50	257.00	257.00
	Filterable	213.00	222.20	228.00	226.40
	Nonfilterable	22.80	24.36	30.70	30.53
Hardness-mg/l	Total	165.0	163.8	170.0	173.0
	Calcium	107.0	103.6	112.0	108.8
	Magnesium	58.0	60.2	59.0	64.2
Alkalinity-mg/l (as $CaCO_3$)	Total	142.0	145.8	148.0	152.4
	Phenolphthalein	0	6.5	2.0	6.7
Gases-mg/l	Dissolved Oxygen	9.80	10.85	9.20	10.02
	Ammonia-Nitrogen (N)	0.410	0.380	0.350	0.301
Anions-mg/l	Carbonate (CO_3)	0.50	8.96	3.30	8.03
	Bicarbonate (HCO_3)	172.0	159.4	174.0	169.6
	Chloride (Cl)	14.360	20.500	15.380	20.375
	Nitrate-Nitrogen (N)	1.090	0.352	1.210	0.400
	Sulfate (SO_4)	27.50	29.55	30.00	30.92
	Phosphorus-Soluble (P)	0.1190	0.1007	0.1240	0.1214
	Silica (SiO_2)	10.10	5.09	10.40	5.40
Cations-mg/l	Calcium (Ca)	42.90	41.53	44.70	43.62
	Magnesium (Mg)	14.00	14.63	14.30	15.62
	Sodium (Na)	10.90	17.51	12.00	17.59
	Total Iron (Fe)	0.410	0.208	0.590	0.442
	Potassium (K)	2.30	2.37	2.40	2.44
Miscellaneous	Color (APHA Units)	42.0	43.6	43.0	45.8
	BOD (mg/l)	2.30	4.74	2.90	5.01
	Turbidity (JTU)	9.220	9.355	12.840	12.825
	Conductivity (umhos)	368.0	386.1	377.0	399.6
	pH	8.060	8.582	8.240	8.567

between the upstream and downstream stations for any of the water quality constituents. When comparing 1976 to 1975, however, some significant differences occurred for certain parameters. These differences occurred in both the upstream and downstream stations (phenolphthalein alkalinity, BOD, nitrate nitrogen, and silica) or in only the upriver stations (chloride and carbonates), suggesting that the differences were naturally occurring and not caused by plant operation.

c. POTENTIAL FOR TOXICITY TO AQUATIC BIOTA. Certain water quality parameters such as toxicants may interact with temperature to enhance their toxic qualities to certain affected biota (Jensen et al., 1969). However, most bioassays are conducted in the absence of thermal variation; the few tests conducted with variable temperature and toxicant levels tend to indicate that elevated temperatures enhance toxic responses by susceptible biota (Jensen et al., 1969). Alkalinity, hardness, and pH have also been shown to potentiate or alleviate toxicity (Becker and Thatcher, 1973, p. M.2). Some water quality constituents measured in the vicinity of PINGP may be potentially toxic to aquatic organisms and may also contribute to or enhance any potential thermal impacts. Toxicants such as metals, phenols, and cyanides (for which data exist) are examined in relation to bioassay information in Appendix Table A-6. The data indicate that several constituents may be toxic to some organisms at the concentrations measured in the river near PINGP, in the absence of thermal synergisms. It must be noted, however, that most of these measurements were taken only once or twice a year, and, therefore, should be considered as conservative (i.e., they probably underestimate high or critical levels actually occurring in the river). The available bioassay literature indicates that phenol and arsenic concentrations measured near the plant should not cause problems when considered separately. Copper, however, may be detrimental to certain phytoplankton, zooplankton, benthos, and fish at the higher concentrations measured near PINGP and, thus, could be considered a critical toxicant at certain times of the year, either by itself or in combination with other toxicants and temperature. Zinc, also, could damage some of the zooplankton at the higher concentrations measured near PINGP. Ammonia, at low levels, is considered a nutrient, whereas in high concentrations, it can act as a toxicant. The latter condition appears to occur periodically near Prairie Island, as evidenced by a measurement of 2.4 mg/l of ammonia nitrogen. This concentration could cause damage to zooplankton, phytoplankton, and fish, as well as certain benthic organisms. However, the most toxic water quality constituent measured near PINGP was cyanide ion, which in 1976 was recorded at 11 mg/l. This greatly exceeds the state standard of 0.02 mg/l, and although only one measurement was taken, the potential for damage at this high concentration is exceedingly great. For instance, bioassay information indicates that most kinds of fish and other biota would be killed or repelled by this concentration if it were maintained over a relatively long period of time. It is likely, however, that the level measured was either an artifact in the measurement or an extremely temporary pulse of highly toxic water originating upriver of PINGP. Elevated lead and mercury concentrations have also been measured in the vicinity of the plant, and although the ecological significance of these levels is not well documented, there is a potential that they could also cause temporary damage to the aquatic ecosystem. It is important to point out that the potential impacts of toxicants shown in Appendix Table A-5 are presented for constituents tested separately. It should be emphasized that sublethal concentrations of toxicants occurring simultaneously could interact synergistically to create an environment incompatible with many forms of aquatic life. Such conditions may exist in the vicinity of PINGP at certain times of the year as evidenced by the water quality data, causing mortality or decreases in diversity exclusive of any effects of PINGP. Moreover, unmeasured toxicants specified in the Clean Water Act of 1977 may periodically contribute to and potentiate unfavorable water quality conditions near PINGP.

C. GENERAL AQUATIC BIOLOGY OF THE MISSISSIPPI RIVER NEAR PINGP

1. Introduction. In this section, baseline ecological conditions in the Mississippi River and associated backwaters near PINGP are described. These data along with hydrological, engineering, and thermal plume information will be utilized in Section VI to describe impacts of past PINGP discharges as well as to predict future impacts.

The Mississippi River near PINGP comprises numerous habitat types, thus creating a complex ecosystem. In addition to fluctuating flow characteristics and water levels, water quality in the river influences the general dynamics and tropic structure of biota near the site. Water quality near PINGP is altered considerably from that upriver of the Twin Cities, primarily as a result of the Minneapolis-St Paul urban complex. Large quantities of treated sewage enter the river from the Metropolitan Treatment Plant near St Paul (see Section III B), and the Minnesota River contributes a considerable amount of sediments and other agricultural-related constituents from runoff. Flows from the St. Croix River, which is relatively clean, tend to dilute the influxes from the Metro Treatment Plant and the Minnesota River; nevertheless, the zone near PINGP can be considered a "recovery" area where the biota begin to benefit from added nutrients without the handicap of low dissolved oxygen. In addition, concentrations of toxicants from sources upriver usually attenuate by the time they reach the recovery zone.

Near PINGP, energy sources for the aquatic food web have allochthonous (outside the river) and autochthonous (within the river) origins. Detritus from runoff and sewage discharge provide a continual food supply for heterotropic metabolism, and autotropic organisms utilize the dissolved nutrients. The backwater lakes connected to the river provide excellent habitats for the proliferation of autotropic primary producers such as phytoplankton, periphyton, and macrophytes, especially considering the abundance of nutrients. Activities of man, however, have reduced natural detrital inputs to the river ecosystem. For instance, as water levels in the pools of the Mississippi River rose, the ratio of shoreline length to surface area decreased. As this ratio became smaller, the relative amount of organic matter (primarily leaf fall) provided decreased.

Moreover, removal of shoreline vegetation for agriculture and urbanization have also decreased availability of litter. Dissolved nutrients, on the other hand, have increased as a result of agricultural runoff and sewage disposal.

The trophic structure in the Mississippi River near PINGP is very complex. The variety of aquatic habitats encourages a diverse biota with many organisms occupying different trophic levels (and possibly several levels simultaneously) during their lives. The lowest trophic level includes photosynthetic organisms (phytoplankton, periphyton, and macrophytes) and detrital feeders (some zooplankton and macroinvertebrate species). These organisms are preyed upon by other organisms, which then become prey for higher level consumers. Bacteria complete the nutrient cycle by decomposing organic matter into useful nutrients.

The Mississippi River near PINGP serves many functions other than wildlife propagation. Fishing and boating are the primary recreational uses of the river and industrial or commercial uses include cargo transport, fishing, sewage disposal, and withdrawal of cooling water for power production.

2. Fisheries.

a. DISTRIBUTION AND ABUNDANCES. Fish have been collected in the vicinity of PINGP since 1970 using a variety of methods including electrofishing, gill nets, trap nets, seines, and trawls. Appendix Tables A-6 and A-7 summarize the methods and Figures III-18 through 21 show the locations sampled. The species collected in the Mississippi River and its connected lakes near PINGP from 1973 through 1977 are listed in Appendix Table K-1. Of the 67 species listed, only four were not collected above Lock and Dam No. 3, and no species on the state or federal threatened and endangered species list have been reported. From the list in Appendix Table K-1, ten species have been chosen as representative of the biological communities and ecological interactions (e.g., trophic levels as defined in Appendix E) that occur in this area. These representative important species (RIS) are walleye, northern pike, channel catfish, white bass, black crappie, gizzard shad, emerald shiner, white sucker, shorthead redhorse, and carp. The first five species represent sport fish from several trophic levels while emerald shiners and gizzard shad are forage fish (food base for other species). The white sucker and shorthead redhorse represent lower trophic levels with the young providing forage while the adults may be taken by recreational or commercial fishermen. Carp are generally considered a nuisance species, particularly when more desirable sport fish are available. However, this species is also commercially fished. These species will be used in assessing the potential impacts of the PINGP thermal discharge, both theoretically and based on field observations.

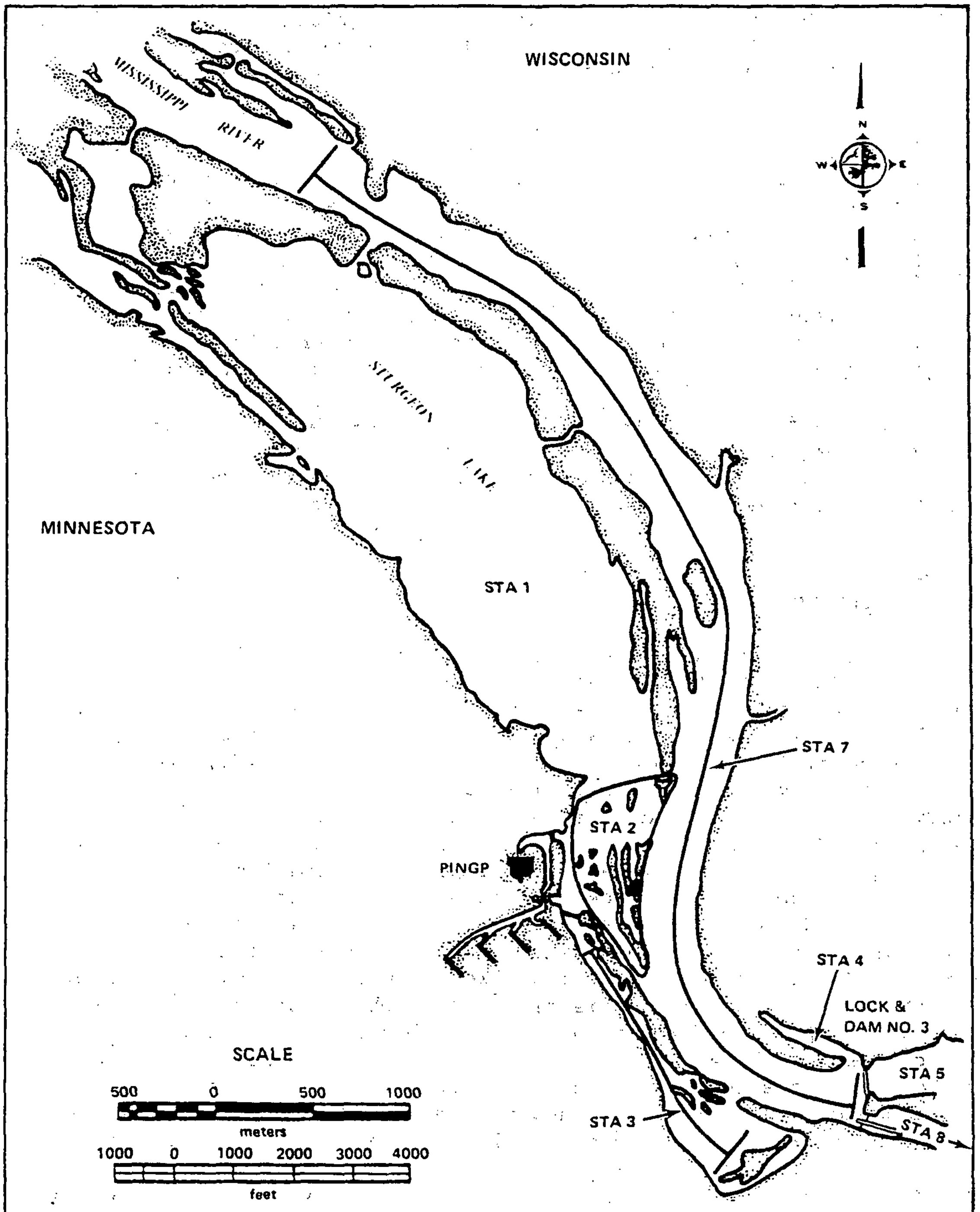


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Figure III-18. Sampling stations for fish in 1970 (Stations 1-6 only), 1971 and 1972. Station 6 (not shown) was at the confluence of the Vermillion River below Lock and Dam No. 3, and Station 8 (not shown) was from Lock No. 3 downriver 4.4 km (2.75 mi).

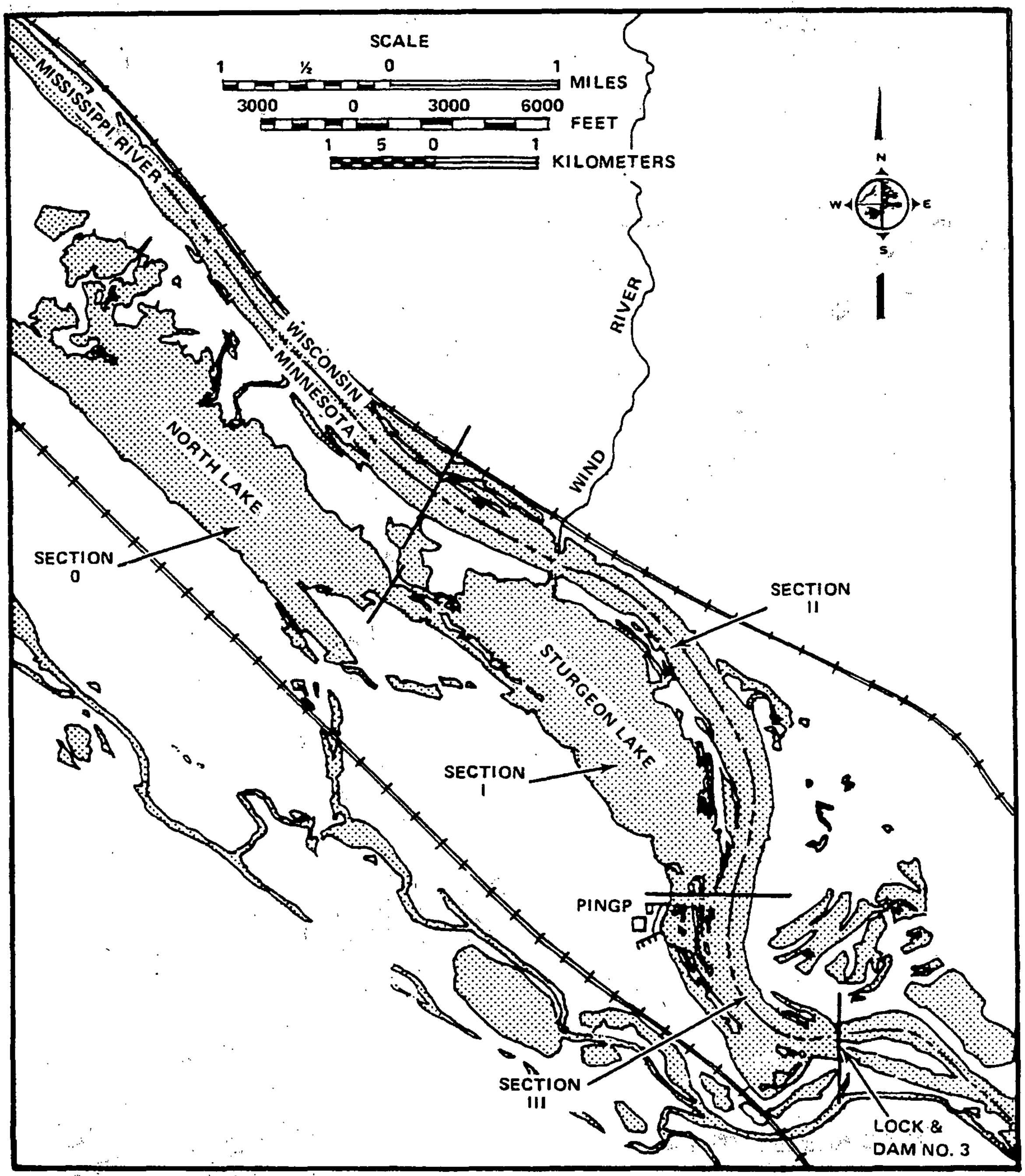

Figure III-19. Sampling locations for fish in 1973 through 1977. Each section was subdivided into 10 stations, and Sections IV-VI were below Lock and Dam No. 3.

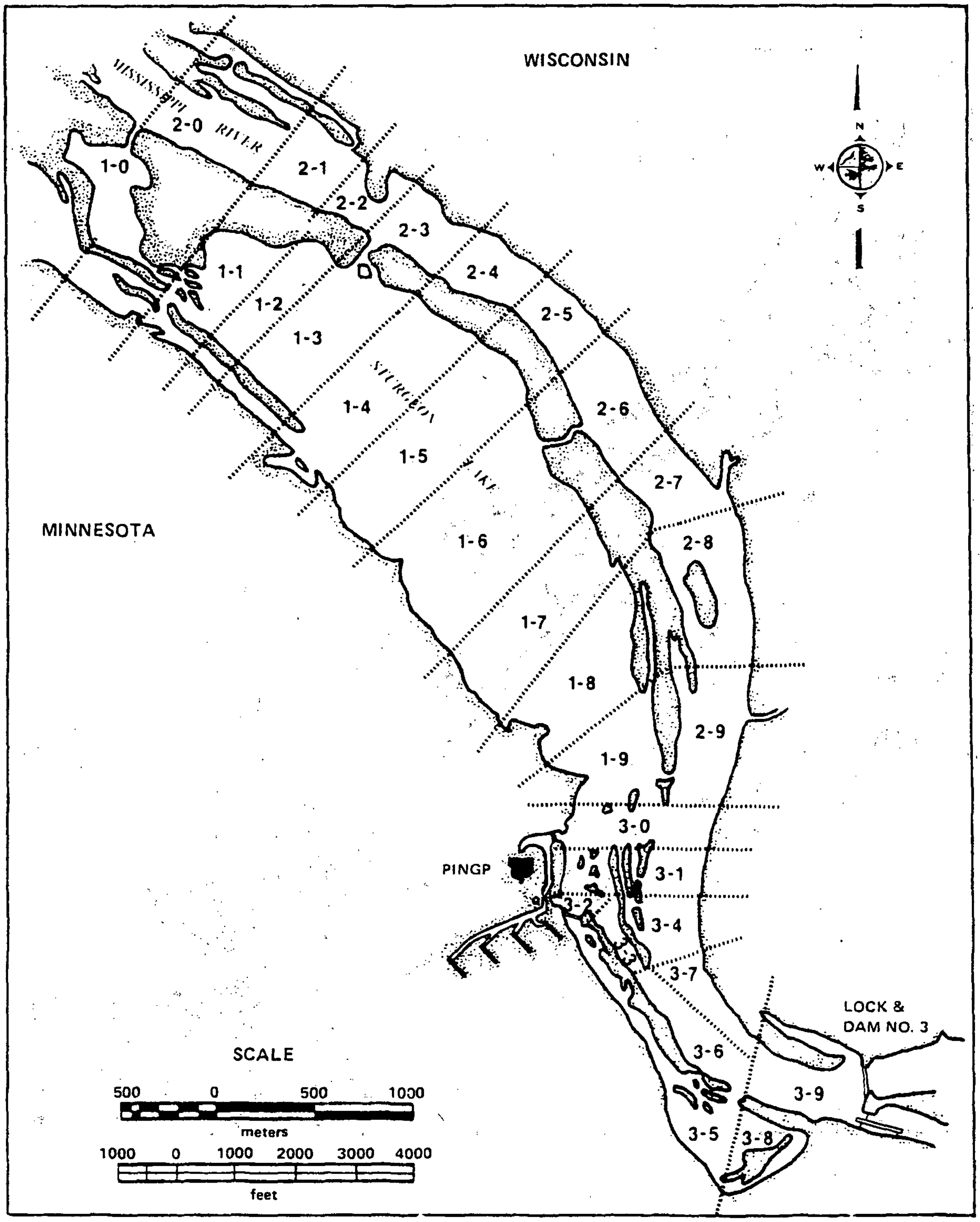

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Figure III-20. Sampling stations for Sectors I through III for 1977 DNR fisheries studies.

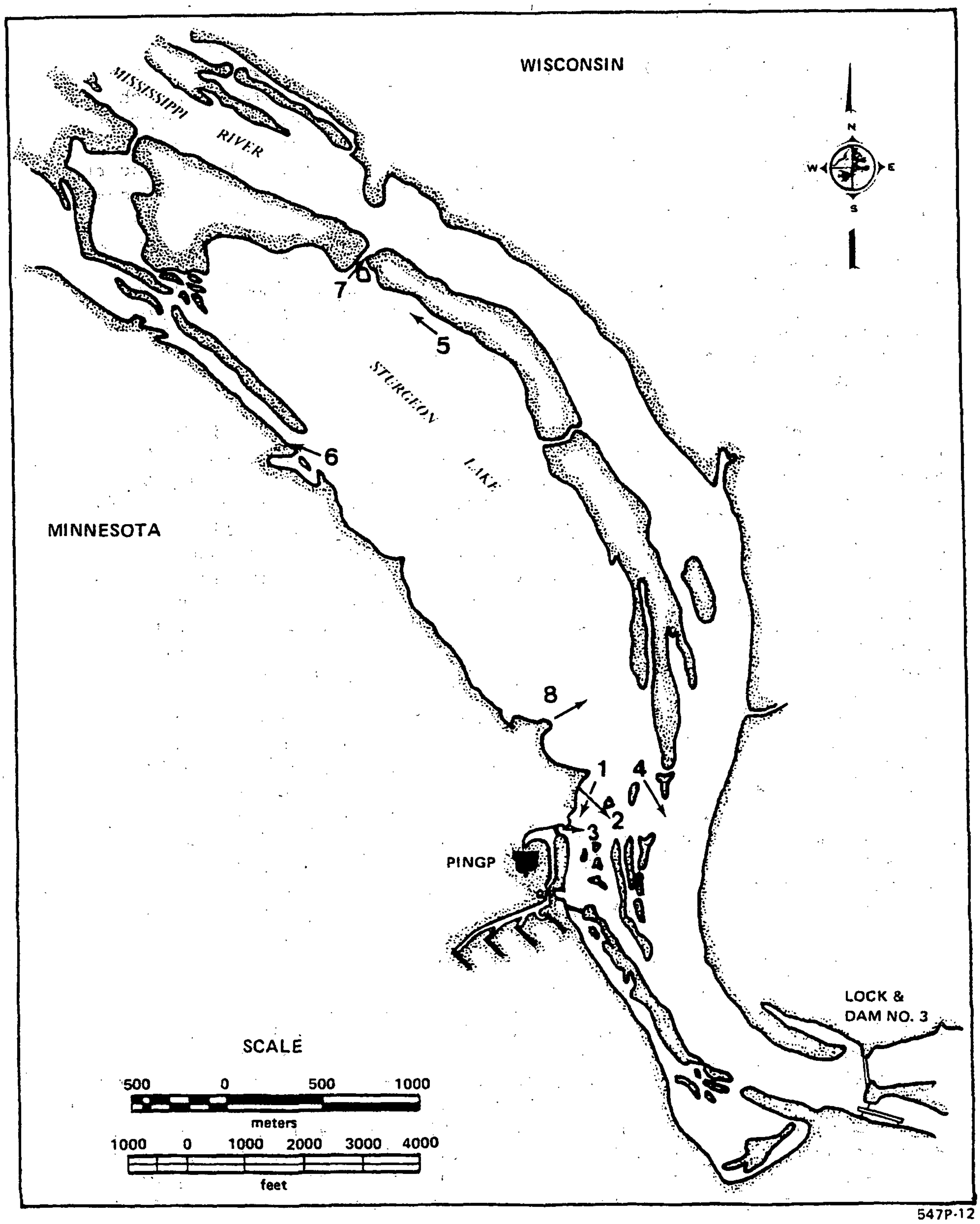


Figure III-21. Larval fish tow locations for 1974 and 1975. Only locations 1 through 4 were sampled in 1974 (Gustafson et al., 1976).

The relative abundances of the major taxa collected above the dam are presented in Table III-8. All five collection methods were combined for all years (1973 through 1976), and the effort expended with each gear varied from year to year. Furthermore, the efficiency of capture for each species varies with size and between gear types, and thus, the abundances presented are only estimates of the actual abundances occurring in the vicinity of PINGP. From the table, it appears that gizzard shad was the numerically dominant species during the warmer months of the year followed by white bass, freshwater drum, and carp. The RIS were fairly abundant in the area with 9 out of 10 ranking in the 15 most abundant species. In addition, each of the RIS, except white sucker (0.1 percent), composed more than 1 percent of the fish collected on an annual basis. Percent composition for each species varied from late spring through fall which may be related to movements or migration, reproduction (e.g., large numbers of young in summer and fall), and mortality.

Annual variations in abundances are shown by season in Figure III-22. for each of the RIS. These are probably not true seasons, however, particularly for spring and summer, since sampling began in late May or early June for "spring" and often extended into early July while "summer" was from the end of the spring sampling through August. Fall sampling was in September and October which should represent this season, at least based on water temperature. Only electrofishing data were used in order to maintain comparability of the data, and thus, actual relative abundances of species should not be inferred from this figure because of gear selectivity. In addition, all stations in Sections I, II, and III were combined, which includes two stations in the PINGP thermal discharge.

For all the abundant species, annual (between year) fluctuations in catch per unit effort (CPE) are quite evident (see Figure III-22) as would be expected since natural populations are seldom in a steady state. These variations may be the result of both density independent (e.g., pollution, changes in river flow, and extreme temperatures) and density dependent (e.g., parasites and diseases, cannibalism, and some types of predation) factors which act to regulate the populations. Shorthead redhorse and carp show similar seasonal trends of declining CPE from spring to fall each year while gizzard shad show the opposite trend. These seasonal variations in abundance may be related to numerous factors as noted previously in this section.

The Mississippi River and its associated backwaters in the vicinity of PINGP provide a variety of habitats for fish and thus may influence the spatial distribution of the RIS. Figure III-23 shows the seasonal variations in CPE for the most abundant RIS over the period 1974 through 1977. The areas compared are Sturgeon Lake (10 stations), the Mississippi River above the plant (10 stations in Section II), and the Mississippi River below PINGP (4 stations). On an annual basis, the abundances are surprisingly similar between areas considering the dissimilarity of habitats and would seem to indicate that the areas are not so dissimilar as far as these species are concerned. This may be due, in part, to the lock and

Table III-8. Species composition (percent) of the major taxa of fish collected in the vicinity of PINGP during the period 1973 through 1976.[1]

TAXA[2]	SPRING[3]	SUMMER[3]	FALL[3]	ANNUAL
Gizzard Shad*	9.9	10.7	36.5	20.8
White Bass*	22.3	12.1	13.5	15.6
Freshwater Drum	10.1	24.6	5.6	12.8
Carp*	16.4	11.8	6.8	11.1
Emerald Shiner*	7.0	4.8	4.5	5.3
Sauger	3.6	1.9	5.6	3.9
Shorthead Redhorse*	4.5	4.5	2.6	3.8
Bluegill	1.3	3.8	5.0	3.6
Black Crappie*	1.6	3.6	3.1	2.8
Channel Catfish*	3.1	3.6	0.5	2.2
White Crappie	1.6	1.4	3.1	2.1
Spottail Shiner	0.9	2.0	2.4	1.8
Shortnose Gar	2.0	2.0	0.9	1.6
Walleye*	1.4	0.5	1.7	1.3
Northern Pike*	2.0	0.7	1.1	1.3
Carpsucker sp.	2.1	1.6	0.4	1.3
N =	12,962	13,976	18,067	45,005

[1]The areas sampled are North and Sturgeon Lakes, the main channel from Brewer Lake cut to the PINGP intake, and from PINGP to Lock and Dam No. 3. The effort expended with each gear type varied from year to year so that the composition may not reflect the actual composition as a result of gear selectivity for some species.

[2]Asterisk indicates RIS.

[3]Seasons are not defined by water temperature but are those presented in the annual reports for the fisheries data. They are generally: spring = late May to early July; summer = early or mid-July through August; and fall = September and October.

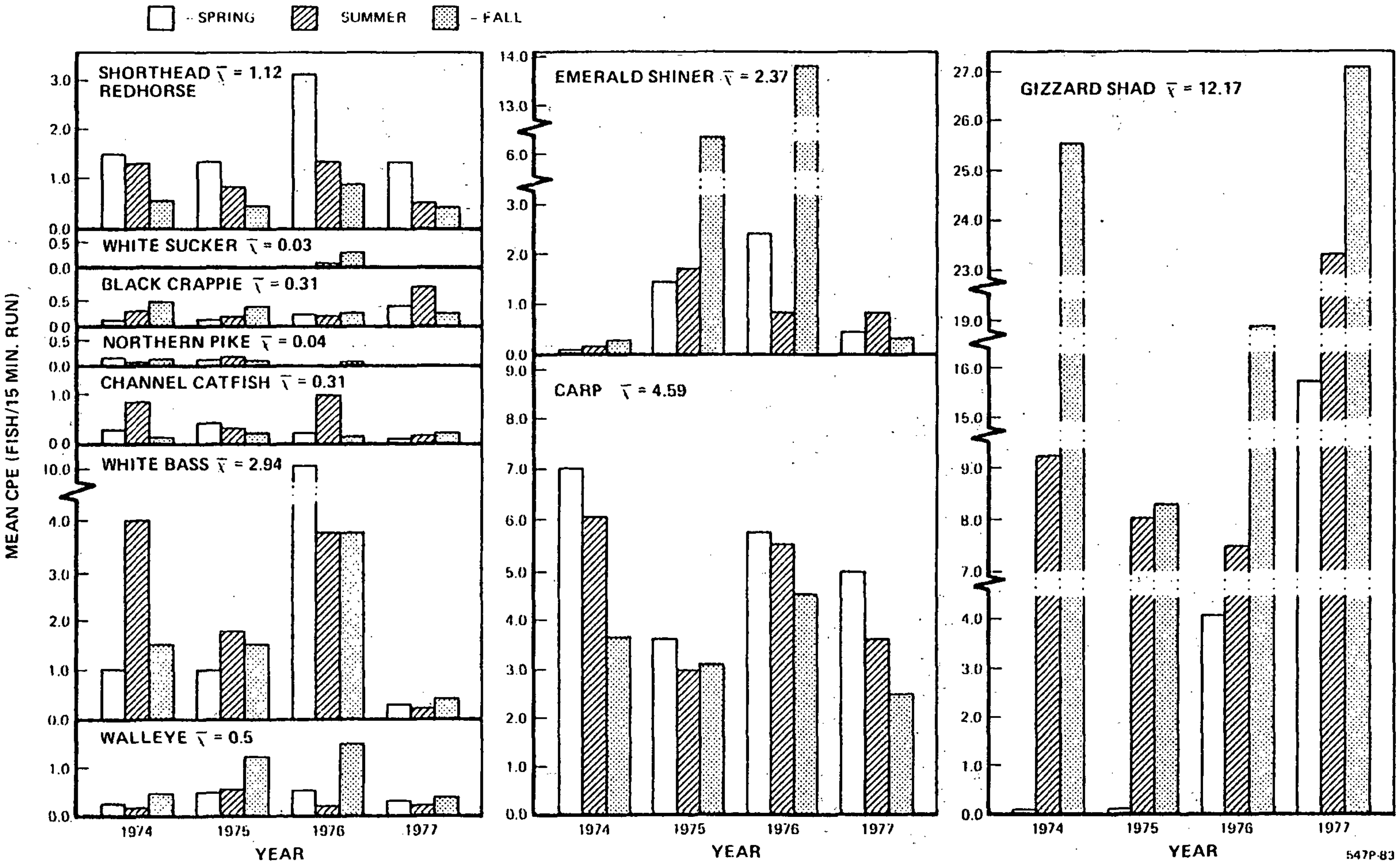
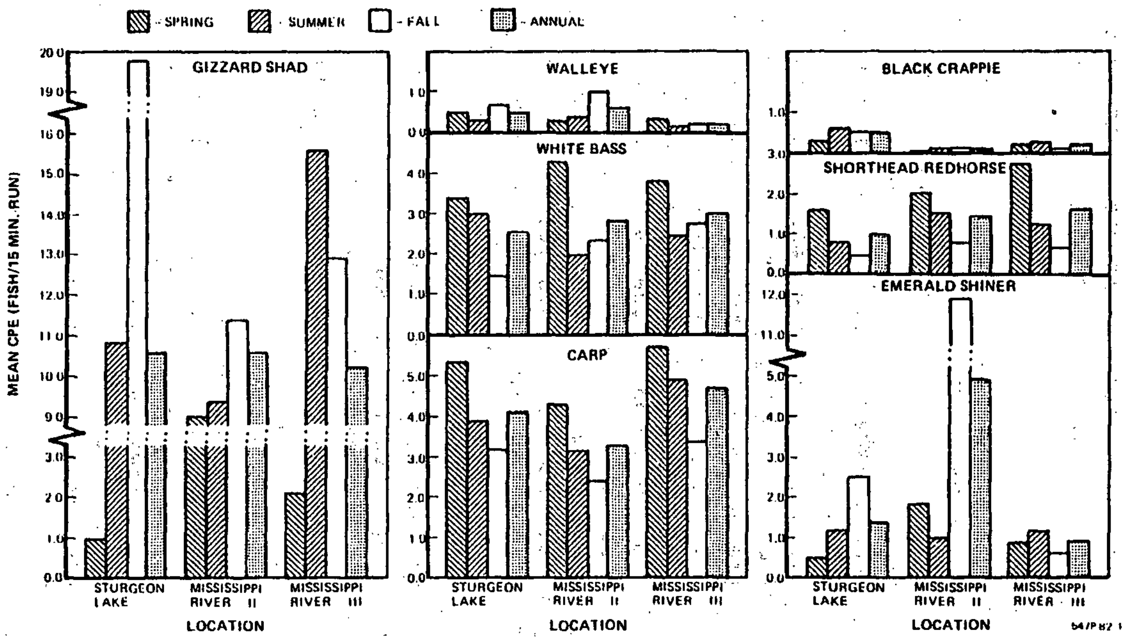


Figure III-22. Mean electrofishing catch per unit effort (CPE) by season for each RIS in Sturgeon Lake and the Mississippi River from Brewer Lake cut to Lock and Dam No. 3 combined over the period 1974 through 1977. This includes data for the PINGP discharge. Seasons are defined in the text (from DNR data).



NOTE. Spring is late May to early July, summer is early mid July through August, and fall is September and October. All stations were used for Section I (Sturgeon Lake) and II while only stations in the River (4, 6, 7, and 9) were used in Section III (see Figure III-20 for locations).

Figure III-23. Spatial distribution of RIS near PINGP based on electrofishing data for the period 1974 through 1977 (from DNR data).

dam system which has created Pool No. 3 in this area. The one exception, emerald shiner, may be a sampling artifact rather than actual differenee in locality since the large fall CPE in Figure III-23 was dominated by two samples (out of 40). This species forms aggregations nearshore in the fall (Scott and Crossman, 1973, p. 442) and the sampling was conducted nearshore.

Larval fish have been collected in the vicinity of PINGP in 1974 and 1975. Sampling was conducted weekly in May through August at the stations shown in Figure III-21 and the larvae were counted but not identified. The data for 1974, although not comparable for abundances to those in 1975, indicate that spawning had begun by 8 May and was almost complete by 26 August with peak densities in mid to late July (Figure III-24). In 1975, spawning had begun before mid-May and was nearly complete by September with the peak density in early June (Figure III-25). The difference in time of maximum abundance is probably a result of annual variations in spawning as related to water temperature. In May of 1975, water temperatures rose much faster than in 1974, and the maximum temperature reached was 21° C (70° F) versus 78° C (64° F). The 1975 data show that densities of larvae were generally higher at the southern end of Sturgeon Lake where water flows out and past PINGP than at the northern end (locations 5, 6, and 7 in Figure III-21). This would seem to indicate that spawning occurs in Sturgeon Lake and at least some of the larvae are flushed out past the plant.

In 1975, larval fish were also sampled weekly at the bar racks of the PINGP intake for an entrainment study. Each 24-hour period was sampled at 4-hour intervals, and the larvae were identified to the lowest taxa possible. The abundances of larval RIS in 1975 were calculated by multiplying the mean density of larvae at locations 1, 2, and 4 (Appendix Table A-8), times the weekly percent composition for each species in the entrainment samples (Appendix Table A-9). For this calculation, the species composition at the intake was assumed to be the same as that for locations 1, 2, and 4 each week, and the sampling efficiency for each species was assumed equal for the two different sampling methods and equipment. The results of these calculations are presented in Figure III-26 for each of the RIS, except northern pike which were not collected. Northern pike generally spawn in April (Franklin and Smith, 1963) and May (June, 1971) with an incubation time of about 2 weeks (Eddy and Underhill, 1974, pp. 199-204) and, thus, may not be collected in mid-May when sampling began. No eggs of any RIS were collected as would be expected since the eggs of these species are not buoyant and most are adhesive (see life history discussion).

White bass, emerald shiner, carp, and gizzard shad were the dominant species. White bass larvae occurred primarily in late May and early June while emerald shiners showed three abundance peaks: late May, early July, and late July. Carp appear to have spawned from May through July although the peak occurred in June. Gizzard shad also have an extended spawning period with major peaks in larval drift in early and late June. Few larvae of the other RIS were collected as can be seen from Figure III-26. The

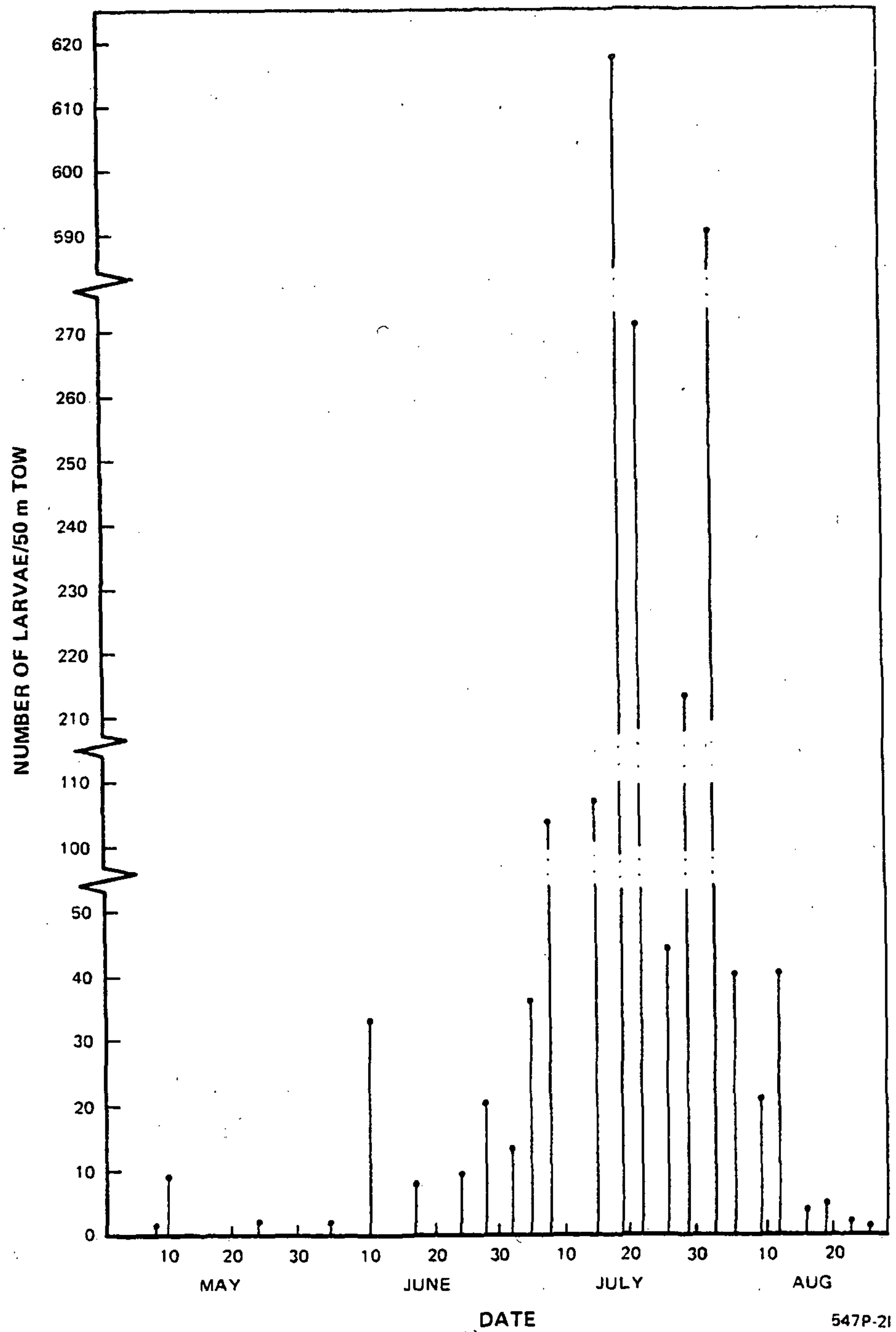


Figure III-24. Mean number of larval fish per 50 m tow at locations 1, 2, and 4 (representative of Sturgeon Lake) near PINGP in 1974. Sampling locations are shown on Figure III-21 (data from Naplin and Geis, 1975).

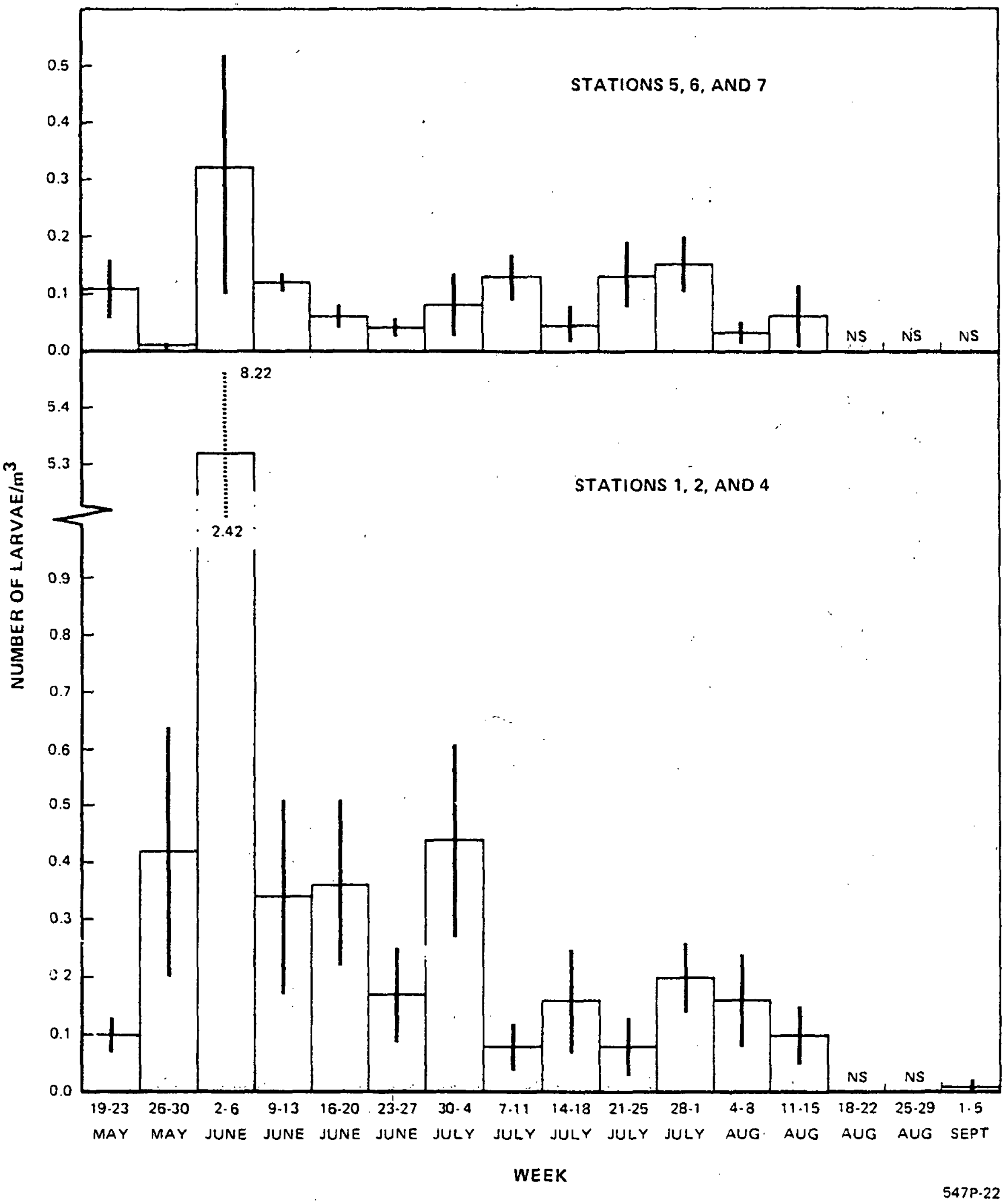


Figure III-25. Mean larval fish densities at PINGP in 1975 based on weekly sampling at the locations shown in Figure III-21. Stations 5, 6, and 7 represent upper Sturgeon Lake and Stations 1, 2, and 4 represent lower Sturgeon Lake. The vertical bars represent the standard error of the mean and NS is no sample (data from Gustafson et al., 1976).

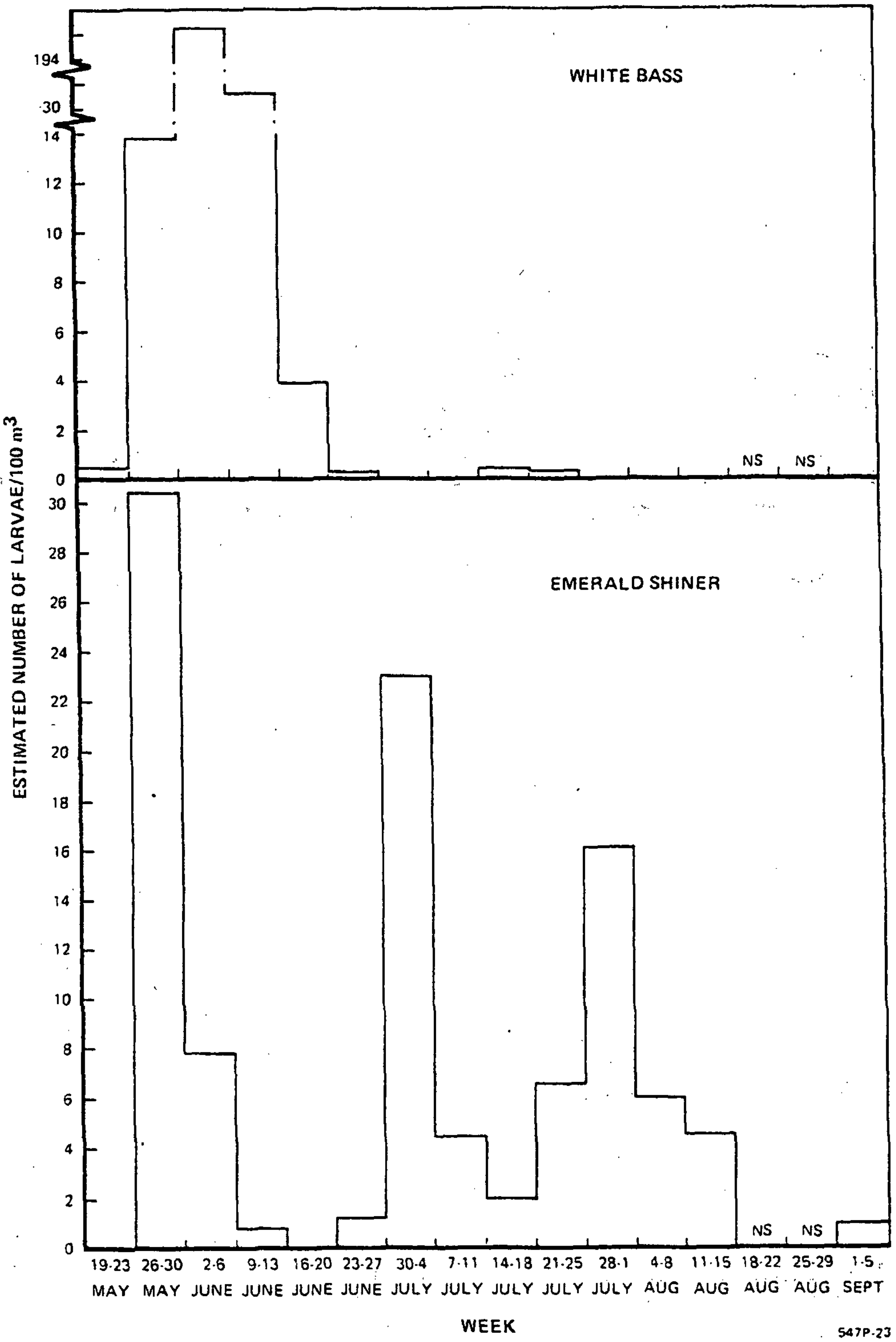


Figure III-26. Estimated density of RIS larval fish drifting past PINGP in 1975. No northern pike larvae were collected. Estimates were calculated from densities at Stations 1, 2, and 4, which represent drift from Sturgeon Lake (Gustafson et al., 1976), and the species composition in the weekly entrainment samples (NUS, 1976).

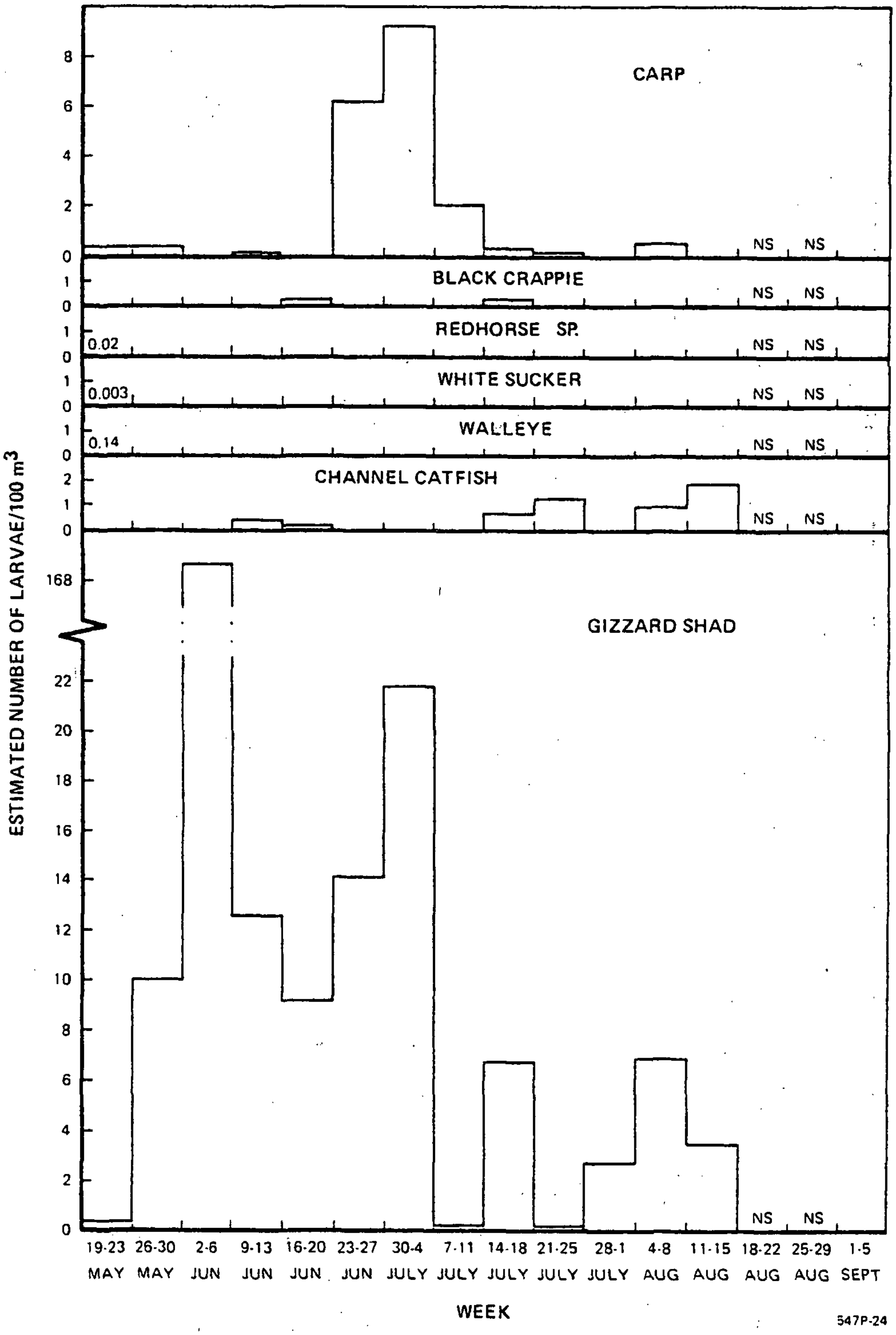


Figure III-26. (Continued).

redhorse, white sucker, and walleye are early spring spawners that usually migrate upstream to spawn, and thus, most spawning in Pool No. 3 would be expected in the tailwaters of Dam No. 2. Channel catfish and black crappie are nesters, and few larvae would be expected in the drift as compared to the other prolific broadcast spawners.

b. LIFE HISTORIES. The following life history information for the representative important species (RIS) is presented as a background upon which to base impact analyses. The reproductive characteristics for these species are summarized in Appendix Table A-10, and the spawning temperatures and times are shown in Figure III-27. Metric units were used throughout this section, and English conversions are given in Appendix F.

Walleye. Walleye live in large lakes and streams from Great Slave Lake to Labrador on the north to northern Alabama and Arkansas on the south and west to Nebraska (Niemuth et al., 1972). They prefer water of low turbidity over a firm substrate and can survive temperature ranges of 0° to 32° C (Goodson, 1966a). Pollution in the Mississippi River below Minneapolis-St Paul and in parts of the Minnesota River has drastically reduced the walleye population in these areas (Eddy and Underhill, 1974, pp. 369-373). This pollution has come from numerous sources, including agriculture, industries, and municipal sewage treatment plants.

In the spring, usually just after the spring thaw, walleye make mass spawning migrations up rivers and streams to tributaries and lakes (Eddy and Underhill, 1974, pp. 369-373). Tagging studies in Oneida Lake, New York, showed that most walleye returned to the same spawning area each year (Forney, 1963). Spawning occurs at 6° to 17° C with the peak at 9° to 10° C. The eggs are randomly broadcast at a depth of less than 1.2 m with most laid in less than 61 cm of water on a clean substrate with flowing water (Niemuth et al., 1972). The eggs are 1.5 to 2.0 mm in diameter and lose their adhesiveness after water hardening (Scott and Crossman, 1973, pp. 690-691). Hatching is in 7 to 26 days, depending on temperature, and DO concentrations below 35 percent saturation increases egg mortality. Females longer than 38 cm lay 35,000 to 600,000 eggs with an average of 28.6 to 99.2 per gram of body weight (Niemuth et al., 1972; Siefert and Spoor, 1974). Males mature at 4 years and females at 5 years of age in Lake Erie (Goodson, 1966a).

Walleye are predators. Young less than 75 mm in length feed upon plankton and then progress to insect larvae and fish with increasing size (Priegel, 1969). Their life span is approximately 7 years although some may exceed this. The maximum recorded length is 92 cm and the weight 10 kg (Niemuth et al., 1972). The largest walleye caught by angling in Minnesota weighed 7.6 kg (DNR, 1977).

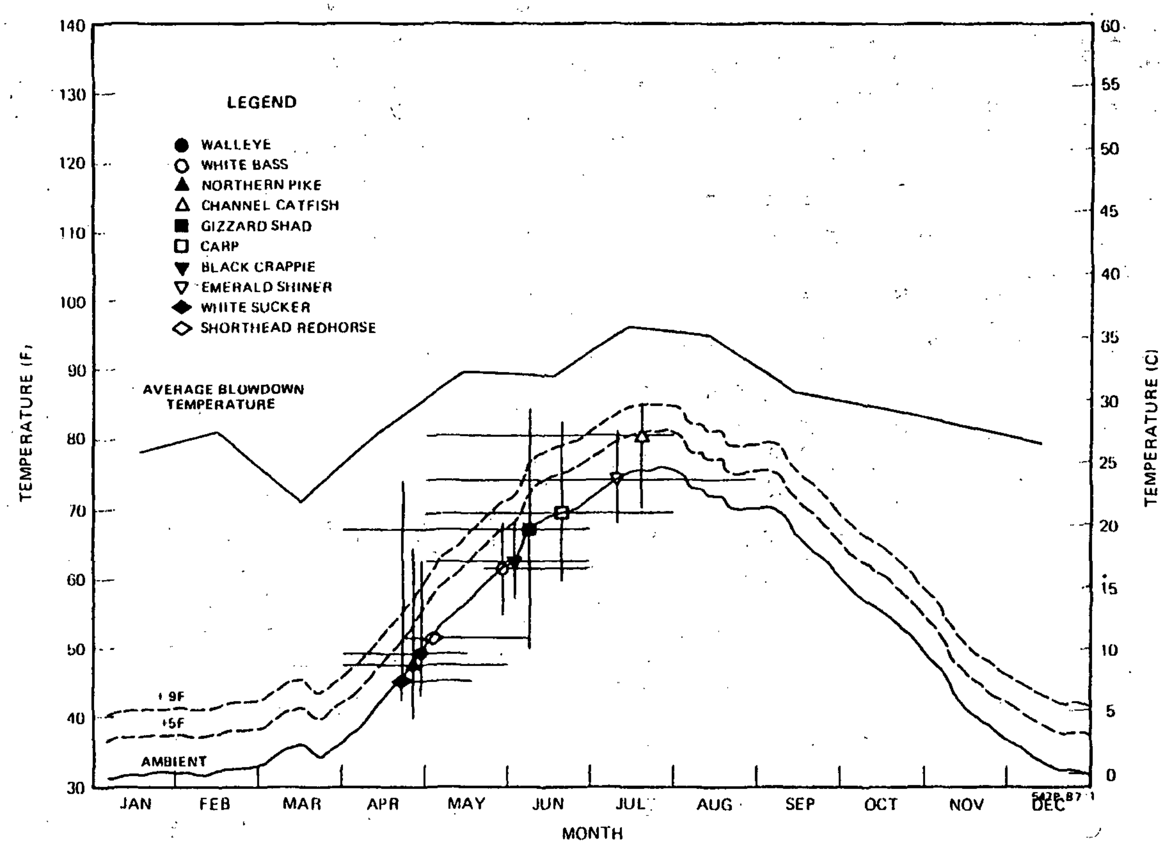


Figure III-27. Spawning temperatures and times for the RIS. The optimum or mean temperature was plotted on the river ambient and the vertical bars indicate the range while the horizontal bars represent the time period. The dashed curves show temperatures of the 5° and 9° F ΔTs in the discharge while the upper curve indicates the monthly average temperature discharged by PINGP.

White Bass. White bass are found from the St. Lawrence River west through the Great Lakes to South Dakota and south in the Ohio and Mississippi drainages to the Gulf of Mexico. Stocking has increased their range. They prefer clear waters since feeding and schooling are sight dependent (Scott and Crossman, 1973, pp. 689-692).

In the spring, adults move upstream into large lakes to spawn, sometimes traveling long distances (Eddy and Underhill, 1974, pp. 335-336). The fish form schools which may be unisexual and move into shallow areas when the water temperature reaches 12.8° to 15.6° C in late May and June. The 0.8 mm adhesive eggs are broadcast near the surface or in midwater during the day and adhere to boulders, gravel, or vegetation as they sink (Scott and Crossman, 1973, pp. 689-692). In Lewis and Clark Lake, spawning occurs when the water temperature is 14.4° to 20° C (Ruelle, 1971), and may continue for 5 to 10 days per population with the adults forming schools again after spawning. Incubation time is 46 hours at 15.6° C (Scott and Crossman, 1973, pp. 689-692), and the newly hatched larvae are 3 mm in length (Ruelle, 1971). Growth is fairly rapid and the YOY may reach 126 to 162 mm by fall. Fecundity is 242,000 to 933,000 eggs per female with an average of 565,000 and varies with the size of the fish. Age at maturity is 3 years in Lake Erie (Scott and Crossman, 1973, pp. 689-692), and 2 years in Minnesota (Eddy and Underhill, 1974, pp. 335-336).

White bass are carnivorous. Young fish feed upon zooplankton such as *Diaptomus, Cyclops, Daphnia,* and copepod nauplii and progress to aquatic insects and fish as they increase in size (Ruelle, 1971). In Iowa lakes, the adults feed primarily upon yellow perch, bluegill, carp, and black crappie, although some also eat crustaceans and aquatic insects such as mayflies. In other areas, small gizzard shad and minnows may form a significant portion of their diet (Scott and Crossman, 1973, pp. 689-692).

Channel Catfish. The distribution of channel catfish ranges from Montana to the Ohio Valley and south through the Mississippi Valley to the Gulf of Mexico and into Florida (Eddy and Underhill, 1974). They occur in swift streams as well as lakes and large reservoirs, preferring sand, gravel, or rubble bottoms without vegetation (Miller, 1966). In Minnesota, they are found in the swift water tributaries of the Mississippi River (Eddy and Underhill, 1974, pp. 299-300).

Spawning takes place in nests in protected areas such as holes or under logs and occurs at 21° to 29° C with an optimum of 26.7° C (Clemens and Sneed, 1957). The eggs are 3.5 to 4.0 mm in diameter, are guarded by the males, and hatch in 5 to 10 days (Scott and Crossman, 1973, pp. 604-610). The young remain in the nest for approximately 1 week before dispersing (Lopinot, 1960). Females produce 6.6 to 8.8 eggs per gram of body weight (Clemens and Sneed, 1957), and the eggs will not develop if the water is less than 15.6° C (Miller, 1966).

Channel catfish are omnivorous, feeding upon fish, invertebrates, and plant material. They feed by sight, taste, or touch (Lopinot, 1960). The maximum size for this species is 90 cm in length and more than 11 kg in weight, although most are only 1.4 to 1.8 kg in Minnesota (Eddy and Underhill, 1974, pp. 299-300). The angling record in Minnesota is 17.5 kg (DNR, 1977).

Northern Pike. Northern pike inhabit lakes and streams east of the Rocky Mountains and north of the Ohio River northwest into Alaska as well as in northern Europe and Asia (Eddy and Underhill, 1974, pp. 199-204).

Just after the ice melts in April, adults ascend small streams or seek flooded grassy areas of lakes (Eddy and Underhill, 1974, pp. 199-204). Spawning occurs at 11° to 17° C in Lake George, Minnesota, and the eggs are broadcast on all types of vegetation except cattails (Franklin and Smith, 1963). The adhesive eggs are 2.5 to 3.0 mm in diameter and usually hatch in about 2 weeks depending on temperature. The yolk sac larvae attach to vegetation with adhesive glands on their heads and feed from the yolk for 6 to 10 days (Scott and Crossman, 1973, pp. 357-359). The females produce 19,200 to 193,000 eggs. Males mature at 2 to 3 years of age and females at 3 to 4 years (June, 1971).

The young feed on zooplankton for the first 2 weeks progressing to larger prey, such as fish fry, after that. They are cannibalistic if food is scarce. The adults feed by sight on fish such as crappie, sunfish, suckers, and minnows (Eddy and Underhill, 1974, pp. 199-204).

Pike grow to a length of more than 1 m and may weigh over 23 kg (Eddy, 1969, p. 64). The angling record for Minnesota is 20.7 kg (DNR, 1977).

Gizzard Shad. Gizzard shad inhabit large rivers and muddy lakes from central Minnesota east to the St. Lawrence drainage and south to New Jersey and brackish waters along the Gulf of Mexico as well as into Mexico (Eddy and Underhill, 1974, pp. 147). Taylor Falls on the St. Croix River is apparently the northern limit of their range in Minnesota.

Spawning occurs in spring and summer, generally in April through June when the water temperature is 10° to 21° C; however, it may take place when the water is as warm as 29° C. The eggs are randomly broadcast at the water surface in shallow water and slowly sink to the bottom. The eggs are 0.75 mm in diameter, adhesive, and hatch in 1.5 to 4 days, at temperatures of 26.7° C and 16.7° C (Miller, 1960). Fecundity for gizzard shad in Lake Erie ranged from 211,380 to 543,910 eggs and averaged 379,000 eggs for 2-year-old fish, and it declined with age. In Elephant Butte Lake (New Mexico), the mean fecundity of 3-year-old fish was 40,500 eggs (Jester, 1972, p. 40). Both males and females mature at 1 to 2 years of age (Carlander, 1969, p. 88).

Young gizzard shad feed upon protozoa, rotifers, and entomostraca while the adults eat phytoplankton and zooplankton (Carlander, 1969, p. 89). Young-of-the-year fish generally school, but older fish do not. The young are important forage fish, and they tend to overpopulate in areas where predation is not sufficient to keep their numbers down (Eddy and Underhill, 1974, p. 148). Gizzard shad grow to 52 mm in length although most do not exceed 25 to 36 mm (Miller, 1960).

Carp. Carp are not native to the United States but were widely introduced from Europe in the 1800s. This species prefers warm waters and is generally not found in trout streams. In the Mississippi River, carp were found above St. Anthony Falls after 1920 and as far upriver as Little Falls by 1935 (Eddy and Underhill, 1974, p. 220). They thrive in eutrophic waters and can tolerate low dissolved oxygen, extreme temperature variations, and pollution as well as high turbidity. They are inactive at temperatures below 30° C (Burns, 1966).

Spawning begins in late April or May when the water reaches 15.6° C (Jester, 1974, p. 38) with maximum activity at 19° to 23° C. Spawning continues through July but does not occur when temperatures exceed 28° C (Swee and McCrimmon, 1966). Adhesive eggs 1 mm in diameter are randomly broadcast in very shallow water, usually over vegetation (Scott and Crossman, 1973, pp. 407-411), and hatching occurs from 3 to 6 days up to 10 to 20 days depending on temperature (Eddy and Underhill, 1974, p. 220; Swee and McCrimmon, 1966). The eggs do not develop at temperatures above 42.5° C, and the rate of egg development is controlled by temperature although sensitivity to temperature extremes varies with developmental stage. For example, a 10 minute exposure to 40° C is lethal to all eggs during the first 6 hours of development, kills some eggs between 6 and 9 hours of development, kills all eggs between 12 and 20 hours of development, and has a diminishing effect therafter (Frank, 1974). Fecundity ranges from 36,000 to 2,208,000 (Swee and McCrimmon, 1966) and is about 220.8 eggs per gram of body weight, with males maturing at 2 years of age while females mature at 3 years (Burns, 1966).

Carp are omnivorous, feeding on plant material, aquatic insects, crustaceans, molluscs, and annelids. They suck up bottom substrate, expel it into the water, and then select the food items. In addition, they sometimes feed on floating animals or algae at the water surface (Scott and Crossman, 1973, pp. 407-411). Their habit of stirring up the bottom and uprooting vegetation makes them a nuisance since this causes turbidity and may also ruin the feeding and spawning beds of other more desirable species. Carp may exceed 61 cm in length and 9 kg in weight with records of fish weighing more than 23 kg (Eddy and Underhill, 1974, p. 220).

Black Crappie. Black crappie are found in medium-sized lakes and large streams from southern Manitoba to Quebec south to Florida and Texas. This species is absent from the deep lakes of northeast Minnesota, particularly in the Lake Superior drainage (Eddy and Underhill, 1974, pp. 360-362). It has been introduced elsewhere (Eddy, 1969, p. 212).

Spawning occurs in May and June. The males make nests in water 1 to 2 m deep and on bottoms that are often softer or muddier than preferred by most centrarchids (Eddy and Underhill, 1974, pp. 360-362). These nests are 20.3 to 38.1 cm in diameter, 1.5 to 1.8 m apart, and may be in colonies. The eggs are 0.93 mm in diameter (Merriner, 1971a), are laid when the water is about 14° to 20° C, and hatch in 3 to 5 days. Black crappie have a very high reproductive potential with females laying 11,000 to 188,000 eggs, and both sexes mature at 2 to 3 years of age (Goodson, 1966b; Scott and Crossman, 1973, pp. 745-750).

Their diet consists of aquatic insects, small crustaceans, minnows, and small fish. In winter they feed more actively than other species of centrarchids (Eddy and Underhill, 1974, pp. 360-362).

Black crappie may reach an age of 8 to 10 years (Scott and Crossman, 1973, pp. 745-750) but seldom exceed 30.5 cm in length. The record weight for Minnesota is 2.3 kg for a fish caught near the mouth of the Vermillion River in 1970 (Eddy and Underhill, 1974, pp. 360-362).

Emerald Shiner. Emerald shiners are most common in lakes and large rivers (Eddy and Underhill, 1974, pp. 253-254) from Lake Athabaska and the western Hudson Bay drainage in Saskatchewan to the St. Lawrence River system and Lake Champlain south to the Trinity River system in Texas and the Potomac River system (Hubbs and Lagler, 1964, p. 81). This species forms large schools near the surface offshore during summer and moves inshore in the fall forming aggregations near piers and docks and in the mouths of rivers (mainly YOY). They move to deeper water for over-wintering and come to the surface at night during spring (Scott and Crossman, 1973, pp. 440-443). This fish is an important forage species for fish as well as birds, and the population size fluctuates widely from year to year.

Spawning generally occurs from May through August (McCormick and Kleiner, 1976), while maximal activity is in late July and August in Lewis and Clark Lake (Fuchs, 1967). Spawning may occur more than once per season. The 0.01 to 0.67 mm diameter eggs are broadcast near the surface in open water when the water is 20° to 27° C, and hatching may be in 24 to 32 hours. The newly hatched larvae are 4 mm in length, and young fry are weak swimmers. The average fecundity is 3,410 eggs per female with maturity at 1 to 2 years of age, and the adults incur post spawning mortalities (Campbell and MacCrimmon, 1970; Fuchs, 1967; McCormick and Kleiner, 1976).

Young emerald shiners feed upon blue-green algae, rotifers, ciliated protozoa, and green algae while the adults primarily eat zooplankton with insects of secondary importance. The adults feed selectively on large organisms with *Daphnia* spp. often composing 90 percent of the stomach contents while forming only 20 percent of the plankton. *Diaptomus* sp. is of secondary importance while *Leptodora* sp. is also preferred (Fuchs, 1967).

Their life span is generally 2 to 3 years with rapid growth during the first year, up to 55 percent of the maximum length (Fuchs, 1967). The usual length of adults is 102 mm although they may attain 127 mm (Eddy and Underhill, 1974, pp. 253-254).

White sucker. The range of the white sucker is from the Mackenzie River Delta east to Ungava and Labrador and south to Georgia and Oklahoma (Scott and Crossman, 1973, pp. 538-543). This species prefers clear cool waters over a hard sand or rock substrate; however, it is very adaptable and occurs in many other habitats including riffles, pools, marshy areas, and soft bottoms (Schneberger, 1972).

In the spring, ripe fish make spawning runs up tributaries (Schneberger, 1972), and the adults may home to certain streams (Scott and Crossman, 1973, pp. 538-543). Spawning generally occurs in mid-May in Minnesota (Eddy and Underhill, 1974, p. 292), and begins when the water temperature reaches 7.2° C. The eggs are broadcast over riffles in streams or gravel in lakes with most activity at night. The yellow eggs are adhesive in quieter waters, and incubation time varies from 8 to 11 days at 10° to 15° C and 12 to 15 days at 10° to 11.7° C to 5 days at 15.6° C. The fry remain in the gravel for 1 to 2 weeks and migrate to the lake when 12 to 14 mm in length. Fecundity ranges from 20,000 to 130,000 eggs per female, but is generally 20,000 to 50,000 or 24.6/gram. The age at maturity is usually 3 to 4 years (Schneberger, 1972; Scott and Crossman, 1973, pp. 538-543).

White suckers are bottom feeders that eat aquatic insects, molluscs, algae, and plant fragments. Young-of-the-year school while older fish do not, except for migration runs. They serve as forage for other species when young (Schneberger, 1972). Growth rates are quite variable, depending on numerous factors. The maximum age is about 17 years, and fish may attain a length of 635 mm and a weight of 3.2 kg (Scott and Crossman, 1973, pp. 538-543).

Shorthead redhorse. The shorthead redhorse occurs from the Mackenzie River basin east of the Rockies to the Hudson Bay drainage and Quebec, south through the Ohio River drainage, and west to Arkansas and Montana (Eddy and Underhill, 1974, pp. 286-287). This species is more abundant in streams than in lakes or reservoirs. In the Des Moines River, the adults prefer fast flowing water over rocks, gravel, or rubble although some may be found over silt bottoms behind eroded bank vegetation while the young prefer fast water habitats (Meyer, 1962).

In spring, the adults may migrate from larger water bodies into streams for spawning (Scott and Crossman, 1973, p. 581) in riffles, but in slower flowing areas than for white suckers (Carlander, 1969, p. 518). In the upper Mississippi River spawning occurs in late May and early June (Eddy and Underhill, 1974, pp. 286-287) and when the water temperature reaches 11° C. Fecundity is 13,500 to 27,150 eggs for 3 to 6 year old adults, and maturity is at age 3 (Meyer, 1962).

Fish longer than 10 cm feed primarily on benthic invertebrates such as chironomids, Ephemeroptera, and Trichoptera (Meyer, 1962). Their life span in Canada is 12 to 14 years. The maximum length recorded was 620 mm for a fish caught in Ohio, and the maximum weight recorded was 2.7 kg for a fish from Lake Erie (Scott and Crossman, 1973, pp. 579-583).

c. THERMAL DATA FOR THE RIS. The temperature requirements and tolerance of fish are the basis for the predictive Type 2 impact analysis discussed later in this demonstration. Of prime concern are the upper thermal tolerances for survival during the spawning season and during summer, maximum temperatures for continued growth, and lower thermal tolerances (cold shock potential). The most pertinent literature thermal data for each of the RIS are presented in Appendix Tables A-11 through A-20 and Appendix Figures A-1 through A-5.

d. SPAWNING AREAS AND MIGRATIONS. No spawning areas have been identified in the vicinity of PINGP during the field surveys. From the information in Appendix Table A-10, however, northern pike, carp, black crappie, and emerald shiner probably spawn in all the backwater areas near PINGP such as North and Sturgeon Lakes. Walleye, white sucker, and shorthead redhorse prefer flowing waters and probably move upstream to the tailwaters of Dam No. 2 or up tributary streams. White bass prefer shallow water over gravel and thus may spawn in areas of riprap near the plant or in the main channel, as well as in natural areas of gravel. Channel catfish probably spawn in the main channel since they prefer protected sites, such as under logs or in holes, in areas with flowing water.

None of the RIS undergo such spectacular mass migrations as salmon or eels, but walleye, suckers, and northern pike will migrate to appropriate spawning areas. Walleye and suckers generally migrate upstream, and the distance is limited by the lock and dam system in the Mississippi River. That walleye migrate to the tailwaters of the dams is evidenced by the excellent fishing for this species and the closely related sauger just below Lock and Dam No. 3 in the spring.

Tagging studies in 1974 (Naplin and Geis, 1975) and 1975 (Gustafson et al., 1976) showed that white bass and walleye were very mobile, while northern pike tended to remain in the area where tagged. In 1974, 24 white bass moved an average of 51.1 km (31.7 mi) and 7 walleye traveled a mean of 43.7 km (27.1 mi) while 6 northern pike averaged only 15.9 km (9.9 mi). In 1975, the mean distance traveled by 35 walleye was 27.5 km (17.1 mi) and by 77 white bass was 29.6 km (18.4 mi).

e. PREDATOR-PREY INTERACTIONS FOR RIS. The trophic relationships of the RIS in aquatic ecosystem near PINGP are quite complex since feeding habits change with age as well as season and food availability. Appendix Table A-21 summarizes the food habits for each of the RIS during the larval stages as well as for juveniles and adults. Larvae of all the species feed on algae, zooplankton, and aquatic insect larvae. As the larvae develop into juveniles and adults their feeding habits change. Gizzard shad become herbivorous, feeding predominantly on phytoplankton. Emerald shiner, carp, white sucker, and shorthead redhorse generally occupy low to intermediate trophic levels, and may provide forage for higher trophic level fish. Their diet includes algae, plant material, and a variety of micro- and macroinvertebrates. Channel catfish, black crappie, and white bass feed upon fish as well as invertebrates, and thus, may occupy more than one trophic level. Walleye and northern pike feed primarily upon fish and other vertebrates as adults although juveniles (and occasionally adults) may sometimes feed upon macroinvertebrates.

In conclusion, the RIS feed upon a variety of prey (ranging from algae to vertebrates) throughout their life, and the piscivorous species prey upon some of the other RIS, particularly emerald shiners and young gizzard shad. These predators may also utilize young of other RIS as forage (e.g., white sucker, carp, shorthead redhorse, white bass, and northern pike).

f. DISEASES AND PARASITES. Fish are host to numerous internal and external parasites ranging from fungi to vertebrates. Table III-9 lists the general taxa of parasites and the types of infestation. Several bacterial or viral diseases, such as bacterial furunculosis and lymphocystis, may infect fish, also. Most parasites and diseases of fish are species-specific and thus cannot be passed to humans. The broad tapeworm (*Diphyllobothrium latum*), however, can infect humans via ingestion of raw or partially cooked fish. Freezing or thorough cooking destroys most parasites although some may be aesthetically displeasing (e.g., large cysts in muscle tissue).

The RIS chosen for this demonstration may be host to a variety of parasites. Gizzard shad are generally free of parasites which may be a result of their herbivorous diet (Miller, 1960). Carp apparently have few parasites, which are predomonantly external or gill flukes, while emerald shiners and shorthead redhorse also are slightly infested (Scott and Crossman, 1973, p. 443; Hoffman, 1967, pp. 321-406). The other RIS may be infected with most of the parasites listed in Table III-9. Two of the more noticeable parasites are externally encysted stage of trematodes which are known as black spot (*Uvulifer amblopli tis*) and yellow grub (*Clinostomum marginatum*).

g. INFLUENCES OF MAN. The Mississippi River in the vicinity of PINGP has been altered by various activities of man for many years. The lock and dam system from Minneapolis to the confluence of the Missouri River was constructed to improve navigation on the upper Mississippi and has changed the free flowing river into a series of lakes or pools. Depths and flows are controlled during moderate to low flows (see Hydrology section) while the areal extent of backwaters is increased.

Table III-9. Taxa of fish parasites and types of infestation (from Hoffman, 1967).

TAXA	INFESTATION
Fungi	External, generally infect damaged or stressed fish
Protozoa	Wide variety of external and internal parasitism
Trematoda (flukes)	
Monogenetic	Generally external, requiring only one host
Digenetic	Generally internal with multi-host life cycle
Cestoda (tapeworms)	Internal with multi-host life cycle
Nematoda	Mainly internal with two host life cycle, one of which is an invertebrate
Acanthocephala	Internal, usually require at least two hosts during life cycle
Hirudinea (leaches)	External
Crustacea (copepods)	External, most common are *Lernaea*, *Ergasilus*, and *Argulus*
Mollusca	External, glochidia of freshwater clams encyst in fins or gills
Vertebrata	External, lampreys

Physical conditions such as temperature and turbidity may also be altered during controlled flows. The biological changes that may have resulted from these alterations have not been monitored, but some estimates can be made. Species preferring fast flowing waters would tend to be found only in the tailwaters of the dams while species preferring lake-like habitats or backwater areas would increase in numbers. Thus, the general aquatic community has probably shifted towards a lacustrine community as a result of the lock and dam system.

The navigation channel is maintained by dredging, although little dredging has been necessary in the vicinity of PINGP (Cin, 20 October 1977). The river is heavily used by commercial and recreational interests during ice-free months, approximately 15 March to 10 December (Erickson, 15 June 1977). In 1976, a total of 6,050 lockages were recorded at Lock No. 3 just downriver from PINGP. Of these, 2,377 were commercial (barges), and 3,671 were for 11,390 pleasure boats (Corps of Engineers, 1977). If barge traffic were assumed to be even throughout the navigation season, an average of 8.8 barges per day would pass PINGP (2,377 barges in 270 days).

In constructing the PINGP intake and discharge, two channels were dredged in the southern end of Sturgeon Lake as described in the Hydrology section, and several areas were ripraped. The areas dredged, however, compose only 3.6 percent of the total surface area of Sturgeon Lake. Riprap was placed at the intake just prior to the skimmer wall, along the dike separating the refuge from the discharge, and along the west side of the discharge canal at Barney's Point. Dredging altered a small area of benthic habitat while the riprap provided a substrate for benthic organisms and fish.

Both commercial and recreational fishing occur in Pool No. 3. The most valuable commercial species are catfish, carp, buffalo, and drum although some suckers, quillback, mooneye, goldeye, bowfin, gar, and turtles are taken, also. The methods used are gill nets, seines, and set lines, and catch data for 1970 through 1974 are presented in Table III-10 for Pool Nos. 3, 4, and 4a (Lake Pepin). From these data it appears that the commercial harvest has been much greater in Lake Pepin than in either Pool Nos. 3 or 4, which is probably the result of greater fishing pressure (MDNR and WDNR records). The catch in Pool No. 3 has increased, and the catch in Pool No. 4 has decreased substantially while that in Lake Pepin has declined slightly. The increased harvest in Pool No. 3 has resulted from a dramatic increase in the catch of carp; the catch of catfish and buffalo has been declining over the same time period, while the catch per unit of effort (amount of gear or number of permits) has increased. For the other two pools, however, the catch per effort has declined. In all three pools, carp have dominated the commercial catch followed by buffalo, drum, and catfish in Pool No. 3; catfish, buffalo, and drum in Pool No. 4; and drum, buffalo, and catfish in Pool No. 4a.

Recreational fishing is open all year in the Mississippi River for all species, except sturgeon for which the season is 30 April through 31 October above Lock and Dam No. 3 (DNR, 1977). Little ice fishing occurs, however, because of limited accessibility and hazardous ice conditions (Naplin and Gustafson, 1975). The sport fishery in the vicinity of PINGP has been estimated by creel census since 1973 in the same sections used for the fisheries studies described previously. Table III-11 summarizes the fishing pressure and harvest in each section for 1973 through 1976. Although the fishing pressure has varied from year to year, it has remained substantially higher below Lock and Dam

No. 3 (Section 4) than in the immediate vicinity of PINGP (Sections 1, 2, and 3). The average number of man-hours (M-H) expended in Section 3 was lower than in either Section 1 or 2, but in terms of effort per unit of water area the fishing pressure has been higher in Section 3. Fishing success, as fish/M-H, has been higher above than below Lock and Dam No. 3 except in 1973; however, the harvest in terms of fish/ha has been substantially higher below the dam. Thus, even though fishing pressure (M-H expended) and total harvest have been higher below Lock and Dam No. 3, the fishing success (fish/M-H) has been higher above Lock and Dam No. 3.

Walleye and white bass were the dominant RIS in the sport catch (Table III-12), particularly in Sections 1 through 3. The only other RIS reported in the sport harvest were channel catfish, northern pike, carp, and black crappie.

Table III-10. Commercial catch (pounds) of carp, buffalo, catfish, and drum in Pool Nos. 3, 4, and 4a during 1970 through 1974 (data from NUS, 1976).

YEAR	POOL		
	3	4	4a
1970	115,716	139,651	1,770,358
1971	37,963	221,690	2,289,455
1972	237,062	76,687	1,149,235
1973	357,581	53,363	1,468,224
1974	245,355	85,383	1,141,130

Table III-11. Creel census data for the vicinity of PINGP in 1973 through 1976.

SECTION[1]	1	2	3	4	YEAR
AREA (ha)	324	180	83	257	
Days Surveyed	198	205	261	261	
Estimated M-H (Total)	1,208	1,983	1,126	109,541	
M-H/ ha-da	0.019	0.054	0.052	1.633	1976[2]
Harvest (Fish/M-H)	0.736	0.960	1.171	0.633	
(Fish/ ha-da)	0.014	0.052	0.061	1.034	
(Fish/ ha)	2.77	10.63	15.89	269.79	
Days Surveyed	207	207	207	268	
Estimated M-H (Total)	394	187	212	88,855	
M-H /ha-da	0.006	0.005	0.012	1.290	1975[3]
Harvest (Fish/M-H)	1.273	0.503	0.500	0.385	
(Fish/ ha-da)	0.008	0.0025	0.006	0.497	
(Fish/ ha)	1.58	0.52	1.24	133.10	
Days Surveyed	218	218	218	218	
Estimated M-H (Total)	812	696	153	46,311	
M-H/ha-da	0.012	0.018	0.009	0.827	1974[4]
Harvest (Fish/M-H)	2.21	2.14	ND	0.63	
(Fish/ ha-da)	0.027	0.039	ND	0.521	
(Fish/ ha)	5.78	8.40	ND	113.58	
Days Surveyed	180	180	180	180	
Estimated M-H (Total)	200	870	500	41,210	
M-H/ha-da	0.003	0.027	0.034	0.891	1973[5]
Harvest (Fish/M-H)	0.36	0.75	0.33	0.69	
(Fish/ha-da)	0.001	0.020	0.011	0.615	
(Fish/ha)	0.19	3.65	2.02	110.66	

[1]Section 1=Sturgeon Lake, Section 2=Mississippi River from Brewer Lake cut to PINGP intake, Section 3=PINGP intake to Lock and Dam No. 3, and Section 4=Lock and Dam No. 3 to Highway 63 bridge.

[2]Geis and Gustafson, 1977.

[3]Gustafson and Diedrich, 1976.

[4]Naplin and Gustafson, 1975.

[5]Hawkinson, 1974.

Table III-12. Percent composition of RIS in the estimated sport harvest near PINGP for 1975 and 1976.

SECTION / SPECIES	1975[1]				1976[2]			
	1	2	3	4	1	2	3	4
Walleye	33	100	50	14	56	14	3	9
White bass	5	0	50	17	24	43	74	32
Channel catfish	0	0	0	1	2	0	6	1
Northern pike	0	0	0	1	3	0	4	<1
Carp	0	0	0	<1	0	7	1	1
Total harvest (No. fish)	501	94	106	34,119	853	1,973	1,333	69,981

[1]Gustafson and Diedrich, 1976.
[2]Geis and Gustafson, 1977.

3. Macroinvertebrates. The many uses of the river are both detrimental and beneficial to the macroinvertebrates that occur in its numerous habitats. Some of the natural controlling factors which influence the distribution and abundance of macroinvertebrates include sediment type and currents. Sediment types vary with location mainly as a result of external inputs (e.g., leaves and sediments) and currents. The latter controls the sediment grain size with finer sediments occurring in slow flow or still areas and coarser sediments in faster flow areas. Currents in the vicinity of PINGP are generally slow, particularly in the backwater areas, because of the lock and dam system. In addition to currents, turbulence caused by the frequent passage of barge tugboats tends to scour the main channel more so than natural currents. Thus, the main channel of the river presents a formidable habitat for most macroinvertebrates. Along the main channel banks, however, manmade structures such as wing dams and bank stabilization mats provide a limited amount of relatively shallow stillwater habitat. PINGP is situated in a backwater area at the southern end of Sturgeon Lake. The plant creates its own intake and discharge currents which are superimposed upon those of the river, and these conditions also limit the distribution of certain macroinvertebrates.

Because the Mississippi River near PINGP is a combination of lake and riverine habitats, both fast-water and still-water macroinvertebrates would be expected therein. The damming of a river usually eliminates many of the stream and current-loving fauna such as Trichoptera (caddisflies), Ephemeroptera (mayflies) and Plecoptera (stoneflies) which are replaced by chironomids (midges). Chironomids are predominantly filter feeders that can endure low DO and are exceedingly fecund. Second in abundance to chironomids and usually displacing them at a later date are the oligochaetes (aquatic earthworms). Acari (aquatic mites) are usually the third largest group. In lakelike habitats where a gentle flow of relatively clean water occurs, certain sessile organisms such as bryazoans (moss animals) may occur also (Baxter, 1977).

Sampling of the macroinvertebrate communities near PINGP began in 1970 (see Figure III-28 and Table III-13 for locations), and since that time a variety of methods have been used to sample the multiple habitats in the area (see Appendix Table A-22). To date, four different methods have been utilized: dredging, artificial substrates, dip netting/hand picking natural substrates, and collecting aerial stages of aquatic macroinvertebrates as they emerge from the water column. From these sampling efforts, at least 371 taxa of macroinvertebrates have been identified (Appendix Table K-2). From 1974 through 1976, 91 taxa were collected by various dredging methods, 103 on artificial substrates, 231 from natural substrates, and 53 in emergence studies. Fifty-three taxa were common to both the dredge and the artificial substrate sampling, whereas 45 were common to the dredge, artificial substrate, and natural substrate sampling methods. Only 10 taxa were common to all four sampling methods. In addition, 176 taxa were collected prior to 1974 by a combination of the dredge, artificial substrate, and natural substrate methods but the specific collection method for each taxa was not delineated.

Dominant macroinvertebrates collected by dredging in 1974 through 1976 are ranked according to their abundance in Appendix Table A-23 at three locations in the vicinity of PINGP. Tubificids (sludge worms) appeared to be numerically dominant near the plant, although dipterans also rated high in abundance. On artificial substrates (Appendix Table A-24), the naidids (worms) were by far the most abundant with a dipteran (*Glyptotendipes*) second in abundance. Trichopterans and ephemeropterans were collected commonly on artificial substrates but rarely in dredge samples. Diversity in both the dredge and artificial substrate samples was relatively low indicating that a few taxa usually dominated the samples. A wide variety of insects were collected in the emergence studies although only those of aquatic origin are relevant to the present study. Dipterans dominated the catch with trichopterans second (Appendix Table A-25). Most of the dipterans in the emergence studies were not identified to genus but the dominant trichoperan was *Hydropsyche*.

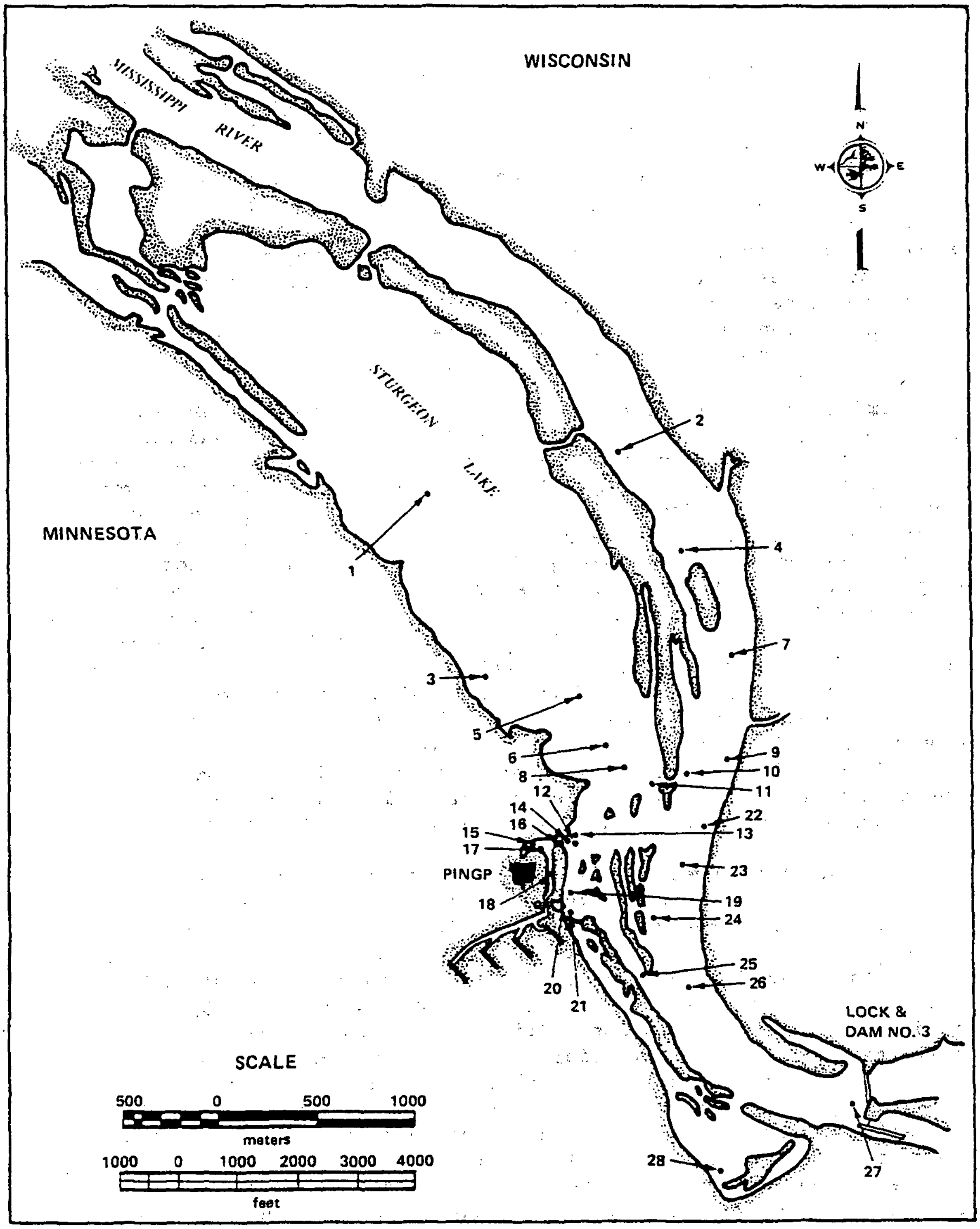


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Figure III-28. HDR station locations for biological studies conducted near PINGP during 1969-1976. For key to NSP stations versus HDR stations see Table III-13.

Table III-13. HDR key to sampling stations comparisons between studies conducted at PINGP.

HDR STATIONS	STATIONS FOR NSP STUDIES						LOCATION
	PHYTOPLANKTON	PRODUCTIVITY	PERIPHYTON	ZOOPLANKTON	MACROINVERTEBRATES	WATER QUALITY	
1		1			SLU (1974)		
2		4					
3		2					
4		5					
5		3			SLL (1974)		
6	6			SL	SL	SL B/T	
7	2 (1974)		1				
8			5				
9	5	6					
10	4			B-1	B-1	B-1 B/T	
11	3						
12				X-1	X-1	X-1 B/T	
13			6				
14	18	9					Intake
15				X-2	X-2		
16	17						
17			3				
18				X-3	X-3	X-3 B/T	Recirc. Canal
19	16	8					Discharge
20			7				
21				Y-1	Y-1	Y-1 B/T	
22	7						
23	8						
24			2				
25			4	Y-2	Y-2	Y-2 B/T	
26				C-1	C-1		
27	9	7		C-4	C-4	C-4 B/T	
28	15						

Four genera of macroinvertebrates (*Hydropsyche, Stenonema, Pseudocloeon,* and *Macronemum*) have been chosen as RIS for this demonstration, and limited site-specific information regarding their abundance and distribution near PINGP is available. *Hydropsyche* and *Stenonema* were frequently collected in artificial substrate samples with *Hydropsyche* being the most abundant (Appendix Table A-26). Maximum densities of both species occurred in mid and late summer and both organisms exhibited relatively patchy distributions.

Little is known about the life histories and feeding habits of macroinvertebrate fauna in large rivers (Hynes, 1970, p. 299), and some of the available data are summarized in Appendix Table A-27. Of the selected RIS, *Stenonema* and *Pseudocloeon* (ephemeropterans) are hemimetabolous; that is, a naiad (nymph) develops from an egg and then molts into a winged sub-imago which emerges from the water. The sub-imago rests and molts into a mature imago. The adult males swarm and the females fly through for copulation. After a few days, the female deposits fertilized eggs either by dropping them from the air or attaching them to trees, the water surface (in foam), or various other substrates. The other two RIS, *Hydropsyche* and *Macronemum* (trichoperans), are homometabolous. In this type of reproduction, larvae hatch from eggs and develop into pupae. After several molts the adult insect emerges from the water usually just before sunset or during twilight. Adult trichoperans live from 1 to 2 months during which time mating occurs.

In the north temperate U.S., the most common type of emergence is seasonal, usually occurring during mid-summer, and appears to be initiated by a combination of temperature thresholds and photoperiod. In addition to mating, emergence may aid in redistribution to compensate for downstream behavioral drift of the aquatic forms or for catastrophic losses. This is substantiated by the observation that the flight of emergent insects is almost exclusively upstream (Shyne, 1977).

Thermal tolerances of macroinvertebrates are summarized in Appendix Figure A-6 and Appendix Tables A-28 and A-29. Information presented in Appendix Table A-28 and Figure A-6 pertain to the types of macroinvertebrates that are likely to drift and encounter the thermal plume from PINGP. It is these drifting macroinvertebrates that are primarily sampled by the artificial substrates. Appendix Table A-29 summarizes thermal data for those organisms that are primarily fixed or sessile and, therefore, subject to elevated temperatures for a period of time considerably longer than for those drifting through the plume. It is difficult to classify major groups of macroinvertebrates with regard to their thermal tolerance because thermal tolerance is generally species-specific. Thus, two species in the same genus may have very different thermal tolerances. Thermal tolerances will be discussed in great detail later in this demonstration (see Section VI).

The only species of macroinvertebrate that is designated as endangered by the U.S. Fish and Wildlife Service is the Higgin's eye pearly mussel (*Lampsilis higginsii*). Since 1970, when sampling for benthic macroinvertebrates began at PINGP, not a single individual of this endangered macroinvertebrate has been collected although another species of the same genus has been collected in the area (Appendix Table K-2).

Nuisance macroinvertebrates occurring in the area include sludge worms (tubificids), leeches (Hirundinea), mosquitos (dipterans), black flies (dipterans), and midges (dipterans) (APHA et al., 1975). An abundance of sludge worms is generally considered objectionable since these organisms usually indicate the presence of "sludge" while leeches are undesirable because they are parasitic. Mosquitos are considered a nuisance as well as a potential public health threat. Mosquitos, however, do not dominate the dipteran macroinvertebrate fauna near PINGP and have not been implicated in any public health problems. Black flies create a rather ubiquitous nuisance in most northern latitudes during late spring and early summer, but outside of being rather annoying, they are generally innocuous. Midges, when emerging from the water in great numbers, can cause a navigation hazard to tugboat captains.

Benthic macroinvertebrates may be classified as pollution sensitive, facultative, or pollution tolerant. The organisms in each of these categories collected near PINGP are listed in Table III-14. The river near the plant site is characterized by few pollution tolerant taxa while many facultative and pollution sensitive macroinvertebrates are present, thus justifying the classification of this section of the river as a recovery zone rather than a polluted or clean water zone.

4. Zooplankton. It is generally understood that rapidly flowing large rivers support relatively sparse populations of zooplankton (Hynes, 1970, p. 110); however, lacustrine plankton populations may develop if the flow rate is less than about 0.2 m/sec, although no simple flow criterion is universally applicable (Baxter, 1977). In general, reservoirs contain regions of fairly rapid flow where plankton populations may be small and other areas of relatively still water where considerable populations may develop. In the upper reaches of a reservoir, zooplankton populations may be small before they drift into quieter waters where they can accumulate as a result of the gradually slowing current and increase their numbers.

Near PINGP, the slow flowing currents (0.2 to 0.5 m^3/sec average) and extensive backwater areas created by Dam No. 3 have allowed the sparse natural zooplankton populations in the Mississippi River to proliferate before passing downstream. Turbulence in the main channel of the river tends to reduce zooplankton populations simply by limiting food sources and by mechanical scouring. A characteristic of the recovery zone of the river near PINGP is that rotifers seem to dominate the zooplankton population. According to Dieterman (1975), as the river progresses from a polluted state immediately downriver from the Twin Cities area, the dominant zooplankton grade from ciliates and bacteria to rotifers near PINGP to crustaceans downriver from Lock and Dam No. 3. Moreover, while progressing downriver from the metropolitan sewage treatment plant, the zooplankton population becomes dominated by individuals with greater longevity.

Zooplankton have been collected near PINGP since 1970 either by pumping or pouring whole water samples through a plankton net to concentrate the catch (Appendix Table A-22). The mesh of the net (probably 64 μm) concentrated most rotifers and crustaceans as well as a few protozoans. Stations were generally sampled both up and downriver (far-field) and in the near-field region of the plant (see Table III-13 and Figure III-28). Approximately 188 taxa of zooplankton were collected over the first seven years of pre-operational and operational sampling (Appendix Table K-3). If euglenoids and other flagellated protists are considered, then almost 200 zooplankton taxa were collected. Numerically, rotifers

Table III-14. Pollution tolerance of selected benthic macroinvertebrates collected in the vicinity of PINGP (from Mason et al., 1971; Weber, 1973).

POLLUTION-SENSITIVE[1]	FACULTATIVE[2]	POLLUTION-TOLERANT[3]
Porifera	Hydrozoa	Oligochaeta
Ecotoprocta	Nematoda	*Branchiura sowerbyi*
Pectinatella magnifica	Ectoprocta	Hirudinea
Mollusca	*Plumatella repens*	*Helobdella stagnalis*
Pelecypoda	Endoprocta	Mollusca
Leptodea fragilis	*Urnatella gracilis*	Gastropoda
Arthropoda	Turbellaria	*Physa* sp.
Hydracarina	Oligochaeta	Hemiptera
Ephemeroptera	Naididae	*Belastoma* sp.
Baetis spp.	*Nais* sp.	*Gerris* sp.
Hexagenia limbata	Hirudinea	Coleoptera
Isonychia sp.	*Dina* sp.	*Berosus* sp.
Stenonema exiguum	*Erpobdella punctata*	*Tropisternus lateralis*
S. interpunctatum	*Placobdella* spp.	Diptera
S. tripunctatum	Mollusca	*Chironomus* spp.
Plecoptera	Gastropoda	*Cricotopus* sp.
Isoperla bilineata	*Ferrissia* sp.	*Cryptochironomus* spp.
Perlesta placida	*Goniobasis* sp.	*Procladius* sp.
Taeneopteryx maura	*Gyraulus* sp.	*Tanypus* sp.
Neuroptera	*Lymnaea* sp.	
Climacea areolaris	*Pleurocera* sp.	
Trichoptera	Pelecypoda	
Agraylea sp.	*Sphaerium* sp.	
Athripsodes tarsi-punctatus	Arthropoda	
Hydropsyche frisoni	Crustacea	
Hydroptila sp.	*Asellus* sp.	
Leptocella sp.	*Crangonyx gracilis* group	
Neureclepsis sp.	*Gammarus lacustris*	
Diptera	*Gammarus* sp.	
Ablabesmyia sp.	*Hyalella azteca*	
Corynoneura sp.	*Orconectes* sp.	
Labrundinia sp.	Ephemeroptera	
Nanocladius sp.	*Caenis* sp.	
Orthocladius sp.	*Stenonema integrum*	
Simulium jenningsii	*Tricorythodes* sp.	
Tribelos sp.	Odonata	
	Enallagma sp.	
	Hemiptera	
	Corixidae	
	Trichoptera	
	Cheumatopsyche sp.	
	Hydropsyche orris	
	Polycentropus sp.	
	Potamyia flava	
	Coleoptera	
	Dineutus nr. *discolor*	
	Dubiraphia sp.	
	Stenelmis spp.	
	Diptera	
	Conchapelopia sp.	
	Cricotopus spp.	
	Dicrotendipes sp.	
	Palpomyia spp. group	
	Polypedilum spp.	
	Parachironomus sp.	
	Psectrocladius sp.	
	Rheotanytarsus sp.	

[1]Pollution-sensitive organisms are those which through bioassy tests and experience are known to require environmental conditions associated with non-polluted habitats; i.e., high DO, near neutral pH, etc.

[2]Facultative organisms are tolerant of a wide range of environmental conditions.

[3]Pollution-tolerant organisms are known to tolerate environmental conditions associated with polluted waters; i.e., low DO, pH, etc.

dominated the zooplankton at all stations during all seasons of the year (Appendix Table A-30). Rotifers were dominated by *Keratella cochlearis* and *Brachionus calyciflorus,* with population densities greatest in summer and fall. *Cyclops vernalis* dominated the copepods while *Bosmina longirostris* and *Chydorus sphaericus* were the most abundant cladocerans. Maximum copepod and cladoceran populations also occurred in summer and fall. Like macroinvertebrates, zooplankton showed patchy distributions, but their diversity was generally higher than that for most macroinvertebrate populations.

Rotifers have shorter lifespans than both copepods and cladocerans. Their fast turnover rate may be one reason why they tend to dominate the summer zooplankton populations of the sluggish water habitats in the vicinity of PINGP. Appendix Table A-27 summarizes the life history and feeding habits for most of the zooplankton taxa. Many of the rotifers and cladocerans are filter feeders although some cladocerans are predatory and the dominant copepod, *Cyclops vernalis,* is also carnivorous. Filter feeding zooplankton are often opportunistic and will feed on bacteria, detritus, or phytoplankton. According to Miller (1971), zooplankton appear to be entrapped among aquatic macrophytes but also reproduce there. Thus, submerged and emergent macrophyte beds in shallow backwater areas along the river are important for the propagation of zooplankton. Larger zooplankton, especially cladocerans and copepods, are favorite prey for almost all types of young fish as well as predatory macroinvertebrates.

The thermal tolerances of zooplankton are summarized in Appendix Figure A-7 and Appendix Table A-31. Cladocerans are generally more tolerant of high temperatures than copepods, although certain members of each group may be more or less tolerant than members of the other group. Rotifers appear to be even more thermally tolerant than either copepods or cladocerans, although little information exists regarding the tolerances of specific rotifers.

No zooplankton have been classified as endangered by the U.S. Fish and Wildlife Service nor are any considered as nuisance or objectionable species found near PINGP. Most protozoans and rotifers, besides being capable of withstanding high temperatures, are also noted for their ability to adapt to and dominate zooplankton populations in nutrient enriched waters. Most cladocerans are in the same pollution tolerant category as rotifers and protozoans. Copepods, however, may be pollution-tolerant, intolerant, or facultative. Again, the composition of zooplankton populations near PINGP re-emphasize that the Mississippi River near PINGP is a zone of recovery from upriver nutrient inputs.

5. Primary Producers.

a. PHYTOPLANKTON. As mentioned previously, the unlimited source of nutrients from upriver and the abundance of shallow water areas bordering the main channel provide the section of the river near PINGP with both allochthonous and autochthonous energy sources for the base of the food web. Phytoplankton utilize both nutrient sources to photosynthesize organic matter for consumption by herbivores. In the main channel of the river, phytoplankton populations may be somewhat depressed because of the higher turbidity and turbulence caused by barge traffic as well as stronger currents while backwaters such as Sturgeon Lake that have lower flushing rates, longer residence times, and slightly higher daytime temperatures tend to enhance phytoplankton growth rates and allow more blooms to occur. Diatoms tend to dominate regions of faster current and blue-green algae areas of slow current, apparently since diatoms are more dense and do not form the same buoyant mats that often allow blue-green algae to float and accumulate in stagnant and slow-moving water. Furthermore, southerly winds may pile up surface phytoplankton into massive concentrations and mats during the summer to augment blooms. Baker (1975) has stated that phytoplankton concentrations and productivity near PINGP, especially in Sturgeon Lake, are probably as high as in any aquatic system considering the unlimited nutrient supply and limited light penetration. It was found that in both Sturgeon Lake and the main channel, primary production can occur only in the upper 50 cm of the water column (Baker, 1974).

Phytoplankton have been sampled more consistently and over a longer timer period than most of the other biological parameters measured at PINGP (Appendix Table A-22). Whole water samples collected since 1969 have been analyzed for phytoplankton density, taxonomy, distribution, productivity, and pigments. A large number of stations (see Table III-13 and Figure III-28) have been established since the beginning of the studies in order to define the phytoplankton populations of the area. More than 300 taxa of phytoplankton and periphyton have been collected near PINGP (Appendix Table K-4) with more than 171 of those being phytoplankton. Incidentally, a total of 60 diatom taxa were common to both phytoplankton and periphyton collections.

Temporal and spatial variations in the abundances of various phytoplankton taxa normally occur in aquatic ecosystems with diatoms generally dominant during spring and fall, green algae in early summer, and blue-greens in mid-summer (especially in nutrient-rich waters). Diatoms, however, dominated phytoplankton year-round at PINGP, whereas greens were second in abundance during most of the year and blue-greens reached maximum abundance during summer and fall, sometimes surpassing green algae in density (Appendix Table A-32). Near PINGP, the centric diatoms, *Stephanodiscus/Cyclotella* spp., were most abundant followed by *Nitzschia acicularis*. Densities of these diatoms were lowest in winter and highest in spring, summer, and fall. *Scenedesmus quadricauda, Ankistrodesmus* spp., *Chlamydomonas* spp., and cryptomonads were the dominant green algae which were most abundant in the fall and summer. Blooms of blue-green algae, such as *Aphanizomenon flosaquae* and *Oscillatoria agardhii*, occurred in surface waters during summer and sometimes in the fall. This seasonal variation in dominance by various phytoplankton taxa is somewhat consistent with the findings of Vollenweider et al. (1974) and Ward and Robinson (1974) for northern U.S. lakes.

Massive blooms of blue-green algae have occurred in the vicinity of PINGP, particularly in Sturgeon Lake, long before the plant became operational. The Mississippi River near PINGP has a Nygaard quotient of 18.5 as compared to 5.3 for the relatively clean Lake Minnetonka (Brook, 1970). The Nygaard quotient is calculated from the relative taxonomic composition of phytoplankton populations, and a high number indicates eutrophic conditions with possible contamination by sewage or cattle-waste runoff. Several reasons for dominance of phytoplankton communities by blue-green algae during the summer have been postulated (Baker, 1977; Keating, 1978). Blue-greens are usually more thermally tolerant to high ambient temperatures than are diatoms, tend to proliferate in nutrient enriched waters, and protect themselves by a form of self-defense known as allelopathy. The latter phenomenon involves the ability of one type of algae to inhibit growth of other types. This inhibition dissipates slowly causing the intensity of diatom blooms that follow blue-green blooms to vary inversely with density of the preceding blue-green algal populations.

Phytoplankton distribution near PINGP was patchy, and annual variations in population densities were as large as 100-fold (Appendix Table A-32). Diversity near the plant ranged from relatively low to relatively high, depending on the time of year. Net productivity was usually relatively high, especially in the summer, and the productivity in 1976 was as much as 3 to 4 times as high as that on similar dates in 1974 and 1975 (Baker, 1977). Phytoplankton density was also twice as high in 1976 as in earlier years while pigment concentrations (i.e., chlorophyll a) were double or triple those in previous years.

Most phytoplankton reproduce continuously with reproductive rates directly related to water temperatures. Some phytoplankton become inactive during unfavorable times of the year, and although they comprise portions of the phytoplankton populations at certain times of the year, this is no indication of their activity (Baker, 1977). Thermal tolerances of phytoplankton are generally higher than those for zooplankton and macroinvertebrates, and most phytoplankton can withstand temperatures much higher than those at which they usually occur (Appendix Figure A-8 and Table A-33). Blue-green algae generally can withstand higher temperatures than diatoms or green algae (Bush et al., 1974).

Although there are many types of algae that are considered objectionable or nuisance species, few can be considered truly noxious in freshwater habitats. Blue-greens generally are the most undesirable phytoplankton, and the genera most commonly associated with taste and odor problems are *Anabaena, Anacystis,* and *Aphanizomenon*. In addition, some diatoms (*Asterionella, Synedra,* and *Tabellaria*) and green algae (*Volvox, Staurastrum,* and *Pandorina*) are associated with objectionable taste and odor in water. *Staurastrum* is also an indicator of clean water while some of these phytoplankton are indicators of polluted water, especially the blue-greens, some diatoms (*Nitzschia* and *Gomphonema*), and some euglenophytes (*Euglena, Phacus,* and *Lepocynclis*) (APHA et al., 1975). It should be emphasized, however, that many of these so-called polluted water or nuisance algae naturally inhabit unpolluted waters, and only when they reach extremely high densities do they become objectionable.

b. PERIPHYTON. Periphyton comprises diatoms, blue-greens, and other types of algae that occur ubiquitously on substrates in freshwater habitats. They grow on whatever substrate is available which at PINGP is primarily in the upper 50 cm of water where light can penetrate. Periphyton contain many of the same taxa that are found in the phytoplankton and in fact contribute many of the planktonic diatoms that are collected in whole water samples. Periphyton communities near PINGP have been defined primarily as the diatoms that are capable of growing upon an artificial substrate (cleaned glass slides suspended just below the water surface over a period of two weeks). The stations sampled are shown in Table III-13 and Figure III-28 and the sampling methods are described in Appendix Table A-22.

A total of 207 periphyton taxa (Appendix Table K-4) have been enumerated near PINGP, and these follow many of the same general seasonal trends as do the planktonic diatoms. Centric diatoms of the genus *Cyclotella* appear to be numerically dominant much of the year, except during winter. *Navicula cincta* and *Nitzschia acuta* occur abundantly throughout the year, including winter (Appendix Table A-34). It is of interest to note that in periphyton, as in many other groups of organisms, different species of the same genus may have remarkably different thermal optima with one species abundant in winter while another is abundant in summer. Periphyton distribution at PINGP was characterized by sizeable temporal and spatial variations. Diversity, however, was consistently high at all stations where it was measured, as was chlorophyll a, except during winter. Phaeophytin a (a degradation product of chlorophyll a) increased relative to chlorophyll a during the summer, indicating increased mortality of periphyton at higher temperatures.

Periphyton, like phytoplankton, reproduce continuously with their reproductive rates related to parameters such as water temperature, nutrient levels, and light. In addition, they can become dormant during periods of sub-optimum environmental conditions. Thermal tolerances of periphyton are summarized in Appendix Tables A-35 and A-33 as well as in Figure A-8. In general, those diatoms that can survive at higher temperatures are more abundant in summer or fall whereas those that prefer lower temperatures are more abundant in winter.

Periphyton are among the first colonizers of solid substrates and may attract invertebrates and be grazed upon by many types of fish. However, they often cause objectionable growths on man-made structures. These growths may be undesirable from a functional standpoint (e.g., reduction of water flow) or from an aesthetic viewpoint (e.g., unsightly growths on boats or piers). In fact, where surface friction is designed to be minimal, the use of biocides or mechanical methods are sometimes necessary to inhibit growth of these organisms.

c. AQUATIC MACROPHYTES. The importance of macrophytes in any aquatic ecosystem cannot be underestimated. Wetlands and marshes provide both direct and indirect benefits to the organisms living on, among, or near them. First and most importantly, they provide an energy source for many large and small primary consumers (herbivores). Secondly, they provide important spawning and feeding habitats for zooplankton, macroinvertebrates, fish, and birds. The importance of these beds to migratory and resident waterfowl as well as predatory birds is well known. Thirdly, macrophyte beds provide shelter for many aquatic organisms and provide one of the most important fish nursery areas in any aquatic habitat. And fourthly, they provide a substrate for periphyton and many sessile invertebrates.

Aquatic macrophytes in the vicinity of PINGP have been recorded by observation from land and aerial photography since 1970. A total of 74 taxa were found near PINGP (Appendix Table K-5): 7 taxa of submerged macrophytes, 18 taxa of emergent macrophytes, and 49 taxa of shoreline and island plants. The location of these macrophyte beds is shown in Figure III-29, and the taxa for each area are listed in Appendix Table A-36. The greatest concentration of macrophyte beds was located in the northern reaches of Sturgeon Lake, and these consisted of pondweeds, wild celery, and bull-rush. Very little habitat for macrophytes was found in the main channel of the river or near PINGP. Pondweed was found in the intake area south to the discharge canal, while along the southwest shore of the discharge canal a variety of macrophytes, including pondweed, spike-rush, bullrush, and *Phragmites* occurred from 1974 to 1976. Distribution of macrophytes depends upon the availability of suitable substrate, water depth, and currents. Siltation, in addition to changing sand bars and mud banks, can bury macrophyte beds during floods and at other times of the year. Furthermore, large fluctuations in water level can obliterate macrophyte beds.

Most macrophytes are flowering plants, requiring alternation of generations and pollen production for reproduction. Water level is critical for the growth and development of new plants, as is type of substrate. Little is known about the thermal tolerances of various macrophytes, and it is often unknown which environmental factor(s) causes the disappearance or appearance of a particular macrophyte taxa. There are no known nuisance or objectionable macrophytes near PINGP, and for reasons stated previously, these plants are generally considered beneficial to aquatic habitats. Marshy areas may be considered as breeding habitats for undesirable insects, such as black flies and mosquitoes;

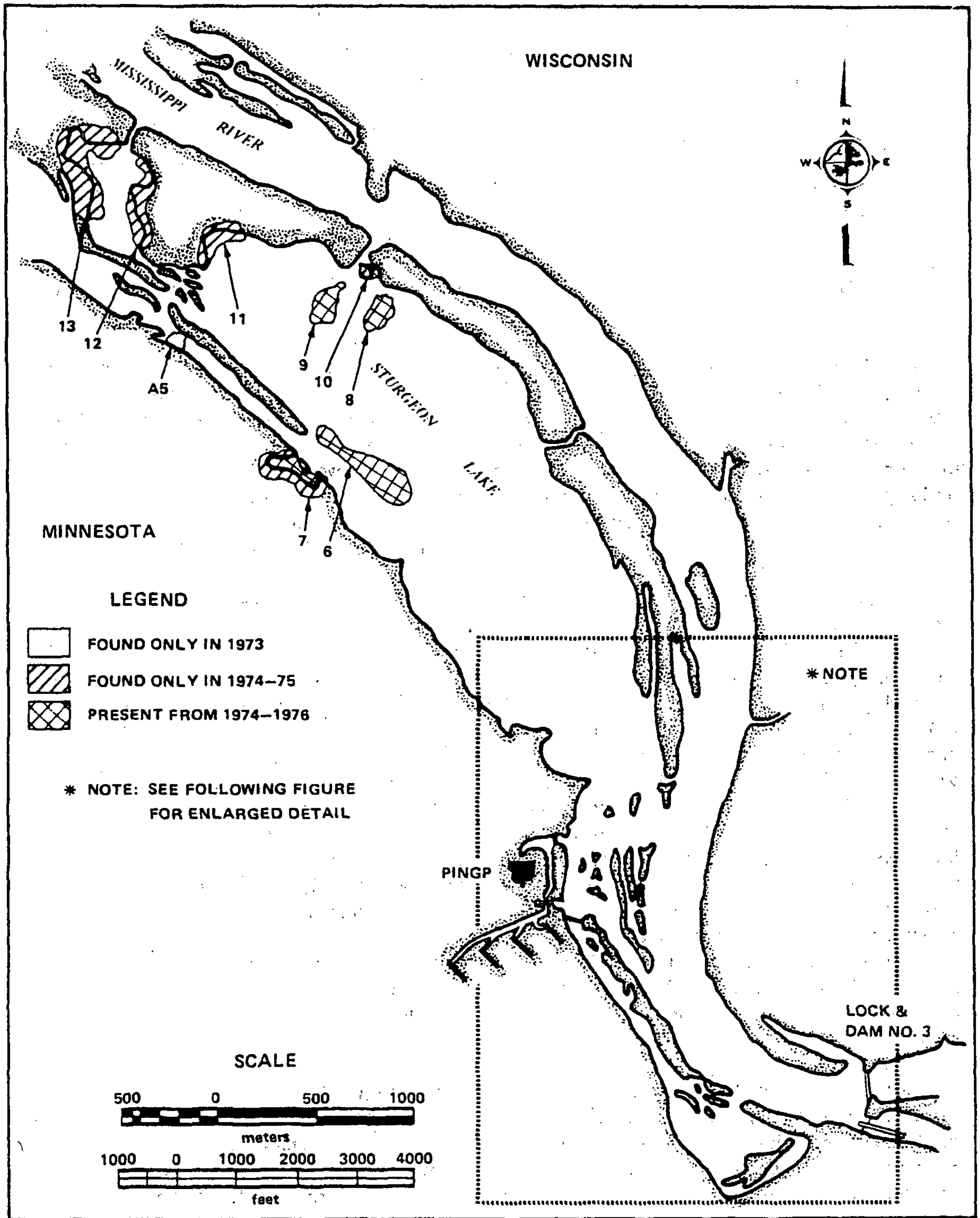

Figure III-29. Locations of macrophyte beds observed near PINGP during 1973 through 1976. For description of areas, see Appendix Table A-36.

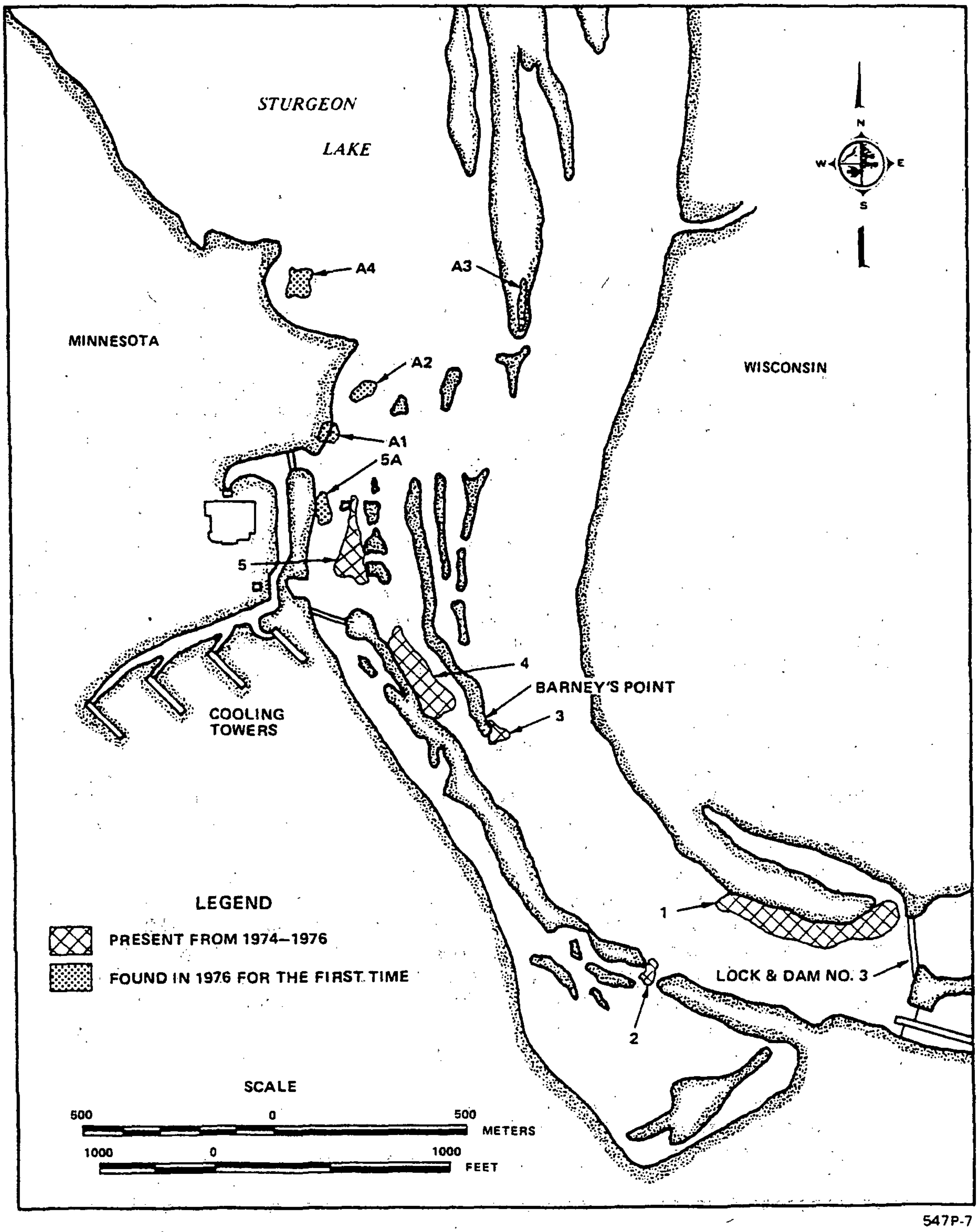

Figure III-29. (continued)

however, under normal environmental conditions, these populations of nuisance organisms are held in check by fish, macroinvertebrates, and zooplankton residing therein.

6. Birds. Northern bald eagles, ducks, and other waterfowl migrate through the Mississippi River Valley in the fall and spring with some overwintering in areas of open water. A thermal discharge such as that at PINGP may influence the numbers overwintering by providing open water and by attracting fish and other organisms utilized as food by the birds.

Eagles migrate into the PINGP area from late September to mid-December and are diffusely distributed until the water begins to freeze (Faanes, 1975). The main concentrations during the fall and winter of 1975-1976 were near Prescott, Trenton, Bay Point Park, and Lock and Dam No. 3, with a few (about 4 percent) at PINGP. Consequently, the latter area does not appear to be an important eagle overwintering area, and peak utilization of the plant area occurred in January (Faanes, 1975). During the fall and winter of 1976-1977, similar numbers were observed near PINGP, although few eagles were observed from January through March which may be the result of the severe winter, and peak utilization of the PINGP area was in mid-November (Hibbard, unpublished). Eagles in the area from Prescott to Lake Pepin fed primarily on gizzard shad although some suckers, redhorses, white bass, and goldeye were eaten (Faanes, 1975).

Ducks and other waterfowl utilize open water areas along the Mississippi River during their migrations, and some may overwinter in the vicinity of PINGP. Mallards are common, and the PINGP thermal discharge may enhance the numbers overwintering in the area (Hibbard, 14 November 1977). Other migratory ducks using the river in the fall of 1976 include goldeneye, lesser scaup, canvasbacks, and redheads along with waterfowl such as swans and cormorants (Hibbard, unpublished).

Peregrine falcons, an endangered species, formerly nested in the Mississippi River Valley as far north as Diamond Bluff (Tordoff, 23 January 1978). Recently some have been transferred to previous nesting sites along Lake Pepin 48 to 80 km (30 to 50 mi) downriver from PINGP (Hibbard, 14 November 1977). None of these have returned and nested successfully thus far but some are expected this year. Experience farther east has shown that approximately 15 years of releasing peregrine falcons is necessary for reestablishment (Tordoff, 23 January 1978). This species feeds upon medium sized birds of many species, including small ducks.

IV. PLANT DESCRIPTION AND OPERATING PROCEDURE

A. CIRCULATING WATER SYSTEM

1. Description. The circulating water system serves as a heat sink for both the condenser and the plant cooling water systems. Condenser cooling water removes latent heat from exhaust steam leaving the low pressure turbine, while plant cooling water removes heat from the in-plant auxiliary machinery.

Most of the circulating water comes from Sturgeon Lake, with little to none coming directly from the main river channel. The calculated percentage of total Mississippi River water in the circulating water makeup for 1975 is shown in Table IV-1. The maximum intake makeup water volume amounts, in general, to less than 5 percent of the mean monthly river flow. The amount of makeup water is small compared to the flow in the main river channel.

The major components of the circulating water system are shown in Figure IV-1, and the flow diagram is presented in Figure IV-2. Note that the flow rates indicated in Figure IV-2 are for the closed cycle mode. The typical flow rates for various cooling modes are discussed in Section IV A.2.

The approach channel has been dredged to a width of 183 m (600 ft) and a depth of 3.1 m (10 ft) at normal pool elevation of 674.5 ft msl. A barrier wall separates the approach channel and the intake canal. The function of this wall is to prevent warm water from the recycle canal from escaping to the river. The barrier wall also effectively prevents recirculation of the blowdown discharge which may be blown upstream by southerly winds during periods of low river flow and prevents floating objects from entering the system. Circulating water is drawn from the approach channel into the intake canal and after mixing with recycled water enters the screenhouse. Trash racks and traveling screens collect organisms and debris from the intake stream to prevent them from entering the circulating water pump basin.

Four vertical shaft, volute type water pumps inside the screenhouse provide 1,350 cfs of water through 84-inch steel inlet pipes to the condensers, and two horizontal centrifugal motor pumps withdraw up to 60 cfs for the plant cooling water system. Each rectangular shaped, welded steel plate condenser is divided into an inner and outer water pass. Crossover piping connects the inner passes in series and also the outer passes in series. There are two interconnected condensers and two

Table IV-1. Percentage of mean monthly Mississippi River flow entering the intake canal, January through September 1975.

MONTH	RIVER FLOW[1]	AVERAGE INTAKE FLOW[2] (cfs)	PERCENT OF MEAN MONTHLY RIVER FLOW ENTERING INTAKE CANAL
January	7,995	175	2.2
February	8,691	289	3.3
March	9,944	281	2.8
April	45,860	414	1.0
May	65,220	618	1.0
June	36,200	326	0.9
July	38,010	761	2.0
August	11,790	541	4.6
September	10,950	378	3.4
October	10,070	265	2.6
November	12,570	190	1.5
December	12,561	175	1.4

[1]1975 USGS data (cfs) at Prescott, Wisconsin.

[2]From PINGP Environmental Event Log.

circulating water pumps per unit. One pump circulates water through the inner pass and the other through the outer pass so that circulating water makes one pass through the tubes of the interconnected condensers. The overall temperature rise through the plant is about 13.8° C (24.8° F). The circulating water carrying approximately 7.86 x 10^9 BTU/hr of rejected heat (total for both units) is then directed to the cooling tower pump suction bay through two concrete pipes (102-inch ID).

From the cooling tower pump suction bay, four cooling tower pumps convey the heated circulating water through individual pipes to header pipes at the top of the four 12-cell crossflow cooling towers. Flow control valves along the header distribute water to the hot water basin which evenly dispenses the water through nozzles to the fill area below. Tower fill is PVC slats used to break the water into fine droplets. The water falls by gravity through the fill section and is collected in a concrete basin at the bottom of each tower. Fans draw air through this fill area to aid in the evaporative heat loss, and the heat is carried into the atmosphere by the air flow. From the basin at the bottom of the

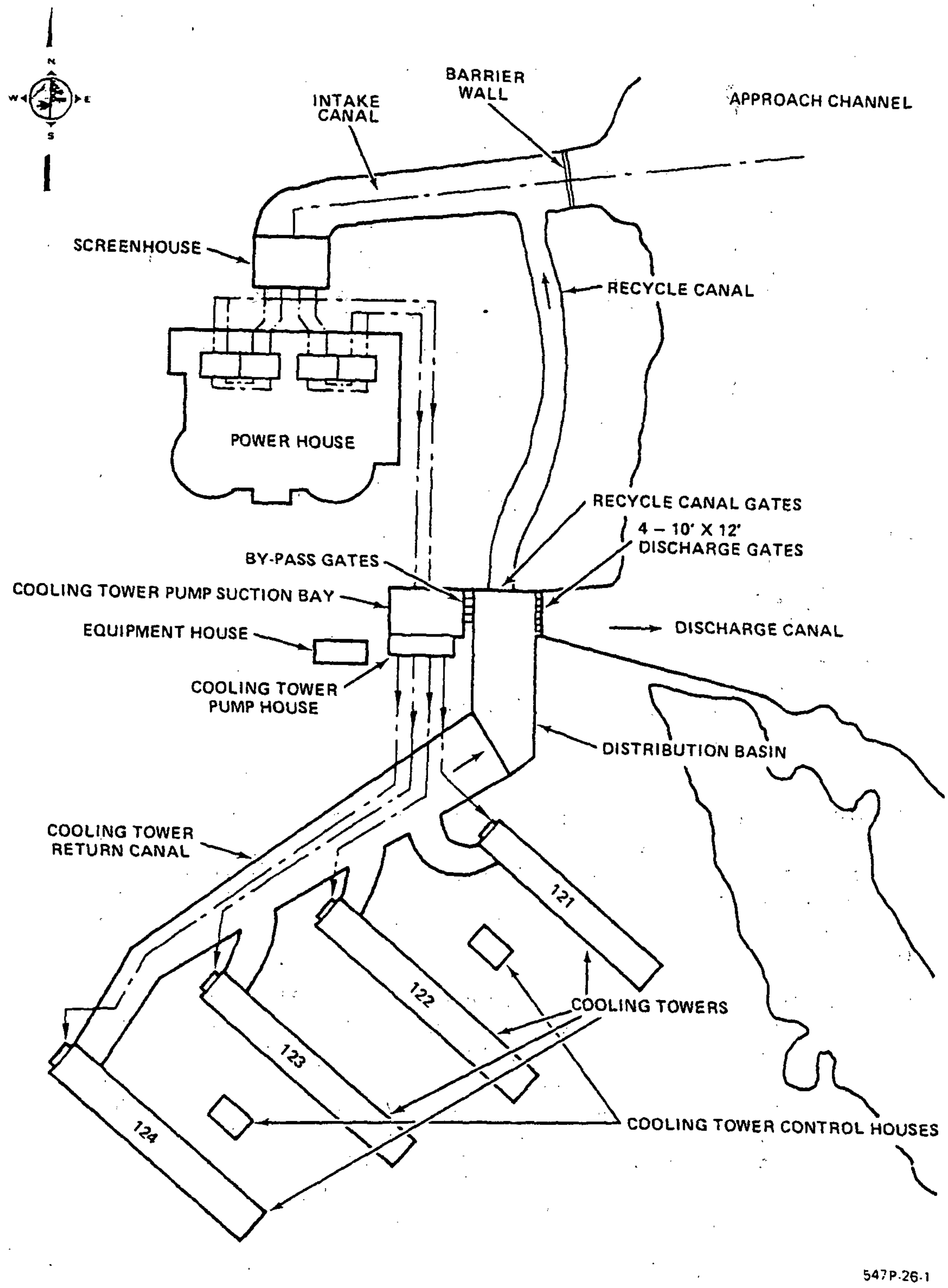

Figure IV-1. Schematic diagram of the circulating water system.

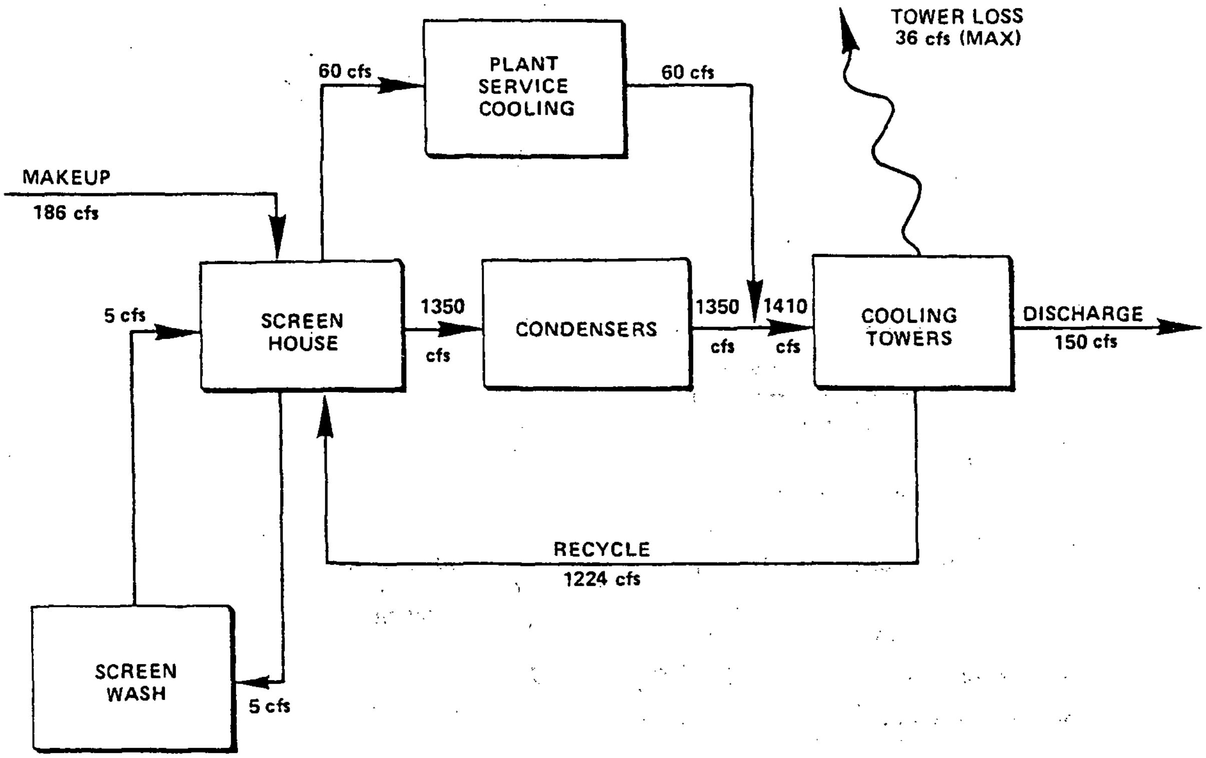

Figure IV-2. Representative flow diagram of the circulating water system (closed cycle).

towers, water flows through the cooling tower return canal to the distribution basin. If desired, circulating water in the cooling tower pump forebay can can be routed directly to the distribution basin through interconnecting gates. Recycle canal gates in the north wall of the distribution basin route the water to the recycle canal for return to the intake canal.

In order to avoid evaporative accumulation of dissolved solids (design concentration factor* = 1.25) in the circulating water system, continuous blowdown is needed. The thermal discharges from blowdowns in both the closed and partial recycle modes are considered in this demonstration. The discharge gates are 10 x 12 ft motor-operated steel gates which can be operated remotely from the control room. After the warmed water leaves the discharge gates, it enters the discharge canal and ultimately the main channel of the river.

$$\text{*Concentration factor} = \frac{\text{volume makeup}}{\text{volume blowdown + drift}}$$

2. Modes of Operation. The circulating water system can be operated in four basic modes: closed, partial recycle, helper, and open cycle. The closed cycle mode is described in III A.1. During this mode of operation, up to 186 cfs of water is withdrawn from the intake canal, a maximum of 36 cfs is evaporated in the cooling towers, and the rest (150 cfs) is discharged into the Mississippi River. A flow diagram for a typical closed-cycle mode of operation is shown in Figure IV-2.

During warm, humid weather periods, two factors act to increase the temperature of the inlet water to the condensers:

(1) the temperature of the water drawn from Sturgeon Lake is higher, and

(2) cooling tower outlet water temperature is increased because of increased wet bulb temperatures.

To maintain a design maximum of 29.4° C (85° F) at the condenser inlets, the volume of water drawn from Sturgeon Lake is increased while the volume of water recycled from the cooling tower discharge is decreased. The volumes of these two sources are thus regulated to maintain an average inlet temperature of no more than 29.4° C (85° F). Since less water is returned to the screenhouse from the cooling towers than under normal closed-cycle conditions, there must be a corresponding increase in blowdown. Functionally, the desired condition is achieved through control of the volume of blowdown water; the intake from the approach channel increases to compensate for the reduced return to the intake canal from the cooling towers, to maintain the required total flow of water through the screenhouse at 1,410 cfs.

When more than 150 cfs of blowdown is discharged, the plant operates in a partial recycle mode. The amount of recycle is calculated as the ratio of makeup water volume to total circulating water flow (1,410 cfs). Figure IV-3 shows a typical flow diagram for 50 percent recycle operation where makeup water is 705 cfs. As condenser inlet temperature increases, blowdown rate will be increased accordingly. When the makeup water rate equals the total circulating water flow, the operation is considered helper cycle mode (Figure IV-4). In Figure IV-4, the total discharge to channel 42 (See Figure III-8) via the discharge canal is 1,374 cfs since a maximum of 36 cfs is evaporated in the cooling towers. Note that the discharged warm water has been cooled in the cooling towers.

If the warm water bypasses the cooling towers and is passed directly to the discharge canal (Figure IV-1), the operation is called open cycle mode. In this mode, after the circulation water reaches the cooling tower pump forebay, the water is allowed to flow into the distribution basin via bypass gates. The water in the distribution basin subsequently flows into the discharge canal. A schematic flow diagram for the open cycle mode is presented in Figure IV-5.

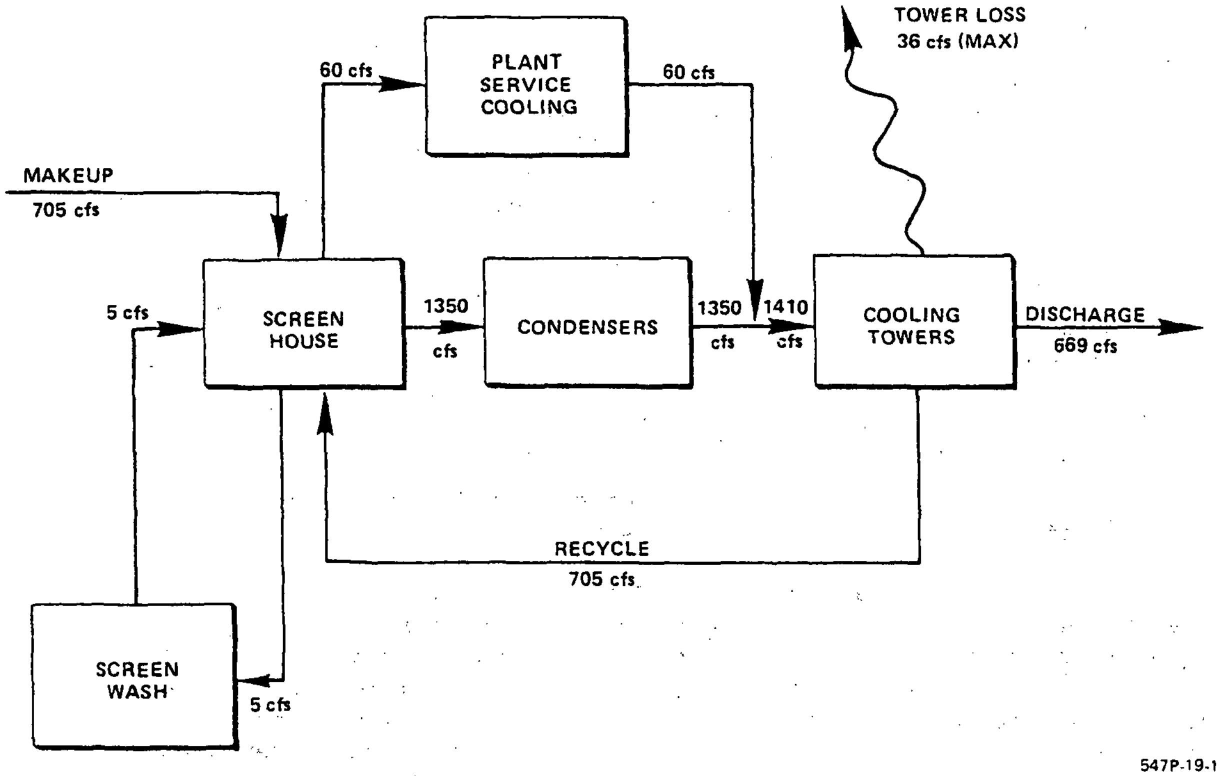

Figure IV-3. Flow diagram for a 50 percent recycle mode.

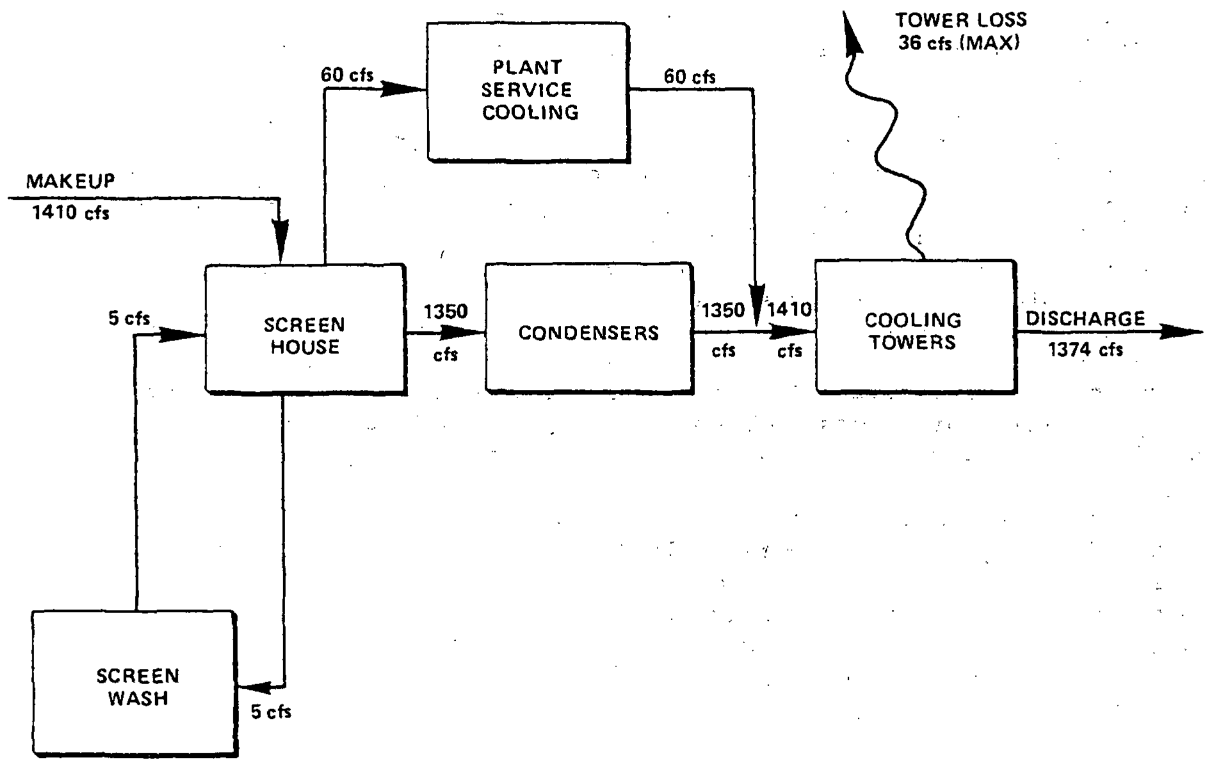

Figure IV-4. Flow diagram for a helper cycle mode.

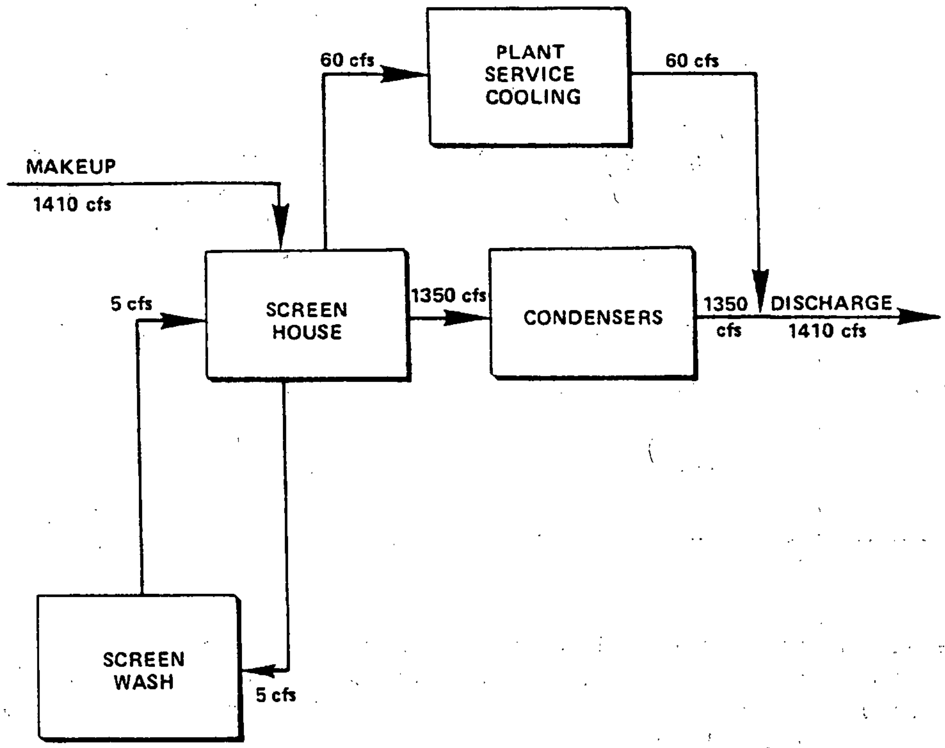

Figure IV-5. Flow diagram for a once-through mode with a maximum withdrawal rate of 1,410 cfs.

The helper and open cycle modes have not been used. Servicing cooling towers may result in bypassing part or all of the circulating water to the distribution basin and then to the discharge canal. The main difference between open cycle and helper cycle modes is that during open cycle operation, circulating water is not cooled by the cooling towers before it is discharged to the river. The makeup flow requirements and the blowdown rates for each mode of operation are summarized in Table IV-2.

3. Chlorination of Plant Cooling Water. Condenser water at PINGP is not chlorinated to prevent biofouling of the condenser surfaces since the Amertap method* is used to clean the condenser tubes. The plant

*(Amertap utilizes many sponge balls, whose diameter is slightly greater than the diameter of condenser tubes, to scrape any surficial deposit from the condenser tubes).

Table IV-2. Modes of operation for PINGP.

OPERATION MODE	COOLING WATER INTAKE OR MAKEUP FLOW (cfs)	RECYCLE CANAL FLOW (cfs)	DISCHARGE OR BLOWDOWN FLOW (cfs)	MAXIMUM EVAPORATIVE LOSS (cfs)
Closed Cycle	186	1,312	150	36
50 Percent Recycle	705	705	669	36
Helper Cycle	1,410	—	1,374	36
Open Cycle (Once Through)	1,410	—	1,410	—

cooling water (service water), however, is chlorinated on the suction side of the two cooling water pumps. The purpose of the chlorination is to prevent fouling of heat exchanger surfaces by growth of algae or other microorganisms. The current method of injecting chlorine is through an electric valve controlled by a timer. The valve is opened every 6 hours and remains open for approximately 30 minutes. The amount of chlorine release is about 22.7 kg (50 lbs)/day or 5.7 kg (12.5 lbs) per each 30-minute release.

Chlorine is stored in liquid form at room temperature in standard 1-ton containers. As many as four containers may be stored at a time. Chlorination is carried out in a well-established procedure by injecting water with elemental chlorine gas. In aqueous solution, the active forms of chlorine are mainly the hypochlorite ion and hypochlorous acid.

In open cycle or helper cycle mode of operation, chlorinated plant cooling water would mix with condenser circulating water and discharge directly to the river. In a closed or recycle mode, part of the mixed water is returned, through the recycle canal, to the intake basin and into the plant curculating/cooling water systems. Elemental chlorine may escape into the atmosphere through surface contact with air in the cooling towers, the recycle canal, and the intake canal. It would be difficult, if not impossible, to compute the chlorine residual in the discharge water; consequently, a monthly measurement of residual chlorine is conducted on the river side of the discharge gates (Table IV-3). The lower threshold of the instrument used is about 0.01 ppm. From these data, it can be concluded that the residual chlorine concentration in the circulating water is too low to be of any biological significance and is much less than the 0.2 ppm specified in the NPDES permit. In

Table IV-3. Typical residual chlorine concentrations in the discharge water and in the cooling water.

	DISCHARGE GATE (River Side) CONCENTRATION (ppm)	COOLING WATER CONCENTRATION (ppm)
November, 1976	0.03	— [2]
December, 1976	0.03	— [2]
January, 1977	— [1]	— [2]
February, 1977	0.03	— [2]
March, 1977	— [1]	— [2]
April, 1977	0.05	— [2]
May, 1977	0.03	— [2]
June, 1977	— [1]	— [2]
July, 1977	0.03	— [2]
August, 1977	0.02	— [2]
September, 1977	0.01	1.10
October, 1977	0.02	0.86

[1]Below detection limit of 0.01 ppm or off scale.

[2]No measurement made.

September 1977, measurement of residual chlorine in the cooling water system (before mixing with the circulating water) was initiated, and the data are presented in Table IV-3 also. The values averaged about 1 ppm and reflect typical concentrations in the cooling water system.

4. Other Chemicals Used. Besides the small amount of chlorine residual in the plant cooling water and radioactive elements originating from the steam blowdown and pump seal water, several other chemicals are discharged into the river via the circulating water system. Three discharge outfalls are connected to the circulating water system: generator blowdown, radwaste effluent, and neutralizer tank effluent. The turbine building sump effluent comprises effluents from the condensate system blowdown, heating system blowdown, and the resin rinse effluent. Flow is from the sump to the cooling water return header and then to the circulating water discharge piping. The flows and constituents of these effluents are summarized in Table IV-4.

Table IV-4. Summary of liquid discharges into the circulating water system including effluent limitations.

SOURCE	MAXIMUM FLOW (cfs)	AVERAGE FLOW (cfs)	CHEMICALS	OIL AND GREASE (mg/ℓ)		ESTIMATED TOTAL SUSPENDED SOLIDS (mg/ℓ)		TURBIDITY (JTU)	pH VALUE	DISCHARGE POINT
				MONTHLY AVERAGE	DAILY MAXIMUM	MONTHLY AVERAGE	DAILY MAXIMUM			
Steam Generator Blowdown	0.39	0.04	Silica, hydrazine morpholine	—	—	30	100	25	4-10	Circulating Water
Radwaste Effluent	0.08	0.01	—[1]	—	—	30	100	25	4-10	Circulating Water
Neutralizing Tank Effluent	0.23	0.12	—[2]	—	—	30	100	25	6.5-8.5	Circulating Water
Condensate System Blowdown	0.39	0.05	—[1]	—	—	30	100	25	4-10	Turbine Building Sump
Heating System Blowdown	0.19	0.03	—[1]	—	—	30	100	25	4-10	Turbine Building Sump
Resin Rinse Effluent[4]	0.02	—	—[1]	—	—	30	100	25	4-10	Turbine Buiding Sump
Turbine Building Sump	0.77	0.31	—[1]	10[3]	15[3]	30	100	25	4-10	Circulating Water

[1]Essentially none.

[2]Table IV-5.

[3]Essentially free of visible oil.

[4]Well water flow ranges from 0.2 to 0.45 cfs.

Neutralizing tank effluents account for most of the chemicals discharged. Liquid effluent from the neutralizing tank is from regeneration of demineralizers for purifying makeup water. During normal batch operation, effluent is released to the circulating water system at a maximum rate of 20,000 gallons per day and at a minimum of 6-hour intervals. Dissolved minerals include approximately 213 kg (470 lbs) of various chemicals occurring naturally in the well water and up to 327 kg (720 lbs) of regeneration and neutralization chemicals. Chemicals in the natural well water are typically Ca^{++}, Mg^{++}, Na^{+}, HCO_3^-, $SO_4^=$, $SiO_2^=$, and Cl^-. Chemicals from the regeneration and neutralization consist primarily of Na^+ and $SO_4^=$. Table IV-5 lists the estimated quantities of these chemicals discharged to the river. The equivalent discharge canal and river concentrations were estimated by assuming complete mixing with the circulating water and the water in the discharge canal (1,410 cfs assumed) and with the river (11,000 cfs assumed). The equivalent increases in concentration are less than 0.8 percent and 0.1 percent in the discharge canal and in the river water flow, respectively. The percentage increase is thus inconsequential.

Table IV-5. Chemical concentrations from neutralizing tank effluents (based on data from AEC, 1973).

CHEMICAL	DAILY DISCHARGE (lbs)	DAILY DISCHARGE (kg)	EQUIVALENT DISCHARGE CANAL CONCENTRATION[1] (mg/ℓ)	EQUIVALENT RIVER CONCENTRATION[2] (mg/ℓ)	NORMAL RIVER CONCENTRATION (mg/ℓ)
Regeneration Chemicals					
Na^+	233	106	0.0300	0.0039	6 to 18
$SO_4^=$	487	217	0.0600	0.0080	10 to 75
Total	720	327	0.0900		
Well Water Minerals[3]					
Ca^{++}	74.4	33.8	0.0092	0.0012	34 to 72
Mg^{++}	23.2	10.5	0.0029	0.0004	11 to 22
Na^+	12.5	5.7	0.0020	0.0002	6 to 18
HCO_3^-	285.0	129	0.0400	0.0048	66 to 235
$SO_4^=$	31.3	14.2	0.0039	0.0005	10 to 75
$SiO_2^=$	24.4	11.1	0.0030	0.0004	0.4 to 13
Cl^-	17.8	8.1	0.0022	0.0003	2 to 25
Total	470.0	213	0.0600		

[1]Assuming a discharge dilution flow rate of 1,410 cfs which includes blowdown and natural dilution in the discharge canal.

[2]Assuming an average river flow rate of 11,000 cfs.

[3]Based on well water analysis of 5/2/72 and on 150,000 gallons of water purified per regeneration cycle (once per day).

B. PLANT PERFORMANCE AND COINCIDENTAL ENVIRONMENTAL CONDITIONS

1. Plant Availability and Plant Outages. Each unit at PINGP is rated at 507 MWe for summer (May through October) and 523 MWe for winter (November through April). Since the plant is a base-load facility, the projected load in 1979 can be considered constant throughout each time period (Forest, 2 February 1978).

Prior to November 1976, plant operation was not considered to be representative of future operation because of mechanical problems with the cooling towers, particularly icing damage related maintenance. These caused substantially lower availability factors and capacity factors in the winters of 1974 and 1975. Availability factor is defined as the percentage of time a unit is on line, regardless of how much electrical power is delivered, while capacity factor is the ratio of actual MW-hours delivered to the rated MW-hours in a given time period, excluding scheduled or planned outages.

During the winters of 1974 and 1975, one or more of the four cooling towers were out of service due to severe gear box damage. In the spring and early summer when the cooling towers were needed most to maintain low makeup water requirements to protect larval fish, they were often being repaired. This resulted in high recycle canal temperatures and, subsequently, high blowdown rates.

The operational period from November 1976 through October 1977 is considered to be more representative of future plant operation than previous years. The availability factor, capacity factor, and the number of outages for each month, are summarized in Table IV-6. In this table, outages are broken down into forced trips and planned trips. A forced trip is a shutdown triggered by built-in safety mechanisms (which automatically terminate the chain reaction in the reactor) because of equipment malfunctions or operator errors. Planned trips (scheduled outages) include scheduled refueling, periodic inspections, major equipment preventive maintenance, reactor operator training, examinations, and plant modification. A planned trip usually involves removal of the main generator from service and is always planned well in advance. Refueling typically occurs about once a year for each unit, and lasts about 6 to 8 weeks. Important equipment maintenance is normally scheduled during refueling periods; however, other scheduled trips are still necessary to fulfill requirements for preventive maintenance and inspection.

As shown in Table IV-6, scheduled refueling of Unit 2 was in October, November, and a part of December 1976 while refueling of Unit 1 extended from the latter part of March through April 1977.

The probability, p, of a forced trip occurring when the other unit is refueling, is calculated from the equation

$$p = 1-(1 - p_t)^{42}$$

Table IV-6. Summary of availability factors, capacity factors, and plant outages for November 1976 through October 1977 (Brown, 7 November 1977). See text.

1977 PLANT OPERATION								
	UNIT 1				UNIT 2			
			NUMBER OF OUTAGES				NUMBER OF OUTAGES	
DATE	AVAILABILITY FACTOR[1]	CAPACITY FACTOR[2]	FORCED TRIP	PLANNED TRIP	AVAILABILITY FACTOR[1]	CAPACITY FACTOR[2]	FORCED TRIP	PLANNED TRIP
Nov 76	98.1	97.4	1 (Inverter Failure, 14 hrs)		Refueling Outage			
Dec 76	100.0	98.0			39.1	31.2	1 (Feed Water Regulator Valve Controller 5 hrs)	2 (Testing and Other Miscellaneous from Outage, 30 hrs)
Jan 77	98.1	96.4	1 (Rod Drop; Bad Fuse, 14.2 hrs)		100.0	98.0		
Feb 77	94.4	92.2		1 (Condenser Cleaning)	93.9	91.5	1 (Generator Executor Malfunction)	1 (Condenser Cleaning, 7.1 hrs)
Mar 77	52.0	46.7	1 (Inverter Failure, 17.1 hrs)	1 (Refueling, 340 hrs)	98.6	97.3	1 (I & C Error During Calibration, 10.2 hrs)	1 (I & C)
Apr 77	Refueling Outage				100.0	98.4		
May 77	89.0	82.6		2 (Testing and Other Miscellaneous Items from Outages, 726 hrs)	97.9	96.4	2 (Condenser Valving Error, 5 hrs; Low Flow 2M Transformer, 10.6 hrs)	
June 77	93.6	91.9		1 (Turbine Work, 46.1 hrs)	97.8	95.0	1 (2M Transformer, 16 hrs)	
July 77	98.8	97.7	1 (Feed Water Regulator Value Controller 8.7 hrs)		100.0	98.5		
Aug 77	100.0	98.2			99.1	93.1	1 (Steam-Feed Water Values Failure, 6.7 hrs)	
Sept 77	100.0	95.8			100.0	98.0		
Oct 77	95.9	94.9	1 (Condenser Polishing Value Error, 3.1 hrs)	1 (Turbine Work, Steam Leaks, 27.1 hrs)	100.0	98.4		
Total Trips			5	6			7	4

[1]Percent of time unit is on line, excluding planned outages.

[2]Delivered energy/rated energy.

where p_t is the probability of a forced trip on any day of the year. Based on the typical plant performance record shown in Table IV-6, forced trips occur about 6 times a year for each unit. Assuming that the planned refueling period is 6 weeks or 42 days (shown as the exponent in the equation), the probability for a forced trip on any day, p_t, is $6/(365-42) = 0.0186$. Thus the probability (p) of a trip during refueling is $1 -(1-0.0186)^{42} = 0.55$. The probability of simultaneous forced trips is $0.0186 \times 0.0186 = 0.00035$ since they are independent events. Refueling outages are not scheduled to occur simultaneously. Table IV-6 shows that all of the forced trips lasted for less than 24 hours, but in the above calculation, each forced trip was assumed to last for a one-day period, which gives a more conservative estimate of p.

2. Past and Proposed Modes of Operation. As described in Section IV A.2, the basic mode of operation is a closed cycle with 150 cfs of blowdown. As the condenser inlet temperature reaches 29.4° C (85° F), blowdown is increased to remove the excessive heat from the circulating water system. Based on 16,156 hours of operating data for 1975 and 1976, the frequency of various blowdown rates and the cumulative frequency of these blowdown rates were summarized in Figure IV-6.

From Figure IV-6, it can be shown that the closed cycle mode was used more than 53 percent of the time during 1975-1976, and blowdown was less than 400 cfs about 81 percent of the time. Plant discharge exceeded 1,000 cfs for about 180 hours or one percent of the time. The higher blowdown rates resulted from the combination of warm intake water temperature, high wet-bulb temperature, and malfunction of cooling towers.

Blowdown rates necessary to maintain a condenser inlet temperature of 29.4° C (85° F) were calculated using the average river temperatures from RWGP, and wet/dry bulb temperatures taken from the Minneapolis-St. Paul Airport for the period 1965 through 1974. The calculated frequency of blowdown rates is presented in Figure IV-7 (dashed lines) and shows blowdown rates of less than 200 cfs would occur 314 days per year. This amounts to 86 percent of the time versus the actual 53.8 percent for 1975 through 1976 (shown in Figure IV-6) when cooling towers did not function properly. A blowdown of 800 cfs would be exceeded only a small percentage of the time.

A proposed operating mode consisting of helper cycle from 16 June through 31 August is also presented in Figure IV-7 (solid lines). With the two and one-half months of helper cycle and zero cooling tower outage, a blowdown rate of 150 to 200 cfs would be expected about 277 days (or 76 percent) per year. Except during helper cycle (about 79 days), the necessity of having blowdown rates higher than 400 cfs during the remainder of the year is essentially eliminated.

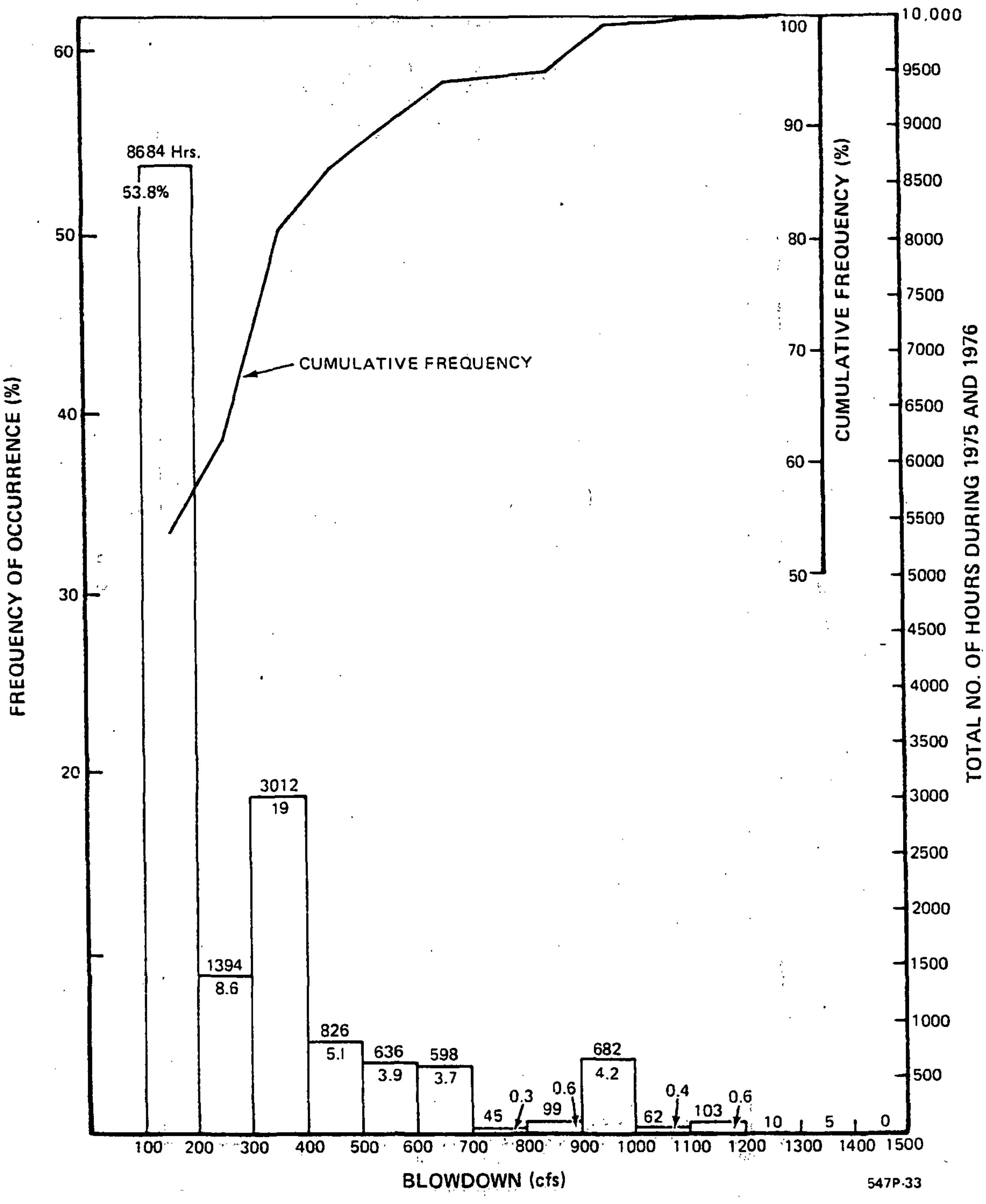

Figure IV-6. Frequency of occurrence and cumulative frequency of various blowdown rates from 1975 through 1976 (from PINGP Environmental Event Log).

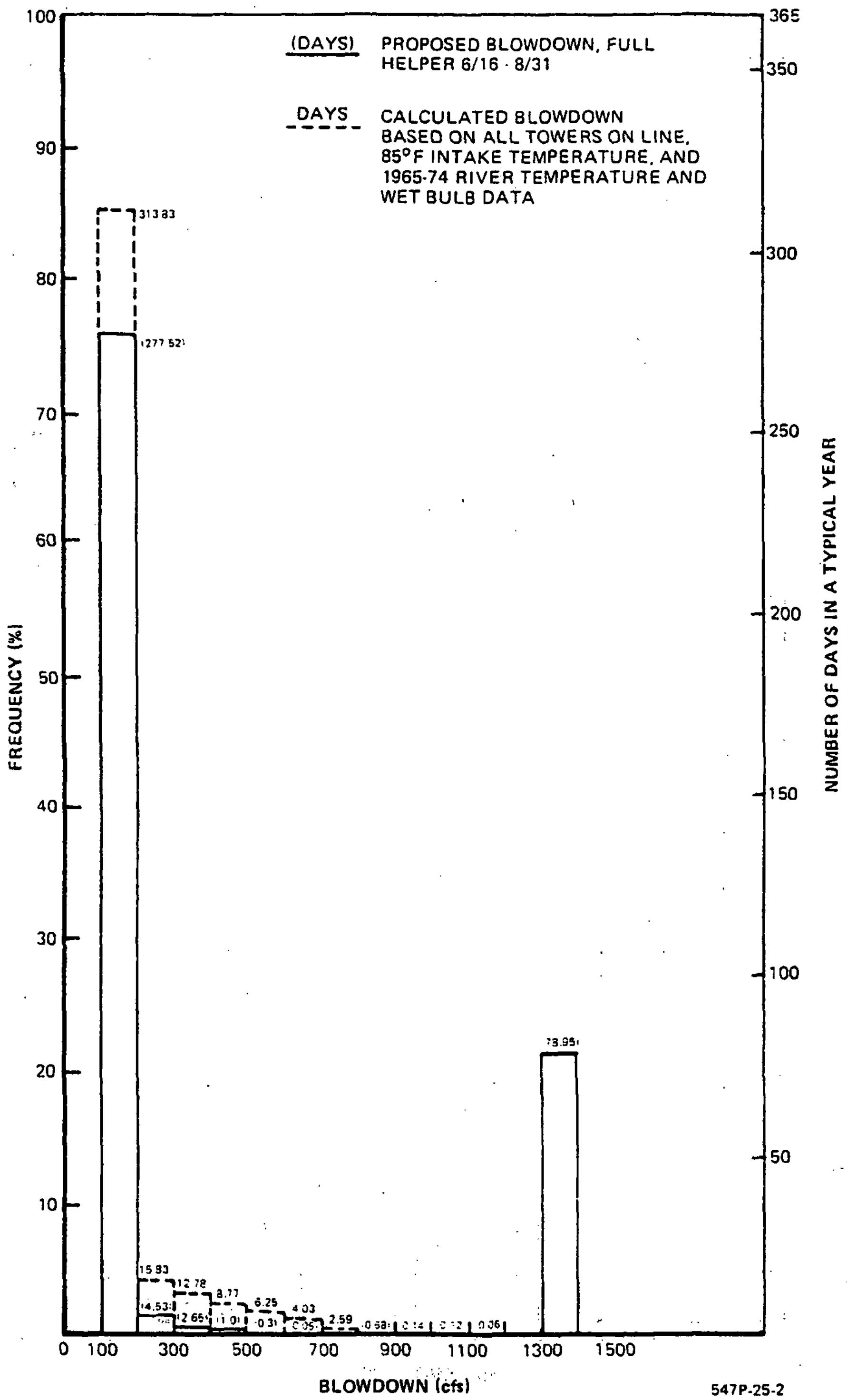

Figure IV-7. Frequency distributions of proposed blowdown rates and the calculated blowdown based on an intake temperature of 29.4° C (85° F).

This proposed mode of operation is designed to increase plant efficiency during summer when the demand is high. Plant efficiency is increased by utilizing the maximum makeup of 1,410 cfs from the river (Sturgeon Lake) without having to recycle partially cooled water from the cooling towers. The total heat rejection rate is not greatly increased with the higher blowdown rate; however, the temperature difference between blowdown and ambient water is proportionally decreased. The monthly breakdowns of computed joint occurrences of blowdown rate and river flow are summarized in Appendix M. In the Appendix, Table M-1 lists the number of hours for a given set of blowdown rate and river flow conditions to occur for the projected present mode of operation (29.4° C intake temperature and no cooling tower outage). Table M-2 lists the same information for the proposed mode of operation (29.4° C intake temperature, no cooling tower outage, and helper cycle from 16 June through 31 August).

V. THERMAL PLUME

A. DESCRIPTION OF THE HYDROTHERMAL MODEL

The numerical model for thermal plume predictions can be divided into three parts. A one-dimensional (1-D) hydrodynamic model developed by Stefan and Anderson (1977) was first used to calculate the overall flow pattern in lower Pool No. 3. This overall flow pattern was then used as an input for computing the velocity field in the near-field region. Due to the irregular geometries of the boundary in this region, a two-dimensional (2-D) model was used for computing both velocity and temperature fields. A closed-form three-dimensional (3-D) solution was used to simulate the thermal dispersion behavior downriver from Barney's Point because of the relatively well-defined river channel geometry. The computations for these three models (1-D, 2-D, and 3-D) are briefly outlined in the following sections.

1. <u>Hydrodynamic Model</u>. The 1-D hydrodynamic model formulated by Stefan and Anderson (1977) employed the simplifying assumption that flow in any channel section is uniformly distributed. The 1-D hydrodynamic model is analogous to pipe flow analysis. The model computes the flow rates for all the channels shown in Figures III-7 and III-8 for a given set of river flows, wind speeds, and wind directions. Laws of mass and energy conservation were applied in the computation. A brief discussion of the hydraulic network analysis is presented in Section III A.2, and detailed descriptions can be found in Stefan and Anderson's report. The results of the channel flow rate estimates were used as inputs for the 2-D model, particularly Channels 36, 26, and 42 (See Figure III-8).

2. <u>2-D Thermal Plume Model</u>. The region in which two-dimensional flow was assumed is shown in Figure V-1 and this defines the near-field area. The input variables for the model were flows in Channels 36, 26, and 42 and intake and blowdown rates. Also shown in the figure are inflows into the region, indicated by a plus (+), and outflows from the region, indicated by a minus (-). The intake flow always has a minus sign and the blowdown always has a plus sign while channel flows may have either sign. Typically, water from Sturgeon Lake flows into the 2-D region through Channel 36, and a part of it flows out to the river through Channel 26 while the remainder flows out of Channel 42. Occasionally, when strong southerly winds occur in conjunction with low river flows, the channel flows may reverse direction.

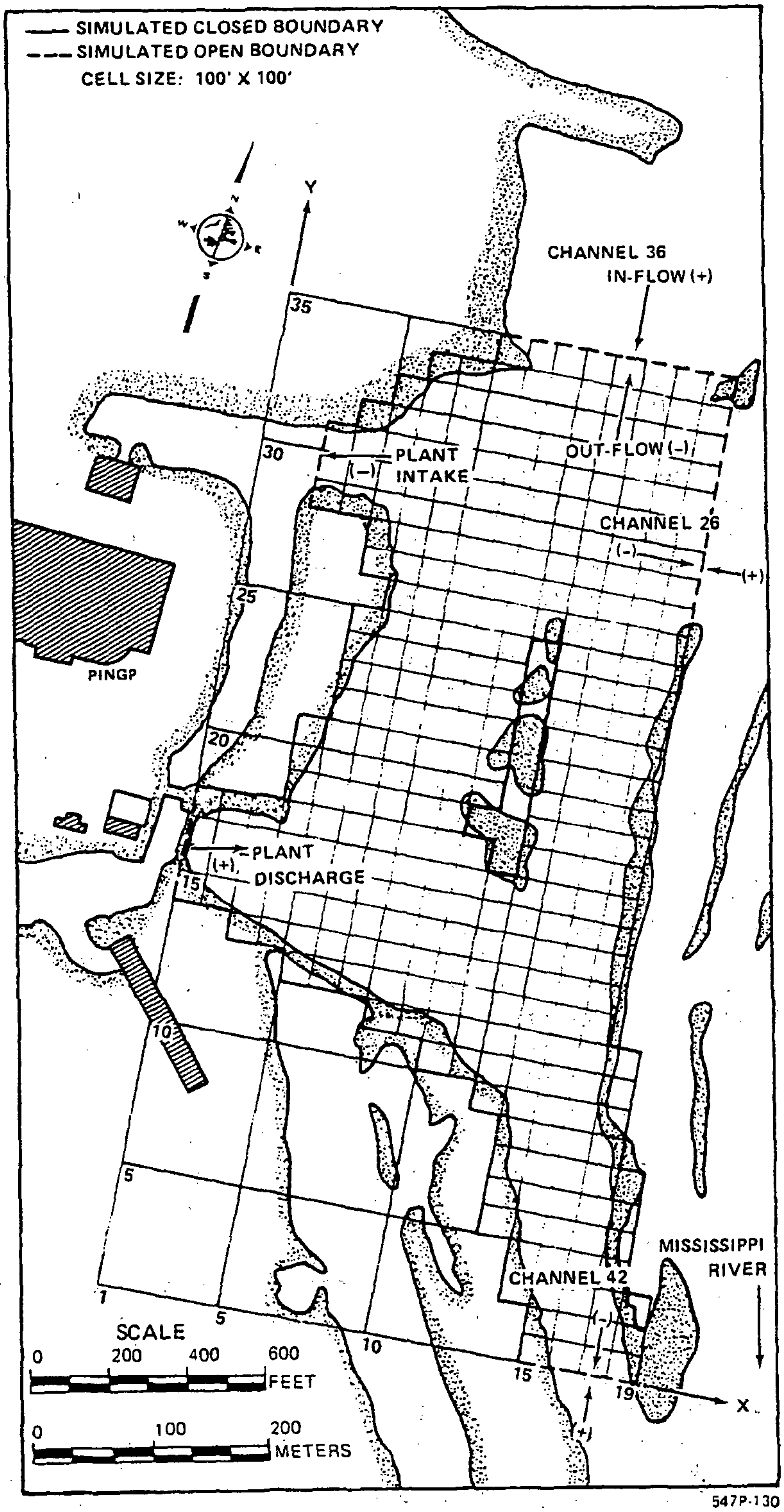

Figure V-1. Boundary conditions and the grid network used in the near-field 2-D thermal plume model analysis. Arrows indicate inflow (+) and outflow (-).

In order to compute the thermal plume dispersion, the velocity field must be defined. For the latter, a grid network (Figure V-1) was selected to approximate the shoreline configuration in the region. The four small islands in the center of the region were assumed to be connected because of the relatively shallow depth occurring between them. The grid network consisted of a 19 x 35 matrix with the y-axis oriented toward north. The heavy solid lines in Figure V-1 were assumed to be closed (impervious) boundaries while the dashed lines indicate open boundaries which in this case were input flow rates.

Since this is a 2-D model, flow was assumed to be constant with depth; therefore, only one velocity vector occurs at each grid point within the site boundary. A continuity equation was combined with two momentum equations to solve for the velocity vector at each grid point. In the momentum equations, the only driving forces were surface wind shear and bottom frictional stress. These three equations (continuity and two equations of momentum) were then normalized (with depth) and combined into a single equation by introducing the stream function. Subsequently, the stream function equation was solved numerically using a successive over-relaxation (SOR) method (Chu, 1968). After the stream function value at each grid point was computed, the two velocity components at each point were calculated as inputs for the energy equation (heat flow equation).

The energy equation was solved with the alternating directional implicit (ADI) method (Yeh, Lig, and Verna, 1973). Boundary conditions used for the energy equation were: uniform heat flux across the plant discharge points [(1,14) through (1,18)], zero heat flux across the closed boundaries, and heat sinks on all the open boundaries. This model description and development is presented in detail in Appendix I.

3. <u>3-D Thermal Plume Model</u>. Downriver from Barney's Point in the main river channel a three-dimensional (3-D) thermal plume model was used for dispersion computation. A closed-form solution for an unsteady point source (Yeh, 1976) was employed for computing the temperature rise (ΔT) in this region. As the river channel approaches uniformity in width, the 3-D model becomes more representative of the actual three-dimensional plume behavior. Assumptions for the 3-D model were: heat source uniformly distributed on the plane perpendicular to Channel 42 at Barney's Point (i.e., no initial thermal stratification), zero heat flux through the shoreline, and uniform velocity across the flow region. The heat source was based on the temperature output of the 2-D model at Barney's Point. The detailed description of the governing equation and its boundary conditions are presented in Appendix I.

B. CASES STUDIED

Sixty-one (61) cases have been modeled using the plume models described in Section V A. These sixty-one cases are:

- Monthly typical operating conditions in 1975 (12 cases)
- Monthly typical operating conditions in 1976 (12 cases)
- Monthly extreme conditions in 1975 (12 cases)
- Monthly extreme conditions in 1976 (12 cases) and,
- Proposed monthly extreme conditions (13 cases)

The parameters used to describe the operating conditions consist of blowdown rate (Q_p), intake flow rate (Q_i), river flow rate measured at Prescott (Q_r), wind speed (W_a) and direction (W_d), flow rates at Channel Nos. 36, 42, and 26 (Q_{36}, Q_{42}, Q_{26}), blowdown temperature (T_p), and ambient river temperature (T_a). The breakdown of these values for each condition modeled is summarized in Table 5-1 through Table 5-5 of Appendix I. Also given in these tables is the predicted temperature rise (ΔT) at Barney's Point, for each condition.

For typical operating conditions, the blowdown rate, intake flow rate, river flow rate, and the river temperature (daily maximum) consisted of average values for the month. Blowdown temperature was computed using values for intake temperature, wet bulb temperature, and the cooling tower performance curve. In general, typical conditions for 1975 are considered to be more representative of average conditions because of the low river flows that occurred in 1976.

The extreme conditions for 1975 and 1976 were chosen as the date when the maximum daily blowdown rate was recorded during each month. For instance, the maximum blowdown rate in July 1975 was 1,200 cfs on 8 July. Then, coincidental operating conditions on this day were used as inputs for the analysis.

The proposed extreme conditions for each month comprised the worst possible environmental conditions of: 7-day, 10-year low river flow; expected maximum blowdown rate for future operation; maximum river temperature ever recorded at RWGP, except for winter months (from November through March) when river temperature was assumed to be 0° C (32° F); and upper fifth percentile wet-bulb temperature for computing blowdown temperature.

To assess the probability of occurrence for the proposed extreme conditions, it can be assumed that all the recorded environmental conditions are statistically independent of each other. In other words, blowdown temperature, blowdown rate, river flow, and river temperature are not correlated within a given month. The 7-day, 10-year low flow frequency is less than 8.4 percent (see Figure III-12) for a given month. The blowdown temperature would not be exceeded 95 percent of the time, and the maximum temperature occurs less than once in the 27-year record, or 0.12 percent of the time. Thus, even if the proposed maximum blowdown rate remains constant throughout the month, the probability that the proposed extreme condition will occur on any day in a given month is 0.084 x 0.05 x 0.0012 = 0.000005 (or 0.0005 percent).

The model results for these typical and extreme operating conditions together with the proposed extreme conditions are presented in Figures 5-1 through 5-15 of Appendix I. These figures will be used as the basis for assessing biological impacts of the thermal discharge in this demonstration.

C. MODEL CALIBRATION

Seven field thermal surveys were conducted at PINGP from 1974 through 1976 (see Appendix N). However, only the thermal survey conducted on 1 August 1975 was used to calibrate the 2-D numerical model since it was the only one with comprehensive water velocity measurements taken in the near-field region. The 5 September 1974 field data were used to calibrate the 3-D model because of the relatively smooth isotherms found immediately downstream of Barney's Point on that date.

The numerical constants derived from the field measurements are the longitudinal diffusivity (K_x) and the lateral diffusivity (K_y) for the 2-D model. The values for these two diffusivities were found to be about the same, 75 ft^2/sec. These values were determined by adjusting the diffusivities so that the computed surface isotherms were similar to those measured in the field on 1 August 1975. The comparison among isotherms based on the selected diffusivities and the field measurements is illustrated in Figure 4-3 of Appendix I.

In the 3-D region, the longitudinal, lateral, and vertical diffusivities are assumed to be proportional to the mean river velocity. The proportionality coefficients a_x, a_y, and a_z were calibrated against field measurements conducted on 5 September 1974. In this calibration, a 76 m (250 ft) wide by 1.8 m (5.2 ft) deep heat source was established as the input for the numerical model. A 1.8 m (5.2 ft) deep source was used since, on the day of field survey, warm water seemed to float in the upper 1.8 m (5.2 ft) of the water column. The proportionality coefficients were determined to be: $a_x = 15$ m (50 ft), $a_y = 1.5$ m (5 ft), and $a_z = 1.5$ cm (0.05 ft). The vertical proportionality coefficient (a_z) was assumed to be orders of magnitude less than a_x and a_y because of the natural buoyancy of water.

In the cases studied, however, a full plane source 76 m (250 ft) wide and 3.1 m (10 ft) deep was used instead of a 1.8 m (5.2 ft) deep plane source. A negligible difference between these two source configurations is expected 152 m (500 ft) downstream from Barney's Point because of the reflecting surface condition assumed in the solution. This set of proportionality coefficients was also used to compare the model with the field data collected on 1 August 1975 (Figure 4-6 of Appendix I). Predicted isotherms compared favorably with the field measurement within approximately 396 m (1,300 ft) downriver of Barney's Point.

D. COMPARISON OF MODEL RESULTS WITH TEMPERATURE STANDARDS

The numerical models previously presented in this section were used to describe the PINGP thermal plume since adequate field data were not available for all of the environmental conditions and months necessary for estimating biological impacts of the discharge. The models were calibrated with field data and thus can be assumed to provide a reasonable representation of the actual plume behavior. The model results will therefore be used for comparison with the state temperature criteria (NPDES permit).

The proposed NPDES permit issued by the MPCA specifies the following limitations:

1. The discharge shall not raise the temperature of the receiving water at the edge of the mixing zone specified below by more than 2.8° C (5° F) above natural based on the monthly average of the maximum daily temperatures, above 30° C (86° F) at any time, or above the following weekly average temperatures* whichever is more stringent:

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)

2. <u>Mixing Zone</u>. The mixing zone shall be the confluence of the discharge canal and the main channel of the Mississippi River at the place commonly known as Barney's Point. The Permittee shall determine compliance by the use of their temperature sensors as they exist at the time of the issuance of this permit.

3. <u>Frequency of Monitoring and Reporting</u>. The Permittee shall monitor the temperature at the edge of the mixing zone continuously and report it along with other monitoring data to the Director.

4. <u>Natural River Water Temperature</u>. The natural river water temperature is the temperature of the river water at a point unaffected by the plant discharge or any other man made source.

*Where the background weekly average temperature of natural origin is normally higher than that specified for a particular month, the natural weekly average temperature may be used as the limiting value which shall not be exceeded at the edge of mixing zone.

5. The final thermal limitations specified above may be subject to modification after opportunity for a public hearing following the completion of the Permittee's 316(a) demonstration pursuant to WPC 36(s)(1) and WPC 36(u)(3).

The natural ambient water temperature, as discussed in Section III B.1, is taken as the condenser inlet temperature measured at RWGP.

These criteria apply to the 1975 and 1976 typical cases under study which are assumed to represent typical conditions for future operation, as well as the proposed extreme cases. Based on the model predictions, thirteen cases were found to exceed the thermal criteria listed above: six cases for 1975 typical conditions, five cases for 1976 typical conditions, and two cases for proposed extreme conditions (Table V-1). From this table, it appears that meeting the 2.8° C (5° F) temperature rise criterion is most difficult during the winter months since the low flow in Channel 42 would not supply an adequate volume of water for dilution before Barney's Point. Little problem would be encountered in meeting the daily maximum thermal criterion of 30° C (86° F) and the weekly average temperature criterion for each month.

In Table V-1, the additional distances required to meet all the thermal criteria are also presented, based on the 3-D model numerical results shown in Tables 5-7 and 5-8 of Appendix I. The distances were interpolated on a log-log plot. These distances ranged from 91 m (300 ft) to 488 m (1600 ft) downriver from Barney's Point. For the August proposed extreme condition, the required compliance distance was not computed because the assumption of strong southerly wind reduces the Channel 42 flow to only 1 cfs. In this case, most of the discharged heat would be blown upriver instead of being diluted in Channel 42.

In terms of thermal criteria exceeded, it is apparent that the proposed extreme conditions do not represent the worst case thermal conditions at Barney's Point. Instead, the conditions reflect the worst case heat recirculation conditions because strong (10 mph) southerly winds were assumed in most cases. The estimated heat recirculation to the intake is summarized in Table 5-6, Appendix I, and varies from 10 to 44 percent for the proposed extreme conditions. For the typical cases, the maximum heat recirculation is 10 percent for 1975 and 28 percent for 1976. The higher the recirculation rate, the less efficient is the cooling system because the rejected heat returns to the intake and thus increases the condenser inlet temperature. The proposed extreme conditions, instead of representing the worst possible thermal conditions at Barney's Point, reflect worst operational conditions at PINGP. These conditions also reflect the worst possible thermal build-up in the near-field area. The warm water, in these instances, often flows out of the near-field region into lower Sturgeon Lake through Channel 36 and into the Mississippi River by way of Channel 26.

Table V-1. Cases where the PINGP proposed NPDES thermal criteria were exceeded. The additional distance required for the discharged thermal plume to meet the criteria is also presented.

MONTH	BARNEY'S POINT				ADDITIONAL DISTANCE REQUIRED TO MEET CRITERIA[1]	
	ΔT		T			
	(C)	(F)	(C)	(F)	(m)	(ft)
January 1975	4.7	8.4[2]	4.9	40.9[2]	335	1100
February 1975	5.0	9.0[2]	5.6	42.1[2]	427	1400
March 1975	4.4	8.0[2]	6.1	43.0	274	900
October 1975	3.0	5.4[2]	16.2	61.2	61	200
November 1975	3.2	5.8[2]	10.0	50.0	91	300
December 1975	4.7	8.5[2]	5.2	41.4	366	1200
January 1976	4.5	8.1[2]	4.6	40.3[2]	305	1000
February 1976	5.2	9.3[2]	6.5	43.7[2]	488	1600
October 1976	3.5	6.3[2]	14.9	58.8	91	300
November 1976	3.9	7.0[2]	7.1	44.7	177	580
December 1976	4.7	8.4[2]	5.2	41.4	335	1100
July Proposed Extreme	2.2	3.9	30.5	86.9[2]	107	350
August Proposed Extreme	1.5	2.7	30.9	87.7[2]	-	-[3]

[1]Extrapolated from Tables 5-7 and 5-8 of Appendix I.

[2]Thermal criteria exceeded.

[3]No distance calculated since flow at Barney's Point was only 1cfs and wind was southerly.

To estimate the frequency of occurrence for various temperature rises (ΔTs) at Barney's Point, a simple complete mixing model was used. The flow rates in Channel 42 for each river flow during calm conditions were calculated using the results from Stefan and Anderson's report (1977). The approximate relationship between these two flow rates, as described in Section IV A.2, is:

$$Q_{42} = 0.14\ Q_r^{0.96}$$

The total heat discharged was based on the present operating mode and was assumed to be fully diluted (no recirculation) in Channel 42. Thus, the temperature rise at Barney's Point is only a function of total heat discharged and the flow rate in Channel 42. The frequency (percent of time) with which various temperatures and ΔTs are calculated to occur at Barney's Point for every month are summarized in Tables V-2 and V-3. A temperature rise exceeding 2.8° C (5° F) could be expected approximately 71 percent of the time during January and February (Table V-2), and the frequency would be less than 46 percent of the time during the remainder of the year. The frequency of occurrence for absolute temperatures expected at Barney's Point during each month is presented in Table V-3. As expected, the maximum daily temperature limit of 30° C (86° F) would be exceeded only during the warm water months of July, August, and September. Based on the above analysis, it is evident that meeting the 30° C (86° F) limit would not be nearly as difficult as meeting the 2.8° C (5° F) temperature rise limit.

The above comparisons and calculations indicated that PINGP will not be able to meet the proposed NPDES thermal criteria, particularly during winter. Therefore, a variance of an additional 488 m (1600 ft) distance downriver would be needed to provide sufficient dilution to meet the mixing zone thermal criteria without derating the plant.

Table V-2. Computed monthly cumulative frequency (as percent) of temperature rise (ΔT) at Barney's Point assuming no wind and full dilution in Channel 42.

ΔT (F)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
19									0.2			
18	0.4	0.1							0.2			0.2
17	0.9	0.4							0.2			1.0
16	1.6	0.4							0.4			1.9
15	2.3	0.8							0.5		0.1	2.3
14	3.2	2.0						0.2	0.7		0.4	2.9
13	4.1	4.0	0.2				0.0	0.4	0.7		1.2	4.2
12	8.0	8.5	1.2				0.2	0.7	1.0		1.7	5.8
11	12.3	12.6	1.9				0.4	1.5	1.3	0.0	1.7	6.7
10	17.1	17.8	2.8				1.2	2.7	1.7	0.1	2.3	7.9
9	24.4	23.5	5.9				2.1	4.8	2.3	0.5	4.2	10.9
8	31.9	33.9	9.2				3.5	7.0	3.0	1.3	6.4	17.7
7	49.0	51.2	15.5				5.8	10.2	4.5	3.1	12.4	32.7
6	70.6	71.0	26.8	0.7		0.1	9.0	14.1	9.3	7.6	19.5	45.8
5	88.7	89.1	40.5	1.5		0.5	13.7	18.9	17.9	17.5	31.4	64.8
4	98.7	93.6	53.0	4.3		2.3	21.1	26.3	32.5	35.0	42.9	80.0
3	100.0	96.1	65.7	9.7		6.2	31.6	37.5	51.3	52.1	49.0	90.0
2	100.0	98.6	80.9	15.3	6.6	16.9	47.9	61.6	78.0	69.6	73.5	99.7
1	100.0	100.0	93.7	55.2	53.1	50.0	75.2	90.0	96.5	91.5	98.0	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	100.0

Table V-3. Computed monthly cumulative frequency of occurrence (percent) for river temperatures at Barney's Point assuming no wind and full dilution in Channel 42.

TEMP (F)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
92									0.1			
91							0.2	0.0	0.2			
90							0.6	0.5	0.3			
89							1.2	1.4	0.4			
88							2.4	2.2	0.5			
87							4.1	3.3	0.6			
86							5.9	5.2	0.6			
85							8.8	7.1	0.9			
84							12.9	9.5	1.2			
83						0.2	18.3	12.9	1.8			
82						0.5	23.0	17.7	2.7			
81						1.0	29.6	23.1	3.7			
80						1.7	37.6	28.5	4.4			
79						3.1	45.6	35.9	5.3			
78						6.2	53.6	43.1	7.0			
77						8.3	62.4	51.2	8.5			
76						12.6	71.6	59.6	11.1			
75						18.6	76.4	67.3	12.5			
74					0.2	24.4	80.4	76.1	15.3			
73					1.4	29.8	85.0	82.2	21.8			
72					2.1	36.8	90.8	91.2	28.2	0.1		
71					3.7	45.3	94.6	95.4	34.4	0.1		
70					4.2	54.8	96.0	96.2	42.6	0.5		
69					4.4	66.6	97.3	97.3	52.6	1.9		
68					5.8	73.3	98.5	98.7	62.5	3.2		
67					7.1	87.7	100.0	99.4	69.7	5.2		
66					8.3	90.7		100.0	79.2	7.3		
65					10.9	94.4			87.0	9.5		
64					16.0	96.7			89.6	12.3		
63					24.8	98.7			91.6	14.9		
62					32.9	100.0			93.7	18.3		
61					39.0				95.0	23.1		
60					47.3				95.7	30.2		
59				0.3	54.0				96.7	36.0		
58				1.7	60.3				97.0	42.5		
57				2.5	70.6				97.7	51.4		
56				5.3	79.5				97.7	61.1		
55				7.0	81.5				98.9	65.8		
54				10.2	87.0				99.4	72.2		
53				15.7	90.6				00.0	78.3		
52				17.5	94.8					82.2	0.7	
51				22.8	95.8					86.5	3.2	0.1
50			0.0	27.2	98.1					90.2	5.4	0.4
49	0.8	0.1	0.5	33.2	98.7					95.0	10.1	1.2
48	1.5	0.4	1.0	38.1	99.7					97.1	14.7	1.9
47	2.3	0.8	1.2	43.8	100.0					98.2	19.8	2.3
46	3.2	2.0	1.7	51.8						99.0	25.7	2.9
45	4.1	3.9	2.5	60.0						100.0	32.4	4.6
44	8.0	8.5	5.0	66.8							42.1	8.1
43	12.3	13.2	8.7	71.0							48.7	11.0
42	17.1	18.3	13.1	78.0							53.9	12.0
41	24.4	24.3	22.3	81.9							62.7	15.9
40	31.6	35.3	32.3	86.5							69.1	23.0
39	49.2	58.9	47.9	90.2							77.0	37.6
38	72.1	75.9	60.0	91.7							83.7	52.2
37	89.5	91.5	70.8	94.3							91.7	74.7
36	98.7	94.0	78.7	96.3							97.6	92.0
35	100.0	96.1	84.2	98.7							99.4	99.2
34		98.6	90.6	99.3							100.0	100.0
33		100.0	97.0	100.0								
32			100.0									

VI. BIOLOGICAL IMPACTS OF THERMAL DISCHARGE

Potential impacts of the PINGP thermal discharge were predicted based on literature data for thermal tolerances and the thermal plume model results for typical and extreme environmental conditions. In all cases, plant operation was assumed to remain essentially the same as at present, that is, closed cycle in winter with a gradual increase in the amount of partial recycle used in summer followed by a decrease to closed cycle again. Site-specific data were also used as much as possible to supplement the literature data and the predictive approach, particularly where literature information was limited.

For fish, the predictive Type 2 approach was the primary focus for impact analysis with some use of relevant field data. Thermal criteria for maintaining growth, reproduction, and winter survival as well as for providing short-term survival of juveniles and adults in summer and of embryos during the spawning period were developed for each RIS from literature data. These were then compared to the thermal plume model results (for typical and extreme environmental conditions) to calculate areas affected and time of occurrence. From this information and the field data, potential impacts were predicted and related to fish populations in the area.

For invertebrates and primary producers, however, information available for the Type 2 approach is limited so emphasis was placed on a reanalysis of the existing field data. A flow chart showing a conceptual summary of site-specific data reanalysis is presented in Figure VI-1 and is discussed in detail in Appendix B. The primary approaches involved are: (A) analysis of differences between stations and between dates and (B) correlation between biological variables and water quality variables (including temperature). Each approach examined plant impact from different perspectives. Approach A determined if spatial and/or temporal variations in biological parameters such as organism density and diversity existed in relation to the PINGP thermal discharge. Approach B, on the other hand, determined if organism density was related to water quality parameters, particularly temperature, regardless of time and space (location).

In Approach A, two-way differences between stations and between dates were first tested by ANOVA. If significant differences were found by ANOVA, Duncan's Multiple Range Test (DMRT) was used to group the stations or dates according to their quantitative similarities. Finally,

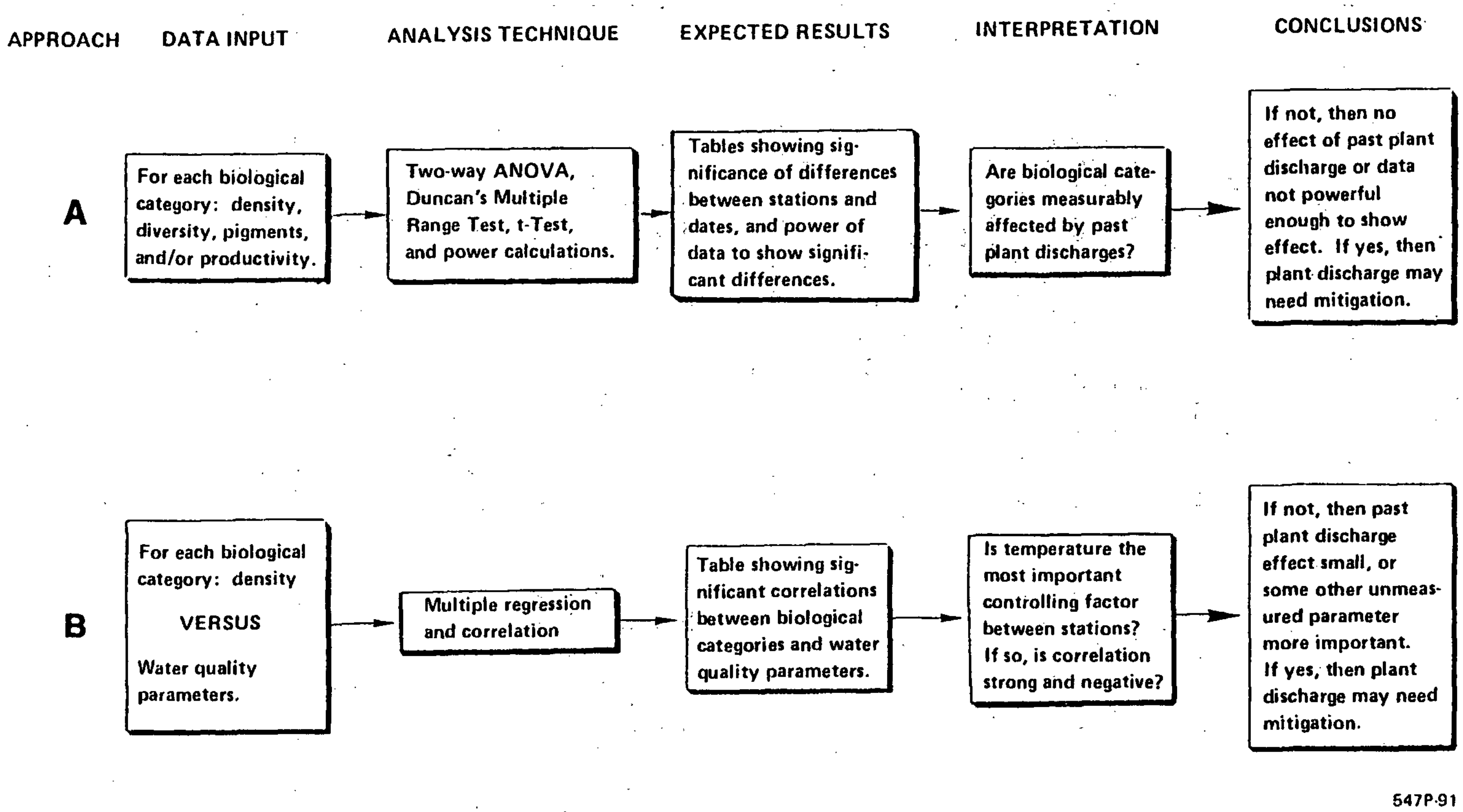

Figure VI-1. Empirical approaches to discharge impact analysis for invertebrates and primary producers at PINGP, using site-specific background data.

the Student's t-Test established whether or not significant differences occurred between specific plume affected and control stations. The t-Test was utilized when ANOVA and/or DMRT indicated that significant differences might have occurred between intake and discharge stations. Approach B quantified by means of correlation or multiple linear regression the degree to which biological parameters may have been influenced by heated water from PINGP. In most instances, only data from 1975 and 1976 were reanalyzed for invertebrates and primary producers, although phytoplankton density data from as early as 1973 were used. When multiple years of data were reanalyzed, all years were combined. In analyzing plume impacts, stations in the immediate vicinity of the plant (HDR Nos. 12 and 21, Figure VI-2) and far-field stations (HDR Nos. 10 and 27) were compared in order to determine impacts inside the plume (within the mixing zone) and in the main channel of the river above and below the confluence of the discharge canal.

For the predictive (Type 2) aspects of the impact analysis, Figure VI-3, invertebrate and algal thermal tolerances were compared with thermal plume predictions for typical and extreme conditions of river flow and ambient water temperature. Such analysis showed, depending on the accuracy of the thermal plume predictions and relevancy of the bioassay information, the degree and extent to which PINGP may threaten the "protection and propagation" of biota near PINGP.

A. FISH

In this section, a description and critique of pertinent site-specific field studies are presented first followed by a discussion of the appropriate thermal criteria. Then, predictions of potential impact to RIS in the discharge area are made for typical and extreme environmental conditions. In predicting the potential impacts, effects of attraction to and avoidance of the thermal discharge are considered in terms of spawning and reproductive success, upper thermal tolerances, cold shock potential, general fish population stability, and the incidence of diseases or parasites. Attraction to and avoidance of the thermal plume is expected to occur at PINGP, and the effects of this are estimated from a combination of literature data (e.g., thermal tolerances), thermal plume model results (areas within various isotherms are in Appendix Tables A-37 through A-42), and site-specific field data. All predictions are quantified to the extent possible by estimating area and time period for exclusion of life functions (by RIS).

1. Field Studies Description and Critique. Although this is primarily a Type 2 predictive demonstration, some of the field data are useful in assessing the thermal impacts of PINGP. Fisheries data have been collected since 1970 by several investigators; however, sampling locations, gear types, and effort have changed over time (within and between years). In addition, the sampling dates for each "season" varied

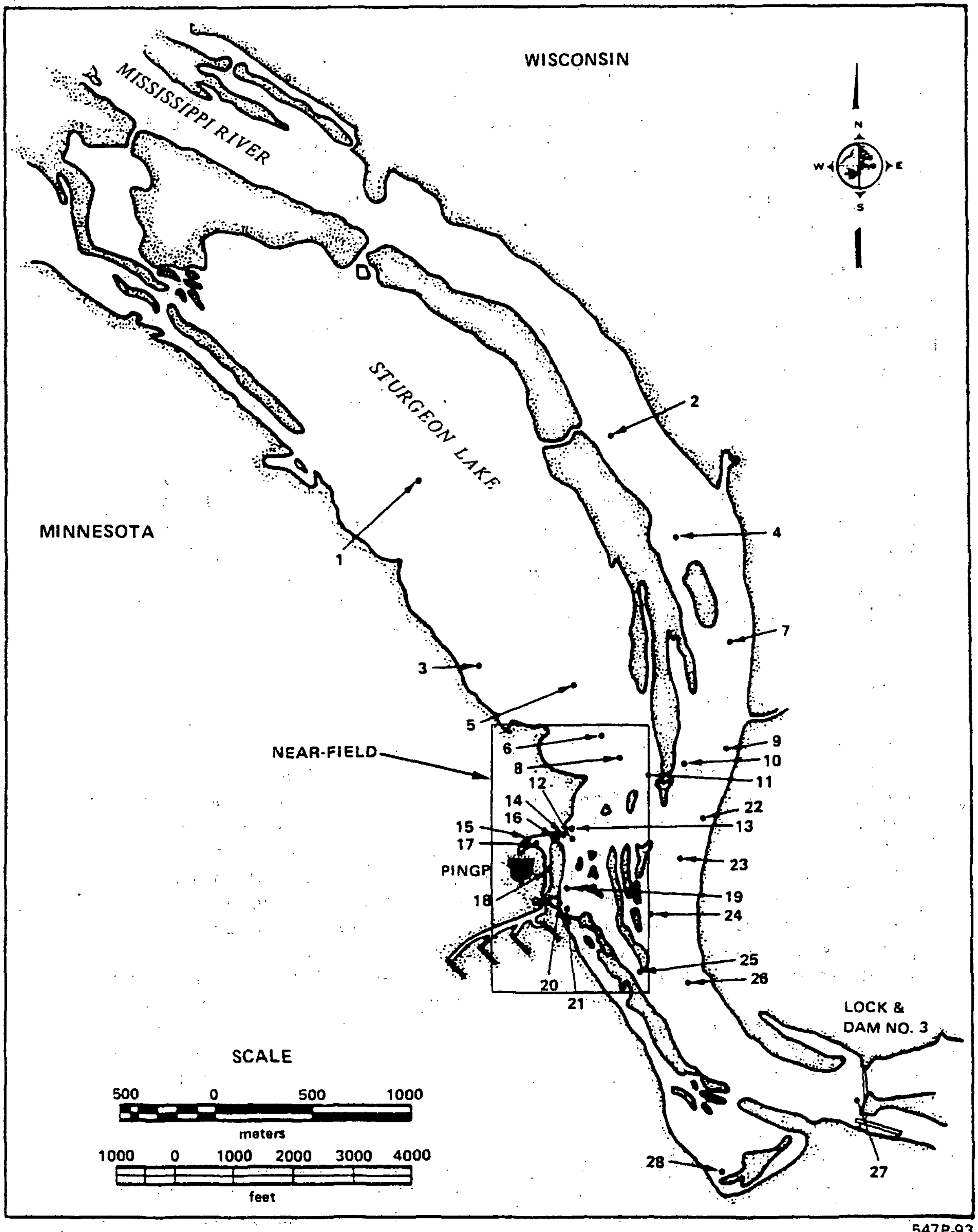

Figure VI-2. HDR designated station locations for invertebrate, primary producer, and water quality sampling conducted near PINGP during 1973-1976. Enclosed area indicates near-field.

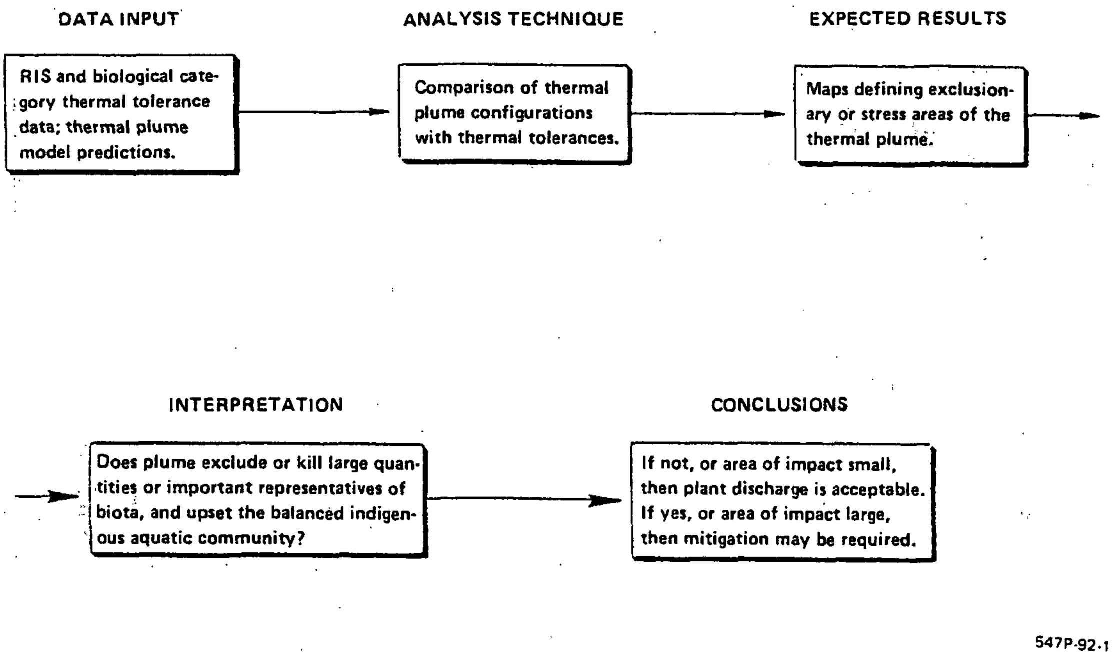

Figure VI-3. The predictive approach for analyzing discharge impacts on invertebrates and primary producers at PINGP using thermal plume predictions and nonsite-specific thermal tolerance data.

from year-to-year, especially for spring, and water temperature was not always recorded. Sampling from 1970 through 1976 has been summarized in Appendix Tables A-6 and A-7. In general, these data are inappropriate for assessing thermal discharge impacts for this demonstration type and have been used primarily in describing the area biology (Section III).

The discharge electrofishing study begun in April 1976, however, has provided some very pertinent information. In this study, standarized 5-minute electroshocking runs were made at the 7 locations shown in Figure VI-4. Sampling frequency was generally twice a month on a bi-monthly basis throughout the year, and water temperatures (surface and bottom) were recorded at the beginning, middle, and end of each run (data are in Appendix Tables A-43 and A-44). Three of the sampling runs (1, 3, and 7) were located along riprap while the remainder were over sandy muck or mud substrates. For the analyses that follow, riprap and soft bottom runs were paired to help eliminate habitat-related differences (1+5 = immediate discharge, 2+3 = far discharge, and 4+7 = control). Run 6 was not used since this area was intermittently influenced by the thermal discharge. During the winter, Runs 4, 6, and 7 were usually ice covered and could not be sampled.

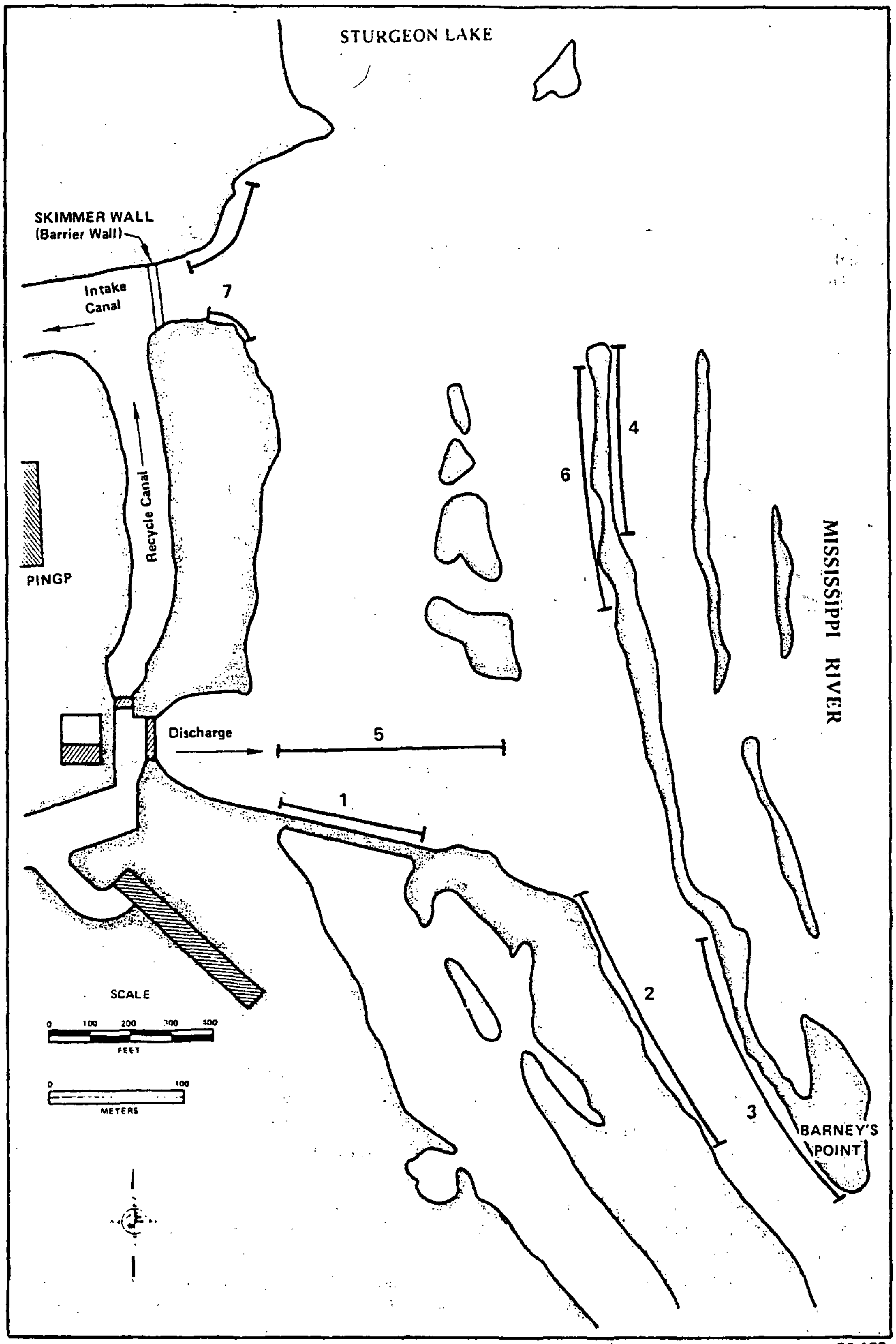

Figure VI-4. Sampling locations for the DNR discharge electrofishing study. Runs 1, 3, and 7 are riprap while runs 2, 4, 5, and 6 are sandy muck or mud (Gustafson and Geis, 1977).

Data from the discharge electroshocking study were used in the following impact analysis to strengthen the predictions based on literature information.

2. Temperature Criteria. EPA recommended temperature criteria (as defined in Brungs and Jones, 1977) for protecting fish during critical life stages throughout the year are utilized in this report, and the following discussion summarizes these criteria. To maintain growth, reproduction, and winter survival, water temperatures in the thermal discharge should not exceed a maximum weekly average temperature (MWAT) that is calculated as follows: For growth, the MWAT is the optimum temperature for growth plus one-third of the upper incipient lethal temperature minus the optimum for growth [MWAT = optimum growth T + (upper incipient lethal T - optimum growth T)/3]. This criterion should be applied considering the normal spatial distribution of the species during the season in which growth occurs (i.e., would the species normally occur in the area influenced by the thermal discharge during its growing season). This criterion, however, does not apply within the mixing zone. For spawning, the MWAT is taken to be the optimum spawning temperature, and if this is not available, the middle of the spawning temperature range is used. The MWAT for winter survival is taken from the nomograph in Figure VI-5.

Short-term exposure to moderately elevated temperatures can be tolerated by fish without adverse effects, and the maximum temperatures depend upon past thermal history of the fish (acclimation), duration of exposure, and ΔT. The relationship of exposure time (minutes) to temperature (°C) is described by the equation:

$$\log \text{time} = a + b\ (T)$$

where a is the Y-axis intercept, b is the slope of the line, and T is temperature in °C. Appendix Table A-45 summarizes a and b values determined at different acclimation temperatures for some of the RIS. The maximum temperature for short-term (24 hours) survival in summer can be calculated from this equation by choosing a and b for the acclimation temperature closest to the MWAT for growth. The safety factor of 2° C (3.6° F) must be subtracted from the resulting temperature to ensure survival of 100 percent of the population since a and b were determined from LT_{50} data. The temperature for short-term survival of embryos during the spawning period is estimated as the maximum spawning temperature or maximum for incubation and hatching, whichever is higher. For adults, short-term survival (24 hours) during the spawning period is calculated using the time-temperature equation for acclimation temperatures closest to the MWAT for spawning. Table VI-1 summarizes the above criteria for each of the RIS to be used for impact analysis in the following sections.

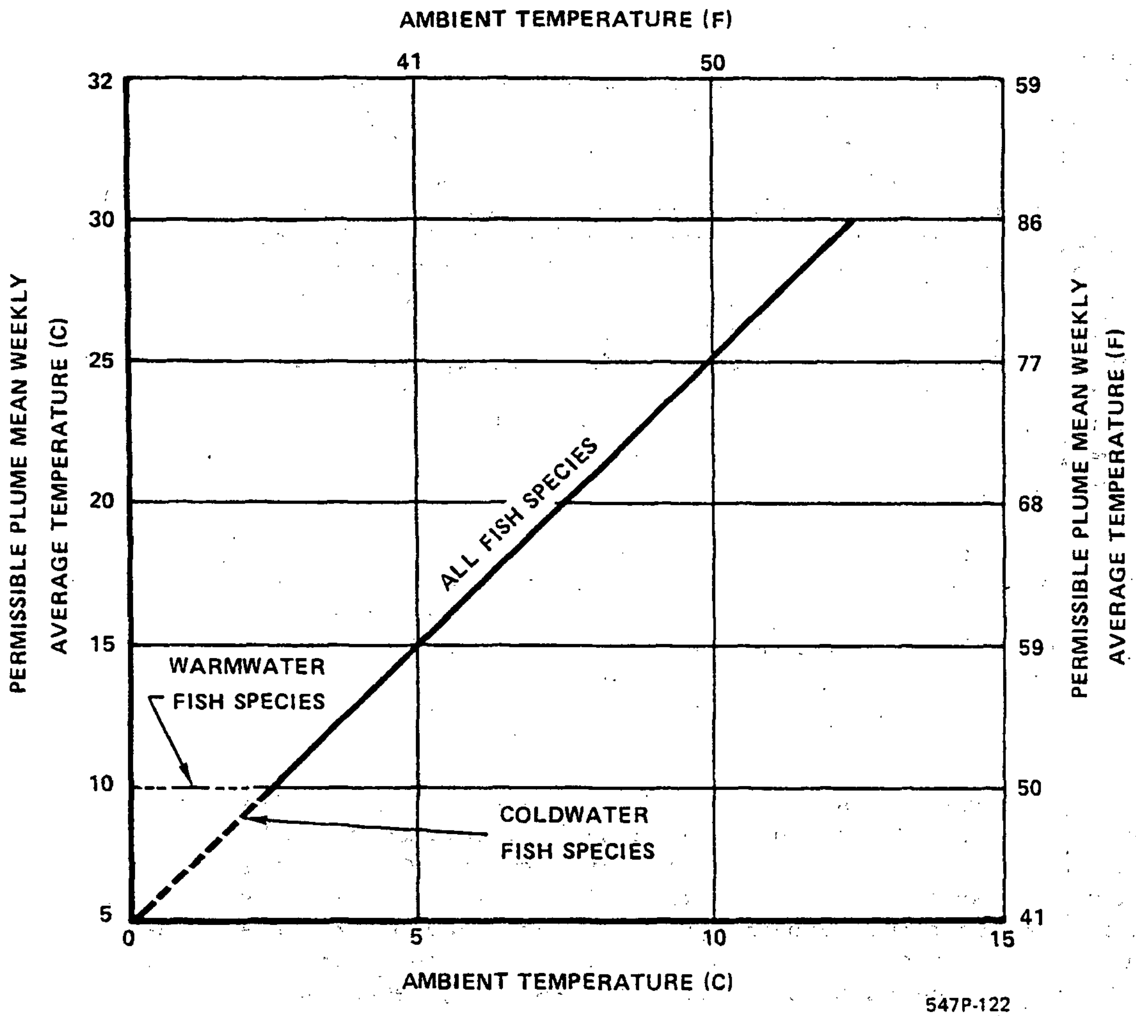

Figure VI-5. Nomograph to determine the permissible maximum weekly average temperature (MWAT) in the plume during winter for various ambient temperatures (adapted from Brungs and Jones, 1977).

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 Appendix Tables A-11 through A-20 and A-45. References are listed with the data.

[2] $MWAT = \text{Optimum for growth} + \frac{\text{Ultimate incipient lethal} - \text{Optimum}}{3}$

[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 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.

3. Attraction to and Avoidance of the Thermal Discharge. Warmed waters in the discharge canal may attract or repel fish depending on temperatures in the discharge and preferred temperatures for each species. Thermal data for each of the RIS have been presented previously (Appendix A), and the preferred temperatures at various acclimation (ambient) temperatures and seasons are shown in Figures VI-6 and 7. Based on these data, all of the RIS should be attracted to some portion of the discharge when ambient river temperatures are low while some species should avoid at least the warmer portions during summer. Table VI-2 summarizes these data and shows that walleye, white sucker, emerald shiner, and northern pike would probably not frequent the mixing zone [≥ 2.8° C (5° F) above ambient] when ambient temperatures are warmest (25° C) in summer. Areas in which the temperature is increased 8° C (14° F) or more during maximum summer temperatures would not be preferred by the other species, except possibly carp.

Even though preferred temperatures of many of the RIS are exceeded in the thermal plume during summer, these species may not necessarily be excluded from this area; it only means that they do not prefer these temperatures. Fish may avoid the areas above their preferred level but enter occasionally for feeding or predator escape. Based on the results of the thermal plume model, the maximum calculated area within which temperatures exceed 31.3° C (88.5° F) is typically 0.7 ha (1.7 A), and the area within which they exceed 27.2° C (81° F) is typically 14 ha (34.6 A) in July. Thus, the areas which exceed the preferred temperatures of some of the RIS are small compared to the available area in Sturgeon Lake [624 ha (800 A)], for example. These calculated areas would be larger during the proposed extreme conditions, but these occur very infrequently (see Section IV B for calculation of occurrence).

Upper lethal temperatures of the RIS more accurately define the areas in the plume that may be excluded from long-term use by the RIS. The upper lethal levels for each species acclimated to ambient temperatures are shown in Figure VI-8. From this figure, it appears that exclusion of some species would begin at the 5° C (9° F) isotherm during the highest ambient temperatures, and estimated exclusion for each species is summarized in Table VI-2. The latter estimates of exclusion, 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 important.

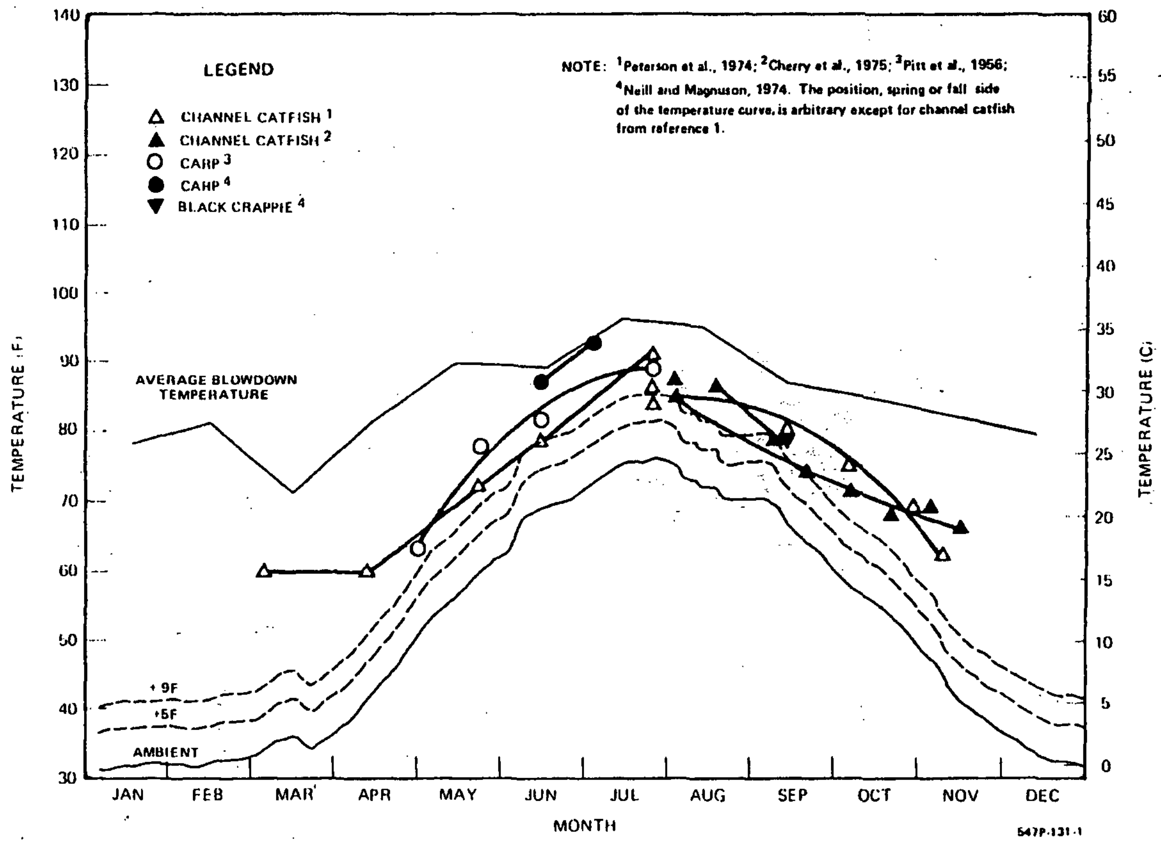

Figure VI-6. Preferred temperatures for juvenile RIS. These data are plotted using river ambient temperatures as acclimation temperature. For these species, preferred temperatures are always above ambient.

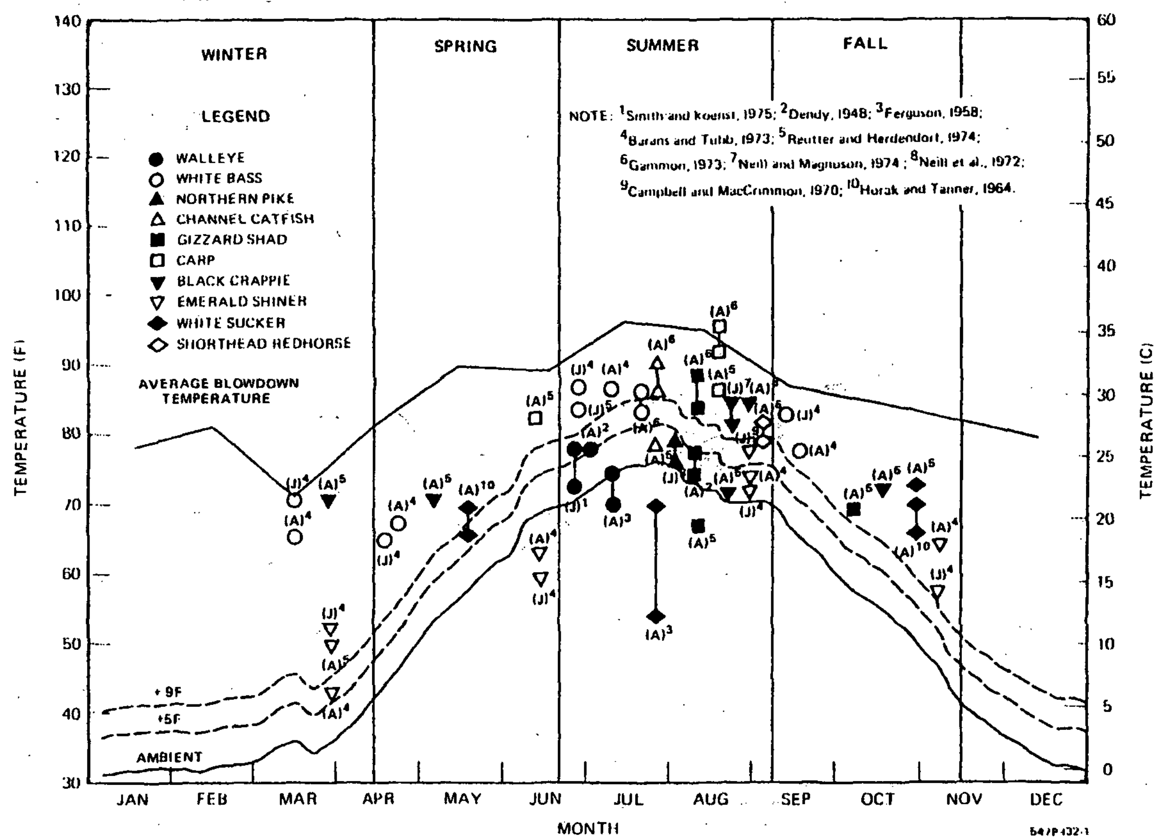

Figure VI-7. Preferred temperatures of juvenile (J) and adult (A) RIS during various seasons. The values plotted apply to the entire season, although they are located arbitrarily within each season. Seasons are defined as winter = < 5° C; spring = 5 to 21° C; summer = < 21° C; and fall = 21 to 5° C. Most of these fish would prefer temperatures above ambient, except for a few species (e.g., white sucker) when waters are warmest.

Table VI-2. Estimated potential effects of increased temperature on the RIS in the vicinity of PINGP.

TEMPERATURE C (F)	RIS NOT IN PREFERRED TEMPERATURE[1]	ESTIMATED RIS 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.
[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.

The maximum area excluded from use in summer for each RIS was calculated based on short-term survival information presented in Tables VI-3 through 12. The largest area excluded during typical conditions is 4.4 ha (10.9 A) for white sucker, and the area is less than 1 ha (2.5 A) for all the other species except walleye and northern pike. No data were available for white bass or shorthead redhorse, but these species should be similar to the other species. For extreme conditions of 7-day 10-year low river flows, maximum daily river temperatures, and maximum blowdown rates the exclusion areas in summer are predicted to be less than 0.5 ha (1.2 A) for channel catfish, gizzard shad, and carp. The areas of exclusion ranged from 0 to approximately 45 ha (0 to ~ 111 A) during May through September with the

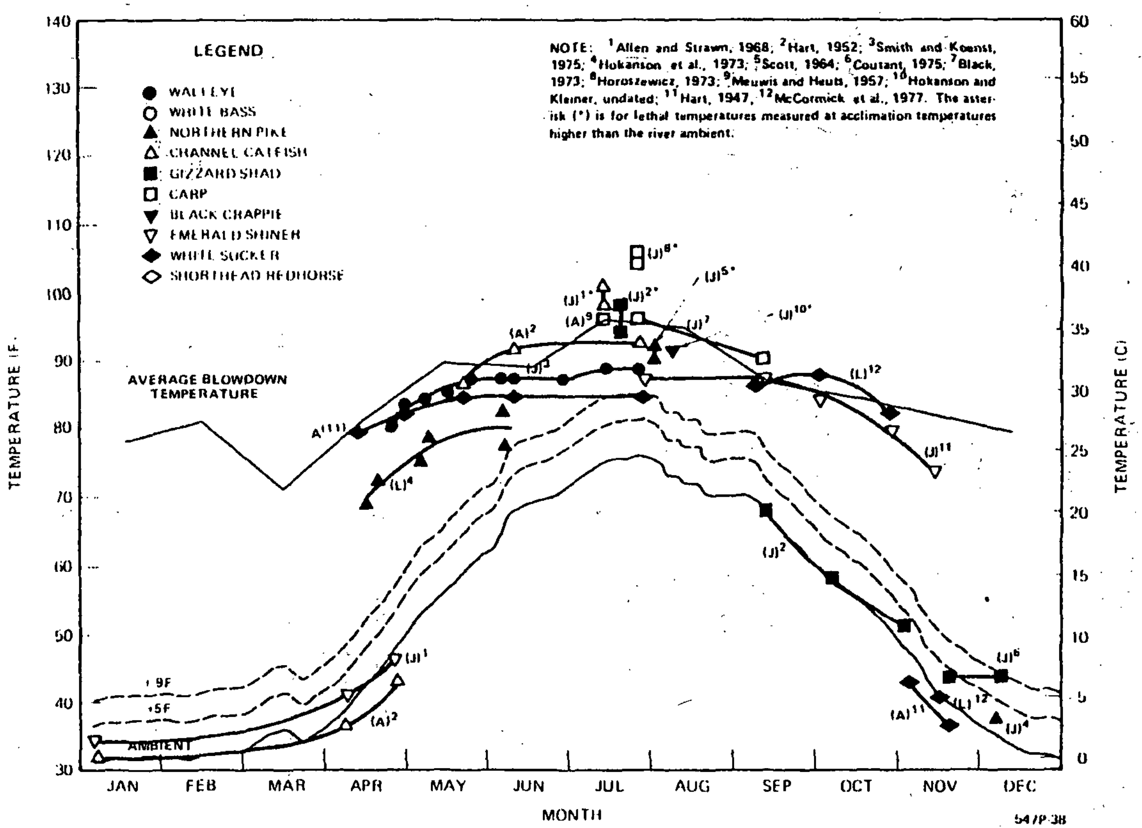

Figure VI-8. Upper and lower lethal thresholds for various life stages (A = adult, J = juvenile, and L = larvae) of the RIS. Upper lethals were plotted for acclimation to river ambient while lower lethals were plotted for acclimation to the maximum discharge temperature.

Table VI-4. Predicted area in the discharge from which various life functions would be excluded under typical and extreme conditions. Estimated time periods for exclusion are also given.

SPECIES: White Bass

PARAMETER	TEMP.[1] (C)	AREA EXCLUDING FUNCTION (HA)[2]		TIME FUNCTION EXCLUDED		REMARKS
		Typical	Extreme[3]	Typical	Extreme[3]	
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.
Maximum for incubation and larval development	26	0.3 2.6	8 -*	May June	May June*	*Ambient river temperature exceeds temperature criteria.
Maximum weekly average for growth	N.D.					

[1]From Table VI-1.

[2]From Appendix Tables A-37 through A-42 and computer printout for June.

[3]Probability of occurrence is < 0.000005 or < 1 hour every 278 years for each month.

Table VI-3. Predicted area in the discharge from which various life functions would be excluded under typical and extreme conditions. Estimated time periods for exclusion are also given.

SPECIES: Walleye

PARAMETER	TEMP.[1] (C)	AREA EXCLUDING FUNCTION (HA)[2]		TIME FUNCTION EXCLUDED		REMARKS
		Typical	Extreme[3]	Typical	Extreme[3]	
Maximum for short-term survival in summer	29.5	2.6 1.5	0.5 to ∿ 45	July August	May through Sept	
Maximum for short-term survival of adult during spawning	25	0.5	15	May	May	Spawn April to mid-May.
Maximum for incubation and larval development	19	0.8 9.0	-*	April May	May*	*Ambient river temperature exceeds temperature criteria.
Maximum weekly average for growth	24.5	-* ∿ 40	∿ 10 -*	July* August	May June* - Sept*	Main river channel (barge channel) may not be suitable habitat.

[1]From Table VI-1.

[2]From Appendix Tables A-37 through A-42 and computer output for April, June, and July.

[3]Probability of occurrence is < 0.000005 or < 1 hour every 278 years for each month.

Table VI-6. Predicted area in the discharge from which various life functions would be excluded under typical and extreme conditions. Estimated time periods for exclusion are also given.

SPECIES: Northern Pike

PARAMETER	TEMP.[1] (C)	AREA EXCLUDING FUNCTION (HA)[2]		TIME FUNCTION EXCLUDED		REMARKS
		Typical	Extreme[3]	Typical	Extreme[3]	
Maximum for short-term survival in summer	30.1	1.8 0.9	< 0.5 > 18	July August	May August	
Maximum for short-term survival of adult during spawning	24	0.8	∿ 30	May	May	Spawn April to early May. Probably do not spawn in discharge area.
Maximum for incubation and larval development	18	1.1 ∿ 17	-*	April May	April* May*	*Ambient river temperature exceeds temperature criteria. Most of discharge area not suitable for spawning.
Maximum weekly average for growth	28.4	0	∿ 40 -*	-	July August*	

[1]From Table VI-1.

[2] From Appendix Tables A-37 through A-42 and computer printout for April, June, and July.

[3] Probability of occurrence is < 0.000005 or < 1 hour every 278 years for each month.

Table VI-5. Predicted area in the discharge from which various life functions would be excluded under typical and extreme conditions. Estimated time periods for exclusion are also given.

SPECIES: Channel Catfish

PARAMETER	TEMP.[1] (C)	AREA EXCLUDING FUNCTION (HA)[2]		TIME FUNCTION EXCLUDED		REMARKS
		Typical	Extreme[3]	Typical	Extreme[3]	
Maximum for short-term survival in summer	35.2	<0.2	<0.5	July August	August	Small area near discharge gates.
Maximum for short-term survival of adult during spawning	33.6	0	<0.5	—	July	Spawn May through July.
Maximum for incubation and larval development	29	0.9 2.8	1 > 20	June July	May July	
Maximum weekly average for growth	31.9	0	∿ 3	—	August	

[1]From Table VI-1.

[2]From Appendix Tables A-37 through A-42 and computer printout for June and July.

[3]Probability of occurrence is < 0.000005 or < 1 hour every 278 years for each month.

Table VI-7. Predicted area in the discharge from which various life functions would be excluded under typical and extreme conditions. Estimated time periods for exclusion are also given.

SPECIES: Gizzard Shad

PARAMETER	TEMP.[1] (C)	AREA EXCLUDING FUNCTION (HA)[2]		TIME FUNCTION EXCLUDED		REMARKS
		Typical	Extreme[3]	Typical	Extreme[3]	
Maximum for short-term survival in summer	34	<0.2	<0.5	July August	August	Small area near discharge gates.
Maximum for short-term survival of adult during spawning	31	<0.1	< 0.5 <6[4]	June	May June	Spawn April through June.
Maximum for incubation and larval development	29	$\sim$1	1	June	May	
Maximum weekly average for growth	N.D.					

[1]From Table VI-1.

[2]From Appendix Tables A-37 through A-42 and computer printout for June.

[3]Probability of occurrence is < 0.000005 or < 1 hour every 278 years for each month.

[4]Extrapolated from May and August values.

Table VI-8. Predicted area in the discharge from which various life functions would be excluded under typical and extreme conditions. Estimated time periods for exclusion are also given.

SPECIES: Carp

PARAMETER	TEMP.[1] (C)	AREA EXCLUDING FUNCTION (HA)[2]		TIME FUNCTION EXCLUDED		REMARKS
		Typical	Extreme[3]	Typical	Extreme[3]	
Maximum for short-term survival in summer	38	0	0	—	—	
Maximum for short-term survival of adult during spawning	30.5	0.5 1.4	~ 8[4] ~16[4]	June July	June July	Spawn May through July.
Maximum for incubation and larval development	33	0.1	<0.5[4]	July	July	Small area near discharge gates but probably not suitable for spawning.
Maximum weekly average for growth	30.2	0	~40	-	August	

[1]From Table VI-1.

[2]From Appendix Tables A-37 through A-42 and computer printout for June and July.

[3]Probability of occurrence is < 0.000005 or < 1 hour every 278 years for each month.

[4]Extrapolated from May and August values.

Table VI-9. Predicted area in the discharge from which various life functions would be excluded under typical and extreme conditions. Estimated time periods for exclusion are also given.

SPECIES: Black Crappie

PARAMETER	TEMP.[1] (C)	AREA EXCLUDING FUNCTION (HA)[2]		TIME FUNCTION EXCLUDED		REMARKS
		Typical	Extreme[3]	Typical	Extreme[3]	
Maximum for short-term survival in summer	31	1 0.3	< 0.5 $\sim$18	July August	May August	
Maximum for short-term survival of adult during spawning	N.D.					Spawn May and June. Little suitable spawning in discharge.
Maximum for incubation and larval development	20	5.4 -*	-*	May June*	May* June*	*Ambient river temperature exceeds temperature criteria. Most of discharge area not suitable for spawning.
Maximum weekly average for growth	26.7	$\sim$40 3	-*	July August	July* August*	

[1]From Table VI-1.

[2]From Appendix Tables A-37 through A-42 and computer printout for July.

[3]Probability of occurrence is < 0.000005 or < 1 hour every 278 years for each month.

Table VI-10. Predicted area in the discharge from which various life functions would be excluded under typical and extreme conditions. Estimated time periods for exclusion are also given.

SPECIES: Emerald Shiner

PARAMETER	TEMP.[1] (C)	AREA EXCLUDING FUNCTION (HA)[2]		TIME FUNCTION EXCLUDED		REMARKS
		Typical	Extreme[3]	Typical	Extreme[3]	
Maximum for short-term survival in summer	30	0.9	< 0.5 ∿ 45	August	May August	
Maximum for short-term survival of adult during spawning	29.5	0.7 2.6 1.5	0.6 ∿ 50	June July August	May August	Spawn May through August.
Maximum for incubation and larval development	27	1.4 ∿ 6 7.6	4.8 -* -*	June July August	May July* August*	*Ambient river temperature exceeds temperature criteria.
Maximum weekly average for growth	29.6	0	∿25	-	August	

[1]From Table VI-1.

[2]From Appendix Tables A-37 through A-42 and computer printout for June and July.

[3]Probability of occurrence is < 0.000005 or < 1 hour every 278 years for each month.

Table VI-11. Predicted area in the discharge from which various life functions would be excluded under typical and extreme conditions. Estimated time periods for exclusion are also given.

SPECIES: White Sucker

PARAMETER	TEMP.[1] (C)	AREA EXCLUDING FUNCTION (HA)[2]		TIME FUNCTION EXCLUDED		REMARKS
		Typical	Extreme[3]	Typical	Extreme[3]	
Maximum for short-term survival in summer	28.4	1.1 4.4 2.7	1.6 -*	June July August	May August*	*Ambient river temperature exceeds temperature criteria.
Maximum for short-term survival of adult during spawning	23.3	1	∿ 50	May	May	Spawn late April to mid-May.
Maximum for incubation and larval development	21	0.5 3.4	 -*	April May	 May*	No suitable spawning area in discharge.
Maximum weekly average for growth	28.4	0	∿ 45 -*	—	July August*	

[1]From Table VI-1.

[2]From Appendix Tables A-37 through A-42 and computer printout for April, June, and July.

[3]Probability of occurrence is < 0.000005 or < 1 hour every 278 years for each month.

Table VI-12. Predicted area in the discharge from which various life functions would be excluded under typical and extreme conditions. Estimated time periods for exclusion are also given.

SPECIES: Shorthead Redhorse

PARAMETER	TEMP.[1] (C)	AREA EXCLUDING FUNCTION (HA)		TIME FUNCTION EXCLUDED		REMARKS
		Typical	Extreme	Typical	Extreme	
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. Probably do not spawn in discharge area.
Maximum for incubation and larval development	N.D.					
Maximum weekly average for growth	N.D.					

[1]From Table VI-1.

maximum occurring in August for walleye and emerald shiner. The maximum area of exclusion for northern pike and black crappie was about 18 ha (44.5 A) and for white sucker was 1.6 ha (4 A). No data were available for white bass or shorthead redhorse, although these species probably are similar to walleye in their tolerances.

During typical summer conditions the areas excluded would only occur in July and August. For extreme conditions, the areas excluded would probably occur only in August for channel catfish and gizzard shad while the area would vary from May through September with a peak in August for the other RIS. The probability that the proposed extreme conditions would occur in any month is less than 0.000005 or a frequency of 1 hour every 278 years. These calculated areas of exclusion represent the maximum in which thermal mortality could possibly occur since the 2° C (3.6° F) safety factor was subtracted from the median tolerance temperature.

Field data collected in the discharge electrofishing study described previously generally support these predictions. Figure VI-9 shows that the mean number of RIS collected in the immediate discharge area (Runs 1+5 in Figure VI-4) is inversely related to the ambient river temperature while the mean catch in the control area (Runs 4+7) shows little relationship to ambient temperature. Regression analyses of total RIS collected in the immediate discharge and control areas versus ambient temperature were performed (see Appendix L). Both polynomial and exponential curves were drawn, and an exponential curve of the form $Y = e^{a+b(T)}$ provided the best fit (Figure VI-10). In this equation, Y is the number of fish, a is the intercept, b is the slope, and T is temperature in °C. The coefficient of determination (R^2) for the discharge regression was 0.60, which indicates that the number of fish collected in the discharge was moderately related to changes in ambient temperature. The regression line has a negative slope which indicates that attraction to the discharge occurs as ambient temperatures decrease. The regression of total RIS in the control area versus ambient temperature (Figure VI-10) shows that the number of fish was less related to temperature ($R^2 = 0.35$), as would be expected. The regression line has a positive slope which indicates that more fish were found in the control area when the water was warm than when cold.

Figure VI-11 shows the mean catch per unit effort in two areas of the discharge and in the control area by season for the dominant RIS. Gizzard shad followed the same seasonal trends in attraction to and avoidance of the plume as for total RIS as would be expected since this species dominated the catch. Carp, the second most abundant species, showed a preference for the southern part of the discharge canal (Runs 2+3) during spring through fall and the immediate discharge area in winter. White bass apparently avoided the discharge in summer but were attracted to the immediate discharge in spring and fall. The number of shorthead redhorse and emerald shiners collected was very low in most seasons precluding most analyses. The redhorse, however, was more abundant in the control area in summer than in the discharge, and emerald shiners were more abundant in the discharge than in the control areas during spring.

Regression of carp and gizzard shad abundances in the discharge (Runs 1+5) and control (Runs 4+7) areas versus ambient river temperature are shown in Figures VI-12 and 13. The numbers of these species in the discharge are only moderately related to ambient temperature since R^2 values were 0.49 for both. The slopes of both discharge regression curves are negative indicating attraction to the plume as ambient temperatures decrease. The numbers of carp and gizzard shad in the control area were poorly related to ambient river temperature.

The R^2 values were tested for significance by calculating an F value (Harnett, 1970, pp. 343 and 348) from the equation

$$F = (n-2)\ R^2 \div (1-R^2)$$

where n is the number of samples (21 for control and 24 for discharge). These F values were then compared to critical F values for n-2 samples and 1 degree of freedom (Harnett, 1970, pp. 512-513). All of the R^2

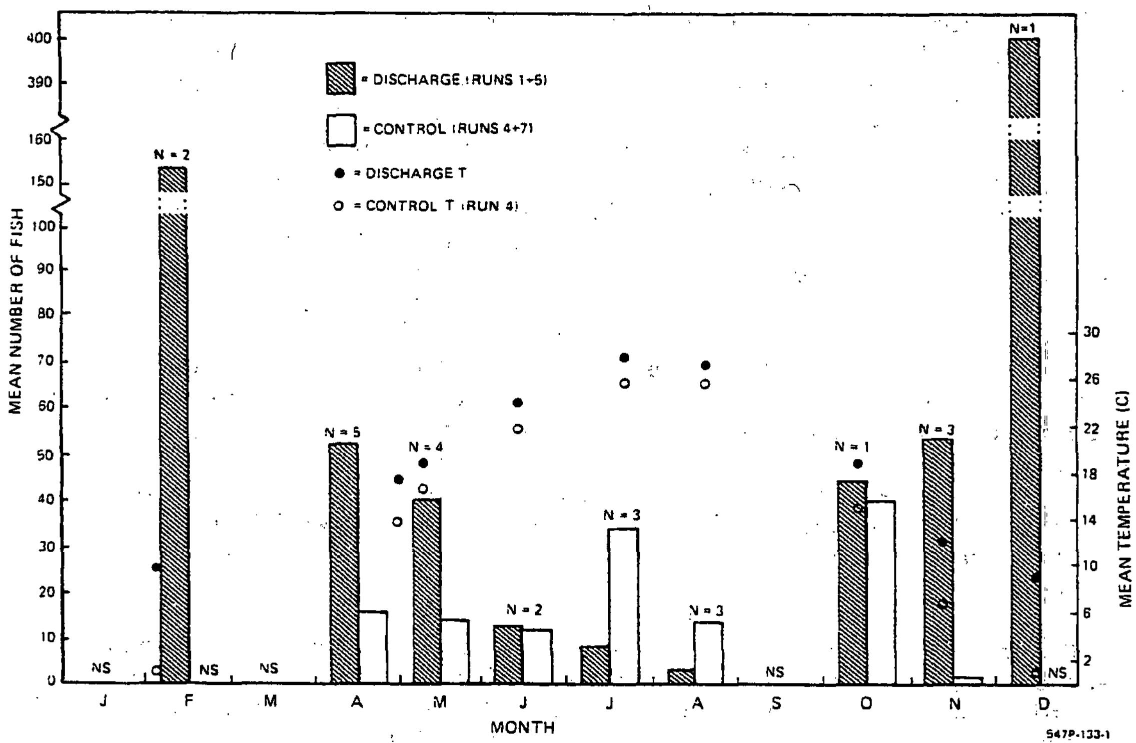

Figure VI-9. Mean number of RIS collected per month in the PINGP discharge (Runs 1 and 5) and at control stations (Runs 4 and 7) near the intake during the period April 1976 through November 1977. The mean temperatures for the samples are also shown (open and closed circles) as well as the number of samples per month (N). NS = no sample.

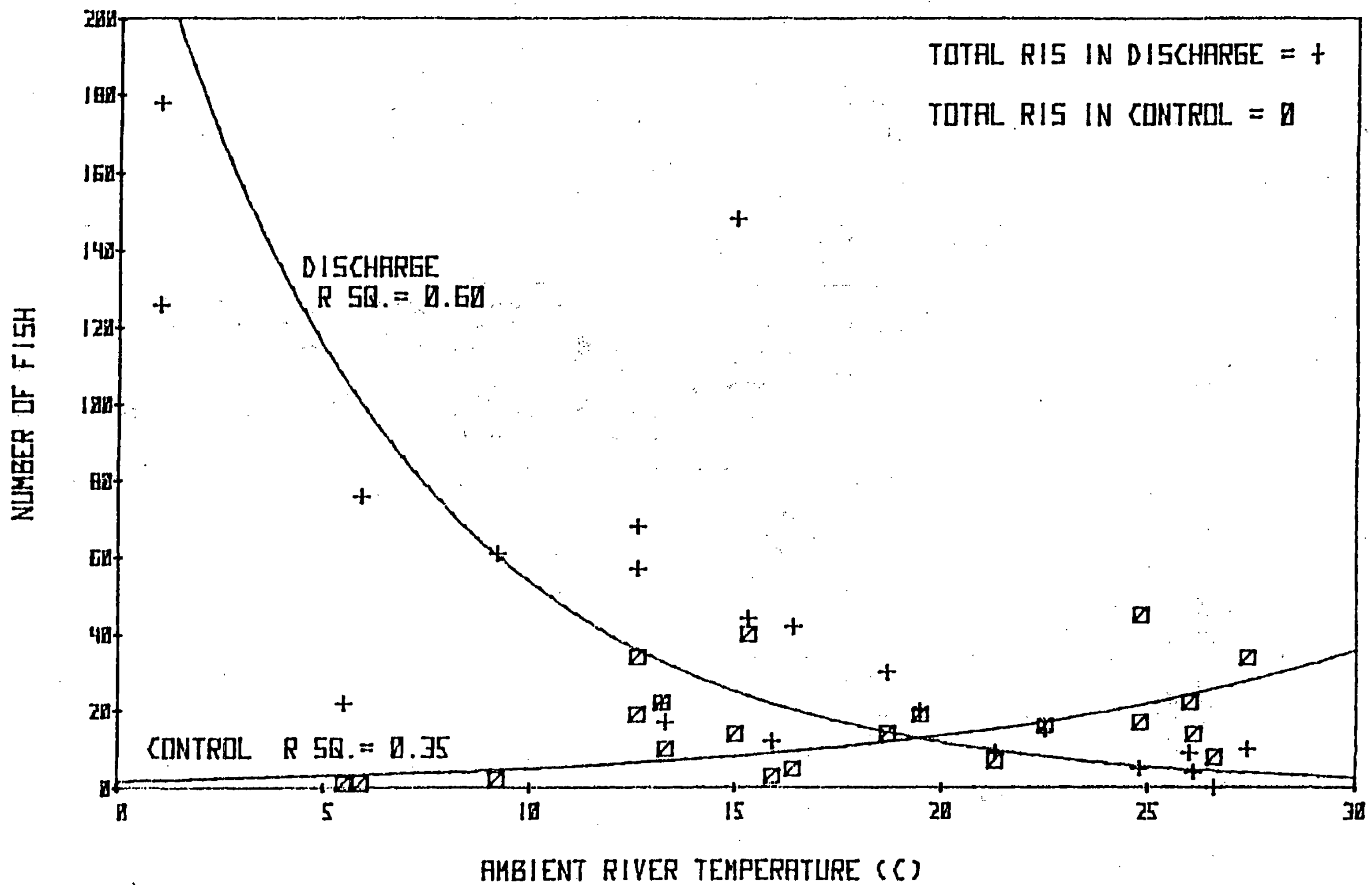

Figure VI-10. Regression of number of total RIS collected in the immediate discharge (Runs 1+5) and control (Runs 4+7) areas against ambient river temperature for the period April 1976 through November 1977 (calculated from DNR unpublished data).

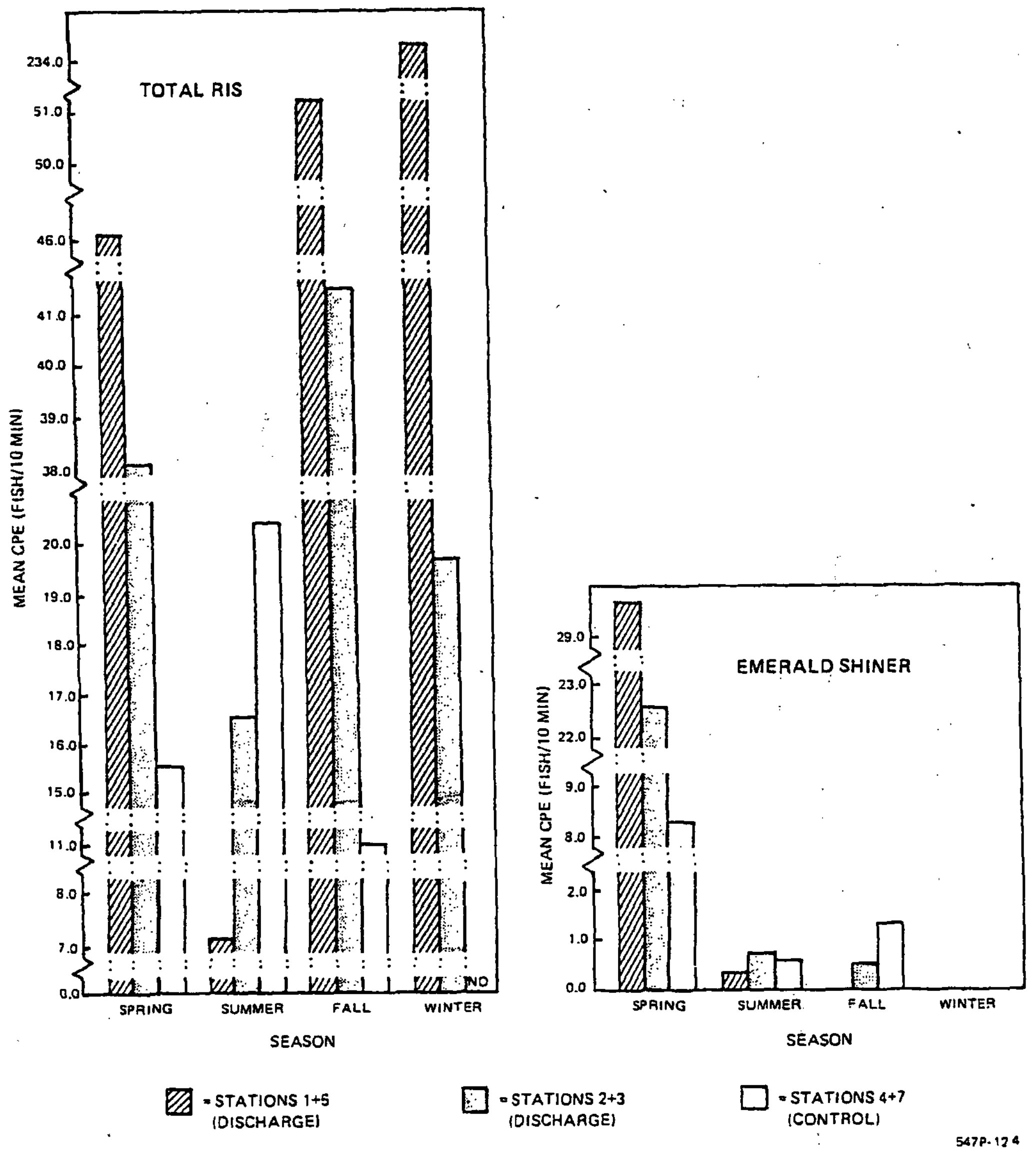

Figure VI-11. Seasonal catch per unit effort at PINGP discharge and control stations for dominant RIS. Data were collected from April 1976 through November 1977, and seasons are defined by water temperature with Spring = 5-21° C, Summer = >21° C, Fall = 21-5° C, and Winter = <5° C (drawn from DNR unpublished data).

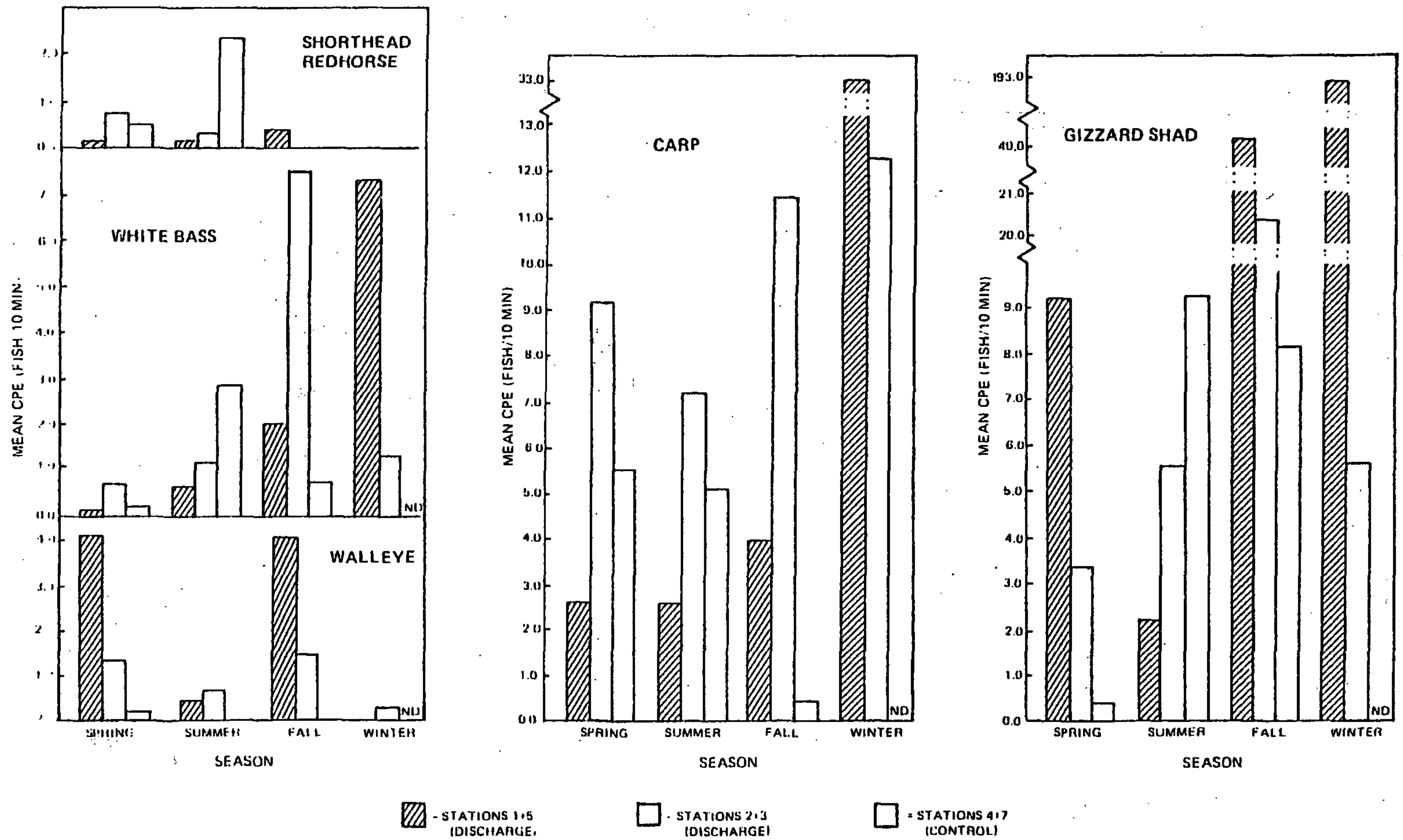

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Figure VI-11 (Continued).

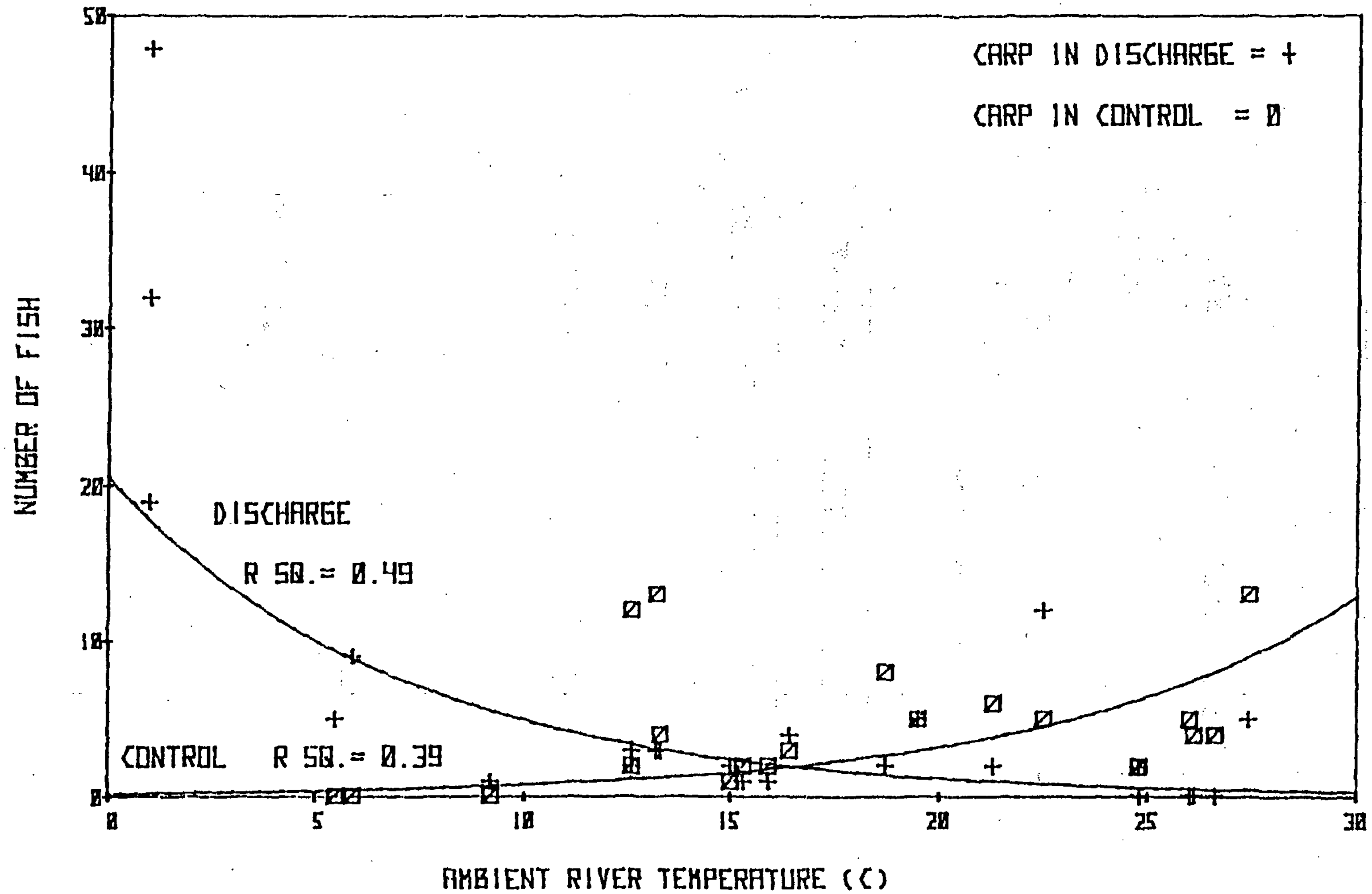

Figure VI-12. Regression of number of carp collected in the immediate discharge (Runs 1+5) and control (Runs 4+7) areas against ambient river temperature for the period April 1976 through November 1977 (calculated from DNR unpublished data).

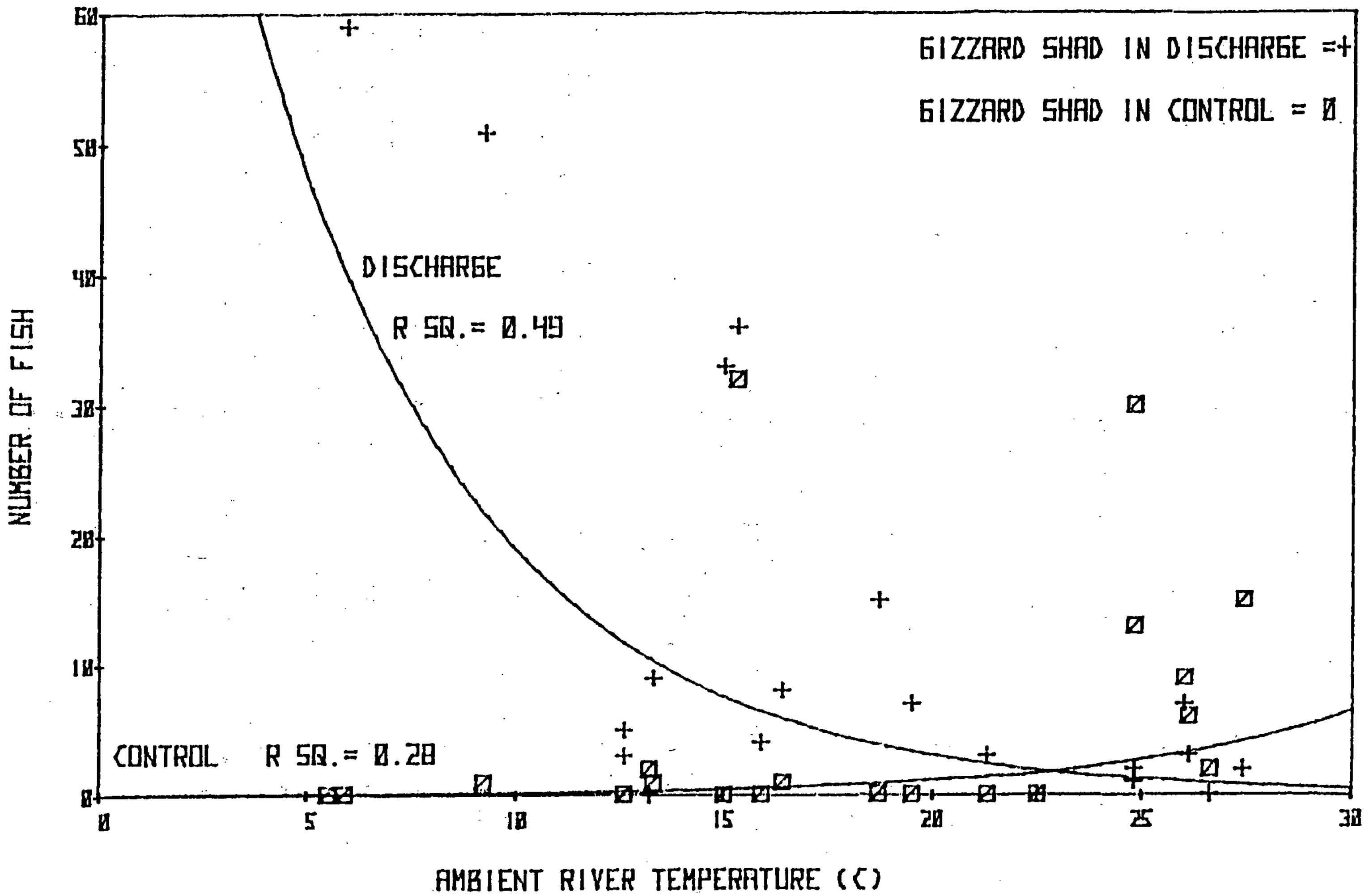

Figure VI-13. Regression of number of gizzard shad collected in the immediate discharge (Runs 1+5) and control (Runs 4+7) areas against ambient river temperature for the period April 1976 through November 1977 (calculated from DNR unpublished data).

values for the regressions were significant ($\alpha = 0.05$), indicating that the number of fish in the discharge and control areas was related to ambient river temperature.

To determine if the apparent differences in numbers of fish collected in discharge and control stations were statistically significant, a chi-square test for independence was performed using the paired run catch data for the most abundant species (data in Appendix Table A-45). The null hypothesis for this analysis assumed an equal catch rate among the three areas (2 discharge and 1 control) during each season (expected situation based on habitat alone), and was rejected when $p < 0.05$ (i.e., 95 percent confidence level). Seasons were defined by ambient river temperatures with winter < 5° C (41° F), spring 5° to 21° C (41° to 70° F), summer > 21° C, and fall 21° to 5° C. The chi-square values and probabilities (p) from this test are presented in Table VI-13, and the null hypothesis was rejected in all cases where sufficient data were available for a valid test. This indicates that the abundances of RIS in the discharge and control areas were not the same as was predicted on the basis of habitat alone. Subtle differences in habitat may exist among the three test areas; however, the major difference is the elevated water temperatures in the two discharge areas. From these analyses, it is concluded that shorthead redhorse, white bass, carp, and gizzard shad avoid the discharge during summer while all species for which sufficient data are available are attracted to the discharge during one or more of the other seasons.

Table VI-13. Results of the chi-square analysis of the discharge electrofishing data for the most abundant RIS by season. The null hypothesis is that the discharge and control areas are the same, and the hypothesis was rejected when $p < 0.05$.

	SPRING		SUMMER		FALL		WINTER	
	Chi²	p	Chi²	p	Chi²	p	Chi²	p
Walleye	38.2	0.00	–[1]		22.8	0.00	–[1]	
White Bass	–[1]		14.5	0.001	8.4	0.02	12.5	0.0004
Gizzard Shad	83.5	0.00	35.4	0.00	131.3	0.00	529.9	0.00
Carp	33.4	0.00	17.2	0.0002	16.7	0.0002	28.3	0.00
Emerald Shiner	105.2	0.00	–[1]		–[1]		–[1]	
Shorthead Redhorse	–[1]		27.91	0.00	–[1]		–[1]	

[1]Sample size too small for valid statistical test.

4. <u>Effects on Spawning and Reproductive Success</u>. Alterations of natural thermal regimes in aquatic ecosystems may adversely affect spawning and reproductive success of various organisms. Short-term temperature fluctuations that result from irregular water uses for projects such as electric power generation, irrigation, and navigation appear to have greater ecological effects than uniform elevations of temperature by a few degrees (Coutant, 1972, p. 13). Shifts in spawning time of up to a month occur as a result of natural changes in temperature regimes, and this suggests that constant thermal additions may not be harmful as long as temperatures for migration, spawning, and development are not eliminated for important species.

PINGP is a base load facility and thus discharges a fairly constant amount of heat to the Mississippi River. Prolonged residence of fish in the thermal plume may induce premature spawning in those species for which temperature is the predominant controlling factor since suitable temperatures would be available sooner than normal (see Figure III-27). Such altered spawning has been observed at several power plants for white sucker and several species of catfish (Coutant, 1970, p. 375). Premature spawning has not been observed during any of the field studies at PINGP although it could occur in walleye, carp, gizzard shad, and emerald shiners. Field studies have shown that these are the dominant RIS in the discharge during spring, and suitable spawning areas for each of these species exist in the discharge area, although walleye may migrate upriver. Suitable spawning areas also exist in Sturgeon and North Lakes as well as parts of the main river channel. All four species are prolific broadcast spawners, and carp and emerald shiners have an extended spawning period (3 to 4 months). The potential impacts of premature spawning in these species to river populations will be discussed along with other effects on river populations in Section VI A.6.

Temperatures within the thermal plume are calculated to exceed the maximum for short-term (24-hour) survival of adults during the spawning period for most of the RIS (Tables VI-3 through 12). During typical conditions, however, the areas within these potentially lethal temperatures are small [less than 2.6 ha (6.4 A)], particularly when compared to areas in the vicinity of PINGP [e.g., Sturgeon Lake is 324 ha (800 A)] which contain abundant spawning habitat. In addition, not all of the discharge area excluded would be suitable spawning habitat for each RIS. For the proposed extreme conditions, the calculated exclusion areas are less than 16 ha (40 A) (less than 5 percent of the area in Sturgeon Lake) for walleye, channel catfish, gizzard shad, and carp while exclusion areas for northern pike, emerald shiner, and white sucker may be 30 to 50 ha (74 to 124 A). The proposed extreme conditions, however, are expected to occur less than 1 hour in a given month every 278 years (see Section IV B) and thus probably will not occur during the life of the plant. These calculated areas of exclusion are the maximum which adults would avoid as being lethal.

The temperature limits for embryo development are lower than those for adult survival which indicates that adults could lay eggs in areas not suitable for their development. The areas calculated to exceed the limits for embryo development are listed in Tables VI-3 through 12 for each RIS. The maximum areas excluded during typical conditions are 17 ha (42 A) for northern pike and 9 ha (22 A) for walleye in May, which is the end of the spawning period for these species. For the other RIS, exclusion areas are less than 7.6 ha (19 A), and these occur during only a portion of the spawning period. The calculated exclusion areas for typical and extreme conditions are the maximum necessary for complete protection of development; that is, 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 may include little or no suitable spawning habitat for some species, such as northern pike and white sucker, thus reducing the potential for impact considerably.

Larvae produced upriver may also be affected by drifting through the PINGP thermal discharge. Based on a hydraulic study of the area (Stefan and Anderson, 1977), most larvae drifting through the PINGP discharge would have originated in Sturgeon Lake. The horizontal and vertical distribution of these larvae in the water column is not known but probably is not uniform since sampling at the bar racks of the screenhouse has shown densities to be highest near the bottom (NUS, 1976, p. 185). Several possible drift pathways through the discharge area are shown in Figure VI-14 for typical conditions, although southerly winds and eddies would lengthen these pathways considerably. To calculate the drift times, average flow rate through the discharge area was assumed to be 6 cm/sec (0.2 fps) based on velocity measurements taken in the August 1975 thermal survey (see Appendix N), and the longest pathway (A) in Figure VI-14 was utilized. The period of time each species is most likely to occur in the drift was estimated from Figure III-26, and then, short-term lethal temperatures (minus 2° C for 100 percent survival) for each RIS (Table VI-14) were compared to the thermal plume model results for typical conditions in the appropriate months. These data indicate that drifting walleye, white bass, northern pike, carp, and white sucker larvae acclimated to ambient river temperatures would not be thermally stressed. The potential for thermal stress to channel catfish larvae drifting through the discharge area exists in July and August since larvae could be exposed to 31° C (88° F) for 23 minutes and 29° to 31° C (84° to 88° F) for 73 minutes in July and 29° to 30° C (84° to 86° F) for 50 minutes in August. The upper tolerance limit of 31° C (50 percent mortality) in Table VI-14 is for an unspecified time of exposure (probably 24-hours or longer) so that shorter exposure (approximately 1 hour) to this temperature would not be expected to have adverse effects on drifting larvae. Furthermore, channel catfish guard their eggs and larvae (see Section III C.2.b) so that few would be expected to occur in the drift.

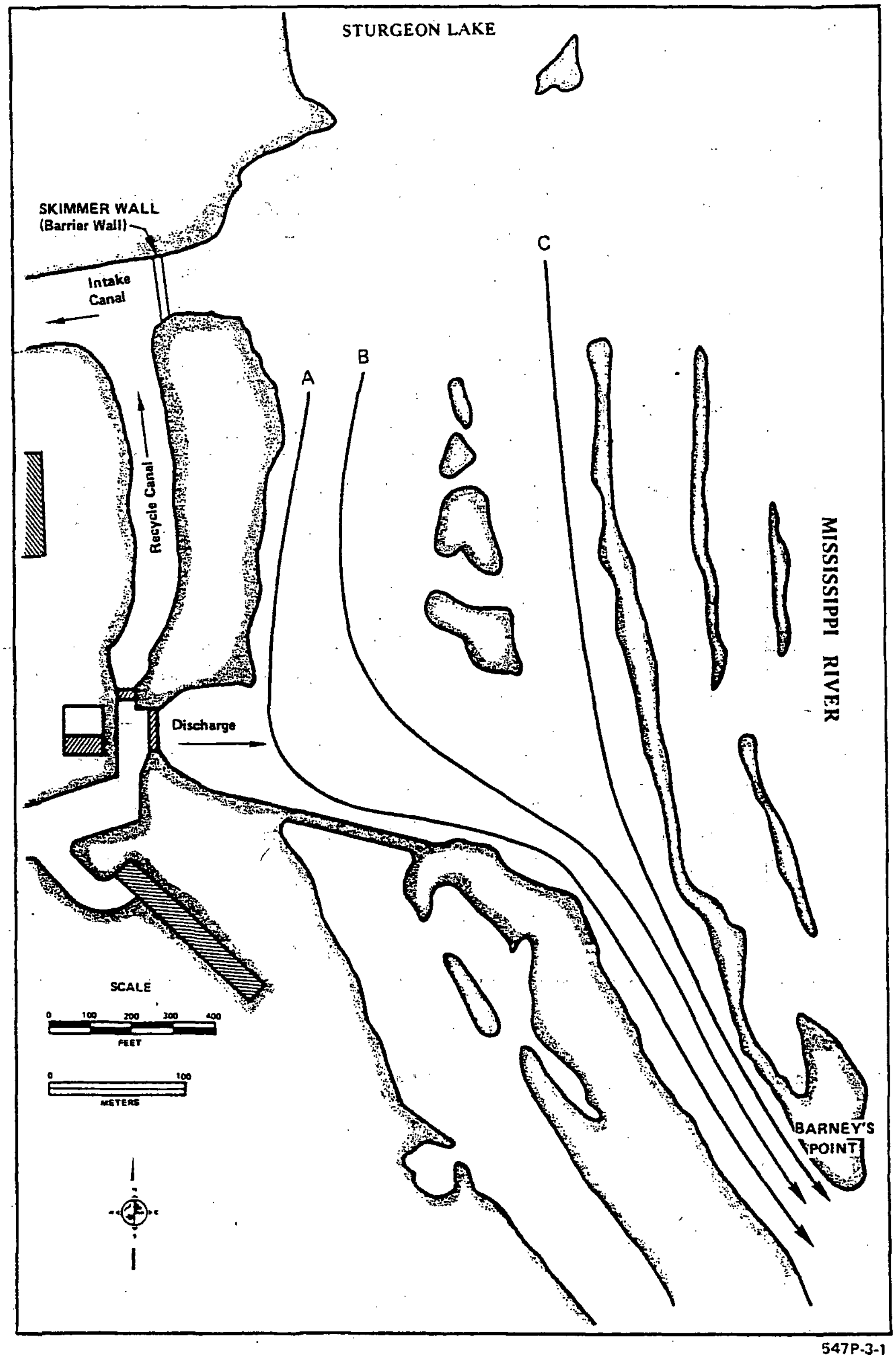

Figure VI-14. Pathways by which planktonic organisms may drift through the PINGP discharge area (without considering recirculation).

Table VI-14. 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

5. <u>Cold Shock Potential</u>. Cold shock may occur during winter when fish that have become acclimated to temperatures in the thermal discharge and recycle canal are suddenly exposed to ambient temperatures either from sudden removal of the heat source (both units shut down) or from swimming out of the plume (predator escape, 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.

To ensure protection of all warm water fish species a 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 (Figure VI-5). 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. Temperatures in the plume routinely exceed the recommended MWAT. During typical winter conditions (December 1975) when ambient temperatures were near 0° C (32° F), plume temperatures exceeded 10° C (50° F) in an area of approximately 4.4 ha (10.9 A). This area is sufficient for fish to congregate and acclimate to the elevated temperatures; thus, the potential for cold shock at PINGP exists. For proposed worst case conditions of 7-day, 10-year low flows and low ambient temperature, the area with temperatures greater than 10° C (50° F) is predicted to be 6.9 ha (17 A).

Both units may shut down simultaneously during winter, and the probability of this has been calculated in Section VI B. During refueling of one unit, the probability of a trip at the other unit is 0.55 (55 percent), and the probability of simultaneous unscheduled trips is 0.0004. Since refueling occurs during winter and early spring, the probability of simultaneous shutdowns and potential cold shock to fish residing in the plume is at least 0.55 per year.

Based on thermal data for the RIS presented in Appendix A (Tables A-11 through A-20), 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 suckers. Cold shock may occur in walleye and emerald shiners acclimated to 20° C (68° F) or higher, while gizzard shad would be very likely to suffer cold shock. The area within the plume (2 unit operation) where temperatures are above 20° C is 0.6 ha (1.5 A) for typical conditions (December) and 0.9 ha (2.2 A) for proposed extreme conditions (January). The areas would be somewhat smaller during one unit operation during refueling. No data are available for predicting cold shock potential in the other RIS; however, shorthead redhorse are probably similar to white suckers in their tolerances, and carp would probably not be adversely affected by cold shock.

Data from the discharge electrofishing study performed at PINGP in the winter of 1976-1977 indicate that gizzard shad and carp are the most abundant RIS in the discharge along with some white bass and black crappie. Thus, cold shock mortality is predicted primarily for gizzard shad. During past operation of PINGP, forced trips have occurred when one unit was refueling, although no surveys were conducted to assess cold shock. Based on past operating experience, procedures have been devised to minimize potential cold shock when a forced trip occurs during refueling. The cooling towers will be bypassed and the discharge gates lowered to allow a more gradual temperature decrease.

To summarize, cold shock effects are predicted to occur at PINGP at least once every two years during the winter refueling of one unit. The species most likely to be affected is gizzard shad, although some white bass, black crappie, and carp may be killed also. Current operating procedures at PINGP are designed to reduce the effects of cold shock, and the potential impacts of cold shock mortality on river populations are discussed in the next section.

6. 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. Furthermore, the evaluation of a single perturbation such as a power plant discharge are often complicated by other activities of man (e.g., sewage disposal, dredging, building dams, etc).

The PINGP 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.

Spawning a few weeks early should not have adverse effects on river populations unless a large proportion of the population were involved and this spawning were unsuccessful. Since population estimates for the RIS are not available for various habitats near PINGP in spring, electrofishing catch per unit effort will be compared to assess relative abundances. Walleye, gizzard shad, and emerald shiner were more abundant in the warmest parts of the discharge than in the intake area (Figure VI-11) while carp were more abundant in the cooler parts of the discharge. A comparison of catch rates during spring in the intake and discharge areas (Figure VI-11) with those in Sturgeon Lake and the Mississippi River (Figure III-23) shows that the density near the intake was similar to the density in Sturgeon Lake for most of the RIS while the catch rate for walleye, gizzard shad, emerald shiner, and carp was considerably higher in the discharge than in either Sturgeon Lake or the Mississippi River. The difference, however, may not be as great as noted here since the two studies were not conducted simultaneously. This may be particularly true for walleye which spawn in April to mid-May. The discharge study data were collected in April and early May while the river study data were collected primarily in late May and June.

To estimate potential effects of premature spawning, relative abundances must be known for the discharge canal area and the area outside the plume for each of the RIS. To calculate abundance from catch rate, two assumptions were made: equal sampling efficiency at all locations, and the locations sampled are representative of the areas to be compared. The first assumption is probably true while the second may not be since fish are usually not evenly distributed in a water body. Mean catch per effort (15 minutes) for each location (from Figures VI-11 and III-23) was multiplied by the surface area of the locality sampled: 324 ha (800 A) for Sturgeon Lake, 180 ha (445 A) for the Mississippi River from Brewer Lake cut to the PINGP intake, 83 ha (205 A) for the Mississippi from the PINGP intake to Lock and Dam No. 3, 4 ha (10 A) for Runs 1+5 in the discharge, and 3 ha (7.5 A) for Runs 2+3 in the discharge. From these calculations, an estimated 13 percent of the walleye collected near PINGP were found in the discharge areas during spring while only 2 percent of the carp and 3 percent of the gizzard shad occurred there. Emerald shiner, on the other hand, appeared to concentrate in the discharge with an estimated 50 percent of the population present there in spring. Two factors, however, weaken the reliability of this estimate. Emerald shiners school and remain offshore in spring and summer seeking deeper waters during the daytime in spring (Scott and Crossman, 1973, p. 442). Electrofishing in Sturgeon Lake and the main channel of the Mississippi River was conducted along the shoreline during daytime and, thus, probably underestimated abundances considerably in spring.

Based on the above calculations, potential premature spawning of carp or gizzard shad in the discharge canal is predicted to have negligible effects on river populations since relatively few fish of these species are present in the discharge during spring. For walleye and emerald shiner, which are calculated to be relatively abundant in the discharge in spring, potential effects of premature spawning on river populations are predicted to be minimal. The relative abundances of these species in the discharge are probably overestimated as a result of differences in the time periods sampled and their patchy distributions, and it is unlikely that all of the fish in the discharge would spawn early. Furthermore, premature spawning in itself should not affect general population levels unless much of it were unsuccessful. Emerald shiners have an extended spawning period (May through August, with maximal activity in summer) and may spawn more than once per season (see Section III C). Thus, spawning a few weeks early by part of the population would be expected to have little affect on the whole population.

Another potential effect of the PINGP discharge on river populations is the exclusion of fish from otherwise suitable spawning areas. Based on data presented in Tables VI-3 through 12, however, the areas potentially excluded from reproduction are less than 10.8 ha (26.7 A) for those species expected to spawn in the discharge, and this is less than 2 percent of the area in Sturgeon Lake and the Mississippi River from Brewer Lake cut to Lock and Dam No. 3. Therefore, exclusion of spawning areas is predicted to have negligible effects on river populations since adequate alternate areas exist nearby.

Thermal stress to larvae drifting through the discharge is not predicted to adversely affect any of the RIS (see Section VI A.2); consequently, no impacts to river populations are expected. Cold shock in winter is predicted to occur primarily to gizzard shad when one unit trips while the other is refueling (greater than 55 percent chance per year); however, no adverse impacts to river populations are expected from such phenomena. Gizzard shad naturally have large winter die-offs (Jester, 1972, p. 46), and the PINGP discharge may provide a thermal refuge for those individuals residing in the plume during the colder months, thus reducing their natural winter mortality rate. Cold shock mortality resulting from plant outages would then represent delayed natural mortality. A further consideration is that this prolific species needs cropping to control population size (Eddy and Underhill, 1974, p. 148).

The PINGP thermal discharge should not inhibit any fish migrations in the area. The discharge is located in a backwater area off the main channel of the river, and the plume entering the river remains along the west (Minnesota) bank of the river which is also the navigation channel. In addition, the temperature increase in the main channel generally does not exceed 2.8° C (5° F). Thus, most of the river is not influenced by the plume and is available for migrations. Walleye and suckers are the only species that may migrate to spawn, and these species can easily avoid the plume.

Less than large scale changes in fish population structure are difficult to predict and nearly impossible to measure as noted previously. Many factors are involved in population structure stability including natural density-dependent compensatory mechanisms and influences of man including fishing, navigation, and pollution. Any potential shifts in fish population structure as a result of the PINGP thermal discharge could be masked by other man-induced or natural changes.

No impacts to endangered species are predicted since no endangered species have been reported in the area.

Potential effects of the PINGP discharge on sport fishing are expected to be beneficial. Fishing pressure in the immediate vicinity of PINGP (Section 3 of creel census) is light compared to that in the tailwaters of Lock and Dam No. 3 (Section 4 of creel census) and occurs mainly during open water months (see Section III C.2.g). Fishing success, however, has remained higher in the vicinity of PINGP than in the tailwaters below Dam No. 3 during plant operation. Fishing success should be enhanced in the immediate discharge area (approximately 6 ha) during spring and fall when fish are attracted to the plume, an area that represents 7 percent of Section 3. This is corroborated by the fact that fishing pressure in the discharge has been observed to be somewhat higher during March and April (Geis and Gustafson, 1977). Thus, some fishermen were apparently taking advantage of the situation, and the catch was primarily white bass.

The PINGP thermal discharge is expected to have negligible effects on RIS predator-prey interactions in the aquatic ecosystem near the plant. The area of potential influence is small (less than 10 ha) in relation to the area of lower Pool No. 3 (587 ha). 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, primarily during the cooler months of the year. Walleye and white bass are the only piscivorous (fish-eating) RIS which show an increased abundance in the discharge that is 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 PINGP thermal discharge and subsequently affect populations through physiological changes such as altered age at maturity. During typical conditions, 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). For walleye and black crappie, however, most of the plume is expected to exceed the MWAT for growth during August and July, respectively. Ambient temperatures in July exceed the criterion for walleye. The plume beyond the mixing zone is located along the west bank of the river main channel which is also the navigation channel. Thus, this area is probably not very suitable 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 were not found to differ significantly (Krosch, 25 October 1977). Consequently, thermal plume effects on growth and river populations are expected to be negligible. During extreme environmental conditions, the areas affected are larger, but the frequency of occurrence (0.000005) of these conditions is so low as to have no measurable effect on fish growth.

7. Effects on Parasites and Diseases. No specific parasitological studies have been performed near PINGP to determine if parasitism or diseases in fish are influenced by the thermal discharge. During routine field sampling, however, the incidence of external parasites and diseases has not been observed to occur more frequently in the discharge than in other areas. These observations are supported by studies at a power plant on the White River, Indiana which have shown no definite influence of the thermal discharge on infestation rate by the ectoparasites, *Lernaea cyprinacea* and *Argulus* sp. The occurrence of *Lernaea* on centrachids did not appear to be related to the effluent (Proffitt and Benda, 1971, p. 60), and this parasite was not found on carp, gizzard shad, channel catfish, or black crappie, while less than one percent of the emerald shiners in both discharge and control areas were parasitized (Whitaker et al., 1973, pp. 81-91). *Argulus* was only found on one carp (Proffitt and Benda, 1971, p. 61).

The incidence of other parasites, particularly internal parasites, is not expected to increase as a result of the PINGP thermal discharge. Several of these require intermediate hosts which may be terrestrial during their life cycle and thus may not be influenced appreciably by PINGP.

B. MACROINVERTEBRATES

1. Discussion and Critique of Sampling Methods. The chronology and methodology of sampling are summarized in Appendix Table A-22. Although a number of methods were utilized for collecting macroinvertebrates near PINGP, the two primary sampling methods during the last two years (1975 and 1976) were dredge and artificial substrate. The basic criticisms summarized by Murarka (1976) covered most of the shortcomings of the macroinvertebrate data collection at PINGP. These included the changing or dropping of stations and methods unjustifiably or without intercalibration. These inconsistencies, possibly a result of changing consultants while monitoring was in progress, have rendered much of the preoperational data useless for statistical comparisons with operational periods. Another problem with the macroinvertebrate data was that the number of replicates collected at each station after the monitoring methods had become relatively standardized was inadequate to show anything but large temporal or spatial variations between stations. Weibe (1971) has shown that single samples collected at two separate stations would have to vary by a factor of four to be significantly different. Replicate samples were taken at some stations during later years, although only one value was reported for each station as a result of replicate pooling. Table VI-15 shows that with no simultaneous replicates taken at each sampling station, only large differences between stations were likely to appear to be statistically significant. Generally, as the number of replicates increases, the power of a statistical test for showing differences between stations increases; that is, the percentage difference between stations required to demonstrate a significant difference decreases with an increase in the number of replicates. The same argument holds for demonstrating the significance of temporal variation at a single station. Further discussion regarding the power of sampling procedures is provided in Appendix B.

The wide variety of sampling techniques used to assess macroinvertebrate populations near PINGP, however, enhances the utility of the information. McConville (1975) summarized both dredge and artificial substrate procedures tested for sampling efficiency near PINGP. Appendix Table A-22 describes the various methodologies used. Even though sampling methods were not standardized until operational years, information on macroinvertebrate populations have been accruing since 1970. This is important in defining the variety of macroinvertebrates occurring near PINGP, especially the occurrence of uncommon taxa which may include unusual, nuisance, or endangered species. The number of macroinvertebrate taxa collected (see Appendix K) is large for midwestern rivers; however,

Table VI-15. Power calculations for non-fisheries biological data collected near PINGP (no simultaneous replicates taken).

BIOTIC CATEGORY	PROPABILITY (AT α = 0.05) OF DETECTING SIGNIFICANT DIFFERENCES BETWEEN STATIONS WHEN SIZES OF DIFFERENCES ARE EXPECTED TO BE: (From Appendix B)		
	SMALL (f = 0.10)[1]	MEDIUM (f = 0.25)[1]	LARGE (f = 0.40)[1]
Macroinvertebrate Density (Dredge)[2,4]	0.09	0.36	0.80
Macroinvertebrate Density (Artificial Substrate)[2,4]	0.08	0.31	0.71
Macroinvertebrate Species Diversity (Dredge)	0.08	0.28	0.66
Macroinvertebrate Species Diversity (Artificial Substrate)[2]	0.07	0.18	0.42
Zooplankton Density[2,4]	0.11	0.53	0.94
Zooplankton Species Diversity[2]	0.07	0.23	0.61
Phytoplankton Density[3,4]	0.09	0.43	0.86
Phytoplankton Type I Productivity[2]	0.10	0.60	> 0.995
Phytoplankton Biovolume[2]	0.08	0.28	0.66
Phytoplankton Species Diversity[2]	0.08	0.28	0.66
Phytoplankton Type III Productivity[2]	0.06	0.46	0.84
Periphyton Density[2,4]	0.08	0.31	0.67
Periphyton Chlorophyll a[2]	0.08	0.31	0.67
Periphyton Species Diversity[2]	0.07	0.23	0.53

[1]Effect size index defined in Appendix B.

[2]Two-way ANOVA.

[3]Crossed and Nested two-way ANOVA.

[4]Natural log transformation.

the federally endangered Higgins Eye pearly mussel has not been collected during the seven years of sampling near the site. Such information is critical in assessing impacts at PINGP because the same mussel has been found both up and downriver from the site at a distance of less than 81 km (50 mi) (Krosch, 25 October 1977).

2. Effects of Past Operation.

a. RESULTS OF DATA REANALYSIS. The following section presents only the results of the data reanalysis. A discussion of the biological relevance of these findings is presented later in Section VI B.2.b.

1) Analysis of Variance (ANOVA) and Duncan's Multiple Range Test. Table VI-16 summarizes a reanalysis of the macroinvertebrate data. For operational years, ANOVA indicates that macroinvertebrate densities for both dredge and artificial substrate samples varied significantly among sampling dates. Comparisons of macroinvertebrate densities among stations for dredge and artificial substrate samples indicate that the densities were also significantly different during the same period. Further analysis of the dredge data using Duncan's Multiple Range Test (DMRT) (Table VI-17; Figure VI-2) shows that only Station 18 (recycle canal) was grouped separately from the other stations. For artificial substrate densities, the group containing Stations 18, 10 (upriver main channel), and 21 (near-field discharge) was found to be significantly different from the group including Stations 12 (near-field intake), 25 (discharge near Barney's Point), and 6 (south-central Sturgeon Lake). Some of the same stations are included in separate groupings because their affinity to other stations is ambiguous. Further analysis with the t-Test (Section VI 2.a.2) was conducted to determine whether or not specific station pairs differed significantly from each other when the DMRT presented ambiguous results.

   Analysis of variance showed species diversity to be significantly different between stations for both artificial substrates and dredge samples over the period 1975 to mid-1977 (Table VI-16). The DMRT (Table VI-17) then grouped artificial substrate diversity Stations 6 and 10 as significantly different from grouped Stations 6, 12, 21, and 25. Station 18 differed significantly from the other station groups. For dredge species diversity Stations 6, 10, 12, and 25 were grouped as significantly different from Stations 18 and 21 during the same period.

   Power calculations are summarized in Table VI-15 and indicate that only large differences between station mean values would likely be detected as significant.

2) Student's One-Tailed t-Test. When the ANOVA indicated that densities varied significantly among stations and the DMRT

Table VI-16. Results of two-way ANOVA for biotic categories sampled near PINGP in 1973-1977 (summarized in Appendix B).

BIOTIC CATEGORY	YEARS RE-ANALYZED	REANALYSIS	DEGREES OF FREEDOM	F[1] VALUE	P > F	SIGNIFICANT DIFFERENCE[5]
Macroinvertebrates						
Density[2] (Dredge)	75-77	Between Stations	6	17.86	0.0001	yes
Density[2] (Dredge)	75-77	Between Months	16	11.76	0.001	yes
Species Diversity (Dredge)	75-76	Between Stations	5	14.57	0.0001	yes
Species Diversity (Dredge)	75-76	Between Months	13	4.50	0.0001	yes
Density[2] (Artificial Substrate)	75-77	Between Stations	5	10.82	0.001	yes
Density[2] (Artificial Substrate)	75-77	Between Months	21	11.71	0.001	yes
Species Diversity (Artificial Substrate)	75-76	Between Stations	5	8.06	0.0001	yes
Species Diversity (Artificial Substrate)	75-76	Between Months	10	9.89	0.0001	yes
Zooplankton						
Density[2]	75-76	Between Stations	6	7.21	0.0001	yes
Density[2]	75-76	Between Months	23	55.45	0.0001	yes
Species Diversity	75-76	Between Stations	6	0.45	0.8445	no
Species Diversity	75-76	Between Months	23	6.07	0.0001	yes
Phytoplankton						
Density[2]	73,75-76	Between years 73 and 75-76	1	4.29	0.0414	yes
Density[2]	75-76	Between years 75 and 76	1	0.00	0.9653	no
Density[2]	75-76	Between Stations	4	1.00	0.4143	no
Density[2]	75-76	Between Months	23	28.71	0.001	yes
Species Diversity	75-76	Between Stations	4	1.06	0.3864	no
Species Diversity	75-76	Between Months	10	2.21	0.0316	yes
Biovolume	75-76	Between Stations	4	1.11	0.1789	no
Biovolume	75-76	Between Months	10	18.48	0.0001	yes
Productivity[3]	76	Between Stations	1	178.16	0.0001	yes
Productivity[3]	76	Between Days	8	6.75	0.0001	yes
Productivity[4]	76	Between Stations	4	14.26	0.0001	yes
Productivity[4]	76	Between Days	34	24.41	0.0001	yes
Periphyton						
Density[2]	75-76	Between Stations	2	15.63	0.0001	yes
Density[2]	75-76	Between Months	22	6.79	0.0001	yes
Species Diversity	75-76	Between Stations	2	1.50	0.2381	no
Species Diversity	75-76	Between Months	14	5.09	0.0001	yes
Chlorophyll a	75-76	Between Stations	2	3.98	0.0256	yes
Chlorophyll a	75-76	Between Months	21	5.85	0.0001	yes
Phaeophytin a	75-76	Between Stations	2	0.36	0.6975	no
Phaeophytin a	75-76	Between Months	21	4.84	0.0001	yes

[1] Type I as defined in Appendix B.
[2] Natural log transformation.
[3] Only near-field intake and discharge stations (HDR Nos. 14 and 19) involved; known as a Type III experiment.
[4] Both near- and far-field stations involved (HDR Nos. 5, 9, 14, 19, and 27); known as a Type I experiment.
[5] The null hypothesis that no difference exists between stations or dates is rejected ($\alpha < 0.05$).

Table VI-17. Results of Duncan's Multiple Range Tests for biotic categories sampled near PINGP, 1973-1977.

BIOTIC CATEGORY	DUNCAN'S MULTIPLE RANGE TEST FOR STATIONS[1] (HDR DESIGNATED STATIONS)			
	A GROUPING[3]	B GROUPING	C GROUPING	D GROUPING
Macroinvertebrate Density[2] (Dredge)	6, 10, 12, 21, 25, 27	18		
Macroinvertebrate Density[2] (Artificial Substrate)	18, 10, 21	12, 25, 6		
Macroinvertebrate Species Diversity (Dredge)	10, 6, 12, 25	21, 18		
Macroinvertebrate Species Diversity (Artificial Substrate)	6, 10	6, 21, 12, 25	18	
Zooplankton Density[2]	27, 10	10, 12, 6	12, 6, 25, 21	21, 18
Phytoplankton Productivity (Type III[4])	14	19		
Phytoplankton Productivity (Type I[5])	14	27, 9, 5	19	
Periphyton Chlorophyll a	13	20, 25		
Periphyton Density[2]	13, 20	25		

[1]Data base derived from Table VI-16.

[2]Indicates natural log transformations.

[3]A grouping is a number of stations (or one station) whose mean value differs significantly (α = 0.05) from other station groupings (see Appendix B for details).

[4]Type III productivity refers to measurements taken only at near-field intake and discharge stations.

[5]Type I productivity refers to measurements taken at several stations, both near- and far-field.

produced ambiguous results regarding specific station groupings, then selected ambiguous station pairs were subjected to the Student's t-Test. The One-Tailed Student's t-Test was utilized to specifically address the questions: 1) are macroinvertebrate densities in the discharge significantly lower than those in the intake, and 2) are densities upriver from PINGP significantly lower than those downriver and influenced by the thermal plume? Table VI-18 shows that for dredge macroinvertebrate density, Station 12 (intake) did not differ significantly from Station 21 (discharge), nor did Stations 10 (upriver) and 27 (downriver) differ significantly. For artificial substrates, only stations in the immediate plant area could be compared since insufficient data were available for the other stations. No significant difference was found between Stations 12 and 21 which clarifies the results of the analysis of variance and Duncan's Multiple Range Test. Since no significant differences were observed in the immediate vicinity of the plant, it is unlikely that significant differences would occur between the up and downriver artificial substrate samples as a result of the PINGP thermal discharge.

3) Multiple Regressions. Stepwise multiple linear regressions were performed, comparing dredge and artificial substrate macroinvertebrate population densities with a limited number of relatively simultaneous (sampled within one week of biological samples) water quality parameters (Table VI-19) collected at hydrographically similar stations (Table III-31). For a complete list of all water quality variables considered, see Appendix B. For dredge macroinvertebrates, neither temperature nor dissolved oxygen was found to be significantly related to total population densities; only bottom suspended residue (sediments) was selected by stepwise regression at a low R^2 value of 0.15. This indicates that macroinvertebrates collected in bottom substrates may have varied in density as a result of parameters other than temperature or dissolved oxygen, and coincided only weakly with concentrations of suspended residue. Surface ammonia was the only water quality parameter selected as related to artificial substrate macroinvertebrate densities ($R^2 = 0.42$). All R^2 values were found to be significant at $\alpha < 0.05$ (see Appendix B). If more intensive water quality sampling had been conducted during the artificial substrate colonization period, better regressions might have resulted.

b. DISCUSSION. Statistical reanalysis of more than two years of operational data tends to confirm the conclusions made by Haynes (1976) and Texas Instruments, Inc. (1977b). In 1975 and 1976, these authors found that the density of macroinvertebrates collected on artificial substrates and in dredge samples was either equal in the intake and discharge or higher in discharge stations on an annual basis. In addition, intake and discharge stations had significantly greater densities than main channel (upriver and downriver) stations for artificial substrate macroinvertebrates. Similarly, Murarka (1976) could not show any significant plant-induced changes to the macroinvertebrate community. Although temperatures in the discharge area varied with time of year and river flow rate, seasonal macroinvertebrate data were not collected frequently enough to test for significant differences between plume and control stations during critically warm times of the year. Thus, the biological monitoring surveys can best be used to show changes in organism density occurring over the annual range of conditions experienced inside and outside the thermal plume. In order to test whether the plume significantly influences macroinvertebrate populations during critical times of the year, short-term intensive studies would have to be performed, involving numerous replicates in the plume and control areas. Although macroinvertebrates colonizing artificial substrates and inhabiting benthic sediments are subject to drift, they tend to show long-term cumulative effects of critical conditions in which they reside. Therefore, it may be justified to say that sampling populations by artificial substrate and dredge on an annual basis inside and outside the plume will probably not show the effects of short-term critical or limiting conditions be they thermal or otherwise. Mortality resulting from short-term critical conditions may be compensated by rapid recolonization and, therefore, may not be obvious in long-term studies.

It was interesting to note from the limited regression analyses that populations sampled by artificial substrate and dredge did not respond negatively to elevated temperatures in the PINGP discharge. Apparently, some other unmeasured parameters, such as toxicants or anomalies in processing samples, caused more variations in total population density than any of the measured water quality parameters. Because populations were similar at all stations, there were probably no controlling factors between stations that did not affect all stations similarly. Characteristics of the populations from artificial substrate and dredge samples other than total population densities may have been influenced by plant operation. For instance, changes in species composition were evident between stations for both dredge and artificial substrate populations (Tables VI-16 and VI-17). Also, changes in growth rate, adult size, or biomass could have occurred. Kititsyna and Sergeeva (1976) found that macroinvertebrates exposed continuously to heated water in a cooling reservoir increased significantly in size compared to others found outside the plume. At the site studied by the above authors, the average temperature differential between plume and control stations was 3° to 5° C (5° to 9° F) with a maximum absolute temperature of 26° C (79° F) which is similar to conditions at PINGP. A similar trend thus could be occurring at PINGP.

Regarding species shifts, Benda and Proffitt (1974) found that densities of mayflies, caddisflies, and certain other invertebrates were depressed within 168 m (550 ft) of a power plant discharge on the White River (Indiana) when discharge temperatures exceeded 31.1° C (88° F). Possible evidence for species shifts in the PINGP plume has been documented (Haynes, 1976). In 1975, Shannon-Weaver diversities were reported to be significantly greater in control (intake) stations for both dredge and artificial substrate samples than at Station 21 (immediately outside the discharge gates). Reanalysis of dredge and artificial substrate species diversity data showed that for dredge data, the near-field plume station (21) and the recycle canal (18) were found to differ significantly from all other stations. For artificial substrate data, near-field plume stations (21 and 25) did not differ significantly from near-field control stations (12 and 6) for species diversity, but Station 18 differed significantly from all other stations. Differences in substrates or currents between stations may have partially caused these inconsistencies, and these are discussed later in this section.

Examination of population densities for RIS shows that only *Hydropsyche* and *Stenonema* were found in sufficient numbers to make comparisons between control and plume stations and then only on artificial substrates. Appendix Table A-26 summarizes the information regarding these two RIS. Although data are insufficient to conduct detailed statistical analysis, densities in plume stations as opposed to non-plume stations appear enhanced. Large seasonal variation is also quite evident.

To summarize, reanalysis of the limited site-specific information indicates that the only measurable effects of PINGP thermal discharges to macroinvertebrates during more than two years of operation may have involved changes in species diversity between plume and control stations, indicating a shift in species composition. Total population densities have remained similar inside and outside the plume over the same period. It is apparent that neither temperature nor bottom substrate variations between stations were significantly related to macroinvertebrate density, although one of these parameters may have influenced changes in species diversity. According to Simonet (1975), bottom sediments and current conditions for various stations were as follows: Stations 25, 27, and 25 were sand with current; Stations 6, 10, and 12 were mud with or without current; and Stations 15, 18, and 21 were light, shifting sand with current. These differences in current and substrate between both near-field and far-field stations may have accounted for some of the variations in diversity between plume and control stations for dredge and artificial substrate macroinvertebrates. Thus, background information does not indicate that the plant has affected the density of macroinvertebrates, although a combination of elevated temperatures, current, and bottom conditions could have caused a difference in diversity for intake and upriver control stations as compared to discharge canal and downriver stations in the plume.

3. Predicted Impacts. Thermal effects on macroinvertebrates depend upon absolute temperature in addition to exposure time and thermal elevation. Macroinvertebrates may be either sessile or drifting, resulting in differing exposures to the PINGP discharge. While drifting, organisms will generally be exposed for shorter periods and to lower elevated water temperatures than those organisms attached to substrates near the head

of the discharge canal at the discharge gates (Figure VI-14). Drift time within the discharge area may be increased substantially by wind-induced recirculation; however, drifting macroinvertebrates will generally be subjected to a lower level of thermal stress than aufwuchs and benthos occurring in the near-field discharge. Table VI-20 lists drift times and maximum exposure temperatures for the longer two pathways in Figure VI-14.

Although literature data (Appendix Tables A-28 and A-29 and Figure A-6) for thermal tolerances of macroinvertebrate RIS are limited, some drift survival predictions can be made regarding proposed plume conditions. All four RIS have been observed to survive maximum temperatures far in excess of any they could encounter in the plume, either drifting or sessile in the discharge canal. The 96-hr LT_{50} for *Stenonema* has been established at 25.5° C (80° F) at an acclimation temperature of 10° C (50° F). *Stenonema* could drift through temperatures up to about 29° C (84° F) for 198 minutes during the proposed extreme conditions in May with an ambient temperature of 22.8° C (73° F). *Stenonema* would be expected to survive such a worst case temperature elevation, however, because its acclimation temperature would be increased by almost 13° C (23° F) and exposure time would be much shorter than the 96-hour LT_{50}. Proposed extreme plume predictions for an ambient temperature of 10° C (50° F) would approximate 17° to 18° C (63° to 64° F) for a maximum drift encounter temperature with no predicted lethal effects. These extreme conditions are predicted to occur at a frequency of less than one hour in a given month over a 278-year period. All other RIS appear to be less sensitive than *Stenonema* to drift stress.

From similar information for non-RIS macroinvertebrates, it appears that most other macroinvertebrates will not be harmed by drifting through the plume. Only in locations closest to the discharge gates should some of the benthic macroinvertebrates (e.g., *Taeniopteryx maura, Baetis tenax,* and *Ephemerella subvaria*) be periodically eliminated. Since other species should take the places of those benthic invertebrates lost from the head of the discharge canal, total densities should not be reduced although species diversity and composition may change.

For fixed benthic or aufwuchs macroinvertebrates, preferred or most common temperature at which a taxon is recorded appears to be the relevant criterion for predicting impact (Tables VI-21 through VI-24). This temperature range has been established at 27° to 29° C (81° to 84° F) for *Hydropsyche* and at 28° C (82° F) for *Macronemum* (Appendix Table A-29). Similar information for the other RIS is lacking. Information presented in thermal matrix Table VI-23 indicates that *Hydropsyche* will be excluded from 6.6 ha (16 A) or less during typical spring to summer conditions which is the equivalent of about 2.0 percent of Sturgeon Lake. Habitat exclusion in the discharge canal is compared to that available in Sturgeon Lake because of the similarity of hydrological conditions (except for the thermal plume) and because of the proximity of the two locations. For proposed extreme conditions, the exclusion area is predicted to vary from about 0.1 ha (0.3 A) in January to the entire discharge canal in August [18 ha (44.5 A)].

Table VI-20. Estimated drift times for plankton through the thermal plume at PINGP for typical and proposed extreme conditions.

CONDITIONS MODELED	ESTIMATED DRIFT TIME (MIN)[1]		HIGHEST EXPECTED TEMPERATURE ENCOUNTERED	
	MAXIMUM	MEAN	DURING MAXIMUM DRIFT	DURING MEAN DRIFT
Typical				
Spring (May 1976)	138	120	22.8° C (73.0° F)	21.7° C (71.0° F)
Summer (August 1975)	120	100	29.4° C (84.9° F)	28.5° C 83.3° F)
Winter (December 1975)	405	388	16.5° C (61.7° F)	11.6° C 52.9° F)
Proposed Extreme				
Spring (May)	198	180	28.8° C (83.8° F)	27.3° C 81.1° F)
Summer (August)	108	93	32.8° C (91.0° F)	32.5° C 90.5° F)
Winter (January)	483	445	16.7° C (62.1° F)	12.5° C 54.5° F)

[1] Time required for a neutrally buoyant particle to drift from the upriver to the downriver extent of the 5° F isotherm in the near-field, assuming an average velocity of 0.2 fps. Drift paths are shown in Figure VI-14.

Table VI-21. Thermal matrix for response of the macroinvertebrate RIS, *Stenonema*, to conditions near PINGP. Organism: *Stenonema*; trophic level: primary consumer; biotic category: macroinvertebrate.

BIOLOGICAL ACTIVITY	TEMPERATURE[1] (C)	AREA EXCLUDING FUNCTION (HA)		TIME FUNCTION EXCLUDED		REMARKS
		TYPICAL[2]	EXTREME[3]	TYPICAL[2]	EXTREME[3]	
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	0	—	—	
Most common temperature taxon recorded at, based on frequency of occurrence of different temperature levels.	ND[4]	—	—	—	—	
Temperature increases which have been shown to affect emergence period.	ND[4]	—	—	—	—	

[1]From Appendix Table A-29.

[2]From Appendix Tables A-37 through A-39.

[3]From Appendix Tables A-40 through A-42.

ND[4] = no data.

Table VI-22. Thermal matrix for the response of the macroinvertebrate RIS, *Pseudocloeon,* to conditions near PINGP. Organism: *Pseudocloeon*; trophic level: primary consumer; biotic category: macroinvertebrate.

BIOLOGICAL ACTIVITY	TEMPERATURE[1] (C)	AREA EXCLUDING FUNCTION (HA)		TIME FUNCTION EXCLUDED		REMARKS
		TYPICAL[2]	EXTREME[3]	TYPICAL[2]	EXTREME[3]	
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.	ND[4]	—	—	—	—	
Most common temperature taxon recorded at, based on frequency of occurrence of different temperature levels.	ND[4]	—	—	—	—	
Temperature increases which have been shown to affect emergence period.	ND[4]	—	—	—	—	

[1]From Appendix Table A-29.

[2]From Appendix Tables A-37 through A-39.

[3]From Appendix Tables A-40 through A-42.

ND[4] = no data.

Table VI-23. Thermal matrix for response of the macroinvertebrate RIS, *Hydropsyche*, to conditions near PINGP. Organism: *Hydropsyche*; trophic level: primary consumer; biotic category: macroinvertebrate.

BIOLOGICAL ACTIVITY	TEMPERATURE[1] (C)	AREA EXCLUDING FUNCTION (HA)		TIME FUNCTION EXCLUDED		REMARKS
		TYPICAL[2]	EXTREME[3]	TYPICAL[2]	EXTREME[3]	
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	0 0	— —	— —	—
Most common temperature taxon recorded at, based on frequency of occurrence of different temperature levels.	27-29	6.6	0.08 to 48	August	May-Aug January	Ambient river temperature exceeded 29° C for August proposed extreme condition; therefore, this RIS's optimum temperature is exceeded naturally.
Temperature increases which have been shown to affect emergence period.	1=2 wk advance 14(±2)=5 mo advance in winter	18.5 1.5	18.5 2.5	All year December	All year January	Coutant (1968) Nebeker (1971)

[1]From Appendix Table A-29.

[2]From Appendix Tables A-37 through A-39.

[3]From Appendix Tables A-40 through A-42.

Table VI-24. Thermal matrix for response of the macroinvertebrage RIS, *Macronemum*, to conditions near PINGP. Organism: *Macronemum*; trophic level: primary consumer; biotic category: macroinvertebrate.

BIOLOGICAL ACTIVITY	TEMPERATURE[1] (C)	AREA EXCLUDING FUNCTION (HA)		TIME FUNCTION EXCLUDED		REMARKS
		TYPICAL[2]	EXTREME[3]	TYPICAL[2]	EXTREME[3]	
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.	ND[4]	—	—	—	—	—
Most common temperature taxon recorded at, based on frequency of occurrence of different temperature levels.	28	1-5	$\geq$1.7	June-August	May-August	River exceeds 28° C in August proposed extreme conditions; therefore, this RIS's optimum temperature is exceeded naturally.
Temperature increases which have been shown to affect emergence period.	>0 = 2 wk advance	18.5	18.5	All year	All year	Hopwood (1975)

[1] From Appendix Table A-29.

[2] From Appendix Tables A-37 through A-39.

[3] From Appendix Tables A-40 through A-42.

[4] ND = no data.

Likewise, 1 to 5 ha (2.5 to 12.4 A) in the discharge canal, comparable to 0.3 to 1.5 percent of Sturgeon Lake, will not be suitable for *Macronemum* for typical conditions in June through August (Table VI-24). Under proposed extreme conditions, the unsuitable area would increase from 1.7 ha (4 A) in May to the entire river in August; however, these conditions are expected to occur at a frequency of less than 1 hour in a given month over a 278-year period. No information on cold shock tolerance was available for macroinvertebrate RIS.

Information regarding thermal effects on emergence schedules are also summarized in Tables VI-23 and VI-24 for both *Hydropsyche* and *Macronemum*. It has been found that a temperature increase of 1° C (2° F) or less may advance emergence by as much as 2 weeks. This would involve the entire discharge canal [18 ha (44.5 A)] which is equivalent to about 5.7 percent of Sturgeon Lake. For *Hydropsyche*, it has been estimated (Nebeker, 1971) that a 14 ± 2° C (25 ± 4° F) temperature elevation occurring in the winter could accelerate emergence by as much as 5 months. In January, the area in the discharge canal affected by at least a 14° C (25° F) ΔT would be 1.5 ha (3.7 A or 0.46 percent of Sturgeon Lake). Nebeker (1971) found that if an insect emerges prematurely, successful reproduction may not be possible because environmental conditions may be unfavorable, or mates may not emerge during the short life span of the too-early insect. In addition, if a difference in time normally occurs between emergence of separate sexes (e.g., in stoneflies) and exposure to elevated temperatures enhances this differential, then reproduction will not occur if no individuals of the opposite sex emerge during the life span of the early emerged insects. In the case of either *Hydropsyche* or *Macronemum*, however, accelerated emergence schedules should not degrade the overall "protection and propagation" of these two taxa. In the first case, even if all the larvae that emerged two weeks early were lost (which is unlikely), this would amount to less than 6 percent of all those produced in Sturgeon Lake alone, and many other backwaters exist in the vicinity of PINGP. On the other hand, should elevated temperature in the discharge initiate emergence 5 months early, this would amount to a loss of less than 0.5 percent of all larvae that would be expected to emerge from Sturgeon Lake during the warmer seasons. These predictions are based on the assumption that macroinvertebrate densities are somewhat similar between discharge and Sturgeon Lake locations (Table VI-17).

In his study of aquatic insect emergence near PINGP, Shyne (1977) found that mayflies (especially *Caenis*) emerged earlier near heated water stations than at control stations, but because heating was sporadic (May-December 1974), other factors may have caused this early emergence. The caddisflies, *Hydropsyche/Cheumatopsyche*, appeared to emerge at equal rates and times from both heated and control stations. Midges emerged earlier in Sturgeon Lake than the simultaneous peak observed at all other stations. Thus, with the possible exception of the mayfly, *Caenis*, emergence of aquatic insects seemed to be unaffected by the thermal plume in 1974.

Comparing the predicted impact of the PINGP discharge with previously observed impacts, it is obvious that field data are inadequate to verify predicted species shifts or changes in abundance of individual species that may have resided in the thermal plume. Practically no information is available regarding the selective processes occurring inside the plume as compared with control stations. If anything (see Appendix Table A-26), artificial substrate abundances of two RIS, *Hydropsyche* and *Stenonema*, were higher during the summer months at discharge than at intake stations. In addition, Haynes (1976) and Texas Instruments, Inc. (1977b) reported that species diversity changed significantly between intake and discharge stations for both artificial substrate and dredge samples, even though combined densities of all organisms remained approximately the same between these stations during both years. Reanalysis of these and newer data (1975-1977) confirmed the differences for macroinvertebrates in the dredge samples, but not for those on artificial substrate samples. Thus, even though thermal tolerance data suggest that some macroinvertebrate RIS may be eliminated from certain benthic portions of the plume during part of the year, site-specific data, at least for *Hydropsyche* and *Stenonema*, show that the reverse may be true. It should be pointed out, however, that the site-specific data on RIS are insufficient and do not necessarily contradict the impacts predicted from the thermal tolerance information; i.e., that losses of some RIS macroinvertebrates may occur in the discharge canal. It also should be pointed out that site-specific data did indicate a general shift in total species composition between intake and discharge stations.

C. ZOOPLANKTON

1. Discussion and Critique of Sampling Methods. Methods for zooplankton sampling are summarized in Appendix Table A-22, and many of the criticisms of data collection mentioned in the macroinvertebrates section apply also to zooplankton. Samples were taken with a Van Dorn (or Kemmerer) bottle or by pumping, and water was then filtered through a plankton net. The mesh of the plankton net was not specified in the earlier studies but presumably was the same for all studies since sampling began in 1970. Plant entrainment mortality testing was begun in 1974, utilizing a pump filtration system, which sampled at a rate of approximately 130 liters/min. Pumping is probably more efficient for sampling agile zooplankton (such as copepods) than is sampling by means of a Van Dorn bottle because of the larger volume sampled and less avoidance of the sampler. Thus, without intercalibration, the two methods are probably not comparable, nor were they designed to be. Patchy zooplankton distribution can also present problems in assessing impact of the plant, no matter what sampling method is used, since an apparent increase or decrease in zooplankton numbers at the discharge in relation to the intake may actually result from variations due to patchiness. Moreover, if no attempt is made to sample the intake and discharge at approximately the same time, allowing for travel time through the plant (especially when discharging at maximum blowdown volume), natural density variations occurring between intake and discharge may be inseparable from those resulting from plant related losses. Thus,

it is important either that enough replicates be taken at each station to define temporal and spatial variation, or that samples of adequate volume be collected to compensate for patchiness. Table VI-15 indicates that with no simultaneous replicates taken, only moderate to large variations between mean station values would be detected as significant. In this, as with other types of sampling, it is obvious that with an increase in number of replicates taken at each station, a smaller percentage difference between stations is required to reveal a significant difference.

Since the viability of the sampled zooplankton at stations other than 14 and 20 (Figure VI-2) was not recorded, it is doubtful that reductions in zooplankton densities at other stations resulting from plant operation could be readily determined. Zooplankton that may have been recently killed as a result of plant operation would remain almost neutrally buoyant for at least several hours and, therefore, inseparable from live organisms after sample preservation. Little is known about zooplankton settling rates after death, but there is some indication that reductions in densities from settling of dead zooplankton in the discharge canal as a result of plant operation may be measurable (Carpenter et al., 1974). However, it is difficult to separate zooplankton losses resulting from plant entrainment and those resulting from plume entrainment. Thus, determination of zooplankton mortality resulting from plume entrainment is, at best, difficult.

4. Effects of Past Operations.

a. RESULTS OF DATA REANALYSIS.

1) Analysis of Variance (ANOVA) and Duncan's Multiple Range Test. Zooplankton data collected near PINGP in 1975 and 1976 (operational years) were reanalyzed, and the ANOVA results are summarized in Table VI-16. Densities varied significantly between stations ($\alpha < 0.001$), and variation between months was also highly significant. Further reanalyses using Duncan's Multiple Range Test (DMRT) (see Table VI-17) indicated that certain station groups differed significantly relative to other station groups. For example, Stations 10 and 27 comprised a group which differed significantly from the group containing Stations 6, 10, and 12. Moreover, grouped Stations 6, 12, 21, and 25 differed significantly from other stations, and stations 18 and 21 combined differed from other groups of stations. Zooplankton species diversities, however, did not differ significantly between stations based on the ANOVA test but did vary seasonally (Table VI-16).

2) Student's One-Tailed t-Test. Since the DMRT showed that certain groups of stations differed significantly from other groups of stations, a directional (one-tailed) Student's t-Test was utilized to determine whether zooplankton were more dense at Station 12 (the intake) than at Station 21 (the immediate discharge area), and did zooplankton density at Station 10 (upriver

of PINGP) exceed significantly that of Station 27 (near Lock and Dam No. 3). The results (Table VI-18) did not demonstrate that significant differences existed between both near-field and far-field stations. As mentioned previously, however, the fact that no differences were shown between stations does not necessarily mean that no differences actually existed. It simply indicates that the power of the data may not have been great enough to show differences if they did occur. It is also likely that if zooplankton were killed by plant operation, they would not have settled out of the water column during the short transit time between stations. Subgroups of the zooplankton (that is, rotifers and crustaceans) showed results similar to those for the total zooplankton analysis.

3) Multiple Regressions. Although zooplankton and its subgroups, rotifers and crustaceans, were not found to vary significantly in density between some stations, densities of these taxa were found to be related to several water quality parameters. For total zooplankton density, five water quality parameters were selected in a stepwise linear regression procedure. The most important of these was temperature (Table VI-19) followed by nitrate, orthophosphate, dissolved oxygen, and ammonia. All selected parameters accounted for 64 percent of the variation recorded in zooplankton numbers. Because temperature was selected as the most important parameter relating to zooplankton densities, this does not necessarily mean that the plant caused this variation. Significant variation between stations and between months did occur (Table VI-16), and thus, variation in zooplankton densities resulted from variations in temperature on both a seasonal basis and a station basis.

Regressions of rotifer density with water quality parameters produced results almost identical to those for total zooplankton. The same five water quality parameters were selected with a total R^2 of 0.66, and temperature was the most important parameter. Crustacean densities were related only to temperature, nitrates, and orthophosphates with a total R^2 of only 0.53. It is important to note, however, that 41 percent of the variation in crustacean densities resulted from temperature which is somewhat higher than 37 percent for rotifers and 35 percent for total zooplankton. All of the R^2 values were high enough to indicate that density of total zooplankton or either of its subgroups were significantly ($\alpha < 0.05$) related to some of the water quality parameters (see Appendix B).

Seasonal correlations (r) of total zooplankton and crustaceans with temperature were always relatively low. During summer, the correlation of total zooplankton populations with temperature appeared to be slightly negative ($r = -0.24$), and crustacean densities showed a similar relationship with temperature ($r = -0.29$) in winter. Both total zooplankton ($r = 0.21$) and crustacean abundances ($r = 0.18$) exhibited positive, but weak, correlations to temperature in spring. These results tend to indicate that although annual temperature fluctuations may influence zooplankton populations through seasonal variation, when considered only on a seasonal basis, temperature is not so important. Thus, the annual influence of temperature variation must be more important than that of spatial influences (such as the thermal plume), or else the seasonal correlations would have been higher than those of the annual correlations. In summary, zooplankton densities are influenced by temperature variation to a moderate extent, with seasonal variations of water temperature a stronger determinant than spatial variation.

b. DISCUSSION. Daggett (1976) found no significant difference in total zooplankton densities between PINGP stations for 1975, although copepods did show a difference at the $p < 0.08$ level. Using Tukey's Multiple Comparison Test, Daggett showed that Stations 6 and 12 (Sturgeon Lake and the intake) had significantly greater copepod densities than Stations 10, 21, and 26 (Sturgeon Lake, the discharge canal, and down-river from Barney's Point). Diversity was high at all stations, but no statistical tests were conducted to ascertain if significant differences occurred between stations. Reanalysis of the data by ANOVA, however, confirmed the expectation that species diversity did not differ significantly between stations. In 1976, data analyses using the Newman Kuels Test (Texas Instruments, Inc., 1977a) showed that copepod densities were significantly higher at the intake (Station 12) than in the discharge (Stations 21 and 25), but Station 5 (Sturgeon Lake) was not significantly different from Station 25. Similar results were found for both cladocerans and copepods; however, rotifers showed no significant differences between stations.

The primary differences between stations that affected abundances of planktonic organisms were temperature and current. Thermal surveys taken during representative periods of 1975 and 1976 (summarized in Appendix N) and water velocity measurements (conducted by Stefan and Anderson, 1977 and Szluha, 1975) have characterized several station differences (Sections III A.3, and B.1). Analyses of field data, however, have shown no large variations in spatial abundance of zooplankton as related to temperature, and insufficient data were available to analyze velocity related effects. Differences in zooplankton densities between intake and discharge may exist, but the number of replicates was insufficient to show anything but large percentage differences. Even if there had been significantly more zooplankton observed at the intake rather than the discharge, the majority of the decrease in density would have probably been caused by plant entrainment rather than plume entrainment, as a result of the greater stress involved in plant entrainment (Davies and Jensen, 1975).

Statistical tests do not indicate that any reductions in species diversity have occurred between intake and discharge stations at PINGP. King (1974) found that no zooplankton species were eliminated from the heated zones of a Missouri cooling reservoir where ΔT's averaged 4° to 6° (7 to 11° F); however, cladocerans and copepods were more abundant in the heated cove, whereas rotifers were more common in the control area. Nevertheless, no significant differences in species diversity were found between the control and heated zones of this reservoir.

Thus, site-specific data for zooplankton indicate that the thermal plume did not significantly alter either density or species diversity at PINGP in 1976 and 1977. However, data were such that only very severe changes would have been detectable, and even then most reductions would probably have resulted from plant rather than plume entrainment.

3. Predicted Impacts. No RIS were selected for zooplankton; however, thermal tolerance information for a number of species found near PINGP is summarized in Appendix Table A-31 and Figure A-7. Although exposure periods differ greatly between thermal tolerance data and expected drift experience, it is expected that most cladocerans, because of their relatively high thermal tolerance, could withstand the maximum thermal increases encountered while drifting in the discharge canal (Table VI-20), even during the hottest part of the summer. On the other hand, the copepod, *Diaptomus,* might be damaged by drifting through the hottest part of the plume during certain times (Table Appendix A-31 and Figure A-7), especially during proposed extreme conditions from June to September when maximum encountered plume temperatures exceed 31° C (88° F). However, acclimation to these thermal maxima will be gradual and duration of exposure to highest temperatures will not exceed 108 minutes. Thus, *Diaptomus* would probably not be killed by drifting through the plume even during the proposed extreme conditions. If, however, there were other mitigating factors, such as abnormally low dissolved oxygen (DO), high levels of a toxicant from upstream, or abnormally long retention times in the discharge canal, then the already-weakened *Diaptomus* may be unfavorably affected by the thermal plume. Similar limitations may occur for *Cyclops vernalis,* although this taxon is slightly more thermally tolerant than *Diaptomus*.

Little information is available on thermal tolerances of rotifers, but they are considered to be generally more thermally tolerant than either cladocerans or copepods (Jensen et al., 1969). Protozoans are known to withstand maximum temperatures of 35° to 40° C (95° to 104° F) after acclimation to only 21° to 25° C (70° to 77° F) (see Appendix Table A-31), and are considered more tolerant than most other types of zooplankton. Brock (1975) suggested that the upper limits for some protozoans approach 50° C (122° F), although diversity may be severely restricted at temperatures below this upper limit.

Although no individual species at PINGP have been selected for statistical analysis, the lack of major variations in density and diversity of zooplankton indicate that the plant has little impact on drifting populations, even in the immediate vicinity of the discharge. Even if a decrease in density and diversity had been observed, the relatively rapid reproductive rates and short life spans of most zooplankton, especially during the summer, would be expected to compensate for any losses incurred due to drifting through the plume at PINGP (EPA, 1976b).

Power plants on large midwestern rivers have rarely caused significant losses in zooplankton, either by plant or plume entrainment (OPPD, 1976). When losses do occur as a result of power plant operation, the loss is largely due to entrainment through the plant rather than by other plant-related causes (Davies and Jensen, 1975).

D. PHYTOPLANKTON

1. Discussion and Critique of Sampling Methods. Phytoplankton have been sampled since 1969 (Appendix Table A-22), and most sampling methods and procedures were state-of-the-art. The following considerations, however, limit their utility. First, it is questionable that diatoms could have been identified to species without leaching or incinerating cell contents before examining frustule sculpturing. Second, although sampling methods have remained somewhat similar since the inception of phytoplankton sampling in 1969, the stations and dates sampled for densities varied considerably prior to 1973. Use of the oxygen production method for determining phytoplankton productivity (Baker, 1975a) instead of the more widely used ^{14}C method limits comparison with some literature. Moreover, location of sampling stations and sampling frequency were inconsistent from year to year. Simultaneous replicates were not collected for density estimates, while only a limited number of productivity samples had replicates. Thus, the power of the data for showing significant difference between stations was rather low except for the few cases where multiple productivity samples were taken (Table VI-15). Little or no tabular data were available, and the results from several stations were generally pooled.

2. Effects of Past Operation.

a. RESULTS OF DATA REANALYSIS.

1) Analysis of Variance (ANOVA) and Duncan's Multiple Range Test. Phytoplankton abundance data were reanalyzed by nested analysis of variance to determine, first, if there was a difference between the preoperational year of 1973 and the operational years of 1975 and 1976, and then whether there was a difference between all stations or months during operational periods (1975 and 1976). Table VI-16 summarizes some of this information and shows that phytoplankton densities appeared to differ significantly between 1973 and 1975-1976. This may or may not have been associated with initiation of plant operation. Differences between station densities for both operational years combined were not significant, although differences between months were highly significant. The latter reflects natural seasonal variations.

Neither phytoplankton biovolume (mg/l) nor Shannon-Weaver diversity differed significantly between stations for 1975 and 1976 (Table VI-16). Net phytoplankton productivity (Type I of Baker, 1977) for the near-field intake station (14) varied significantly from the near-field discharge station (19), whereas both of these near-field intake and discharge stations differed significantly from the far-field Sturgeon Lake (5) and river stations (9 and 27) (Table VI-17). Intensive near-field Type III (of Baker, 1977a) productivity studies confirmed these results, showing significant variation between intake (14) and discharge (19) stations (Table VI-17).

Power calculations summarized in Table VI-15 indicate that phytoplankton values estimated by means of simultaneous replicates, such as with some of the productivity studies (Type III), were more suited to detecting moderate differences between station means than were samples collected without simultaneous replicates. No t-Test was needed for confirming Type III productivity station differences, as the Duncan's Multiple Range Test already showed that the two stations were significantly different. Similarly, no t-Tests were conducted for density differences since ANOVA indicated that all station densities were essentially alike.

2) Multiple Regressions. In order to determine if any of the selected water quality parameters were significantly related to phytoplankton abundances, stepwise multiple regression was performed. Table VI-19 indicates that only surface ammonia was significantly related ($\alpha < 0.05$) to phytoplankton abundances with an R^2 of 0.47. Such an affinity is not high and tends to indicate that some other factors may have acted separately or in combination to cause the majority of the phytoplankton variation in density, either temporal or spatial. Productivity data were not regressed against water quality values for lack of adequate coincidental data.

b. DISCUSSION. The above analyses tend to confirm the general conclusions stated in the annual reports (Baker and Baker, 1974; Baker, 1975a, 1976a, and 1977a) that no variations in density, biovolume, or species diversity were obvious between control and plume stations. Near-field control and plume stations, however, differed significantly in productivity. Reduced productivity (both gross and net) in the discharge most likely resulted from plant entrainment damage rather than from inhibition by the plume as samples were taken very near the discharge gates. In addition, Baker (1975a) was unable to detect any difference in phytoplankton productivity between main channel stations upriver and downriver from the plant. Because productivity in Sturgeon Lake was generally higher than that in the main channel, any reductions of phytoplankton productivity due to passage through the plant might be misleading when compared with main channel stations upriver and downriver from the plant. Baker (1977a) estimated that phytoplankton productivity in the

Mississippi River was reduced by as much as 30 percent in midsummer, 1976, as a result of PINGP operation (as extrapolated from near-field Type III studies). This conclusion, however, is misleading since nearly simultaneous far-field productivity measurements (Type I) taken both up- and downriver from the plant were found to vary by as much as 325 percent. Thus, projected loss of primary productivity in the river as a result of PINGP operation should be considered in conjunction with the variability inherent in the system. And to show upriver to downriver reduction in phytoplankton productivity, an adequate number of replicates need to be collected to define the variation in sample estimates. Without proper sampling design, testing, and verification, predicting impacts upon the river phytoplankton productivity is very difficult.

The indication (Table VI-16) that phytoplankton densities varied significantly between the preoperational years (1973) and operational years (1975 and 1976) may have resulted from plant operation. However, comparison between more years of preoperational and operational data would be necessary to reach a definitive conclusion. Climatic variations or long-term changes in water quality would require years of assessment in order to separate plant from non-plant induced effects.

3. Predicted Impacts. In general, phytoplankton are some of the most thermally tolerant of all planktonic organisms susceptible to plume entrainment at PINGP. Appendix A-33, A-35 and Figure A-8 summarize information on thermal tolerances of phytoplankton either found or expected to be found in the vicinity of the plant. Diatoms are dominant throughout most of the year whereas green algae occur most commonly in early summer and blue-green algae in mid-summer to early fall. This succession of groups occurs in response to annual cycles in ambient temperature, among other things, as a result of variable thermal tolerances. Thus, blue-green algae are the most thermally tolerant of the three dominant groups of phytoplankton, and most can probably survive the hottest temperatures expected to occur in the plume during midsummer. Some diatoms also can survive high temperatures as shown in Appendix Figure A-8. The short-term survival temperature for mesophilic diatoms is about 30° C (86° F) although total biomass for drifting forms may not decrease until 36° C (97° F) is reached. Green algae can tolerate a wide range of temperatures, also depending on the species. Thus, it is unlikely that any species will be detrimentally affected by drifting through the plume. Most phytoplankton are capable of withstanding temperature elevations as great as any occurring in the plume (Table VI-20) during the time of the year when each phytoplankton taxon occurs. Moreover, no true thermal bioassays for phytoplankton which define limits of short-term mortality have been found in the literature. Many phytoplankton are capable of becoming physiologically inactive when encountering unfavorable environmental conditions, such as abnormally high temperature, but this does not indicate that they are permanently damaged. According to Baker (1977a), productivity near Prairie Island tends to increase until ambient temperatures reach about 16° C (61° F) for

spring diatom flora, whereas blue-green algae reach maximum productivity between 28° C (82° F) and 35° C (95° F) in summer. Thus, productivity reductions observed in the discharge (as compared to intake) during 1976 probably resulted from thermal and physical stresses occurring during plant entrainment rather than during plume entrainment. If anything, phytoplankton productivity is enhanced during all times of the year as a result of entrainment into the PINGP plume. Thermal elevations, maximum temperatures, and drift exposure times in the discharge canal were usually not limiting to most seasonally occurring phytoplankton.

As mentioned previously, analyses of phytoplankton densities and productivity indicate that plume entrainment at PINGP does not affect phytoplankton, even during midsummer. This tends to confirm the impacts predicted from thermal tolerance data. Brock and Hoffman (1974) detected some shifts in species composition between intake and discharge stations near a power plant on Lake Monona, Wisconsin, when discharge temperatures exceeded 40° C (104° F), although variations in water velocity may have accounted for some of the differences. These same authors also found that primary productivity was quite high in the discharge canal at 42.5° C (108.5° F), while none was observed in thermally unaffected stations when samples were heated to this same temperature. These findings suggest that algae living in the vicinity of the discharge comprise species more capable of functioning at higher temperatures than those occurring at thermally unaffected stations. Elevated plume temperatures at PINGP are not expected to significantly alter either phytoplankton composition, abundance, or productivity because drift time through the plume is relatively short. The small potential losses that may be sustained as a result of passage through the plume should be easily compensated by river phytoplankton since their life spans and turnover rates are generally very short. Thus, no long lasting or major impact upon receiving water phytoplankton populations is expected to occur.

E. PERIPHYTON

1. Discussion and Critique of Sampling Methods. Periphyton studies suffered from many of the same deficiencies as did phytoplankton (Appendix Table A-22) studies. Although replicates were collected, they were not reported (Appendix Table A-22), and samples were collected rather inconsistently by station and date with the predominance of samples collected between midsummer and early fall. The frequency and number of sampling locations were greatly diminished during other times of the year because of unsafe sampling conditions, damage to samples by ice, vandalism, and high river flow (Baker, 1974; 1975b, 1976b, 1977b). One of the most critical omissions during operational years was that of Station 27, the only one located in the downriver plume area.

Periphyton studies included density estimates, taxonomic identification, chlorophyll *a*, and phaeophytin *a* measurements. Baker (1976b), however, suggested that his procedures for periphyton analysis did not "do justice to" rare species which may have been most heat-sensitive, nor did they measure the actual or climax periphyton community occurring on natural substrates near PINGP. Thus, whatever periphyton colonized artificial substrates during the 2-week incubation period was undoubtedly dissimilar to those colonizing the rip-rap and other natural substrates occurring in the river and Sturgeon Lake near PINGP. However, no other better quantitative method for measuring variations in periphyton populations has been suggested in the literature and thus, the glass substrate method can be considered as state-of-the-art.

2. Impacts of Past Operation.

a. RESULTS OF DATA REANALYSIS. Periphyton for 1975 and 1976 were reanalyzed from only three stations using analysis of variance (ANOVA) and Duncan's Multiple Range Test (DMRT) since data from other stations were insufficient. ANOVA revealed significant differences between stations for density and chlorophyll *a* but not for species diversity and phaeophytin *a* (Table VI-16). Annual variations in all parameters, however, were significant, but these were probably related to natural seasonal fluctuations. Further analysis using DMRT (Table VI-17) showed that grouped Stations 13 (intake) and 20 (discharge) differed significantly from Station 25 (discharge) for density while Station 13 differed significantly from Stations 20 and 25 combined for chlorophyll *a*.

Power calculations (Table VI-15) for periphyton parameters indicated that the probability of detecting small variations between station means were minimal, and with no simultaneous replicates, even large variations will be detected with a probability of 0.53 to 0.67 at an $\alpha = 0.05$ level.

No t-Tests were conducted because the few stations involved in ANOVA and DMRT provided enough information to determine specific station differences.

b. DISCUSSION. Baker (1977b), contrary to the above findings, stated that phaeophytin *a* (a degradation product of chlorophyll *a*) concentrations appeared to be higher at heated stations than in unheated stations. This tends to indicate, according to Baker, that deterioration of periphyton was greater at stations affected by the plume than at those not affected. In addition, Baker concluded that periphyton abundance between stations inside and outside the thermal plume did not differ greatly, although he did not report details of statistical analyses used to test these differences. Results of the data reanalysis are ambiguous for abundance, probably as a result of too few samples (low power). Baker also qualitatively observed that periphyton residing on substrates continually influenced by the thermal plume exhibited a different flora than those found outside the plume as a result of variations in thermal optima. However, only diatom populations were analyzed, and therefore, quantitative dominance of blue-greens over diatoms during the summer in discharge stations as opposed to nondischarge stations could not be determined. The taxonomic composition of attached diatoms did not vary greatly between the intake and discharge stations at any time of the year (Baker 1977b), but a marked seasonal succession of dominant diatom species inhabiting the artificial substrates in general was observed. Moreover, reanalysis of the data (ANOVA) showed no significant difference in diatom species diversity between intake and discharge stations, but did show a significant difference between months (Table VI-16).

3. Predicted Impacts. Diatoms were the only taxa of periphyton studied on artificial substrates, and thus, thermal tolerance of only this group will be related to the predicted plume. Appendix Tables A-33 and A-35 summarize available thermal tolerance information for diatoms, and it is obvious from this information that although thermal tolerances and optima of diatoms vary widely between species, they generally are high (> 30° C). Thus, species composition may be altered in those areas of the plume where tolerances are exceeded for some species. Analysis of background periphyton data for conditions similar to those expected for future operational conditions tend to support the prediction of negligible impact for periphyton populations inhabiting substrates in the PINGP plume. It is important to note, however, that even though high temperatures will tend to eliminate certain diatom species (e.g., *Nitzschia tryblionella*) at least some species will be capable of colonizing the substrates, even during the warmest times of the year. Thus, no overall reduction in periphyton production is expected in the discharge as compared to nonplume affected stations.

Hickman and Klarer (1974) studied the effects of a thermal effluent on epiphytic algae in Lake Walbamum, Canada, and found that the thermal discharge rarely extended the seasonal maxima in abundance of various groups of diatoms beyond those occurring outside the thermal influence. However, the growth of two diatoms, *Epithemia turgida* and *Mougeotia* sp., were found to be detrimentally affected by the thermal discharge. In the above study these algae were observed colonizing the emergent macrophyte, *Scirpus validus*, rather than on glass artificial substrates. Similarly, few detrimental effects on periphyton can be expected near the PINGP site. General abundances of total periphyton are not expected to be reduced because continual succession to more thermally tolerant species should occur as temperature increases to summer highs. Furthermore, cold shock as a result of plant outages during winter months should not cause damage to periphyton because of the wide range of temperatures that most primary producers can accommodate.

F. AQUATIC MACROPHYTES

1. Discussion and Critique of Sampling Methods. Macrophyte analysis comprised mainly qualitative observations of changes in the extent and composition of submerged, emergent, and shoreline macrophytes in the vicinity of PINGP (Appendix Table A-22). Quantitative sampling, such as measurements of standing crop, would be necessary for statistical

comparisons within and between years as well as between stations. Quantitative measurements also would be useful for determining relative species abundance at various stations. The macrophyte studies that were conducted, however, provide a good data base, both before and after PINGP start-up, for estimating operational impacts.

2. Effects of Past Operation. No reanalyses were conducted in addition to those analyses by the original authors because none of the results were quantified; however, the observations by the investigators were useful in assessing impact of plant operation (Figure III-37 and Appendix Table A-36). In 1975, Mueller (1976) noted a reduction in submerged aquatic macrophytes in the discharge area as compared to previous years and suggested that this may have resulted from high water during the growing season, bottom changes due to scouring or siltation, general climatic changes, or the heated effluent. In 1976, however, he found that the distribution and general abundance of macrophytes had increased over 1975 levels, especially at Barney's Point, which is near Station 25. The amount of macrophyte habitat within the discharge area was extremely limited (Figure III-47), and the macrophytes were subject to numerous limiting environmental stresses other than the thermal stress plume (Mueller, 1977). Thus, any decreases in the limited macrophyte populations in the discharge canal, no matter why they occurred, can be considered to have negligible effects on the aquatic ecosystem since large macrophyte beds occur in the shallow water areas of the nearby backwater lakes, especially the northern section of Sturgeon Lake.

3. Predicted Impacts. No species-specific information on thermal tolerances of macrophytes occurring in the vicinity of PINGP has been found. The upper limits for various biota, including vascular plants, is about 45° C (113° F) (Brock, 1975), and this temperature will not be reached under any circumstances within the PINGP discharge. Thus, the thermal plume should not reduce the general abundances of macrophytes as a result of temperature only, although species composition may change. Site-specific and literature data indicate that no detrimental effects of the PINGP thermal plume on macrophyte beds in the area are expected, and, as stated previously, if detrimental effects do occur, they would be confined to an extremely small zone since limited habitat is available for macrophytes within the thermal plume.

G. BIRDS

The PINGP thermal discharge may affect eagles and waterfowl primarily by providing an open water area during winter for feeding (fish attracted to plume) and resting. The potential impacts of the PINGP thermal discharge on eagles are predicted to be minimal since few eagles appear to frequent the plant area compared to other locations between Prescott and

Lake Pepin (see Section III C.b). Those that are present may remain in the area longer because of the open water in the discharge channel during winter; however, the available data are insufficient to determine if eagles remain longer than if the discharge were not present. Fish attracted to the discharge in late fall and winter, particularly gizzard shad, could benefit the eagles by providing an abundance of forage. In addition, the PINGP thermal discharge would not be expected to adversely impact the migrations or survival of ducks and other waterfowl and may even be beneficial by providing open water and food.

Peregrine falcons, an endangered species, are being reintroduced along Lake Pepin (see Section III C.b). The potential impacts to this species are expected to be minimal and indirect since they do not require open water and feed upon other birds (including small ducks). Thus, if the PINGP thermal discharge were to have any impacts on the falcons, assuming they became reestablished in the area, the effects would probably be beneficial.

VII. CONCLUSIONS

Several conclusions can be drawn regarding the predicted impacts of continued thermal discharges from PINGP on the indigenous populations of fish, invertebrates, and primary producers. Attraction to and avoidance of the thermal plume occurs during various seasons of the year, at least for some species of fish. Subsequent effects on spawning, growth, migrations, predator-prey interactions, parasites and diseases, and winter survival are expected to be minimal, however, in terms of maintaining the existing indigenous fish populations. Thermal effects on primary producers and invertebrates, including early emergence of some aquatic insects, are predicted to be minimal within the thermal plume and negligible for the populations in lower Pool No. 3. Impacts to waterfowl and raptors frequenting the vicinity of PINGP are predicted to be minimal, and these would probably be beneficial rather than adverse. These conclusions will be discussed in more detail in the following paragraphs.

Fish are predicted to be attracted to the thermal plume when ambient river temperatures are low and at least some species should avoid the discharge when ambient temperatures are high. These predictions are substantiated by field data which indicate that white bass, carp, gizzard shad, and shorthead redhorse avoid the warmest discharge area in summer and the RIS for which adequate data existed were attracted to the plume during one or more of the other seasons. The areas of exclusion calculated from thermal tolerance data and the thermal plume model results for typical summer environmental conditions ranged from 4.4 ha (10.9 A) for white sucker to less than 1 ha (2.5 A) for the other RIS, except walleye and northern pike which had intermediate areas. Exclusion is predicted to occur only in July and August, and the calculated areas are conservative estimates (i.e., the maximum to prevent thermal mortality to any juveniles or adults). These are small, particularly when compared to the available habitats nearby such as Sturgeon Lake [324 ha (800 A)]; therefore, exclusion of these areas during summer is not expected to adversely affect indigenous fish populations.

The PINGP thermal discharge could affect fish spawning primarily through inducing premature spawning, excluding large areas from spawning, or killing embryos and larvae present in or drifting through the plume. However, the following considerations suggest that these impacts will be minimal. Premature spawning could occur for carp, emerald shiner, walleye, and gizzard shad but is not expected to reduce reproductive success. Furthermore, no premature spawning has been observed during past field surveys. The areas predicted to be excluded from adult spawning during typical environmental conditions are less than 2.6 ha (6.4 A). The calculated areas precluding embryo development are 17 ha (42 A) for northern pike and 9 ha (22 A) for walleye in May (end of spawning period) while the areas are less than 7.6 ha (19 A) for the other RIS. Suitable spawning habitat for each RIS does not exist throughout these calculated exclusion areas, and adequate spawning areas exist nearby in both the backwater lakes and the main river channel. Larval fish drifting through the plume are not expected to be thermally stressed. Thus, potential thermal impacts on spawning and reproductive success are predicted to be negligible.

The potential for cold shock mortality exists at PINGP since fish are attracted to the plume in winter and plume temperatures exceed the maximum weekly average temperature (MWAT) recommended for protection of warm water species from cold shock. The probability of an unscheduled trip occurring when the other unit is refueling is 0.55 so that cold shock would occur at least once every 2 years. Based on field surveys at PINGP, gizzard shad was the most abundant species in the discharge although some white bass, carp, and black crappie were present. Of the RIS, gizzard shad is the most sensitive to cold shock, but any winter losses of this species are not expected to adversely affect river populations since it is a very prolific species and large winter die-offs normally occur when ambient temperatures approach 0° C (32° F).

Other effects on river populations are also expected to be minimal. Migrations, predator-prey interactions, growth rates, and the incidence of parasites and diseases should be negligibly affected by the thermal discharge. Sport fishing may be benefitted through increased fishing success in the discharge during spring.

Reanalysis of site-specific invertebrate and primary producer data showed that impacts appear to be minimal or non-existent in most of these biotic categories. Only phytoplankton primary productivity, periphyton chlorophyll a, and macroinvertebrate species diversity for dredge samples were found to differ significantly between intake and discharge stations. These differences, however, most likely were not the result of PINGP thermal discharges. Annual variations in water temperatures appear to regulate zooplankton abundances to some extent, but the influence of spatial variations (as between intake and discharge) was negligible. Temperature was not significantly related to phytoplankton, artificial substrate macroinvertebrate, or dredge macroinvertebrate densities.

Based on the predictive analysis of comparing invertebrate and primary producer thermal tolerances with plume configurations, no mortalities are expected for phytoplankton, zooplankton, or macroinvertebrates drifting through the plume. Most habitat in the discharge canal that is otherwise suitable for aquatic macroinvertebrates, will not be rendered unsuitable as a result of high temperatures, except for small portions during proposed extreme environmental conditions. For instance, the area in the discharge canal equivalent to approximately one to six percent of Sturgeon Lake may be avoided by the macroinvertebrates, *Hydropsyche* and *Macronemum* (RIS).

This does not mean, however, that these two taxa will be killed or even excluded from the discharge areas during extreme conditions, only that they will be less common at higher temperatures than in other areas. Site-specific information for these two species during the unusually warm, low flow year of 1976 indicated that they did not avoid the discharge canal.

A two-week acceleration of the emergence schedules for some aquatic macroinvertebrates is predicted for the entire area of the discharge canal (equivalent to about 5.7 percent of Sturgeon Lake). In an area of 1.5 ha (3.7 A) which is 0.5 percent of Sturgeon Lake, a five-month acceleration of emergence schedules is predicted for *Hydropsyche* during typical conditions. Early emergence, however, has not been observed to occur in the past in the PINGP discharge canal; thus, little impact to most categories of aquatic insects is expected from operation of PINGP.

Other predictive results indicate that warmer water areas of the discharge canal may favor more thermally tolerant taxa, but these areas would be insignificant compared to the area in Sturgeon Lake. The heated plume should not favor the encroachment or proliferation of nuisance organisms, such as blue-green algae; blooms of these phytoplankton have occurred seasonally long before PINGP became operational. Moreover, no federally protected flora or invertebrate fauna will be impacted by the thermal discharge.

Finally, no impacts to aquatic macrophytes are predicted since their occurrence and distribution near PINGP appear to be more influenced by fluctuations in water level, sedimentation, and current conditions than by temperature. Any losses of aquatic macrophytes that may result from thermal discharge would be small. Suitable habitat for these plants in the discharge canal is extremely limited in comparison to the total distribution of macrophytes in Sturgeon Lake.

Eagles, waterfowl, and peregrine falcons are not expected to be adversely affected by the PINGP thermal discharge. Availability of open water and a food source may even be beneficial.

Therefore, it is concluded that the thermal discharge resulting from past operation of PINGP has not caused appreciable harm to any aquatic organisms, and the protection and propagation of a balanced indigenous biota has been maintained. In the future, the discharge plume is predicted to cause neither appreciable harm nor adverse levels of impact to aquatic biota.

REFERENCES

Allen, K.O., and K. Strawn. 1968. Heat tolerance of channel catfish, *Ictalurus punctuatus*. Proc. 21st Ann. Conf. S.E. Assoc. Game and Fish Comm., 1967:399-411.

Altman, P., and D. Dittmer, eds. 1966. Tolerance to temperature extremes: animals. Part V. Aquatic invertebrates. Pages 81-87 *in* Environmental biology. Fed. Am. Soc. Exp. Biol. Bethesda, MD.

American Public Health Association (APHA), American Water Works Association (AWWA), and Water Pollution Control Federation (WPCF). 1975. Standard methods for the examination of water and wastewater, 13th ed. APHA, AWWA and WPCF. Washington, D.C.

Anderson, R.A. 1975. Thermal plume surveys. Pages 19-62 *in* Environmental monitoring and ecological studies program 1974 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol. 1. (Northern States Power Co., Minneapolis, MN)

Andrews, J.W., and R.R. Stickney. 1972. Interaction of feeding rates and environmental temperature of growth, food conversion, and body composition of channel catfish. Trans. Amer. Fish. Soc. 101:94-99.

Andrews, J.W., L.H. Knight, and T. Murai. 1972. Temperature requirements for high density rearing of channel catfish from fingerling to market size. Prog. Fish-Cult. 34:240-241.

Baker, A.L. 1977a. Primary productivity of the phytoplankton community in the Mississippi River at Prairie Island. Pages 2.1.2-1 through 2.1.2-72 *in* Environmental monitoring and ecological studies program 1976 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol. 1. (Northern States Power Co., Minneapolis, MN)

Baker, A.L. 1977b. 1976 studies of the attached algae in the vicinity of PINGP. Pages 2.2-1 through 2.2-62 *in* Environmental monitoring and ecological studies program 1976 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol. 1. (Northern States Power Co., Minneapolis, MN)

Baker, A. L. 1976a. Studies of the productivity of the phytoplankton of the Mississippi River at Prairie Island—1975. Pages 2.1.1-1 through 2.1.1-35 *in* Environmental monitoring and ecological studies program 1975 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol. 1 (Northern States Power Co., Minneapolis, MN)

Baker, A.L. 1976b. 1975 studies of the attached algae in the vicinity of PINGP. Pages 2.2-1 through 2.2-59 *in* Environmental monitoring and ecological studies program 1975 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol. 1. (Northern States Power Co., Minneapolis, MN)

Baker, A.L. 1975a. Primary productivity of the phytoplankton in the Mississippi River at Prairie Island; the effects of heated water discharge on the levels of production; and a turbidometric analysis of mass flow. Pages 299-362 *in* Environmental monitoring and ecological studies program 1974 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol. 1. (Northern States Power Co., Minneapolis, MN)

Baker, A.L. 1975b. Attached algae in the Mississippi River at Prairie Island 1974. Pages 363-411 *in* Environmental monitoring and ecological studies program 1974 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol. 1. (Northern States Power Co., Minneapolis, MN)

Baker, A.L. 1974. Studies of the periphyton of the Mississippi River, near PINGP—1973. Pages C-7.1 through C-7.40 *in* Environmental monitoring and ecological studies program 1973 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol 2. (Northern States Power Co., Minneapolis, MN)

Baker, K.K. and A.L. Baker. 1974. Studies of the phytoplankton of the Mississippi River, near the PINGP—1973. Pages C-6.1 through C-6.35 *in* Environmental monitoring and ecological studies program 1973 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol 2. (Northern States Power Co., Minneapolis, MN)

Barans, C.A. and R.A. Tubb. 1973. Temperatures selected seasonally by four fishes from western Lake Erie. J. Fish. Res.Bd. Canada 30:1697-1703.

Bardach, J.E., J.H. Ryther, and W.D. McLarney. 1975. Aquaculture: the farming and husbandry of freshwater and marine organisms. Wiley-Interscience, New York. 868 pp.

Barker, N.A. 1935. Photosynthesis in diatoms. Arch. Microbiol. 6:141-156.

Barnes, R.D. 1963. Invertebrate zoology. W.B. Saunders Co., Philadelphia. 632 pp.

Baxter, R.M. 1977. Environmental effects of dams and impoundments. Ann. Rev. Ecol. Syst. 8:255-283.

Becker, C.D., and T.O. Thatcher. 1973. Toxicity of power plant chemicals to aquatic life. Batelle Pacific NW Labs., Richland, WA.

Benda, R.S., and M.A. Proffitt. 1974. Effects of thermal effluents on fish and invertebrates. Pages 435-447 *in* J.W. Gibbons and R.R. Sharitz, eds. Thermal ecology. U.S.A.E.C. CONF. 730505.

Beyerle, G.B., and J.E. Williams. 1973. Contribution of northern pike fingerlings raised in a managed marsh to the pike population of an adjacent lake. Prog. Fish-Cult. 35(2):99-103.

Black, E.C. 1953. Upper lethal temperatures of some British Columbia freshwater fishes. J. Fish. Res. Bd. Canada 10:196-210.

Brett, J.R. 1944. Some lethal temperature relations of Algonquin Park fishes. Publ. Ont. Fish. Res. Lab. 63:1-49. *Cited in* Brungs, W.A., and B.R. Jones. 1977. Temperature criteria for freshwater fish: protocol and procedures. EPA-600/3-77-061.

Brock, T.D. 1975. Predicting the ecological consequences of thermal pollution from observations on geothermal habitats. Pages 599-622 *in* Proceedings of a symposium on environmental effects of cooling systems at nuclear power plants. CONF-740820; STI/PUB/378; IAEA-SM-187/9.

Brock, T.D., and J. Hoffmann. 1974. Temperature optima of algae living in an outfall of a power plant on Lake Monona. Trans. Wisc. Acad. Sci., Arts and Letters 62:195-203.

Brook, A.J. 1971. Phytoplankton. Pages 1-9 *in* Environmental monitoring and ecological studies program 1970 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. (Northern States Power Co., Minneapolis, MN)

Brown, H.W. 1974. Handbook of the effects of temperature on some North American fishes. Am. Elect. Power Serv. Co., Canton, OH. 524 pp.

Brown L.A. 1929. The natural history of cladocerans in relation to temperature. I. Distribution and temperature limits of vital activities. Am. Nat. 63:248-264.

Brungs, W.A., and B.R. Jones. 1977. Temperature criteria for freshwater fish: protocol and procedures. EPA Environ. Res. Lab, Duluth, MN, EPA-600/3-77-061. 130 pp.

Burns, J.W. 1966. Carp. Pages 510-515 *in* A. Calhoun, ed. Inland fisheries management. Calif. Dept. Fish and Game.

Bush, R.M., E.B. Welch, and B.W. Mar. 1974. Potential effects of thermal discharges on aquatic systems. Environ. Sci. Tech. 8(6):561-568.

Campbell, J.S., and H.R. MacCrimmon. 1970. Biology of the emerald shiner *Notropis atherinoides* Rafinesque in Lake Simcol, Canada. J. Fish. Biol. 2:259-273.

Carlander, K.D. 1969. Handbook of freshwater fishery biology. Vol. 1. Iowa State Univ. Press, Ames. 752 pp.

Carlson, D.M. 1972. Responses of planktonic cladocerans (Crustacea) to heated waters. M.S. Thesis. Cornell Univ., Ithaca, NY.

Carpenter, E.J., B.B. Peck, and S.J. Anderson. 1974. Summary of entrainment research at the Millstone Point Nuclear Power Station, 1970 to 1972. Pages 31-36 *in* L.D. Jensen, ed. Proc. second workshop on entrainment and intake screening. EPRI Publ. No 74-949-00-5. Electric Power Res. Inst., Palo Alto, CA.

Cherry, D.S., K.L. Dickson, and J. Cairns, Jr. 1975. Temperature selected and avoided by fish at various acclimation temperatures. J. Fish. Res. Bd. Canada 32:485-491.

Chu, C.K. 1968. Computational fluid dynamics. Vol. IV, American Institute of Aeronautics and Astronautics, selected reprint series.

Clemens, H.P., and K.E. Sneed. 1957. The spawning behavior of the channel catfish *Ictalurus punctatus*. U.S. Dept. Int., Fish and Wildlife Service, Special Scientific Report—Fisheries No. 219. 11 pp.

Coker, R.E. 1934. The reaction of some freshwater copepods to high temperature with a note concerning the rate of development and relation to temperature. J. Elisha Mitchell Sci. Soc. 50:143-159.

Corps of Engineers. 1977. Log of annual lockages. St. Paul. 2 pp.

Corps of Engineers. 1974. Reservoir regulation manual, Appendix 3, Lock and Dam No. 3. Mississippi River Nine Foot Channel Navigation Project, St. Paul District. 33 pp.

Coutant, C.C. 1975. Resistance of gizzard shad to instantaneous cold shock. Part III, Ch. 7. ORNL Environ. Sci. Div. Publ. No. 653, ORNL-5016:41-42. (Oak Ridge National Laboratory, Oak Ridge, TN)

Coutant, C.C. 1974. 4. Power plant effects. Pages 24-33 *in* Environmental sciences division annual progress report for period ending September 30, 1973. Part I, ORNL Publication No. 570. (Oak Ridge National Laboratory, Oak Ridge, TN)

Coutant, C.C. 1972. Biological aspects of thermal pollution. II. Scientific basis for water temperature standards at power plants. CRC Critical Reviews in Environ. Control 3(1):1-24.

Coutant, C.C. 1970. Biological aspects of thermal pollution. I. Entrainment and discharge canal effects. CRC Critical Reviews in Environ. Control 1(3):341-381.

Coutant, C.C. 1968. The effect of temperature on the development of bottom organisms. Pages 9.13-9.14 *in* Biological effects of thermal discharges: annual progress report for 1967. USAEC Res. and Dev. Rep. No. BNWL-714 Pacific NW Lab.

Coutant, C.C. 1962. The effect of a heated water effluent upon the macroinvertebrate riffle fauna of the Delaware River. Proc. Penn. Acad. Sci. 36:58-71.

Curry, L.L. 1965. A survey of environmental requirements for the midge (Diptera: Tendipedidae). Pages 127-140 *in* C.M. Tarzwell, ed. Biological problems in water pollution. 3rd Seminar. PHS Bur. 999-WP-25.

Daggett, R.F. 1976. Zooplankton study. Pages 2.3.1-1 through 2.3.1-80 *in* Environmental monitoring and ecological studies program 1975 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol. 1. (Northern States Power Co., Minneapolis, MN)

Davies, R.M., and L.D. Jensen. 1975. Zooplankton entrainment at three mid-Atlantic power plants. J. Water Poll. Control Fed. 47(8): 2130-2142.

Dendy, J.S. 1948. Predicting depth distribution of fish in three TVA storage-type reservoirs. Trans. Amer. Fish. Soc. 75(1945):65-71.

Dieterman, L. 1974. Water chemistry. Pages C-1.1 through C-1.78 *in* Environmental monitoring and ecological studies program 1973 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol. 1 (Northern States Power Co., Minneapolis, MN)

Dieterman, S.M. 1975. A short-term impact study of the zooplankton population dynamics in Pool 3 of the Mississippi River near the Northern States Power Red Wing Nuclear Power Plant (sic). M.S. Thesis. St. Mary's College. Winona, MN. 40 pp.

Duncan, T.O., and M.R. Myers. Artificial rearing of white bass, *Roccus chrysops,* Rafinesque. Unpublished data. South Central Reservoir Investigations, Bureau Sport Fisheries and Wildlife, Fayetteville, Arkansas. *Cited in* Brungs, W.A., and B.R. Jones. 1977. Thermal criteria for freshwater fish: protocol and procedures. EPA-600/3-77-061.

Eberley, L.W. 1977. Upstream-downstream water chemistry. Pages 1.2-1 through 1.2-21 *in* Environmental monitoring and ecological studies program 1976 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol. 1. (Northern States Power Co., Minneapolis, MN)

Eberley, L.W., and S.F. Schmidt. 1976. Thermal plume surveys. Pages 1.4-1 through 1.4-19 *in* Environmental monitoring and ecological studies program 1975 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol. 1. (Northern States Power Co., Minneapolis, MN)

Eddy, S. 1969. How to know the freshwater fishes, 2nd edition. Wm. C. Brown Co. Publishers, Dubuque, IA. 286 pp.

Eddy, S., and J.C. Underhill. 1974. Northern fishes. Univ. of Minn. Press, Minneapolis. 414 pp.

Edison Electric Institute and Utility Water Act Group (EEI and UWAG), 1977. Comments on "Draft interagency 316(a) technical guidance manual and guide for the thermal effects sections on nuclear facilities environmental impact statement, May 1, 1977." EEI and UWAG, 69 pp.

Faanes, C. 1975. Ecology of wintering bald eagles near the Prairie Island Nuclear Generating Plant. Pages 2.7.3.1-1 through 2.7.3.1-24 *in* Environmental monitoring and ecological studies program 1975 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol 2. (Northern States Power Co., Minneapolis, MN).

Faber, D.J. 1967. Limnetic larval fish in northern Wisconsin lakes. J. Fish. Res. Bd. Canada 24:927-937.

Ferguson, R.G. 1958. The preferred temperature of fish and their midsummer distribution in temperate lakes and streams. J. Fish Res. Bd. Canada 15(4):607-624.

Fogg, G.E., and C.W. Reimer. 1962. Environmental requirements of plankton algae and their effects on water quality. Pages 19-28 *in* Biological problems in water pollution control. U.S. Dept. H.E.W.

Forney, J.L. 1963. Distribution and movement of marked walleye in Oneida Lake, New York. Trans. Amer. Fish Soc. 92:47-52.

Frank, M.L. 1974. Relative sensitivity of different development stages of carp eggs to thermal shock. Pages 171-176 *in* J.W. Gibbons and R.R. Sharitz, eds. Thermal ecol., AEC Sym. Ser. 32, CONF 730505.

Franklin, D.R., and L.L. Smith, Jr. 1963. Early life history of the northern pike, *Esox lucius L.,* with special reference to the factors influencing the numerical strength of year classes. Trans. Amer. Fish. Soc. 92(2):91-110.

Fuchs, E.H. 1967. Life history of the emerald shiner, *Notropis atherinoides,* in Lewis and Clark Lake, South Dakota. Trans. Amer. Fish. Soc. 96(3):247-256.

Gammon, J.R. 1973. The effect of thermal inputs on the populations of fish and macroinvertebrates in the Wabash River. Purdue Univ. Water Resources Res. Center, Lafayette, IN. Tech. Rept. 32. 106 pp.

Gammon, J.R. 1971. The response of fish populations in the Wabash River to heated effluents. Proc. 3rd Nat. Symp. Radioecol. CONF-710501 1:513-523.

Geis, J.L., and S.P. Gustafson. 1977. Progress report on the Prairie Island creel survey, March 6 - November 21, 1976. Pages 2.5.3-1 through 2.5.3-60 *in* Environmental monitoring and ecological studies program 1976 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol. 2 (Northern States Power Co., Minneapolis, MN)

Ginn, T.C., W.T. Waller, and G.J. Lauer. 1974. The effects of power plant condenser cooling water entrainment on the amphipod *Gammarus.* Water Res. 8:973-975.

Goodson, L.F., Jr. 1966a. Walleye. Pages 423-426 *in* A. Calhoun, ed. Inland fisheries management. Calif. Dept. Fish and Game.

Goodson, L.F., Jr. 1966b. Crappie. Pages 312-332 *in* A. Calhoun, ed. Inland fisheries management. Calif. Dept. Fish and Game.

Gustafson, S.P., and P.J. Diedrich. 1976. Progress report on the Prairie Island creel survey March 1 - November 23, 1975. Pages 2.5.3-1 through 2.5.3-35 *in* Environmental monitoring and ecological studies program 1975 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol. 2. (Northern States Power Co., Minneapolis, MN)

Gustafson, S.P., and J.L. Geis. 1977. 1976 progress report on the Prairie Island fish population study. Pages 2.5.2-1 through 2.5.2-148 *in* Environmental monitoring and ecological studies program 1976 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol. 2. (Northern States Power Co., Minneapolis, MN)

Gustafson, S.P., J.L. Geis, and P.J. Diedrich. 1976. 1975 progress report on the Prairie Island fish population study. Pages 2.5.2-1 through 2.5.2-13 *in* Environmental monitoring and ecological studies program 1975 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol. 2. (Northern States Power Co., Minneapolis, MN)

Harnett, D.L. 1970. Introduction to statistical methods. Addison-Wesley Publ. Co., Massachusetts. 530 pp.

Hart, J.S. 1952. Geographical variations of some physiological and morphological characters in certain freshwater fish. Univ. Toronto, Toronto, Ontario. Biological Series No. 60. *Cited in* Brungs, W.A., and B.R. Jones. 1977. Temperature criteria for freshwater fish: protocol and procedures. EPA-600/3-77-061.

Hart, J.S. 1947. Lethal temperature relations of certain fish of the Toronto region. Trans. Roy. Soc. Canada. Ser. III 41(5):57-71.

Hawkinson, B.W. 1974. Progress report on the Prairie Island creel survey May 10 - November 5, 1973. Pages C-5.59 through 5.85 *in* Environmental monitoring and ecological studies program 1973 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol. 1. (Northern States Power Co., Minneapolis, MN)

Haynes, C.M. 1976. Macroinvertebrate study. Pages 2.4-1 through 2.4-92 *in* Environmental monitoring and ecological studies program 1975 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol. 1. (Northern States Power Co., Minneapolis, MN)

Hickman, M., and D.M. Klarer. 1974. The growth of some epiphytic algae in a lake receiving thermal effluent. Arch. Hydrobiol. 74:403-436.

Hirayamo, K., and R. Hirano. 1970. Influences of high temperature and residual chlorine on marine phytoplankton. Marine Biol. 7:205-213.

Hoffman, G.L. 1967. Parasites of North American freshwater fishes. Univ. of Calif. Press, Berkeley and Los Angeles. 486 pp.

Hokanson, K.E.F., and C.F. Kleiner. Effects of constant and diel fluctuations in temperature on growth and survival of black crappie. Unpublished data, U.S. Environmental Protection Agency, Duluth, Minnesota. *Cited in* Brungs, W.A., and B.R. Jones. 1977. Temperature criteria for freshwater fish: protocol and procedures. EPA-600/3-77-061.

Hopwood, A.J. 1975. Monticello ecological studies program, macroinvertebrates. Pages 123-205 *in* 1974 annual report, Monticello Nuclear Generating Plant. (Northern States Power Co., Minneapolis, MN)

Horak, D.L., and H.A. Tanner. 1964. The use of vertical gill nets in studying fish depth distribution, Horsetooth Reservoir, Colorado. Trans. Amer. Fish. Soc. 93:137-145.

Horoszewicz, L. 1973. Lethal and "disturbing" temperatures in some fish species from lakes with normal and artificially elevated temperatures. J. Fish. Biol. 5:165-181.

Hubbs, C.L., and K.F. Lagler. 1964. Fishes of the Great Lakes region. Univ. of Mich. Press, Ann Arbor. 213 pp.

Huet, N. 1953. *Cited in* Meuwis, A.L., and M.J. Heuts. 1957 Temperature dependence of breathing rate in carp. Biol. Bull. 112(1):97-107.

Hynes, H.B.N. 1970. The ecology of running waters. Univ. Toronto Press, Toronto.

Jensen, L.D., R.M. Davies, A.S. Brooks, and C.D. Meyers. 1969. The effects of elevated temperatures upon aquatic invertebrates. John Hopkins Univ., Baltimore, MD. Prep. for Edison Electric Inst. RP-49, EEI Publ. 69-900.

Jester, D.B. 1974. Life history, ecology, and management of the carp, *Cyprinus carpio* Linnaeus, in Elephant Butte Lake. Agri. Expt. Sta. Res. Rept. 273, New Mexico State Univ., Las Cruces. 80 pp.

Jester, D.B. 1972. Life history and ecology of the gizzard shad, *Dorosoma cepedianum* (Le Sueur) with reference to Elephant Butte Lake. Agri. Expt. Sta. Res. Rept. 218, New Mexico State Univ., Las Cruces. 56 pp.

June, F.C. 1971. The reproductive biology of northern pike, *Esox lucius*, in Lake Oahe, an upper Missouri River storage reservoir. Reservoir Fish. Limnol., Am. Fish. Soc. Spec. Publ. No. 8:53-71.

Keating, K.I. 1978. Blue-green algal inhibition of diatom growth: transition from mesotrophic to eutrophic community structure. Science 199: 971-973.

Kelso, J.R.M. 1972. Conversion, maintenance, and assimilation for walleye, *Stizostedion vitreum vitreum*, as affected by size, diet, and temperature. J. Fish. Res. Bd. Canada 29:1181-1192.

Kilambi, R.V., J. Noble, and C.E. Hoffman. 1970. Influence of temperature and food conversion efficiency of the channel catfish. Proc. 24th Ann. Conf. S.E. Assoc. Game and Fish Comm. 1969:519-531.

King, R.G. 1974. The effects of heat water discharge on zooplankton in a 4500 acre Missouri reservoir. M. S. Thesis. Univ. Missouri at Columbia. 78 pp.

Kititsyna, L.A., and O.A. Sergeeva. 1976. Influence of heating on size and weight in invertebrate populations in the cooling reservoir of Kurakhovska State Regional Electric Power Station. Soviet J. Ecol. 7(5):475-477.

Kreuger, J.F. 1975. Thermal tolerance determinations for Lake Michigan zooplankton, July 1972-March 1973. Pages 39-120 *in* Evaluation of thermal effects in southwestern Lake Michigan, Special studies 1972-1973. Rept. to Commonwealth Edison Co. by Industrial Bio-Test Labs., Inc. Northbrook, IL.

Lopinot, A. 1960. Channel catfish facts in artificial lakes and ponds. Outdoors in Illinois 7(1).

Martin, W.J., and J.B. Gentry. 1974. Effects of thermal stress on dragonfly nymphs. Pages 133-145 *in* J.W. Gibbons and R.R. Sharitz, eds. Thermal ecology. U.S.A.E.C. CONF-730505.

Mason, W.T., A.Q. Lewis, and J.B. Patterson. 1971. Macroinvertebrate collections and water quality monitoring in the Ohio River Basin 1963-1967. Off. Techn. Prog., Ohio Basin Reg. and Anal. Qual. Control Lab., Water Qual. Off., EPA. 52 pp.

McConville, D.R. 1975. Comparison of artificial substrates in bottom fauna studies on a large river. J. Minn. Acad. Sci. 41: 21-24.

McCormick, J.H. 1976a. Temperature effects on the growth of juvenile white bass. U.S. Environmental Protection Agency, Duluth, Minnesota. *Cited in* Brungs, W.A., and B.R. Jones. 1977. Thermal criteria for freshwater fish: protocol and procedures. EPA-600/3-77-061.

McCormick, J.H. 1976b. Temperature effects on white bass (*Morone chrysops*) embryo development, and survival of one-day-old larvae. U.S. Environmental Protection Agency, Duluth, Minnesota. *Cited in* Brungs, W.A., and B.R. Jones. 1977. Thermal criteria for freshwater fish: protocol and procedures. EPA-600/3-77-061.

McCormick, J.H., B.R. Jones, and K.E.F. Hokanson. 1977. White sucker (*Catostomus commersoni*) embryo development, and early growth and survival at different temperatures. J. Fish. Res. Bd. Canada 34:1019-1025.

McCormick, J.H., and D.F. Kleiner. 1976. Growth and survival of young-of-the-year emerald shiners (*Notropis atherinoides*) at different temperatures. J. Fish. Res. Bd. Canada 33:839-842.

McGinnis, R., D. Zimmel, and E. Martin. 1978. Multiple linear regression analysis of Prairie Island temperatures versus Red Wing temperatures. Unpublished report by Northern States Power Co.

Merriner, J.V. 1971a. Egg size as a factor in intergeneric hybrid success of centrarchids. Trans. Amer. Fish Soc. 100(1):29-32.

Merriner, J.V. 1971b. Development of intergeneric centrarchid hybrid embryos. Trans. Amer. Fish Soc. 100(4):611-618.

Meyer, W.H. 1962. Life history of three species of redhorse (*Moxostoma*) in the Des Moines River, Iowa. Trans. Amer. Fish. Soc. 91:412-419.

Miller, E.E. 1966. Channel catfish. Pages 440-463 *in* A. Calhoun, ed. Inland fisheries management. Calif. Dept. Fish and Game.

Miller, E.F. 1972. Zooplankton study. Pages 50-97 *in* Environmental monitoring and ecological studies program 1971 annual report, Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. (Northern States Power Co., Minneapolis, MN)

Miller, R.R. 1960. Systematics and biology of the gizzard shad (*Dorosoma cepedianum*) and related fishes. Fisheries Bulletin 173 60:371-392.

Minnesota Department of Natural Resources (DNR). 1977. Minnesota Fishing Regulations.

Minnesota Pollution Control Agency (MPCA). 1975. Minnesota's guide for biological demonstrations for administration of 316(a) and (b) of the Federal Water Pollution Control Act Amendments of 1972 and Minnesota Regulation WPC 36(u)(3). 83 pp.

Mueller, K.N. 1977. Aquatic vegetation study. Pages 2.6-1 through 2.6-17 *in* Environmental monitoring and ecological studies program 1976 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol. 2. (Northern States Power Co., Minneapolis, MN)

Mueller, K.N. 1976. Prairie Island aquatic vegetation study 1975. Pages 2.6-1 through 2.6-13 *in* Environmental monitoring and ecological studies program 1975 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol. 2. (Northern States Power Co., Minneapolis, MN)

Muewis, A.L. and M.J. Huets. 1957. Temperature dependence of breathing rate in carp. Biol. Bull. 112(1):97-107.

Muraka, I.P., Project Leader. 1976. An evaluation of environmental data relating to selected nuclear power plant sites. Div. Env. Impact Studies, Argonne Nat. Lab, Argonne, IL. 54 pp. + Appendices.

Naplin, R.L., and J.L. Geis. 1975. 1974 progress report on the Prairie Island fish population study. Pages 563-715 *in* Environmental monitoring and ecological studies program 1974 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol. 2. (Northern States Power Co., Minneapolis, MN)

Nebeker, A.V. 1971. Effect of high winter water temperatures on adult emergence of aquatic insects. Water Res. 5:777-783.

Nebeker, A.V., and A.E. Lemke. 1968. Preliminary studies on the tolerance of aquatic insects to heated waters. J. Kan. Entomolog. Soc. 41:413-418.

Neill, W.H., and J.J. Magnuson. 1974. Distributional ecology and behavioral thermoregulation of fishes in relation to heated effluent from a power plant at Lake Monona, Wisconsin. Trans. Amer. Fish. Soc. 103:663-710.

Neill, W.H., J.J. Magnuson, and G.G. Chipman. 1972. Behavioral thermoregulation by fishes: a new experimental approach. Science 176:1442-1443.

Niemuth, W., W. Churchill, and T. Wirth. 1972. Walleye: its life history, ecology and management. Wisconsin Dept. Nat. Res., Publ. No. 227-72. 20 pp.

NUS. 1976. Section 316(b) demonstration for the Prairie Island Nuclear Generating Plant on the Mississippi River near Red Wing, Minnesota. Prep. for No. States Power Co. (NUS Corp., Pittsburg, PA)

Omaha Public Power District (OPPD). 1976. Zooplankton. Pages 5.1-5.41 *in* Fort Calhoun Station Unit No. 2 environmental report. Construction permit stage. Vol. 3. Suppl. 1. NRC Docket No. 50-548.

Omernick, J.M. 1977. Nonpoint source-stream nutrient level relationships: a national survey. EPA-600/3-77-105. Corvallis Env. Res. Lab., Off. Res. Dev., U.S.E.P.A., Corvallis, OR. 151 pp.

Patrick, R. 1969. Some effects of temperature on freshwater algae. Pages 161-185 *in* P.A. Krenkel and B.L. Parker, eds. Biological aspects of thermal pollution. Vanderbilt Univ. Press, Nashville, TN.

Peterson, S.E., R.M. Schutsky, and S.E. Allison. 1974. Temperature preference, avoidance and shock experiments with freshwater fishes and crayfishes. [Ichthyological Assoc., Inc.] Bull. 10. Drumore, PA.

Pitt, T.K., E.T. Garside, and R.L. Hepburn. 1956. Temperature selection of the carp (*Cyprinus carpio* Linn.). Can. J. Zool. 34:555-557.

Priegel, G.R. 1969. Food and growth of young walleye in Lake Winnebago, Wisconsin. Trans. Amer. Fish. Soc. 98:121-124.

Proffitt, M.A., and R.S. Benda. 1971. Growth and movement of fishes, and distribution of invertebrates, related to a heated discharge into the White River at Petersburg, Indiana. Water Resources Research Center, Rept. of Invert. No. 5, Indiana Univ., Bloomington. 94 pp.

Reutter, J.M., and C.E. Herdendorf. 1974. Laboratory estimates of the seasonal final temperature preferenda of some Lake Erie fish. Proc. 17th Conf. Great Lakes. Res.:59-67.

Robach, S.S. 1965. Enviornmental requirements of Trichoptera. Pages 118-126 *in* C.M. Tarzwell, ed. Biological problems in water pollution. U.S.H.E.W.

Ruelle, R. 1971. Factors influencing growth of white bass in Lewis and Clark Lake. Reservoir Fish. Limnol., Special Publ. No. 8 of Am. Fish. Soc.:411-423.

Schaeperclaus, W. 1949. *Cited in* Meuwis, A.L., and M.J. Heuts. 1957. Temperature dependence of breathing rate in carp. Biol. Bull. 112(1):97-107.

Schmidt, S.F. 1977. Water chemical analyses. Pages 1.1-1 through 1.1-73 *in* Environmental monitoring and ecological studies program 1976 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota. Vol. 1. (Northern States Power Co., Minneapolis, MN)

Schneberger, E. 1972. The white sucker: its life history, ecology and management. Wisconsin Dept. Nat. Resources Publ. No. 245-72. 18 pp.

Schwabe, G.H. 1936. Beiträge zur Kenntris isländischer thermalbiotope. [In German]. Arch. Hydrobiol., Suppl. Bd. 6(2):161-352.

Scott, D.P. 1964. Thermal resistance of pike *(Esox lucius L.)*, muskellunge, *(E. masquinongy* Mitchell), and their F_1 hybrid. J. Fish. Res. Bd. Canada 21:1043-1049.

Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd. Canada. Bull. 184. 966 pp.

Seaburg, K.G., and J.B. Moyle. 1964. Feeding habits, digestive rates, and growth of some Minnesota warmwater fishes. Trans. Amer. Fish. Soc. 93:269-285.

Sherberger, F.F., E.F. Benfield, K.L. Dickson, and J. Cairns, Jr. 1977. Effects of thermal shocks on drifting aquatic insects: a laboratory simulation. J. Fish. Res. Bd. Canada 34:529-536.

Shyne, J.T. 1977. Adult aquatic insect emergence from Pool No. 3 of the upper Mississippi River. M.S. Thesis. St. Mary's College. Winona, MN. 155 pp.

Wallace, N.M. 1955. The effect of temperature on the growth of some freshwater diatoms. Not. Nat. Acad. Nat. Sci. Phil. No. 280:1-11.

Ward, F.J., and G.G.C. Robinson. 1974. A review of research on the limnology of West Blue Lake, Manitoba. J. Fish. Res. Bd. Canada 31(5):977-1005.

Weber, C.I. 1973. Biological field and laboratory methods for measuring the quality of surface waters and effluents. Nat. Env. Res. Center, EPA. Cincinnati, OH.

Weibe, P.H. 1971. A computer model study of zooplankton patchiness and its effects on sampling error. Limnology and Oceanography 16:29-38.

West, B.W. 1966. Growth, food conversion, food consumption, and survival at various temperatures of the channel catfish, *Ictalurus punctatus* (Rafinesque). M.S. Thesis, Univ. AR, Tucson, AR *Cited in* Brungs, W.A., and B.R. Jones. 1977. Temperature criteria for freshwater fish: protocol and procedures. EPA-600/3-77-061.

Whitaker, J.O., Jr., and R.A. Schlueter. 1973. Effects of heated discharge on fish and invertebrates of White River at Petersburg, Indiana. Water Resources Research Center, Rept. of Invert. No. 6, Indiana Univ., Bloomington. 123 pp.

Yeh, G.T. 1976. Analytical three-dimensional transient modeling of effluent discharge. Water Resources Research J. 12(3):533-539.

Yeh, G.T., F.H. Lia, and A.P. Verna. 1973. Unsteady temperature prediction for cooling ponds. Water Resources Research J. 9(6):555-1,563.

Yellayi, R.R. 1972. Ecological life history and population dynamics of white bass, *Morone chrysops* (Rafinesque) in Beaver Reservoir. Part 2. A contribution to the dynamics of white bass, *Morone chrysops* (Rafinesque), population in Beaver Reservoir, Arkansas. Report to Arkansas Game and Fish Commission. Univ. of Arkansas., Fayetteville. *Cited in* Brungs, W.A., and B.R. Jones. 1977. Thermal criteria for freshwater fish: protocol and procedures. EPA-600/3-77-061.

SECTION 316(a) DEMONSTRATION
FOR THE PRAIRIE ISLAND NUCLEAR GENERATING PLANT
ON THE MISSISSIPPI RIVER NEAR
RED WING, MINNESOTA
NPDES PERMIT NO. MN0004006

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MINNEAPOLIS, MINNESOTA

AUGUST 1978

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HDR ecosciences

APPENDICES CONTENTS

APPENDICES

APPENDIX A

DATA CATALOG

TABLES

Table		Page
A-38.	Areas within various isotherms from the thermal plume model (Appendix I) for typical summer (August 1975) conditions.	A-53
A-39.	Areas within various isotherms from the thermal plume model (Appendix I) for typical winter (December 1975) conditions.	A-54
A-40.	Areas within various isotherms from the thermal plume model (Appendix I) for winter (January) proposed extreme conditions.	A-55
A-41.	Areas within various isotherms from the thermal plume model (Appendix I) for spring (May) proposed extreme conditions.	A-56
A-42.	Areas within various isotherms from the thermal plume model (Appendix I) for summer (August) proposed extreme conditions.	A-56
A-43.	Mean temperatures (C) at each discharge electrofishing study station.	A-57
A-44.	Catch per unit effort (fish/5 min. run) at each station for the discharge electrofishing study.	A-58
A-45.	Constants for the time-temperature equation.	A-62
A-46.	Data used in chi-square analysis.	A-63

FIGURES

Table A-1. Weekly averages of river flows at Prescott and weekly averages of daily minimum, mean, and maximum river river temperatures at RWGP.

WEEK	AVERAGE RIVER FLOW AT PRESCOTT (CFS), 1928-1976 WATER YEARS	AVERAGE RIVER TEMPERATURE (F)[1] 1959-1974		
		DAILY MINIMUM	DAILY MEAN	DAILY MAXIMUM
1	7,708.98	31.83	31.83	31.83
2	7,339.34	32.00	32.00	32.00
3	7,225.15	32.00	32.00	32.00
4	7,174.02	32.00	32.00	32.00
5	7,099.16	32.00	32.00	32.00
6	7,237.80	32.00	32.00	32.00
7	7,520.71	33.00	33.00	33.00
8	7,414.34	33.00	33.00	33.00
9	10,572.30	33.57	33.80	34.00
10	9,503.06	35.71	35.79	35.86
11	12,145.74	36.00	36.25	36.43
12	19,058.00	38.71	34.15	34.57
13	25,535.21	36.81	37.14	37.57
14	31,902.23	38.71	39.20	39.61
15	41,044.88	41.84	42.51	43.10
16	44,447.32	46.24	46.92	47.57
17	38,903.51	49.77	50.51	51.18
18	33,368.15	53.22	53.91	54.64
19	30,584.25	55.31	55.87	56.43
20	29,034.46	58.25	58.92	59.60
21	26,800.12	61.13	61.74	62.37
22	25,585.12	62.64	63.22	63.88
23	24,410.03	67.98	68.50	69.04
24	23,599.21	69.37	69.93	70.46
25	24,276.94	69.73	70.36	70.97
26	22,745.10	72.11	72.81	73.42
27	21,531.30	73.26	73.92	74.43

Table A-1 (Continued).

WEEK	AVERAGE RIVER FLOW AT PRESCOTT (CFS), 1928-1976 WATER YEARS	AVERAGE RIVER TEMPERATURE (F)[1] 1959-1974		
		DAILY MINIMUM	DAILY MEAN	DAILY MAXIMUM
28	18,545.98	74.36	75.10	75.70
29	15,398.42	74.93	75.70	76.27
30	14,712.39	74.73	75.44	76.01
31	12,529.88	73.95	74.71	75.33
32	12,477.81	72.31	72.90	73.48
33	12,106.50	71.15	71.85	72.51
34	10,775.48	69.13	69.32	70.36
35	10,345.17	69.71	70.39	70.89
36	10,844.72	69.14	69.82	70.31
37	10,758.98	65.10	65.76	66.28
38	11,214.63	62.29	62.36	63.38
39	11,170.74	58.70	59.27	59.69
40	10,800.03	57.07	57.60	58.02
41	11,052.53	55.15	55.60	56.01
42	11,766.70	53.02	53.53	53.96
43	12,188.12	49.59	50.06	50.43
44	12,310.90	46.50	46.89	47.16
45	12,114.20	42.23	42.65	43.02
46	11,771.57	39.96	40.31	40.59
47	11,612.73	37.64	37.94	38.21
48	10,044.37	36.04	36.30	36.56
49	6,925.00	33.57	34.08	34.57
50	6,946.43	32.43	32.52	32.57
51	7,363.57	32.17	32.29	32.33
52	8,593.91	32.00	32.00	32.00

[1]Records for weeks 1-13 and weeks 48-52 were not continuous.

Table A-2. Monthly averages of river flows at Prescott and monthly averages of daily minimum, mean, and maximum river temperatures at RWGP.

MONTH	AVERAGE RIVER FLOWS AT PRESCOTT (CFS), 1928-76 WATER YEARS	AVERAGE RIVER TEMPERATURE[1] (F) 1959-1974		
		DAILY MINIMUM	DAILY MEAN	DAILY MAXIMUM
January	7,336.43	31.97	31.97	31.97
February	7,406.90	32.63	32.66	32.67
March	15,206.27	34.84	35.05	35.29
April	38,608.93	44.17	44.81	45.38
May	29,933.31	57.74	58.34	58.99
June	24,213.27	69.07	69.69	70.29
July	17,471.02	74.28	75.00	75.56
August	11,695.80	71.12	71.78	72.38
September	10,941.29	64.08	64.72	65.19
October	11,532.39	53.14	53.62	54.00
November	11,601.14	40.04	40.38	40.69
December	8,549.96	32.83	33.03	33.17

[1]Records for January, February, March, and December were not continuous.

Table A-3. 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			37.3
59				1.0	56.6	100.0			94.3	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 (Continued).

TEMPERATURE	PERCENT OF TIME TEMPERATURE EQUALED OR EXCEEDED												
	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	ANNUAL
56				5.6	77.4				98.7	41.5	0.0		43.1
55				8.3	81.4				98.7	49.4	0.6		44.4
54				11.5	84.5				99.0	55.5	0.9		45.5
53				14.5	88.5				99.1	62.1	1.3		46.5
52				17.2	90.4				99.3	68.4	2.4		47.7
51				20.7	92.3				99.9	73.0	4.2		48.7
50				25.8	93.6				100.0	81.3	6.7		50.2
49				29.3	95.4					85.6	7.7		51.0
48				34.2	96.0					88.7	8.7		51.9
47				37.3	97.0					91.1	11.1		52.6
46			0.0	42.9	97.4					93.2	15.5		53.5
45			0.1	48.1	98.6					98.3	19.3	0.0	54.9
44			0.4	54.8	99.3					99.4	24.5	0.1	56.1
43			0.7	58.9	99.6					99.6	29.6	0.2	57.0
42			1.2	63.8	99.6					99.9	36.8	0.5	58.0
41			2.1	69.3	99.8					100.0	42.5	0.6	59.0
40			3.7	73.9	99.9						51.1	0.6	60.3
39		0.0	6.0	78.4	100.0						56.6	0.7	61.3
38		0.4	11.0	84.0							63.6	1.3	62.7
37		0.7	16.4	86.2							70.0	2.2	64.1
36		0.8	25.0	89.9							75.2	4.2	65.7
35	0.0	2.4	37.3	93.7							79.9	9.3	68.1
34	0.4	7.5	50.4	97.2							86.2	18.1	71.3
33	5.5	18.9	59.1	99.7							90.0	35.0	75.
32	99.6	99.7	100.0	100.0							100.0	100.0	100
NO.	832	757	821	774	802	774	800	788	763	811	791	824	9537

Table A-4. Flow and selected constituent concentrations for the Metropolitan Wastewater Treatment Plant effluents in 1975 and 1976 (MWTP, unpublished).

PARAMETER	MAIN EFFLUENT 1976			MAIN EFFLUENT 1975			ASH POND 1976			ASH POND 1975		
	MAX	MIN	AVE	MAX	MIN	AVE	MAX	MIN	AVE	MAX	MIN	AVE
Wastewater Flow, mgd	214	171	196[1,2]	232	174	202[1,2]				3.0	2.56	2.85[2,3]
Dissolved Oxygen, mg/l	3.5	0.8	2.6	4.3	1.3	2.8	8.1	3.3	4.3			
Biochemical Oxygen Demand, mg/l	135	26	67	156	21	41	9.9	24	59	22.0	7.0	17[4]
Ammonia, mg/l	14.9	9.2	12.3	14.9	7.1	10.6	17.9	7.4	12.0	12.0	11.0	11.0[5]
Nitrite and Nitrate, mg/l	1.24	.12	.38	1.11	< .08	.25	.36[6]	.03[6]	.18[6]	1.41	1.18	1.30[5,6]
Total Phosphorus	5.5	3.2	4.2	5.1	2.4	3.5	2.7	1.5	2.1	2.0	1.8	1.9[5]
pH	8.1	7.0		8.4	7.0		9.6	8.8		9.8[4]	8.8[4]	
Copper, µg/l	250	60	130	120	30	70						
Mercury, µg/l	1.3	0.3	0.7	6	<.2	1.5						
Lead, µg/l	140	<50	100	100	<50	<90						
Zinc, µg/l	270	130	180	260	110	170						
Cyanide, µg/l	132	47	74	80	21	48						

[1]Design flow, 218 mgd.

[2]Influent.

[3]Three monthly values only.

[4]Four monthly values only.

[5]Two monthly values only.

[6]NO_3 only.

Table A-5. Selected representative toxicity values for certain water quality constituents found in the Mississippi River at Lock and Dam No. 3, 1972-1976 (from Becker and Thatcher, 1973).

TOXICANT	STATE STANDARD[1]	MEASURED MAX CONC. NEAR PINGP[1]	BIOASSAY TEST LEVELS[1]	TEST CHEMICAL	ORGANISM	RESPONSE
Phenols	0.01	≈0.01	0.56-0.75	Sodium pentachlorophenate	*Pomoxis annularis*	Caused losses
			0.06	" "	"fish"	Can be lethal under laboratory conditions
			0.05	Pentachlorophenol sodium salt	*Notropis atherinoides*	Minimum lethal concentration, 100% survival in 120 m
Arsenic	No standard	0.002	0.5	Sodium arsenite	*Lepomis macrochirus*	48 hr-TLm
Copper	0.01	0.023	0.43	Copper	*Pimephales promelas*	96 hr-TLm, chronic, hard water
			0.1	"	*Daphnia magna* (cladoceran)	Killed
			0.06-0.5	"	*Spirogyra*	Maximum non-inhibitory at 20 C
			0.06-0.125	"	*Orconectes rusticus* (crayfish)	Acute toxicity threshold, young
			0.06	"	*Daphnia magna* (cladoceran)	48 hr-TLm, acute; without food
			0.05	"	*Microregma heterostoma* (protozoan)	Toxic threshold; 28 hr, 27 C
			0.035	"	*Daphnia magna* (cladoceran)	50% reproductive loss in 3 weeks, (tests at 18 C, pH 7.4-8.2)
			0.027	Copper chloride	" " "	Threshold concentration, immobilization in 64 hr; Lake Erie water, 25 C
			0.027	" "	" " "	Threshold concentration sub-lethal; immobilization in 64 hr, 25 C
			0.025	Copper	*Pimephales promelas*	Most died within 8 hr, soft water; with 1000 ug/l zinc
			0.024	Copper sulfate	*Cyprinus carpio*	Growth decreased, minimum
			0.013-0.030	Copper	*Pimephales promelas*	Sub-lethal concentrations affecting growth and reproduction; hard water
			0.01	Copper sulfate	*Physa heterostropha* (young snails)	96 hr-TLm; hard water, 21.1 C
			0.0098	Copper (Cu^{++})	*Daphnia magna* (cladoceran)	48 hr-TLm, acute: without food
			0.005	Copper	*Nitzschia palea* (diatom)	Prevents growth entirely
			0.001	Copper sulfate	"hydra"	Damaged

Table A-5 (Continued).

TOXICANT	STATE STANDARD[1]	MEASURED MAX CONC. NEAR PINGP[1]	BIOASSAY TEST LEVELS[1]	TEST CHEMICAL	ORGANISM	RESPONSE
Mercury	No standard	0.0023		No data → → →		
Zinc	No standard	0.140	0.235	Zinc	*Lepomis macrochirus*	Inhibited spawning and killed new fry
			0.358	Zinc (ion)	*Daphnia magna* (cladoceran)	3 week-TLm, chronic, 18 C
			0.070	"	" " "	16% reproduction loss in 3 weeks; 18 C, pH 7.4-8.2
			0.024	Zinc sulfate	" " "	Killed in hard water
Ammonia (N)	1	2.4	2.7	Ammonia (free)	*Tubifex* sp. (oligochaete worm)	Lethal level
			2.5	Ammonia	*Lepomis macrochirus*	Toxic level; toxicity dependent on pH and extent of ionization
			1.1	" (un-ionized)	*Gambusia affinis*	1000 min-TLm; 22 C, pH 7.8 (pH and temp. profoundly affect toxicity)
			1.0-2.0	Ammonia	"fish"	Lethal
			0.4-0.5	"	*Aphanizomenon* sp. (algae)	Complete disappearance
			0.3	Ammonia (free)	*Stylaria* sp.	Lethal level
			0.3-1.0	Ammonia	"fish"	Lethal in hatchery ponds under warm temperatures and low flows
			0.29	Ammonia (un-ionized)	*Perca fluviatilus*	7 day-TLm
			0.2-0.4	Ammonia (free)	*Planaria* spp. (Turbellarian)	Lethal level
			0.08	"	*Actinosphaerium* sp. (protozoan)	Lethal level
Cyanide	0.02	11	5.0	Sodium cyanide	*Lepomis cyanellus*	Moderately effective as repellant (lake studies)
			1.0	"	*Ictalurus natalis*	100% kill in 5-10 hr; 24-26 C, pH 7.0-8.2
			0.8	"	"minnows"	100% mortality in 24 hr
			0.53-0.65	Cyanide	"fish"	Toxic; toxicity increased over 1.2 to 25.4 C
			0.432	"	*Physa heteroclita* (snail)	96 hr-TLm, acute; with 3.9 mg/l zinc (Zn^{++})
			0.26	"	*Lepomis macrochirus*	" " "
			0.24	" (CN^-)	" "	Total kill in 96 hr
			0.2	Potassium cyanide	*Daphnia magna* (cladoceran)	24 hr and 48 hr-TLm, acute
			0.16	"	*Scenedesmus quadricauda* (algae)	Toxicity threshold, 4 days at 24 C

Table A-5 (Continued).

TOXICANT	STATE STANDARD[1]	MEASURED MAX CONC. NEAR PINGP[1]	BIOASSAY TEST LEVELS[1]	TEST CHEMICAL	ORGANISM	RESPONSE
Cyanide (cont.)	0.02	11	0.06	Cyanide	*Lepomis macrochirus* *L. auritus* *Micropterus dolomieu* *Notemigonus crysoleucas* *Pimephales promelas* *Pomoxis annularis*	No species survived more than 10 hr; 25 C, both static and constant flow bioassays
Lead	No standard	0.7	No Data → → →			

[1]All constituents are measured in mg/l.

Table A-6. Summary of adult and juvenile fish sampling near PINGP during 1970 through 1976 (from PINGP annual reports).

YEAR	SAMPLING METHODS	SAMPLING FREQUENCY	STATIONS SAMPLED[1]	INVESTIGATORS	REMARKS
1970	Trap nets (Fyke) with 10 ft wings	Summer—overnight sets; fall (Sept to 2 Oct)—7 sets	Unspecified	Miller of St. Mary's College	No data for summer trap net
	Electrofishing: 230 v, 3-phase AC	Summer (1-24 Aug) and fall (8-22 Sept)	Station 1		
	Seine (1/4 in. mesh)	Not specified	Shores of Station 1; beaches along main channel in pool No. 3		
1971	Trap nets (Fyke) with 10 ft wings	Spring, summer, and fall	Above Lock and Dam No. 3 in Stations 1-4	Miller of St. Mary's College	Trap nets mainly in Station 1; some scales taken for aging
	Experiment gill nets	Summer and fall— < 24 hr sets	Above Lock and Dam No. 3		
	Electrofishing: same as 1970	Spring, summer, and fall	Unspecified		
	Seine	Spring, summer, and fall	Unspecified		
1972	Trap nets	Summer and fall— 52 sets in fall	Unspecified	Miller of St. Mary's College	
	Hoop nets	Unspecified	Unspecified		
	Gill nets	Summer and fall— 28 sets in fall	Unspecified		
	Seine	Unspecified	Unspecified		
1973	Trap nets	1 24-hr set/station in summer (Aug) and fall (Oct)	Sections 0 (10 sta), I (10 sta), and III (7-8 sta)	Hawkinson of Minn. DNR	Scale samples taken for aging; Summer= late July-Aug and Fall=Sept-Oct
	Electrofishing: 230 v, 3-phase AC	1 15-min run/station in fall	Sections 0 (4 sta), I (6 sta), II (4 sta), and III (6 sta)		
	Gill nets: 250' x 6' with 50' sections of 1.5, 2, 2.5, 3, and 4 in. mesh	1 24-hr set/station in fall (Sept and Oct)	Sections 0 (5 sta), I (10 sta), and III (3 sta)		
	Seine: 1/4 in. mesh and 100 ft long with 8 ft bag	Summer and fall	Selected stations with suitable shoreline		
	Trawl (otter)	Summer (Aug)	Intake and discharge areas		
	Creel census	Surveyed each section several times from 10 May to 5 Nov	Sections I - IV	Hawkinson of Minn. DNR	
1974	Trap nets	1 24-hr set/station each season	All except Section II	Naplin and Geis of Minn. DNR	Tagging study for movement: scales taken for aging; Spring=May-June Summer=July-Aug and Fall=Sept - Oct; length-weight and condition factor
	Electroshocking: same as 1973	1 15-min run/station each season; some night shocking also	All Sections		
	Gill nets: same as 1973	1 24-hr set/station in Spring and fall	Sections 0 (10 sta), I (10 sta), and III (5 sta)		
	Seine: 50' x 4' with 4' x 4' x 4' bag and 1/4 in. mesh	Spring, summer, and fall	2-3 stations/section with suitable shoreline		
	Trawl (otter)	Spring, Summer, and fall	2 stations in Section 0 and at intake and discharge		
	Creel census	Surveyed each section several times 30 April to 3 Dec	Sections I - IV	Naplin and Gustafson of Minn. DNR	

Table A-6. (Continued).

YEAR	SAMPLING METHODS	SAMPLING FREQUENCY	STATIONS SAMPLED[1]	INVESTIGATORS	REMARKS
1975	Trap nets	4 24-hr sets/station each season	Sections 0 (4 sta), I (5 sta), and III (5 sta)	Gustafson, Geis, and Diedrich of Minn. DNR	Scale samples for aging; tagging study; Spring=May-mid July, Summer=mid July -Aug, and Fall=Sept-Oct
	Electroshocking: same as 1973	1 15-min run/station each season; night sampling in summer and fall	All sections in day; night at selected stations		
	Gill nets: same as 1973	2 24-hr sets/station in spring and fall	4 stations each in Sections 0, I, and III		
	Seine: same as 1974	Spring, summer, and fall	3 stations each in Sections 0-III		
	Trawl (otter)	2 7-min trawls/station each season	2 stations in Section 0 and at intake and discharge		
	Creel census	Surveyed each section several times 1 March - 23 Nov	Sections I-VI	Gustafson and Diedrich of Minn. DNR	
1976	Trap nets	Same as 1975	Same as 1975	Gustafson and Geis of Minn. DNR	Same as 1975
	Electroshocking: same as 1973[2]	Same as 1975 with no night samples	Same as 1975		
	Gill nets: same as 1973	Same as 1975	Same as 1975		
	Seine: same as 1974	Same as 1975	Same as 1975		
	Trawl (otter)	Same as 1975	Same as 1975		
	Creel census	Surveyed each section several times 6 March-21 Nov	Sections I-VI	Geis and Gustafson of Minn. DNR	

[1]Sampling conducted below Lock and Dam No. 3 is not included, except for the creel census. Locations are shown in Figures III-18, 19, and 20.

[2]Discharge electrofishing study (DES) was begun in April as an additional study and is described in Section VI A.

Table A-7. Summary of larval fish sampling near PINGP (Naplin and Geis, 1975; NUS, 1976).

YEAR	SAMPLING METHODS	SAMPLING FREQUENCY	STATIONS SAMPLED	INVESTIGATORS	REMARKS
1974	Net of 1 m^2 mouth area and 787 μm mesh; towed a measured distance (50-250 m)	Once a week at each location, 3 May - 26 Aug	Locations 1-4 in Figure III-21	Naplin and Geis of Minn. DNR	No taxonomy; no flow meters; towed at various angles to current
1975	Same net as 1974 with flow meter until 30 June; 1 m diameter net with 560 μm mesh 3 July on; volume sampled 30-286 m^3	Once a week at each location, 16 May-15 Aug and 1-5 Sept	Locations 1-8 in Figure III-21	Gustafson, Geis, and Diedrich of Minn. DNR	Changed nets in mid program; no taxonomy
	42.5 cm square nets (0.181 m^2) with 560 μm mesh and flow meters; stacked to sample entire water column	2 hours in every 4 hours over a 24-hr period, once a week from 25 Apr - 5 Sept	Bar racks of intake; middle of recirculation canal and plant side of skimmer wall also for part of study	Mueller of NSP	Taxonomy to species if possible

Table A-8. Mean density of larval fish collected at PINGP in 1975 (data from Gustafson et al., 1976).

DATE	MEAN NUMBER LARVAE/m^3 ± SE					
	STATIONS 1 AND 2 (LOWER STURGEON LAKE)		STATIONS 5, 6, AND 7 (UPPER STURGEON LAKE)		STATIONS 1, 2, AND 4 (LOWER STURGEON LAKE)	
19-23 May	0.15 ±	0.02	0.11	0.06	0.10	0.03
26-30 May	0.64	0.20	0.01	0.01	0.42	0.22
2-6 June	7.80	3.11	0.32	0.21	5.32	2.90
9-13 June	0.50	0.17	0.12	0.02	0.34	0.17
16-20 June	0.54	0.01	0.06	0.02	0.36	0.15
23-27 June	0.25	0.07	0.04	0.02	0.17	0.08
30-04 July[1]	0.63	0.12	0.08	0.06	0.44	0.17
7-11 July	0.12	0.02	0.13	0.04	0.08	0.04
14-18 July	0.24	0.10	0.04	0.03	0.16	0.09
21-25 July	0.10	0.06	0.13	0.06	0.08	0.05
28-1 July	0.26	0.03	0.15	0.05	0.20	0.06
4-8 August	0.21	0.09	0.03	0.02	0.16	0.08
11-15 August	0.15	0.03	0.11	0.06	0.10	0.05
18-22 August	NS[2]		NS		NS	
25-29 August	NS		NS		NS	
1-5 September	0.01	0.01	NS		0.01	0.01

[1]Changed nets.

[2]No sample.

Table A-9. Percent of total density for each RIS in the PINGP entrainment samples collected in 1975 (NUS, 1976).

DATE	SPECIES									
	WALLEYE	NORTHERN PIKE	CHANNEL CATFISH	WHITE BASS	BLACK CRAPPIE	WHITE SUCKER	REDHORSE SPP.	EMERALD SHINER[1]	GIZZARD SHAD	CARP
15 May	17.3	0.5	0.0	25.2	0.0	0.0	0.0	0.0	0.0	19.7
21 May	0.9	0.0	0.0	3.3	0.0	0.02	0.1	0.3	1.2	2.9
29 May	0.0	0.0	0.0	21.5	0.0	0.0	0.0	47.6	15.7	0.6
5 June	0.0	0.0	0.0	25.0	0.0	0.0	0.0	1.0	21.6	0.0
12 June	0.0	0.0	0.8	60.0	0.0	0.0	0.0	1.6	24.7	1.6
19 June	0.0	0.0	0.3	7.2	0.6	0.0	0.0	0.2	17.0	0.0
26 June	0.0	0.0	0.0	1.0	0.0	0.0	0.0	5.0	56.6	24.6
2 July	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.7	34.6	14.6
10 July	0.0	0.0	5.6	0.0	0.0	0.0	0.0	38.0	9.6	17.1
17 July	0.0	0.0	5.6	0.8	1.3	0.0	0.0	8.4	28.2	1.3
24 July	0.0	0.0	0.0	1.4	0.0	0.0	0.0	65.9	1.0	1.4
31 July	0.0	0.0	3.7	0.0	0.0	0.0	0.0	62.1	10.2	0.0
7 August	0.0	0.0	8.9	0.0	0.0	0.0	0.0	28.9	32.8	2.2
14 August	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.8	23.7	0.0
21 August	0.0	0.0	0.0	0.0	0.0	0.0	0.0	37.7	11.5	0.0
28 August	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
4 September	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0

[1] Identification questionable.

Table A-10. Reproductive characteristics of the fish RIS.

SPECIES	SPAWNING PERIOD	PREFERRED HABITAT	SPAWNING TEMP. (C)	FECUNDITY	EGG CHARACTERISTICS	INCUBATION TIME (DAYS)	REFERENCE
Walleye	April to Mid-May[2]	Shallow moving water over clean substrate[1]	6-17 peak 9-10[1]	35,000-600,000; 28.6-99.27/g[1]	1.5-2.0 mm not adhesive after hardening[2]	7-26 at 14-4.4 C[1]	[1]Niemuth et al., 1972 [2]Scott and Crossman, 1973, pp. 767-774
White Bass	Late May and June[1]	Shallow water over gravel[3]	12.8-15.6[1] 14.4-20[2]	242,000-933,000[1]	0.8 mm[1] adhesive	2 at 15.6 C[1]	[1]Scott and Crossman, 1973, pp. 690-691 [2]Ruelle, 1971 [3]Eddy and Underhill, 1974, pp. 335-336
Channel Catfish	May through July[2]	Protected sites[3]	21-29 optimum 26.7[4]	6.6-8.8/g[4]	3.5-4.0 mm[3]	5-10[3] at 27.8-15.6 C	[1]Miller, 1966 [2]Lopinot, 1960 [3]Scott and Crossman, 1973, pp. 604-610 [4]Clemens and Sneed, 1957
Northern Pike	April[3] and May[2]	Shallow areas with vegetation[4]	11-17[3] 4-18 peak 8.4[2]	19,200-193,000[2]; 19.8/g[4]	2.5-3.0 mm[3] adhesive	26 at 6 C[5] -14[4,1] 5 at 18-20 C[5]	[1]Eddy and Underhill, 1974, pp. 199-204 [2]June, 1971 [3]Franklin and Smith, 1963 [4]Scott and Crossman, 1973, pp. 357-359 [5]Swift, 1965
Gizzard Shad	April through June[1]	Open shallow water[1]	10-29[1]	40,500 - 379,600[1]	0.75 mm[1] adhesive	3.5-4[1] at 26.7-16.7 C	[1]Miller, 1960 [2]Jester, 1972, p. 40
Carp	Late April or May[1] through July[5]	Very shallow water[5]	15.6[3]-28[5] peak 19-23[5]	36,000-2,208,000[5]; 220.8/g[2]	1 mm[4] adhesive	3-6[5] 10-20[1]	[1]Eddy and Underhill, 1974, p.220 [2]Burns, 1966 [3]Jester, 1974, p.34 [4]Scott and Crossman, 1973, pp. 407-411 [5]Swee and McCrimmon, 1966
Black Crappie	May and June[1]	Nests in shallow water[1]	14-20[3,5]	11,000-188,000[1]	0.93 mm[2] adhesive[5]	3-5[5] 2.4 at 18.3 C[4]	[1]Eddy and Underhill, 1974 pp. 360-362 [2]Merriner, 1971a [3]Goodson, 1966b, pp. 312-332 [4]Merriner, 1971b [5]Scott and Crossman, 1973, pp.745-750
Emerald Shiner	May through August[4]	Open water near surface[2]	20-23[3] 20-27[4]	3,410[3]	0.21-0.67 mm[3]	1-1.5[3]	[1]Fuchs, 1967 [2]in Carlander, 1969, p.416 [3]Campbell and MacCrimmon, 1970 [4]McCormick and Kleiner, 1976
White Sucker	Late April to mid May[1]	Swift water over riffles in streams and gravel in lakes[2]	6-23[4] optimum ≈ 7.2[2]	20,000-139,000[2] usually 20,000-50,000[3] 24.6/g[1]	adhesive[3]	8-11 at 10-15 C[3] 5 at 15.6 C[2] 12-15 at 10-12 C[2]	[1]Eddy and Underhill, 1974, p.292 [2]Schneberger, 1972 [3]Scott and Crossman, 1973, pp. 538-543 [4]Brown, 1974
Shorthead Redhorse	Late April[3] to late May and early June[1]	Riffles in streams[2]	≈ 11[3]	13,500-27,150[3]			[1]Eddy and Underhill, 1974, pp.286-287 [2]Carlander, 1969, p.518 [3]Meyer, 1962

Table A-11. Thermal data for walleye.

PARAMETER	ACCLIMATION T (C)	LARVAE	JUVENILE	ADULT	REFERENCES
Lethal Threshold					(1) Smith and Koenst, 1975
Upper (1) (96-Hr TL_m)	8		24		(2) Ferguson, 1958
	10		28.6		(3) Dendy, 1948
	12		29		(4) Kelso, 1972
	14		29.5		(5) Niemuth et al., 1972
	16		30.6		
	18		30.5		
	20		30.5		
	22		30.5		
	24		31.5		
	26		31.6		
Lower (96-Hr TL_m)	25		8		
Preferred				21-23[1] (2)	
			22-25 (1)	25[1] (3)	
Growth					
Optimum			22 (1)	20 (4)	
Range			16-28 (1)		
Reproduction	OPTIMUM		RANGE		
Migration			3-7 (5)		
Spawning	6-9[2] (1)		6-17 (5)		
Incubation and Hatch	9-15 (1)		6-19 (1)		

[1]Field data.

[2]For fertilization.

Table A-12. Thermal data for white bass.

PARAMETER	ACCLIMATION T (C)	LARVAE	JUVENILE	ADULT	REFERENCES
Lethal Threshold					(1) Duncan and Myers, undated
Upper					(2) Barans and Tubb, 1973
					(3) Gammon, 1973
					(4) Reutter and Herdendorf, 1974
Lower (Percent mortality not given)	17	14 (1)			(5) Gammon, 1971
					(6) McCormick, 1976a
					(7) Ruelle, 1971
					(8) Scott and Crossman, 1973, pp. 689-692
					(9) Yellayi, 1972
Preferred	Summer		28(4)-30(2)	30(2), 28-29.5[1] (3)	(10) McCormick, 1976b
	Fall		28 (2)	25 (2)	
	Spring		18 (2)	19 (2)	
	Winter		21 (2)	18 (2)	
	Summer			22-29 (5)	
Growth					
Optimum			24-30 (6)		
Range					
Reproduction	OPTIMUM		RANGE		
Migration			14-20 (7)		
Spawning			13-16 (8)		
Incubation and Hatch			16(9)-26(10)		

[1] Field data.

Table A-13. Thermal data for channel catfish.

PARAMETER	ACCLIMATION T (C)	LARVAE	JUVENILE	ADULT
Lethal Threshold Upper (24-Hr threshold)	15			30.4 (2)
	20			32.8 (2)
	25 (2), 26 (1)		36.6 (1)	33.5 (2)
	29	31 (3)		
	30		37.7 (1)	
	34		38.3 (1)	
Lower	15			0 (2)
	20			3 (2)
	25			6 (2)
Preferred	Summer			26-32(11)
	Summer			25 (5)
	Summer			30-32[1] (6)
	Fall			25 (5)
				32 (7)
	2		-,15[2] (8)	
	5		17,15[2] (8)	
	6		18.9 (9)	
	9		20.4 (9)	
	10		20.6,18.5[2] (8)	
	12		19.9 (9)	
	15		21.7 (9)	
			23.8,22.0[2] (8)	
	18		22.9 (9)	
	20		27.0,25.4[2] (8)	
	21		26.1 (9)	
	24		29.4 (9)	
	25		30.2,28.9[2] (8)	
	27		29.5 (9)	
	30		30.5 (9)	
			32.4[2] (8)	
Growth Optimum		29-30 (3)	28-30 (10)	
Range		27-31 (3)	26-34 (11)	
Reproduction	OPTIMUM		RANGE	
Migration				
Spawning	27 (12)		21-29 (12)	
Incubation and Hatch			24-28 (12)	

REFERENCES

(1) Allen and Strawn, 1968
(2) Hart, 1952
(3) West, 1966
(4) Gammon, 1971
(5) Reutter and Herdendorf, 1974
(6) Gammon, 1973
(7) Kilambi et al., 1970
(8) Peterson et al., 1974
(9) Cherry et al., 1975
(10) Andrews et al., 1972
(11) Andrews and Stickney, 1972
(12) Clemens and Sneed, 1957

[1]Field data.

[2]Falling and rising field temperatures, respectively

Table A-14. Thermal data for northern pike.

PARAMETER	ACCLIMATION T (C)	LARVAE	JUVENILE	ADULT	REFERENCES
Lethal Threshold					
Upper	12, 12.6	24, 26[1] (1)			(1) Hokanson et al. 1973
	18	25, 28[1] (1)			(2) Scott, 1964
	6,7	20.5, 23[1] (1)			(3) Ferguson, 1958
	25		32.3 (2)		(4) Franklin and Smith, 1963
	27.5		32.8 (2)		(5) Swift, 1965
	30		33.3[2] (2)		
Lower	17.7	< 3[1] (1)			
Preferred			24, 26[3] (3)		
Growth					
Optimum		21 (1)	26 (1)		
Range		18-26 (1)			
Reproduction	OPTIMUM		RANGE		
Migration	2.2-2.8 (4)		1.1-4.4 (4)		
Spawning			11-17 (4)		
Incubation and Hatch	12 (1), 16 (5)		6-18 (1)		

[1]At hatch and free swimming

[2]Ultimate incipient level

[3]Grass pickerel and musky, respectively

Table A-15. Thermal data for gizzard shad.

PARAMETER	ACCLIMATION T (C)	LARVAE	JUVENILE	ADULT	REFERENCES
Lethal Threshold					(1) Hart, 1952
Upper	25		34.0-34.5(1)		(2) Coutant, 1975
	30		36.0 (1)		(3) Reutter and Herdendorf, 1974
	35		36.5 (1)		(4) Dendy, 1948
Lower	25		10.8 (1)		(5) Gammon, 1973
	30		14.5 (1)		(6) Miller, 1960
	35		20.0 (1)		(7) Carlander, 1969
	20, 17.5		6.5 (2)		
Preferred	Summer			19.0 (3)	
	Fall			20.5 (3)	
	Summer			23-25[1] (4)	
	Summer			28.5-31 (5)	
Growth					
Optimum					
Range					
Reproduction	OPTIMUM		RANGE		
Migration					
Spawning	10-21 (6)		10-29 (7)		
Incubation and Hatch					

[1]Field data

Table A-16. Thermal data for carp.

PARAMETER	ACCLIMATION T (C)	LARVAE	JUVENILE	ADULT	REFERENCES
Lethal Threshold Upper (24-hr TL_{50}) (1)	20		31-34 (1)		(1) Black, 1953
	26		36 (1)		(2) Horoszewicz, 1973
	25-27		40-41 (2)		(3) Meuwis and Heuts, 1957
	24		39 (3)	36 (3)	(4) Pitt et al., 1956
					(5) Reutter and Herdendorf, 1974
					(6) Gammon, 1973
					(7) Neill and Magnuson, 1974
					(8) Gammon, 1971
					(9) Huet, 1953
Preferred	10		17 (4)		(10) Schaeperclaus, 1949
	15		25 (4)		(11) Tatarko, 1965
	20		27 (4)		(12) Swee and McCrimmon, 1966
	25,30,35		31,31,32(4)		(13) Jester, 1974, p. 38
	Summer			29.7(5),33-35[1] (6)	(14) Burns, 1966, pp. 510-515
	20-22		30-33.5 (7)		(15) Frank, 1974
	Spring			27.4 (5)	
	Summer			27-34[1] (8)	
Growth					
Optimum		20-25 (9), 27(10)			
Range		16-30 (11)			
Reproduction	OPTIMUM		RANGE		
Migration					
Spawning	19-23 (12)		16(13)-28 (12)		
Incubation and Hatch	17-22 (14)		?-33 (15)		
	Limit for 10 min. exposure of early embryo is 35°.				

[1]Field data

Table A-17. Thermal data for black crappie.

PARAMETER	ACCLIMATION T (C)	LARVAE	JUVENILE	ADULT
Lethal Threshold				
Upper (Ultimate incipient level)	29		33 (1)	
Lower				
Preferred	Summer 20-22	18-20 (2)	27-29[1] (3) 26.5-30 (3)	21.7 (4), 29 (5)
	Fall			22.2 (4)
	Winter			20.5 (4)
	Spring			21.0 (4)
Growth				
Optimum			22-25 (1)	
Range (limits of zero growth)			11-30 (1)	
Reproduction	OPTIMUM		RANGE	
Migration				
Spawning			14 (6) - 20 (7)	
Incubation and Hatch				

REFERENCES

(1) Hokanson and Kleiner, undated

(2) Faber, 1967

(3) Neill and Magnuson, 1974

(4) Reutter and Herdendorf, 1974

(5) Neill et al., 1972

(6) Goodson, 1966b, pp. 312-332

(7) Scott and Crossman, 1973 pp. 745-750

[1]50 percent catch/effort

Table A-18. Thermal data for emerald shiner.

PARAMETER	ACCLIMATION T (C)	LARVAE	JUVENILE	ADULT	REFERENCES
Lethal Threshold					(1) Hart, 1947
Upper (1)	5		23.2		(2) Barans and Tubb, 1973
	10		26.7		(3) Campbell and MacCrimmon, 1970
	15		28.9		(4) McCormick and Kleiner, 1976
	20		30.7		(5) Reutter and Herdendorf, 1974
	25		30.7		
Lower (1)	15		1.6		
	20		5.2		
	25		8.0		
Preferred	Summer		22 (2), 25 (3)	23 (2)	
	Fall		14 (2)	18 (2)	
	Winter		11 (2)	9.3 (5), 6 (2)	
	Spring		15 (2)	17 (2)	
Growth					
Optimum			29 (4)		
Range			24-31 (4)		
Reproduction	OPTIMUM		RANGE		
Migration					
Spawning			20-27 (4)		
Incubation and Hatch					

Table A-19. Thermal data for white sucker.

PARAMETER	ACCLIMATION T (C)	LARVAE	JUVENILE	ADULT	REFERENCES
Lethal threshold				26.3 (2)	(1) McCormick et al. 1977
Upper	5			27.7 (2)	(2) Hart, 1947
	10	28[1] (1)		29.3 (2)	(3) Brett, 1944
	15	31 (1)			(4) Carlander, 1969
	20 (2), 21 (1)	30 (1)		29.3 (2)	(5) Schneberger, 1972
	25			29.3 (2)	(6) Brown, 1974
	25-26		31 (3)		(7) Horak and Tanner, 1964
Lower	20		2-3 (4)	2.5 (2)	(8) Reutter and Hendendorf, 1974
	21	5[1], 4.8[2] (1)			(9) Ferguson, 1958
	25			6 (2)	(10) Scott and Crossman 1973, pp. 538-543
Preferred	Spring-fall			19-21 (7)	
	Fall			22.4 (8)	
	Summer			12-21 (9)	
Growth					
Optimum		26.9 (1)			
Range		24-27 (1)			
Reproduction	OPTIMUM		RANGE		
Migration			10-? (10)		
Spawning	$\sim$ 7.2 (5)		6-23 (6)		
Incubation and Hatch	15 (1)		9-21 (1)		

[1]7-day TL50 for swimup

[2]7-day TL50 for newly hatched

Table A-20. Thermal data for shorthead redhorse.

PARAMETER	ACCLIMATION T (C)	LARVAE	JUVENILE	ADULT	REFERENCES
Lethal threshold					
Upper					(1) Gammon, 1971 (2) Gammon, 1973 (3) Meyer, 1962
Lower					
Preferred	Summer			23-27[1] (1)	
	Summer			26-27.5[1] (2)	
Growth					
Optimum					
Range					
Reproduction	OPTIMUM		RANGE		
Migration					
Spawning			11-? (3)		
Incubation and Hatch					

[1]Shorthead and golden redhorses

Table A-21. Food habits during various life stages for the fish RIS.

SPECIES	LARVAE	JUVENILE & ADULT
Walleye	*Diaptomus* sp., *Leptodora* sp., and Chironomid larvae[1]	yellow perch, frogs, and salamanders,[2] gizzard shad,[3] chironomids, white bass fry and northern pike fry[1]
White Bass	*Cyclops* and *Diaptomus*[4]	gizzard shad,[3] emerald shiner, corixids, chironomids, *Diaptomus*, *Leptodora* and *Diaphanosoma*[4]
Channel Catfish		crayfish, snails, worms, clams, fish, and seeds,[5] gizzard shad[3]
Northern Pike	*Daphnia*, *Ceriodaphnia*, *Cyclops*, *Hyalella*, tendipidid larvae, and Ephemeroptera and Zygoptera nymphs[6]	yellow perch, other fish, and frogs[2] gizzard shad[3]
Gizzard Shad	Protozoa and Entomostraca[3]	phytoplankton and *Euglena*[3]
Carp	zooplankton[7]	aquatic insects, plant material, crustaceans, molluscs, and annelids[8]
Black Crappie		*Hyalella*, *Chaoborus*, *Chironomus*, small yellow perch and bass, minnows, and sunfish,[2] gizzard shad[3]
Emerald Shiner	*Trichocera*, *Cyclops bicuspidatus*, and copepod nauplii,[9] blue green algae[10]	*Daphnia*, *Leptodora*, *Diaptomus*, *Bosmina*, *Cyclops*, diatoms, desmids and algae[11]
White Sucker	rotifers, copepod nauplii, *Cyclops bicuspidatus*, and cladocerans[9]	aquatic insects, molluscs, algae, and aquatic plants[12]
Shorthead Redhorse		immature chironomids, Ephemeroptera, and Trichoptera[13]

REFERENCES

[1] Priegel, 1969

[2] Seaburg and Moyle, 1964

[3] Miller, 1960

[4] Ruelle, 1971

[5] Lopinot, 1960

[6] Franklin and Smith, 1963

[7] Bardach et al., 1972

[8] Scott and Crossman, 1973, pp 407-411

[9] Siefert, 1972

[10] Fuchs, 1967

[11] Campbell and MacCrimmon, 1970

[12] Schneberger, 1972

[13] Meyer, 1962

Table A-22. Summary of sampling methods for non-fisheries biota collected near PINGP during 1969 through 1976 (from PINGP annual reports).

BIOTIC CATEGORY	YEAR[1]	COLLECTION METHOD	SAMPLING FREQUENCY	STATIONS & LOCATIONS[2]	PRINCIPAL INVESTIGATOR(s)	AFFILIATION	DATA ANALYSIS AND PROCESSING	REMARKS
Phytoplankton	1969	Whole surface water	Inconsistent, approx. bi-weekly (May to Oct)	8 HDR Stations: 2, 6, 7, 10, 11, 22, 23, 28 plus 1 5.6 km upriver and 5 within 3.2 km downriver from Lock & Dam No. 3	Brook	U. Minn.	Density, taxonomy	Not all stations sampled during each collection
	1970	Whole surface water	Inconsistent, approx. bi-weekly (May to Oct)	Same as 1969	Brook	U. Minn.	Density, taxonomy and primary productivity (DO)	Not all stations sampled during each collection. Primary productivity measured by light and dark bottle DO evolution
	1971	Whole surface water	Inconsistent, approx. bi-weekly (May to Oct)	Same as 1969	Brook	U. Minn.	Density, taxonomy	Not all stations sampled during each collection
	1972	Whole surface water	Inconsistent, approx. bi-weekly (July to Oct)	Same as 1969	Brook	U. Minn.	Same as in 1971	Not all stations sampled during each collection
	1973	Whole surface water	Biweekly (Mar to Nov)	Same as 1969, plus HDR Stations 16 and 19	Baker and Baker	U. Minn. and U.N.H.	Same as in 1971	
	1974	Whole surface water	Same as in 1973, but more frequently in mid-summer	Same as 1973 plus 9 HDR Stations: 1, 2, 3, 4, 5, 9, 14, 19, 27	Baker and Baker	U. Minn. and U.N.H.	Density, taxonomy, biomass (biovolume), primary productivity (DO), chlorophyll a (Lorenzen), suspensoids (turbidity)	Biomass measurements calculated from densities which later were shown to be low by a factor of 10^3 Primary productivity 2 to 4 hour mid-day incubation period at 50 cm water depth in Sturgeon Lake near HDR Station 8
	1975	Whole surface water	Same as in 1973, but more frequently in mid-summer (May to Dec)	7 deleted: all stations downriver from Lock and Dam No. 3, HDR Station 2, and Station 5.6 km upriver from Lock & Dam No. 3	Baker and Baker	U. Minn. and U.N.H.	Same as in 1974	
	1976	Whole surface water	Same as in 1973, but more frequently in mid-summer (Mar to Nov)	Same as in 1975	Baker and Baker	U. Minn. and U.N.H.	Same as in 1974	Many density samples were lost in late summer and fall. Productivity samples were incubated at 25 cm depth

Table A-22. (Continued).

BIOTIC CATEGORY	YEAR[1]	COLLECTION METHOD	SAMPLING FREQUENCY	STATIONS & LOCATIONS[2]	PRINCIPAL INVESTIGATOR(s)	AFFILIATION	DATA ANALYSIS AND PROCESSING	REMARKS
Periphyton	1972	Artificial substrates—glass slides	Biweekly (Jul to Nov) 2 week *incubation*	4 HDR stations: 7, 17, 24, and 25	Environmental Science Service Section	NSP	Pigment analysis of chlorophyll a and phaeophytin a by Lorenzen method	Slides were scaped for cell counts and taxonomy, but left unanalysed until next year because of change of consultants. Slides held in plexiglass floats suspended at approximately 1 - 2 m depth, with vertical orientation to minimize siltation.
	1973	Same as for 1972	Biweekly (Aug to Dec) — 2 week incubation	Same as 1972, plus 3 - HDR stations (8, 13, and 20) maintained in ice-free periods and locations	Baker	U.N.H.	Same as 1972, except with addition of density and taxonomy	Density and taxonomy for 1972 samples were also determined. Slides only with maximum growth were selected for cell counting.
	1974	Same as for 1972	Biweekly, in ice-free times of the year and locations	Same as in 1973, plus 1 station located less than 1.6 km downriver from Lock and Dam No. 3	Baker	U.N.H.	Same as in 1973 except no phaeophytin a	
	1975	Same as for 1972	Same as for 1974	Same as in 1974, less station downriver from Lock and Dam No. 3	Baker	U.N.H.	Same as in 1974, except phaeophytin a re-initiated	
	1976	Same as for 1972	Same as for 1974	Same as in 1975	Baker	U.N.H.	Same as in 1975	Periphyton, other than centric and pennate diatoms, were occasionally observed but not recorded.
Aquatic Macrophytes	1970	Observation by boat and collection	Once in summer, presumably	1 to 4 transects in sections A to G within 6.4 km up and downriver from Lock and Dam No. 3	Miller	St. Mary's College	Taxonomy and bed size	Willows considered as macrophytes.
	1971	Same as for 1970	Same as in 1970	Same as in 1970	Miller	St. Mary's College	Taxonomy and bed size	
	1973	Aerial photography and observation by boat	Same as in 1970	Upriver from Lock and Dam No. 3 to head of Sturgeon Lake	Vose	St. Mary's College	Taxonomy and bed size	

Table A-22. (Continued).

BIOTIC CATEGORY	YEAR[1]	COLLECTION METHOD	SAMPLING FREQUENCY	STATIONS & LOCATIONS[2]	PRINCIPAL INVESTIGATOR(s)	AFFILIATION	DATA ANALYSIS AND PROCESSING	REMARKS
Aquatic Macrophytes (Continued)	1974	Observation and collection by boat and wading, raking, and shoreline walking	Jun 10 to Aug 24 at 1 to 2 trips per 2 week period	Immediate plant site, refuge, main river channel, shorelines and islands from Lock and Dam No. 3 to plant intake area, Sturgeon Lake	Mueller	NSP	Taxonomy and bed size	Plants were classified as submerged and emergent.
	1975	Same as 1974	July 23; Aug 6; Sept 4; Oct 23	Approximately the same as in 1974, except omission of upper Sturgeon Lake	Mueller	NSP	Taxonomy and bed size	Only submerged plants studied
	1976	Same as 1974	June 4, 7, 9, 11; July 30; Aug 13 Sept 3	Same is in 1975	Mueller	NSP	Taxonomy and bed size	
Zooplankton	1970	Pumping 19 ℓ through "plankton net" from 0.3 - 0.9 m	Biweekly during ice-free time of year	8 HDR stations: 2, 4, 9, 12, near 25, near 26, near 28, near 27; 7 within 4.8 km down-river from Lock and Dam No. 3	Miller	St. Mary's College	Density and taxonomy	Taxonomy only to genus, at best.
	1971	19 ℓ "concentrated" with "plankton net", surface and subsurface samples taken at each station considered as replicates	Weekly, June and July	2 4-station transects located near the head of Sturgeon Lake, perpendicular to the lake axis; 1 4-station transect crossing mouth of Sturgeon Lake near HDR Station 5. 1 4-station transect parallel to plant intake near HDR Station 13, extending toward the river channel (16 total stations in Sturgeon Lake plus 15 in main river channel as in 1970)	Miller	St. Mary's College	Density and taxonomy	Taxonomy to genus
	1972	19 ℓ concentrated through "Wisconsin plankton net", subsurface	Same as 1970	Same as in 1970	Miller	St. Mary's College	Density and taxonomy	Taxonomy to species in many cases

Table A-22. (Continued).

BIOTIC CATEGORY	YEAR[1]	COLLECTION METHOD	SAMPLING FREQUENCY	STATIONS & LOCATIONS[2]	PRINCIPAL INVESTIGATOR(s)	AFFILIATION	DATA ANALYSIS AND PROCESSING	REMARKS
Zooplankton (Continued)	1973	Same as 1972	Same as for 1972	4 HDR stations: 2, 12, 25, 27 plus 1 immediately downriver from Lock and Dam No. 3. 4 transects same as in 1971 in Sturgeon Lake vicinity	Szluha	St. Mary's College	Density and taxonomy	Taxonomy to species in many cases.
	1974	24ℓ concentrated through "Wisconsin plankton net"; 4ℓ Van Dorn samples taken from top, mid, and bottom depth where possible at each station. Entrainment samples collected with suction pump and filtered through 64μm mesh netting at 130ℓ/min. (Total sample volume 1300-2000ℓ)	Apr to Dec; inconsistent "monthly"; entrainment samples collected July 30, Aug 14, Sept 4, Nov 21, and Dec 18	3, 3-station transects in Sturgeon Lake corresponding roughly to HDR Stations 1, 3, and 8; 2 HDR stations (15 and 18); 3 stations at the north end of Sturgeon Lake; 1 HDR station (10); 2 HDR stations (14 and 20) for entrainment samples; depth integrated in intake; bottom sample in discharge	Szluha; Middlebrook (entrainment)	St. Mary's College; NSP	Density and taxonomy; motility	River and lake flow patterns studied by dye dispersion; variation in density by depth was studied in recycle canal. Night samples were also collected in recycle canal.
	1975	4.2ℓ Van Dorn or Kemmerer bottle samples at at 3 depths; total volume 12.6 to 37.8ℓ filtered through 64μm mesh net. Entrainment methods same as 1974, except Σ vol. 800-1300ℓ	Approximately once/month where and when possible; entrainment sampling reported to May 1976; collected monthly	8 HDR statons: 6, 10, 14, 16, 18, 21, 24, 25 and one station within 1.6 km downriver from Lock and Dam No. 3; entrainment stations same as in 1974	Daggett; Middlebrook	Ecology Consultants, Inc.; NSP	Density and taxonomy; motility	Excellent taxonomy

Table A-22. (Continued).

BIOTIC CATEGORY	YEAR[1]	COLLECTION METHOD	SAMPLING FREQUENCY	STATIONS & LOCATIONS[2]	PRINCIPAL INVESTIGATOR(s)	AFFILIATION	DATA ANALYSIS AND PROCESSING	REMARKS
Zooplankton (Continued)	1976	3, 6.2ℓ Van Dorn Bottle samples collected at each station; otherwise same as in 1975	Same as in 1975; entrainment to May 1977	Same as in 1975 except station downriver from Lock and Dam No. 3 deleted (8 stations total)	Anonymous	Texas Instruments, Inc.	Density and taxonomy	
Macro-invertebrates	1970	Peterson dredge (no size given); qualitative observation of natural substrates	Once in July, twice in Aug, once in Sept, for quantitative samples; unknown for qualitative samples	Same stations as 1970 zooplankton	Miller	St. Mary's College	Density (where quantitative) and taxonomy	Preliminary studies
	1971	Concrete and balsa blocks (each block approx. 10 x 10 x 8 cm); Qualitative observation of natural substrates	Artificial substrates colonized for 30 days before removal in ice-free locations and periods	Same stations as 1970	Miller	St. Mary's College	Density (where feasible) and taxonomy	New artificial substrate experiment
	1972	Same as 1971 except Peterson dredge used again	June, July, Sept, Oct for artificial substrates; 5 dredge samples per station in Aug only	12 transects across river channel with 2 stations each, from headwaters of Sturgeon Lake to within 3.2 km downriver from Lock and Dam No. 3; also HDR Stations 2, 4, 8, 28, 27, and 3 within 3.2 km downriver of Lock and Dam No. 3	Miller	St. Mary's College	Density (quantitative samples) and taxonomy	

Table A-22. (Continued).

BIOTIC CATEGORY	YEAR[1]	COLLECTION METHOD	SAMPLING FREQUENCY	STATIONS & LOCATIONS[2]	PRINCIPAL INVESTIGATOR(s)	AFFILIATION	DATA ANALYSIS AND PROCESSING	REMARKS
Macro-invertebrates (Continued)	1973	Artificial substrates: 1) concrete & balsa wood (as in 1971) 2) concrete block (31.6x 31.6x8 cm, approx. 18 kg) (Britt, 1955);	Artificial substrate: uncertain	Same as in 1972, plus HDR stations 12, 15, 18, and 21 for artificial substrates	Miller and McConville	St. Mary's College	Density (quantitative) and taxonomy	Mostly experiemental; many artificial substrate samples lost due to weather or vandalism
		dredge: 1) Peterson (15 cm sq.?) 2) Ponar (22.9 cm sq.?)	Dredge: initiated in Oct, replicates (?), once/mo when and where possible.	Dredge at HDR stations 1, 2, 10, 26, near 28, 27, 12, 15, 18, 21, 25, and 3 stations and within 1.6 km downriver of Lock and Dam No. 3				
		Qualitative observation on natural substrates	Randomly collected until Oct, then once a month	Qualitative sampling along shoreline where possible, or after Oct at shoreline locations near HDR stations 8, 15, 18, 21, 27; 1 upriver approx. 6.4 km from Lock & Dam No. 3 and 2 within 3.2 km downriver from Lock and Dam No. 3				
	1974	UV light traps	Traps emptied every 2-3 days from about May 13 to Dec 7	Near HDR stations 6 (along shore), 12, 21, and 25	Shyne	St. Mary's College	Taxonomy and relative density of emergent insects;	Problems with collection, preservation, and storage
		Qualitative observation of natural substrates;	Apr 19, June 22, Aug 31, Oct 12	Same as in 1973	Shyne	St. Mary's College	Taxonomy	
		Quantitative: 1) 22.9 cm sq. Ponar and 15 cm sq. Peterson dredges	Once/mo when and where ice-permitting	3 HDR stations: 15 and 18 (a & b) (Ponar); 11 HDR stations: 1, 2, 5, 6, 10, 12, 21, 25, 26, 27, and near 28, and two stations within 1.6 km downriver from Lock and Dam No. 3 (Peterson)	Simonet	St. Mary's College	Density and taxonomy	

Table A-22. (Continued).

BIOTIC CATEGORY	YEAR[1]	COLLECTION METHOD	SAMPLING FREQUENCY	STATIONS AND LOCATIONS[2]	PRINCIPAL INVESTIGATOR(s)	AFFILIATION	DATA ANALYSIS AND PROCESSING	REMARKS
Macroinvertebrates (Continued)	1974 (Cont.)	2) artificial substrates: a) concrete block (31.6x 31.6x8 cm) as in 1973 b) barbeque basket (Mason et al., 1970)	30 day colonization period, ice-permitting	Stations depending on substrate type. Blocks at HDR stations 12, 15, 18, 21, 25, and 16, and one below Lock and Dam No. 3. Baskets at HDR stations 1, 5, 10, 12, 15, 18, 21, 25, and near 28.	Simonet	St. Mary's College	Density and taxonomy	
	1975	Qualitative: dip netting and hand picking of natural substrates	May, July, Sept, and Nov	Same as in 1974	Haynes	Ecology Consultants, Inc.	Taxonomy	
		Quantitative: 1) 15 cm sq. Peterson dredge; 30.5 cm sq. Peterson dredge 2) artificial substrate with 30.5 cm sq area (Hester and Dendy, 1962)	3 replicates at each station/mo Mar only; after Mar 30-45 days exposure period, ice permitting	Same as in 1974	Haynes	Ecology Consultants, Inc.	Density and taxonomy	
	1976	Qualitative: dip netting and hand picking of natural substrates	Bimonthly from Mar through Nov	Same as in 1974	Anonymous	Texas Instruments, Inc.	Taxonomy	
		Quantitative: 1) 30.5 cm sq. Peterson dredge 2) artificial substrates of 30.5 cm sq. area (Hester-Dendy, 1962)	3 replicates per station every 45 days Jan to Dec Every 45 days Feb through Nov	8 HDR stations: 6, 10, 12, 18, 21, 25, 26, 27 7 HDR stations: 6, 10, 12, 15, 18, 21, 25.	Anonymous	Texas Instruments, Inc.	Density and taxonomy	

[1] Unit 1 began operation in December 1973 and Unit 2 in December 1974.

[2] See Figure III-28 for locations.

Table A-23. Ranking of benthic macroinvertebrate abundances at three locations near PINGP during 1973 through 1976 for dredging samples. Diversities and evenness indices are also included.

BENTHIC MACROINVERTEBRATES (DREDGE SAMPLES)	1976												1975						1974												1973		
	FALL[1]			SUMMER[2]			SPRING[3]			WINTER[4]			FALL			SUMMER			FALL			SUMMER			SPRING			WINTER			FALL		
	U[5]	I[6]	D[7]	U	I	D	U	I	D	U	I	D	U	I	D	U	I	D	U	I	D	U	I	D	U	I	D	U	I	D	U	I	D
Oligochaeta (Segmented worms)																																	
Tubificidae																																	
Miscellaneous spp.	4	2	4	3	4	4	2	3	—		2	—	2	2			3		2	2	2	2		2	2	1	2	2	2			2	2
Nematoda (round worms)																																1	
Unidentified spp.		2		2	2			1	—	—		—						1	1														
Arthropoda (joint-footed organisms)																																	
Diptera																																	
Chironomus spp.	3	2	3	3	3	3		2	—	—	2	—	2	2					2[8]	3[8]	2[8]	1[8]	2[8]	2[8]	1[8]	2[8]	1[8]	2[8]	2[8]		2[8]	2[8]	2[8]
Palpomyia spp.							2	2	—	—		—	1				1																
Procladius spp.	3	3	3	3	3	3		3	—	—	3	—	2	2	1		2																
Tanypus spp.		1	1	2	2				—	—		—					1																
Tanytarsus spp.				2		1			—	—		—																					
Ceratopogonidae																																	
Unid. spp.	2	3	2	1	2	2			—	—		—									2				1						1		1
Ephemeroptera																																	
Caenis sp.									—	—	1	—				1																	
Shannon Weaver Diversity[9]	1.01	.60	.35	2.25	1.02	1.05	1.68	2.19	—	—	1.43	—	2.41	2.97	.92	1.95	1.42	.32										—	—	—	—	—	—
Evenness Index[10]	.33	.21	.14	.76	.37	.42	.61	.69	—	—	.68	—	—	—	—	—	—	—										—	—	—	—	—	—

Key: Abundance: 1 = 1.0-9.9; 2 = 10-99; 3 = 100-999; 4 = 1,000-9,999 organism/m^2 or in 1974 and 1973 org/dm^3; — = no sample; blank indicates no organisms found

[1]Usually near mid-October
[2]Usually near mid-July
[3]Usually near mid-April
[4]Usually near mid-January
[5]U - upriver (usually near NDR station 10)
[6]I - intake (usually near NDR station 12)
[7]D - downriver (usually near NDR station 27)
[8]Total Chironomidae
[9]S.W. Diversity $\bar{d} = -\sum_{i}^{s}\left[\frac{n_i}{N}\log_2\frac{n_i}{N}\right]$, where N is total number of all individuals of all taxa in sample, n_i is number of individuals in the i^{th} taxa, and s is the number of taxa in sample.

[10]Eveness (e) = $\bar{d}/\bar{d}_{max}$, where $\bar{d}_{max}$ is the maximum possible diversity for a given $s = \log_2 s$.

Table A-24. Ranking of drift macroinvertebrate abundances (artificial substrate) at three locations near PINGP for 1975 and 1976. The diversity and evenness indices are also shown.

DRIFT (ARTIFICIAL SUBSTRATE) MACROINVERTEBRATES	1976												1975					
	FALL[1]			SUMMER[2]			SPRING[3]			WINTER[4]			FALL			SUMMER		
	U[5]	I[6]	D[7]	U	I	D	U	I	D	U	I	D	U	I	D	U	I	D
Oligochaeta (segmented worms)																		
Naididae																		
Miscellaneous spp.	5	5	5	3	5	5	—	—	—	—	—	2	5	5	6	—	2	—
Nematoda (round worms)																		
Unidentified spp.		1			1	1	—	—	—	—	—		2	3	3	—		—
Arthropoda (Joint-footed animals)																		
Diptera																		
Glyptotendipes spp.	4	4	4	4	4	5	—	—	—	—	—		3	3	3	—	4	—
Ephemenoptera																		
Caenis spp.		1	1		1	1	—	—	—	—	—				1	—	2	—
Trichoptera																		
Neureclipsis spp.	2		1	3	1	2	—	—	—	—	—		2	2	2	—	3	—
Cheumatopsyche spp.	1			3			—	—	—	—	—		2		2	—	2	—
Shannon Weaver Diversity[8]	.97	1.04	.52	2.29	1.26	1.14	—	—	—	—	—	0	.76	.22	.11	—	1.96	—
Evenness Index[9]	.36	.45	.21	.62	.42	.39	—	—	—	—	—	0	—	—	—	—	—	—

Key: Abundance: 1 = 0.0-9.9; 2 = 10-99; 3 = 100-999; 4 = 1,000-9,999; 5 = 10,000-99,999; 6 = 100,000-999,999 org/m^2
— = no sample; blank indicates no organisms found

[1] Usually near mid-October
[2] Usually near mid-July
[3] Usually near mid-April
[4] Usually near mid-January
[5] U = upriver (usually near HDR station 10)
[6] I = intake (usually near HDR station 12)
[7] D = downriver (usually near HDR station 27)
[8] S.W. Diversity $\bar{d} = -\sum_i^s \left[\frac{n_i}{N} \log_2 \frac{n_i}{N}\right]$, where N is total number of all individuals of all taxa in sample, n_i is number of individuals in the i^{th} taxa, and s is the number of taxa in sample.
[9] Evenness (e) = $\bar{d}/\bar{d}_{max}$, where $\bar{d}_{max}$ is the maximum possible diversity for a given s = $\log_2$ s.

Table A-25. Composition of orders of emergent aquatic insects collected from the Mississippi River near PINGP, 13 May through 6 December 1974 (from Shyne, 1977).

ORDER/FAMILY	HDR STATION 6		HDR STATION 12	
	NUMBER	PERCENT	NUMBER	PERCENT
Trichoptera				
Hydropsychidae	151,277	81.89	9,155	52.26
Psychomiidae	13,406	7.26	4,228	24.14
Leptoceridae	7,240	3.90	1,171	6.68
Hydroptilidae	12,801	6.93	2,960	16.89
Other	4	*	3	*
Total	184,728	100.00	17,517	100.00
Ephemeroptera				
Caenidae	740	51.75	2,980	86.85
Ephemeridae	670	46.85	439	12.80
Other	20	1.40	12	0.35
Total	1,430	100.00	3,431	100.00
Diptera				
Chironomidae	440,602	99.13	71,581	98.69
Other	3,888	0.87	947	1.31
Total	444,490	100.00	72,528	100.00

*less than 0.10 percent

Table A-26. Abundance and distribution of *Hydropsyche* spp. (Trichoptera) and *Stenonema* spp. (Ephemeroptera) in 1975 and 1976 (from Haynes, 1976; Texas Ins., Inc., 1977).

DATE	ARTIFICIAL SUBSTRATE (No./m^2)									
	Hydropsyche spp.					*Stenonema* spp.				
	U[1]	SL[2]	I[3]	Di[4]	B[5]	U	SL	I	Di	B
October 1976						2.7				
August 1976					8					
July 1976	3,542	129	48		105					
June 1976				65			59			
March 1976				54	2.7					
April 1976				8.1					2.7	
December 1975				27					27	
November 1975	351		3.6	27	75.6			72		72
September 1975						67.5	10.8	10.8		10.8
August 1975	4,657	4,320	124	1,608	3,996	162	173	67.5	43.2	119
July 1975		5,724	75.6	359			65	173	35	
May 1975				10.8					5.4	

[1]HDR Station 10 (Upriver)
[2]HDR Station 6 (Sturgeon Lake)
[3]HDR Station 14 (Intake)
[4]HDR Station 21 (Discharge)
[5]HDR Station 25 (Barney's Point)

Table A-27. Life history and feeding habits of major invertebrate groups characteristic of the Mississippi River, lakes, and creeks near PINGP.

GROUP	METAMORPHOSIS	LIFE STAGES	DURATION OF LIFE STAGE	HABITAT	FEEDING HABITS	BREEDING HABITS
Ephemeroptera[1]	Simple	Nymph Subimago Adult	1 year 1-2 days 1-2 days	Aquatic Terrestrial Terrestrial	Herbivorous Does not feed Does not feed	Swarms after final molt and lays eggs on surface of water
Plecoptera[1]	Simple	Nymph Adult	1-3 years Unavailable	Aquatic Terrestrial	Carnivorous or herbivorous Either does not feed or is herbivorous	Lays eggs on surface of water
Trichoptera[1]	Complete	Nymph Pupa Adult	1 year Unavailable 1 month	Aquatic Aquatic Terrestrial	Carnivorous or herbivorous Does not feed Liquid foods	Lays eggs on surface of water or on objects near water
Coleoptera[1]	Complete	Nymph Pupa Adult	Unavailable Unavailable Unavailable	Aquatic or terrestrial Terrestrial Terrestrial	Carnivorous, herbivorous or omnivorous Does not feed Carnivorous or herbivorous	Lays eggs in the water on algae, roots or stones
Diptera[1]	Complete	Nymph Pupa Adult	Unavailable Unavailable Unavailable	Aquatic or terrestrial Terrestrial Terrestrial	Unavailable Unavailable Unavailable	Unavailable
Oligochaeta[2]	Not applicable	Cocoon Young Adult	8 days to 10 weeks Unavailable Unavailable	Aquatic or terrestrial Terrestrial Terrestrial	Detritus feeder or parasitic	Asexual division, sexual (hermaphroditic). Cocoon in mud or on vegetation
Hirundinea[2]	Not applicable	Cocoon Young Adult	5 days to 10 weeks Unavailable Unavailable	Aquatic Aquatic Aquatic	Carnivorous Parasitic Scavenger	Cocoon buried in mud or attached to submerged objects, vegetation or brood eggs. Hermaphroditic.
Copepoda[2]	Direct	Nauplius Copepodid Adult	1 week to 1 year	Aquatic Aquatic Aquatic	Herbivorous, carnivorous, and parasitic	Sexes separate eggs brooded
Rotifera[2]	Not applicable	Young Adult	Unavailable Unavailable	Aquatic Aquatic	Herbivorous, carnivorous, and parasitic	Sexual, but dioecious; some parthenogenic. Eggs attached to substrate or female. Some ovoviviparous.
Cladocera[2]	Gradual	Neonate Juvenile Adult	Unavailable Unavailable 1-3 months	Aquatic Aquatic Aquatic	Herbivorous or carnivorous	Parthenogenic or sexual, nonviviparous.
Isopoda[2]	Direct	Manca Young Adult	Unavailable Unavailable Unavailable	Benthic, Pseudo-planktonic	Parasitic or scavenger	Sexes separate eggs brooded.
Amphipoda[2]	Direct	Young Adult	Unavailable Unavailable	Benthic Pseudo-planktonic	Carnivorous, parasitic or omnivorous	Sexes separate eggs brooded.
Acarina[2]	Unavailable	Larva Nymph Adult	Unavailable Unavailable Unavailable	Aquatic Aquatic Aquatic	Carnivorous, parasitic, or scavenger	Sexual
Gastropoda[2]	Not applicable	Trocophore Veliger Adult	Unavailable Unavailable Unavailable	Planktonic Benthic, Neustonic, terrestrial	Herbivorous, carnivorous or scavenger	Hermaphroditic, lays egg masses on submerged objects, oviparous

[1]USNRC, 1975.

[2]Barnes, 1963.

Table A-28. Summary of macroinvertebrate thermal tolerances.

TAXA	ACCLIMATION TEMPERATURE (C) AND SEASON	LT_{50} (C)	EXPOSURE TIME	REFERENCE
Ephemoptera				
Isonychia spp.[2]	10, spring fall 13, spring 16, spring 18, spring 25, summer 18, fall 10, fall	26 30 32.5 35 34.5 31 30, 34 30, 33	5-40 min Significant mortality (α=0.05) after 1-7 days	Sherberger et al., 1977
Baetis tenax[2]	10	21	24 hour	Altman and Dittmer, 1966
Stenonema tripunctatum[1]	10	25.5	96 hour	Nebeker and Lembke, 1965
Ephemerella subvaria[2]	10	21.5	96 hour	Nebeker and Lembke, 1965
Trichoptera				
Hydropsyche spp.[2]	16, fall 21, fall 24, summer 20, spring	31, 35, 36 30, 38 38 38	10-30 min Significant mortality (α=0.05) after 1-10 days	Sherberger et al., 1977
Odonata				
Libellula sp.[2]	15 25 25.5	45 43 47	Lethal Temperature at 10°C/min increase rate	Martin and Gentry, 1974
Boyeria vinosa	10	32.5	96 hour	Nebeker and Lembke, 1968
Ophiogomphus rupinsulensis	10	33	96 hour	Nebeker and Lembke, 1968

Table A-28. (Continued).

TAXA	ACCLIMATION TEMPERATURE (C) AND SEASON	LT_{50} (C)	EXPOSURE TIME	REFERENCE
Plecoptera				
Isogenus frontalis	10	22.5	96 hour	Nebeker and Lembke, 1968
Taeniopteryx maura[1]	10	21	96 hour	Nebeker and Lembke, 1968
Hemiptera				
Notonecta glauca[2]	25.5	44-46		Altman and Dittmer, 1966
Diptera				
Aedes spp. and *Anopheles* spp. *Culex* spp.	—	35-47		Altman and Dittmer, 1966
Atherix variegata[2]	10	32	96 hour	Nebeker and Lembke, 1968
Tanytarsus brunnipes[2]	17	29	96 hour Immediate temperature rise-22 hour exposure	Nebeker and Lembke, 1968
Chironomus riparius[2]	17	34.5	96 hour	Nebeker and Lembke, 1968
C. albimanus[2]	17	35	96 hour	Nebeker and Lembke, 1968
C. longistylus[2]	17	35.5	96 hour	Nebeker and Lembke, 1968
Amphipoda				
Gammarus fasciatus[1]	2 10 20 25	27 30 35 38	30 min 30 min 30 min 30 min	Ginn, et al., 1974

Table A-28. (Continued).

TAXA	ACCLIMATION TEMPERATURE (C) AND SEASON	LT_{50} (C)	EXPOSURE TIME	REFERENCES
Platyhelminthes *Dugesia tigrina*[1]	13	32-33	14 day	Jensen et al. 1969
D. dorotocephala[2]	13	30-31	4 day	Jensen et al. 1969

[1]Species found near PINGP

[2]Genus found near PINGP.

Table A-29. Macroinvertebrate thermal data.

TAXA	MAXIMUM TEMPERATURE TOLERATED (C)	OPTIMUM TEMPERATURE (C)	REFERENCE
Trichoptera			
Hydropsyche spp.[2]	38	27-29	Sherberger et al., 1977
	41		Trembley, 1961
Macronemum spp.[2]	35	28	Robach, 1965
Ephemeroptera			
Stenonema spp.[2]	32	-	Trembley, 1961
Pseudocloeon spp.[2]	40.7	-	Trembley, 1961
Diptera			
Simulium spp.[2]	41.5	-	Trembley, 1961
Chironomidae			
Chironomus attenuatus[2]	32.8	-	Curry, 1965
Cricotopus spp. (6)[2]	32.8-34	-	Curry, 1965
Cryptochironomus digitatus[2]	30.0	-	Curry, 1965
Glyptotendipes lobiferus[2]	32.8	-	Curry, 1965
Harnischia tenuicaudata[2]	30.0	-	Curry, 1965
Micropsectra dives	26.7	-	Curry, 1965

Table A-29. (Continued).

TAXA	MAXIMUM TEMPERATURE TOLERATED (C)	OPTIMUM TEMPERATURE (C)	REFERENCE
Chironomidae (cont.)			
Phaenopsectra jucundus	26.7	-	Curry, 1965
Polypedilum fallax[2]	32.8	-	Curry, 1965
Procladius culiciformes[2]	32.8	-	Curry, 1965
Coleoptera			
Berosus spp.[2]	41	-	Trembley, 1961
Odonata			
Argia spp.[2]	41	-	Trembley, 1961
Trichoptera			
Agraylea spp.[2]	41	-	Trembley, 1961
Ephemeroptera			
Tricorythodes spp.[2]	32	-	Trembley, 1961
Ephemerella sp.[2]	30	-	Trembley, 1961
Isonychia sp.[2]	30	-	Trembley, 1961
Heptagenia sp.[2]	28	-	Trembley, 1961
Trichoptera			
Oxyethira sp.[2]	32	-	Trembley, 1961

Table A-29. (Continued).

TAXA	MAXIMUM TEMPERATURE TOLERATED (C)	OPTIMUM TEMPERATURE (C)	REFERENCE
Trichoptera (cont.)			
Psychomyia sp.[2]	30	-	Trembley, 1961
Athripsodes sp.[2]	27	-	Trembley, 1961
Coleoptera			
Elmidae unidentified spp.[3]	30	-	Trembley, 1961
Diptera			
Empididae unidentified spp.[3]	30	-	Trembley, 1961

[1]Species found near PINGP
[2]Genus found near PINGP
[3]Family found near PINGP

Table A-30. Ranking of zooplankton abundances at three locations near PINGP during 1975 and 1976. Diversity and evenness indices are also presented.

ZOOPLANKTON	1976												1975											
	FALL[1]			SUMMER[2]			SPRING[3]			WINTER[4]			FALL			SUMMER			SPRING			WINTER		
	U[5]	I[6]	D[7]	U	I	D	U	I	D	U	I	D	U	I	D	U	I	D	U	I	D	U	I	D
Rotatoria (Rotifers)																								
Brachionus calyciflorus	3	3	3	4	4	5	3	3	3	—	2	—	4	4	5	4	4	4				—	3	—
B. urceolaris							2	2	2	—	2	—						2				—	1	—
Keratella cochlearis	5	5	5	5	5	5	3	3	3	—	4	—		4	4	2	3	2	2	2		—	3	—
K. quadrata							3	3	3	—	2	—							2	2		—	2	—
Polyarthra sp.	3	3	4	4	4	4	2	2	2	—	3	—	3	2	2	2	3	3			2	—	2	—
Copepoda (Copepods)																								
Cyclops vernalis	3	3	4	4	4	4	2	1	2	—		—	2	2	2	2	3	2	1	1	2	—	1	—
Cladocera (Cladocerans)																								
Bosmina longirostris	3	3	3	2		3	2	2	2	—	2	—	2	2	2	4	3	4		1	2	—	2	—
Chydorus sphaericus	4	4	4				2	2	2	—	2	—	3	3	3	2		2		1		—		—
Shannon Weaver Diversity[8]	2.04	1.44	2.08	2.18	2.13	2.65	2.00	2.01	1.88	—	2.33	—	—	—	—	—	—	—	—	—	—	—	—	—
Evenness Index[9]	.51	.37	.51	.56	.58	.68	.46	.44	.42	—	.60	—	—	—	—	—	—	—	—	—	—	—	—	—

Key: Abundance: 1 = 0.01-0.09; 2 = 0.1-0.9; 3 = 1.0-9.9; 4 = 10-99; 5 = 100-999 org/ℓ; — = no sample; blank indicates no organisms found

[1]Usually near mid-October
[2]Usually near mid-July
[3]Usually near mid-April
[4]Usually near mid-January
[5]U = upriver (usually near HDR station 10)
[6]I = intake (usually near HDR station 12)
[7]D = downriver (usually near HDR station 27)
[8]S.W. Diversity $\bar{d} = -\sum_{i}^{s}\left[\frac{n_i}{N}\log_2\frac{n_i}{N}\right]$, where N is total number of all individuals of all taxa in sample, n_i is number of individuals in the i^{th} taxa, and s is the number of taxa in sample.

[9]Evenness (e) = $\bar{d}/\bar{d}_{max}$, where $\bar{d}_{max}$ is the maximum possible diversity for a given $s = \log_2 s$.

Table A-31. Summary of zooplankton thermal tolerances.

TAXA	ACCLIMATION TEMPERATURE (C)	LT_{50} (C)	EXPOSURE TIME	REFERENCE
Copepoda				
Diaptomus spp.[1]	1	28.4	30 min	Kreuger, 1975
	5	30.4	30 min	
	10	31.0	30 min	
	15	31.2	30 min	
	20	31	30 min	
Cyclops vernalis[1]	21	32.3	30 min	Coker, 1934
	27.5	35	30 min	
	35.5	40	30 min	
Cladocera				
Daphnia pulex[1]	—	44	30 sec	Altman and Dittmer, 1966
Scapholeberis kingi[1] *Simocephalus vetulus*[1]	21	38-43	30 min	Carlson, 1972; Brown, 1929
Latanopsis occidentalis	—	46	—	Altman and Dittmer, 1966
Macrothrix rosea[2]	—	50	—	Altman and Dittmer, 1966
Moina macrocopa[2]	—	48	30 min	Altman and Dittmer, 1966
Sida crystallina[1]	—	40	30 min	Altman and Dittmer, 1966
Ciliophora				
Colpoda cucullus	21	40	2 min	Altman and Dittmer, 1966
Paramecium caudatum	20	39	—	Altman and Dittmer, 1966
Rhizopoda				
Amoeba proteus	—	35.5-38.3	60 min	Altman and Dittmer, 1966

[1]Species found near PINGP

[2]Genus found near PINGP.

Table A-32. Ranking of phytoplankton abundances at three locations near PINGP during 1970 and 1974-1976. Diversities, chlorophyll a concentrations, and productivity are also presented.

PHYTOPLANKTON	1976 FALL[1] U[6]	1976 FALL I[7]	1976 FALL D[8]	1976 SUMMER[2] U	1976 SUMMER I	1976 SUMMER D	1976 SPRING[3] U	1976 SPRING I	1976 SPRING D	1976 WINTER[4] U	1976 WINTER I	1976 WINTER D
Chrysophyta (Diatoms)												
Nitzschia acicularis	-	4	3	3	3	2	3	3	3	1	2	2
Stephanodiscus/ Cyclotella spp.	-	5	5	5	5	5	4	5	5	2	3	3
Gomphonema olivaceum	-											
Chlorophyta (Green Algae)												
Scenedesmus quadricauda	-	3	3	3	3	3	2	3	2			
Ankistrodesmus spp.	-		3	2		2	3	2	3		1	1
Chlamydomonas spp.	-		3	2		2		2		1	2	
Cryptomonads	-	3	3	3			3		3			
Cyanophyta (Blue-Green Algae)												
Aphanizomenon flos-aquae	-			2		3						
Oscillatoria agardhii	-		3	3	3	3		2			1	
Shannon Weiner Diversity[9]	-	0.74	0.80	2.58	2.71	2.31	2.20	1.33	1.57	2.95	2.67	2.65
Net Productivity	2	3	2	3	3	3	1	2	2	-	-	-
Chlorophyll a	3	3	-	3	3	-	2	-	-	-	-	-

PHYTOPLANKTON	1975 FALL U	1975 FALL I	1975 FALL D	1975 SUMMER U	1975 SUMMER I	1975 SUMMER D	1975 SPRING U	1975 SPRING I	1975 SPRING D	1975 WINTER U	1975 WINTER I	1975 WINTER D
Chrysophyta (Diatoms)												
Nitzschia acicularis		2	2	2	2	2	3	3	3	-	-	-
Stephanodiscus/ Cyclotella spp.	4	5	4	4	4	4	5	5	5	-	-	-
Gomphonema olivaceum				2	2	2				-	-	-
Chlorophyta (Green Algae)												
Scenedesmus quadricauda	2	3	3		2	2	2			-	-	-
Ankistrodesmus spp.	3	2	3	3	3	2	3		3	-	-	-
Chlamydomonas spp.			2		2	2		2	3	-	-	-
Cryptomonads	3	3	3	3	2	2	3		3	-	-	-
Cyanophyta (Blue-Green Algae)												
Aphanizomenon flos-aquae				1	2		2	2	2	-	-	-
Oscillatoria agardhii				1	2	2				-	-	-
Shannon Weiner Diversity[9]	-	-	-	-	-	-	-	-	-	-	-	-
Net Productivity	2	2	2	2	2	2	-	-	-	-	-	-
Chlorophyll a	2	3	-	2	2	-	-	-	-	-	-	-

PHYTOPLANKTON	1974 FALL U	1974 FALL I	1974 FALL D	1974 SUMMER U	1974 SUMMER I	1974 SUMMER D	1974 SPRING U	1974 SPRING I	1974 SPRING D	1974 WINTER U	1974 WINTER I	1974 WINTER D	1970 SUMMER[5] U	1970 SUMMER I	1970 SUMMER D
Chrysophyta (Diatoms)															
Nitzschia acicularis		2	2	-	2	2	2	-	3		-		-	-	-
Stephanodiscus/ Cyclotella spp.	5	5	5	3	4	4	4	-	4	3	-	3	-	-	-
Gomphonema olivaceum				2	2	2	2	-	3		-		-	-	-
Chlorophyta (Green Algae)															
Scenedesmus quadricauda	3	3	3	2	2	2		-			-		-	-	-
Ankistrodesmus spp.	3	3	3	2	2	2	2	-	3		-		-	-	-
Chlamydomonas spp.	2		2	2	2	2		-	2		-		-	-	-
Cryptomonads	3	3	2	3	2	3	2	-	2		-	1	-	-	-
Cyanophyta (Blue-Green Algae)															
Aphanizomenon flos-aquae	2	3	4	3	2	3	1	-		1	-		-	-	-
Oscillatoria agardhii	2	2	2	2	3	2		-			-		-	-	-
Shannon Weiner Diversity[9]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Net Productivity	2	2	2	2	3	2	-	-	-	-	-	-	2	-	2
Chlorophyll a	-	-	-	2	-	2	-	-	-	-	-	-	-	-	-

Key: Chlorophyll a: 1 = 1.0-9.9; 2 = 10-99; 3 = 100-999 ppb
Net Productivity: 1 = 0.01-0.09; 2 = 0.1-0.9 ppm O_2/hr; — = no sample
Abundance: 1 = 1.0-9.9; 2 = 10-99; 3 = 100-999; 4 = 1,000-9,999; 5 = 10,000-99,999 org/ml; — = no sample; blank represents no organisms found

[1] Usually near mid-October
[2] Usually near mid-July
[3] Usually near mid-April
[4] Usually near mid-January
[5] August 28
[6] U = upriver (usually near BDR station 10)
[7] I = intake (usually near BDR station 12)
[8] D = downriver (usually near BDR station 27)
[9] S.W. Diversity

$$d = -\sum_{i}^{s}\left[\frac{n_i}{N}\log_2\frac{n_i}{N}\right],$$ where N is total number of all individuals of all taxa in sample, n_i is number of individuals in the i^{th} taxa, and s is the number of taxa in sample.

Table A-33. Phytoplankton and periphyton thermal tolerances.

TAXA	TEMPERATURE WHERE OCCURRING (C)		REFERENCE
	MINIMUM	MAXIMUM	
Nitzschia tryblionella[1]	11.5	25	Patrick, 1969
Diploneis oculata	21	30	Patrick, 1969
Amphora coffeaeformis[2]	25	33	Patrick, 1969
Nitzschia filiformis[1]	25	35	Patrick, 1969
Rhopalodea gibberula	25	36	Patrick, 1969
Navicula cincta[1]	25	40	Patrick, 1969
Oscillatoria tenuis[1]	29	44	Patrick, 1969
Pinnularia microstauron[1]	25	45	Patrick, 1969
Gomphonema parvulum[1]	25	45	Patrick, 1969
Lyngbya sp.[2]	25	48.2	Patrick, 1969
Euglena viridis[2]	—	35	Altman and Dittmer, 1966
Euglena gracilis[2]	—	38-42(44)	Altman and Dittmer, 1966
Chlamydomonas sp.[2]	—	42[3]	Hirayamo and Hirano, 1970

[1] Species found near PINGP.
[2] Genus found near PINGP.
[3] Completely inhibited photosynthesis in 10 min.

Table A-34. Ranking of periphyton abundances at three locations near PINGP from 1972 through 1976. Diversity and pigment concentrations are also presented.

PERIPHYTON	1976 FALL[1] U[5]	1976 FALL[1] I[6]	1976 FALL[1] D[7]	1976 SUMMER[2] U	1976 SUMMER[2] I	1976 SUMMER[2] D	1976 SPRING[3] U	1976 SPRING[3] I	1976 SPRING[3] D	1976 WINTER[4] U	1976 WINTER[4] I	1976 WINTER[4] D
Chrysophyta (Diatoms)												
Cyclotella kutzingiana	4	4	4	5	5	5	4		5	–	–	
C. meneghiana	4	5	5	5	6	5	5		5	–	–	
Diatoma vulgare var. *producta*	5						6	6	5	–	–	
Fragillaria intermedia		4		5	4		5	4	5	–	–	
Gomphonema parvulum	4	4		5		5	6	5	5	–	–	
Navicula cincta	4	4	4	5		5	4	5	6	–	–	3
Nitzschia acuta	4	4		6	5	5	6	6	6	–	–	3
N. dissipata		4						5	5	–	–	
Shannon Weiner Diversity[8]	3.81	2.95	2.21	2.81	1.96	2.94	3.30	2.54	3.70	–	–	3.50
Chlorophyll *a*	3	3	3	3	3	3	3	–	–	–	–	1
Phaeophytin *a*	2	2	3	3	3	3	1	–	–	–	–	1

PERIPHYTON	1975 FALL U	1975 FALL I	1975 FALL D	1975 SUMMER U	1975 SUMMER I	1975 SUMMER D	1975 SPRING U	1975 SPRING I	1975 SPRING D	1975 WINTER U	1975 WINTER I	1975 WINTER D
Chrysophyta (Diatoms)												
Cyclotella kutzingiana	4	4			4	4	5	4				
C. meneghiana	5	4	4		4	4		4		–	–	2
Diatoma vulgare var. *producta*	5							4		–	–	
Fragillaria intermedia	4		4	5	4		6	5	5	–	–	2
Gomphonema parvulum	5	5	5	6	6	6	5	6	6	–	–	2
Navicula cincta	5	6	6	6	5	5	5	6	5	–	–	
Nitzschia acuta	4	4	5		4		6	5	6	–	–	2
N. dissipata	5	5	6	6	5	6		6	6	–	–	3
Shannon Weiner Diversity[8]	3.85	2.38	3.18	2.20	3.75	2.19	3.53	3.63	3.64	–	–	2.80
Chlorophyll *a*	3	3	4	3	3	3	3	3	3	–	–	1
Phaeophytin *a*	1	2	2	1	2	3	1	2	3	2	2	–

PERIPHYTON	1974 FALL U	1974 FALL I	1974 FALL D	1974 SUMMER U	1974 SUMMER I	1974 SUMMER D	1974 SPRING U	1974 SPRING I	1974 SPRING D	1973 FALL U	1973 FALL I	1973 FALL D	1972 FALL U	1972 FALL I	1972 FALL D	1972 SUMMER U	1972 SUMMER I	1972 SUMMER D
Chrysophyta (Diatoms)																		
Cyclotella kutzingiana	4	4	4	5	6	6	4	5	3					–				
C. meneghiana	3	3			5	5		4						–				
Diatoma vulgare var. *producta*	5	4	4		4	4			3					–				
Fragillaria intermedia		3		4					5					–				
Gomphonema parvulum	5	5	5	6	5	5				5	4	4	4	–	3	6		5
Navicula cincta	4	4	4	6	6	6	4	5	4	5	6	4	5	–	5	6		5
Nitzschia acuta	4	3	4	5	5	5	4	5	3					–				
N. dissipata	4	3	4	6	6	6		5		4	6			–		6		5
Shannon Weiner Diversity[8]	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Chlorophyll *a*	3	3	3	3	3	3	3	4	3	3	3	3	2	–	2	3	–	2
Phaeophytin *a*	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1	1	–	1

Key:

Phaeophytin *a*: 1 = .01-.09; 2 = 0.1-.99; 3 = 1.0-9.9; 4 = 10-99; – = no sample

Chlorophyll *a*: 1 = .01-.09; 2 = 0.1-.99; 3 = 1.0-9.9; 4 = 10-99 $\mu g/cm^2$; – = no sample

Abundance: 1 = 1.0-9.9; 2 = 10-99; 3 = 100-999; 4 = 1,000-9,999; 5 = 10,000-99,999 organisms/cm^2; 6 = 100,000-999,999 org/cm^2; – = no sample; blank indicates no organisms found

[1] Usually near mid-October
[2] Usually near mid-July
[3] Usually near mid-April
[4] Usually near mid-January
[5] U = upriver (usually near NDR station 10)
[6] I = intake (usually near NDR station 12)
[7] D = downriver (usually near NDR station 27)
[8] S.W. Diversity

$$d = -\sum_{i}^{s}\left[\frac{n_i}{N}\log_2\frac{n_i}{N}\right]$$

where N is total number of all individuals of all taxa in sample, n_i is number of individuals in the ith taxa, and s is the number of taxa in sample.

Table A-35. Periphyton thermal criteria.

TAXA	MAXIMUM TEMPERATURE FOR SURVIVAL (C)	OPTIMUM TEMPERATURE (C)	REFERENCE
Nitzchia tryblionella[1]	25	-	Schwabe, 1936
N. filiformis[1]	35	-	Schwabe, 1936
N. linearis[1]	30	-	Wallace, 1955
N. amphibia[1]	36	-	Fogg and Reimer, 1962
N. acuta[1]	-	20	Baker, 1977
N. sp.[2]	40[3]	-	Barker, 1935
Navicula cincta[1]	40	20	Altman and Dittmer, 1966; Baker, 1977
Pinnularia microstauron[1]	45	-	Altman and Dittmer, 1966
Gomphonema parvulum[1]	45	10	Altman and Dittmer, 1966; Baker, 1977
Asterionella formosa[1]	-	4	Stoermer and Ladewski, 1974
Cocconeis scutellum[1]	34-36	-	Stoermer and Ladewski, 1974
Cyclotella comta[1]	-	18	Stoermer and Ladewski, 1974
C. meneghiana[1]	-	30	Baker, 1977
Cymbella sp.[2]	29	-	Fogg and Reimer, 1962
Melosira islandica[1]	-	5	Stoermer and Ladewski, 1974
M. varians[1]	36	-	Fogg and Reimer, 1962
M. italica[1]	-	7	Stoermer and Ladewski, 1974
M. granulata[1]	-	17	Stoermer and Ladewski, 1974
Stephanodiscus astraea[1]	-	2.5	Stoermer and Ladewski, 1974
Synedra acus[1]	-	10	Baker, 1977
Diatoma vulgare var. *producta*	-	5	Baker, 1977
Fragilaria intermedia	-	5	Baker, 1977

[1]Species found near PINGP.
[2]Genus found near PINGP.
[3]Photosynthetic rate irreversibly lowered.

Table A-36. Dominant species comprising major beds of submerged and emergent aquatic vegetation in the vicinity of PINGP.

LOCATION NUMBER	LOCATION
1	Wisconsin Shore Immediately Upstream of Lock & Dam No. 3 *Potamogeton crispus* *Potamogeton filiformis* *Potamogeton nodosus* *Potamogeton pectinatus* *Sagittaria spp.*
2	Refuge Outlet *Potamogeton crispus* *Potamogeton filiformis* *Potamogeton pectinatus*
3	Barney's Point *Potamogeton crispus* *Potamogeton pectinatus*
4	Discharge Canal-Southwest Shore *Potamogeton crispus* *Eleocharis ovata* *Eleocharis palustris* *Scirpus fluviatilis* *Scirpus validus* *Phragmites communis*
5	Between PINGP Intake and Discharge Areas *Potamogeton crispus* *Potamogeton nodosus*
5a	Shoreline Between PINGP Intake and Discharge Areas *Potamogeton pectinatus*
6	Sturgeon Lake at Mouth of Buffalo Slough *Potamogeton crispus* *Potamogeton filiformis* *Potamogeton natans* *Potamogeton nodosus* *Potamogeton pectinatus*

Table A-36. (Continued).

LOCATION NUMBER	LOCATION
7	Bay at Mouth of Buffalo Slough *Potamogeton crispus* *Potamogeton filiformis* *Potamogeton nodosus* *Potamogeton pectinatus* *Sagittaria cuneata* *Sagittaria latifolia* *Scirpus fluviatilis* *Phragmites communis* *Sparganium eurycarpum* *Typha angustifolia* Cyperaceae (unidentified) *Zizania aquatica*
8	Sturgeon Lake "Cut" Delta—East Half *Potamogeton filiformis* *Potamogeton pectinatus* *Potamogeton crispus*
9	Sturgeon Lake "Cut" Delta—West Half *Potamogeton crispus* *Potamogeton pectinatus*
10	Side Channel of Sturgeon Lake "Cut" *Vallisneria americana* *Potamogeton crispus* *Potamogeton pectinatus* *Potamogeton nodosus*
11	North Shore of Sturgeon Lake *Sagittaria spp.* *Scirpus fluviatilis* *Phragmites communis*
12	East Shore of Brewer Lake *Sagittaria spp.*

Table A-36. (Continued).

LOCATION NUMBER	LOCATION
13	West Shore of Brewer Lake *Sagittaria spp.* *Scirpus fluviatilis* *Phragmites communis*
A1	Intake Area, Outside of Skimmer Wall *Potamogeton pectinatus*
A2	Bay Upstream of PINGP Intake *Potamogeton pectinatus*
A3	Bay at End of the Long Island Separating Sturgeon Lake and the Main Channel *Potamogeton pectinatus* *Potamogeton crispus*
A4	Point on West Side of "Lab Bay" *Potamogeton pectinatus* *Potamogeton crispus*
A5	Buffalo Slough Cyperaceae (unidentified) *Polygonum sp.* *Eleocharis sp.* *Anacharis canadensis* *Ceratophyllum demersum*

Table A-37. Areas within various isotherms from the thermal plume model (Appendix I) for typical spring (May 1976) conditions (determined by computer planimetry). River temperature = 16.5° C (61.7° F) and river flow = 11,028 cfs.

ΔT (F)	ABSOLUTE TEMPERATURE		AREA		
	(C)	(F)	(ft^2)	(m^2)	(ha)
18	26.5	80	19,412	1,083	0.1
15	24.8	77	51,058	4,743	0.5
12	23.1	74	117,740	10,938	1.1
10	22.0	72	206,750	19,207	1.9
9	21.5	71	275,766	25,619	2.6
8	20.9	70	364,257	33,840	3.4
6	19.8	68	638,574	54,324	5.4
5	19.2	67	779,430	72,409	7.2
4	18.7	66	1,159,270	107,696	10.8
2	17.6	64	2,187,072	203,179	20.3

Table A-38. Areas within various isotherms from the thermal plume model (Appendix I) for typical summer (August 1975) conditions (determined by computer planimetry). River temperature = 24.4°C (76° F) and river flow = 11,790 cfs.

ΔT (F)	ABSOLUTE TEMPERATURE		AREA		
	(C)	(F)	(ft^2)	(m^2)	(ha)
12.5	31.3	88.5	16,194	1,504	0.2
10	30.0	86.0	97,854	9,091	0.9
9	29.4	85.0	156,313	14,522	1.5
7.5	28.5	83.5	292,051	27,132	2.7
5	27.2	81.0	714,288	66,357	6.6
4	26.6	80.0	1,030,128	95,699	9.6
3	26.1	79.0	1,529,365	142,078	14.2

Table A-39. Areas within various isotherms from the thermal plume model (Appendix I) for typical winter (December 1975) conditions (determined by computer planimetry). River temperature = 0.5° C (32.9° F) and river flow = 12,561 cfs.

ΔT (F)	ABSOLUTE TEMPERATURE		AREA		
	(C)	(F)	(ft^2)	(m^2)	(ha)
45	25.5	77.9	6,060	563	0.06
40	22.7	72.9	23,076	2,144	0.2
35	19.9	67.9	59,555	5,533	0.6
30	17.2	62.9	95,116	8,836	0.9
25	14.4	57.9	159,795	14,845	1.5
20	11.6	52.9	301,347	27,995	2.8
17	9.9	49.9	475,726	44,195	4.4
15	8.8	47.9	553,997	51,466	5.2
10	6.1	42.9	901,820	83,779	8.4
9	5.5	41.9	1,140,719	105,973	10.6
5	3.3	37.9	1,804,367	167,626	16.8

Table A-40. Areas within various isotherms from the thermal plume model (Appendix I) for winter (January) proposed extreme conditions (determined by computer planimetry). River temperature = 0° C (32° F) and river flow = 3,699 cfs.

ΔT (F)	ABSOLUTE TEMPERATURE		AREA		
	(C)	(F)	(ft^2)	(m^2)	(ha)
50	27.8	82	8,902	827	0.08
45	25.0	77	31,835	2,958	0.3
40	22.2	72	59,567	5,534	0.6
35	19.4	67	95,658	8,887	0.9
30	16.7	62	165,667	15,391	1.5
25	13.9	57	305,022	28,337	2.8
20	11.1	52	561,199	52,135	5.2
15	8.3	47	921,918	85,646	8.6
10	5.6	42	1,648,929	153,186	15.3
9	5.0	41	1,720,787	159,861	16.0

Table A-41. Areas within various isotherms from the thermal plume model (Appendix I) for spring (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		AREA		
	(C)	(F)	(ft^2)	(m^2)	(ha)
12.5	29.7	85.5	50,151	4,659	0.5
10	28.3	83.0	174,145	16,178	1.6
9	27.8	81.0	281,460	26,148	2.6
7.5	26.9	80.5	516,518	47,985	4.8
5	25.6	78.0	1,180,507	109,669	11.0
3	24.4	76.0	2,230,161	207,182	20.7

Table A-42. Areas within various isotherms from the thermal plume model (Appendix I) for summer (August) proposed extreme conditions (determined by computer planimetry). River temperature = 29.4° C (85° F) and river flow = 3,390 cfs.

ΔT (F)	ABSOLUTE TEMPERATURE		AREA		
	(C)	(F)	(ft^2)	(m^2)	(ha)
6.5	33.0	91.5	54,454	5,059	0.5
6	32.8	91.0	188,154	17,480	1.8
5	32.2	90.0	670,391	62,279	6.2
4	31.7	89.0	1,280,753	118,982	11.9
3	31.1	88.0	1,919,618	178,333	17.8

Table A-43. Mean temperatures (C) at each discharge electrofishing study station. Surface and bottom temperatures at the beginning, middle, and end of each run were averaged (DNR, unpublished data).

DATE	STATION						
	1	2	3	4	5	6	7
22 April 1976	17.6	13.9	14.6	13.9	16.7	13.1	13.1
28 April 1976	18.0	13.6	14.7	12.6	17.2	12.8	13.8
29 April 1976	18.7	14.2	14.2	13.3	16.9	13.2	13.1
6 May 1976	16.6	14.8	14.3	12.6	15.5	12.7	12.4
19 May 1976	22.0	23.2	21.3	19.5	20.3	21.9	19.0
1 June 1976	24.1	26.4	22.4	21.3	23.4	24.1	22.2
25 June 1976	24.5	25.8	24.1	22.5	24.9	24.7	22.2
22 July 1976	28.3	29.1	27.8	27.4	28.0	27.7	28.9
13 August 1976	28.3	28.0	27.3	26.6	27.2	27.1	27.4
19 August 1976	28.7	29.5	26.9	26.1	26.6	27.7	26.3
13 October 1976	19.5	19.0	18.8	15.3	19.3	19.9	14.9
19 November 1976	12.5	10.7	9.1	5.9	9.6	7.1	4.4
15 December 1976	10.4	9.9	9.9	NS[1]	8.2	NS	NS
2 February 1977	9.6	11.7	10.5	NS	9.7	7.5	NS
3 February 1977	12.6	6.7	7.6	NS	8.8	NS	NS
25 April 1977	18.1	16.3	15.3	15.0	15.7	14.7	14.1
27 April 1977	19.3	17.7	18.7	15.9	18.1	15.9	15.6
3 May 1977	19.3	18.9	17.4	16.4	18.0	18.1	17.1
6 May 1977	21.4	22.4	19.6	18.7	19.2	20.2	19.8
12 July 1977	27.5	28.7	28.3	24.8	27.7	28.6	25.0
25 July 1977	29.8	29.4	29.5	26.0	28.1	28.7	26.1
29 August 1977	26.4	26.6	26.7	24.8	25.8	26.5	25.2
4 November 1977	16.3	16.6	12.3	9.2	15.3	10.8	9.5
14 November 1977	11.1	7.7	5.3	5.5	8.3	5.6	9.5

[1]NS = no sample because of ice cover.

Table A-44. Catch per unit effort (fish/5 min. run) at each station for the discharge electrofishing study (DNR, unpublished data).

DATE	SPECIES	STATION 1	2	3	4	5	6	7
22 April 1976	Walleye	4		1				
	White bass	1						1
	Channel catfish				2			
	Northern pike	1						
	Gizzard shad						15	2
	Carp	2	1	1	10	1		3
	Emerald shiner	13						4
28 April 1976	Walleye	6		2				
	White bass			1				
	Northern pike							1
	Gizzard shad	1		1		4		
	Carp	2	1	6				2
	Emerald shiner	32	10	1		12		31
	Shorthead redhorse		1					
29 April 1976	Walleye	2		2		2		1
	White bass			1				
	Channel catfish			1				
	Gizzard shad			1		9		1
	Carp	3	1	13	1			3
	Emerald shiner		57	2		1		3
	Shorthead redhorse				1			
6 May 1976	Walleye	9						
	White bass			1				
	Gizzard shad	1				2		
	Carp	3	1	12	4		5	8
	Emerald shiner	53	118	3				7
	Shorthead redhorse						1	
19 May 1976	Walleye	8	7		1		1	
	White bass		1	1	1			
	Gizzard shad	1	1			6		
	Carp	5	3	3	3		2	2
	Emerald shiner			4				10
	Shorthead redhorse		5		2		1	

Table A-44. (Continued).

DATE	SPECIES	STATION						
		1	2	3	4	5	6	7
1 June 1976	Walleye	4	3	1			2	
	White bass		1					1
	Channel catfish		1					
	Gizzard shad	1				2		
	Carp	2	6	3	3		5	3
	Emerald shiner						1	
	Shorthead redhorse			1			1	
25 June 1976	Walleye			1				
	White bass		1	2				
	Channel catfish	1	1					
	Gizzard shad		3				2	
	Carp	9		6	2	3	3	3
	Black crappie	1						
	Emerald shiner	1	5					
	Shorthead redhorse				6			5
22 July 1976	White bass			1				3
	Channel catfish	3						
	Gizzard shad	2		1	2		1	13
	Carp	5	3	8	2			11
	Black crappie			1				
	Emerald shiner							1
	Shorthead redhorse							2
13 August 1976	Channel catfish			1				
	Gizzard shad		1	1	1		1	1
	Carp		1	8	3		1	1
	Shorthead redhorse				1			1
19 August 1976	White bass			3				3
	Channel catfish			1				
	Gizzard shad		2		6	3	4	
	Carp		3	5	1			3
	Emerald shiner					1		
	Shorthead redhorse				1			

Table A-44 (Continued).

DATE	SPECIES	STATION						
		1	2	3	4	5	6	7
13 October 1976	Walleye	5		2				
	White bass	1			2			1
	Gizzard shad	22	25	11	3	14	23	29
	Carp	1	8	5	1			1
	Emerald shiner			1				3
	Shorthead redhorse	1						
19 November 1976	Walleye	1	1					
	White bass	7	8	7				
	Gizzard shad	45		5		14		
	Carp	9	2	8				
	Emerald shiner							1
15 December 1976	Walleye		1					
	White bass	1				1		
	Gizzard shad	1	17		NS[1]	377	NS	NS
	Carp	17	1	1		2		
2 February 1977	White bass	7	1	1			1	
	Gizzard shad				NS	69	56	NS
	Carp	46	27	8		2		
	Black crappie	2						
3 February 1977	Walleye							
	White bass	11		1		2		
	Gizzard shad				NS	132	NS	NS
	Carp	31				1		
	Black crappie	1						
25 April 1977	Walleye	2						
	Gizzard shad	10	2	1		23		
	Carp	1		14		1		1
	Emerald shiner	111	1	1				13
27 April 1977	Walleye	1				1		
	White bass		1					
	Gizzard shad	2	14			2		
	Carp	1	4	4	2			
	Emerald shiner	5	2	3				1

[1]NS = no sample because of ice cover.

Table A-44. (Continued).

DATE	SPECIES	STATION						
		1	2	3	4	5	6	7
3 May 1977	Walleye	1						
	Gizzard shad	4	1	1		4	6	1
	Carp	4		7	1			2
	Emerald shiner	26				2	10	
	Shorthead redhorse	1						1
6 May 1977	Walleye	1						
	White bass						3	
	Gizzard shad	10	9			5		
	Carp	2	1	11	6		6	2
	Emerald shiner	12		1				6
12 July 1977	White bass	2					1	9
	Gizzard shad	1	13		6		9	24
	Carp		1	1	1		1	1
	Emerald shiner	1						4
	Shorthead redhorse	1						
25 July 1977	White bass	2	1		1		1	5
	Gizzard shad		9	1	3	7		6
	Carp		2	3	2		2	3
	Black crappie		2					
	Emerald shiner			1				
	Shorthead redhorse				1			1
29 August 1977	White Bass	1						1
	Gizzard shad		9	5		2		13
	Carp	2	2	6	1			1
	Shorthead Redhorse			1				1
4 November 1977	Walleye	9						
	White bass		3				1	
	Gizzard shad	40	27	NS		11		1
	Carp	1						
	Emerald shiner							1
14 November 1977	Walleye	1						
	Gizzard shad					15		
	Carp	5						
	Black crappie	1			1			

Table A-45. Constants for the time-temperature equation log time = a + b(T) for the RIS (Brungs and Jones, 1977).

SPECIES	ACCLIMATION TEMP. (C)	a	b	DATA LIMITS		DATA SOURCE
				UPPER	LOWER	
Channel Catfish	26	34.7119	-0.8816	39.0	36.6	Allen and Strawn, 1968
	30	32.1736	-0.7811	40.6	37.4	
	34	26.4204	-0.6149	42.0	38.0	
	25	34.5554	-0.8854	37.5	35.5	
	30	17.7125	-0.4058	40.0	37.5	
	35	28.3031	-0.6554	41.0	38.0	
	15	34.7829	-1.0637	31.5	30.5	Hart, 1952
	20	39.4967	-1.1234	34.0	33.0	
	25	46.2155	-1.2899	35.0	34.0	
Northern Pike	25	17.3066	-0.4523	34.5	32.5	Scott, 1964
	27.5	17.4439	-0.4490	35.0	33.0	
	30.0	17.0961	-0.4319	35.5	33.5	
Gizzard Shad	25	47.1163	-1.3010	35.5	34.5	Hart, 1952
	30	38.0658	-0.9694	38.0	36.5	
	35	31.5434	-0.7710	39.0	37.0	
	25	32.1348	-0.8698	35.5	35.0	
	30	41.1030	-1.0547	38.0	36.5	
	35	33.2846	-0.8176	39.0	36.5	
Emerald Shiner	5	20.9532	-0.7959	24.5	23.5	Hart, 1947
	10	36.5023	-1.2736	27.5	27.0	
	15	47.4849	-1.5441	30.5	29.5	
	20	33.4714	-0.9858	32.5	31.5	
	25	26.7096	-0.7337	34.0	31.5	
White Sucker	5	33.6957	-1.1797	27.5	27.0	Hart, 1947
	10	18.9890	-0.6410	29.0	28.0	
	15	31.9007	-1.0034	30.0	29.5	
	20	27.0023	-0.8068	31.5	30.0	
	25	22.2209	-0.6277	32.5	29.5	

Table A-46. Data used in chi-square analysis. Total number of each RIS collected in the immediate discharge (Runs 1+5), far discharge (Runs 2+3), and intake or control (Runs 4+7), during the period April 1976 through November 1977 (DNR, unpublished data).

SPECIES	STATION	SPRING[1]	SUMMER[1]	FALL[1]	WINTER[1]
Walleye	1 & 5 2 & 3 4 & 7	37 12 2	4 5 0	16 3 0	0 1 ND[2]
White Bass	1 & 5 2 & 3 4 & 7	1 6 2	5 9 23	8 15 3	22 4 ND
Gizzard Shad	1 & 5 2 & 3 4 & 7	84 31 4	18 45 75	161 41 33	579 17 ND
Carp	1 & 5 2 & 3 4 & 7	24 83 50	21 58 41	16 23 2	99 37 ND
Emerald Shiner	1 & 5 2 & 3 4 & 7	267 203 75	3 6 5	0 1 5	0 0 ND
Shorthead Redhorse	1 & 5 2 & 3 4 & 7	1 6 4	1 2 19	1 0 0	0 0 ND

[1]Seasons are defined by ambient river temperature as:
spring = 5 to 21° C
Summer = > 21° C
Fall = 21 to 5° C
Winter = < 5° C

[2]No data.

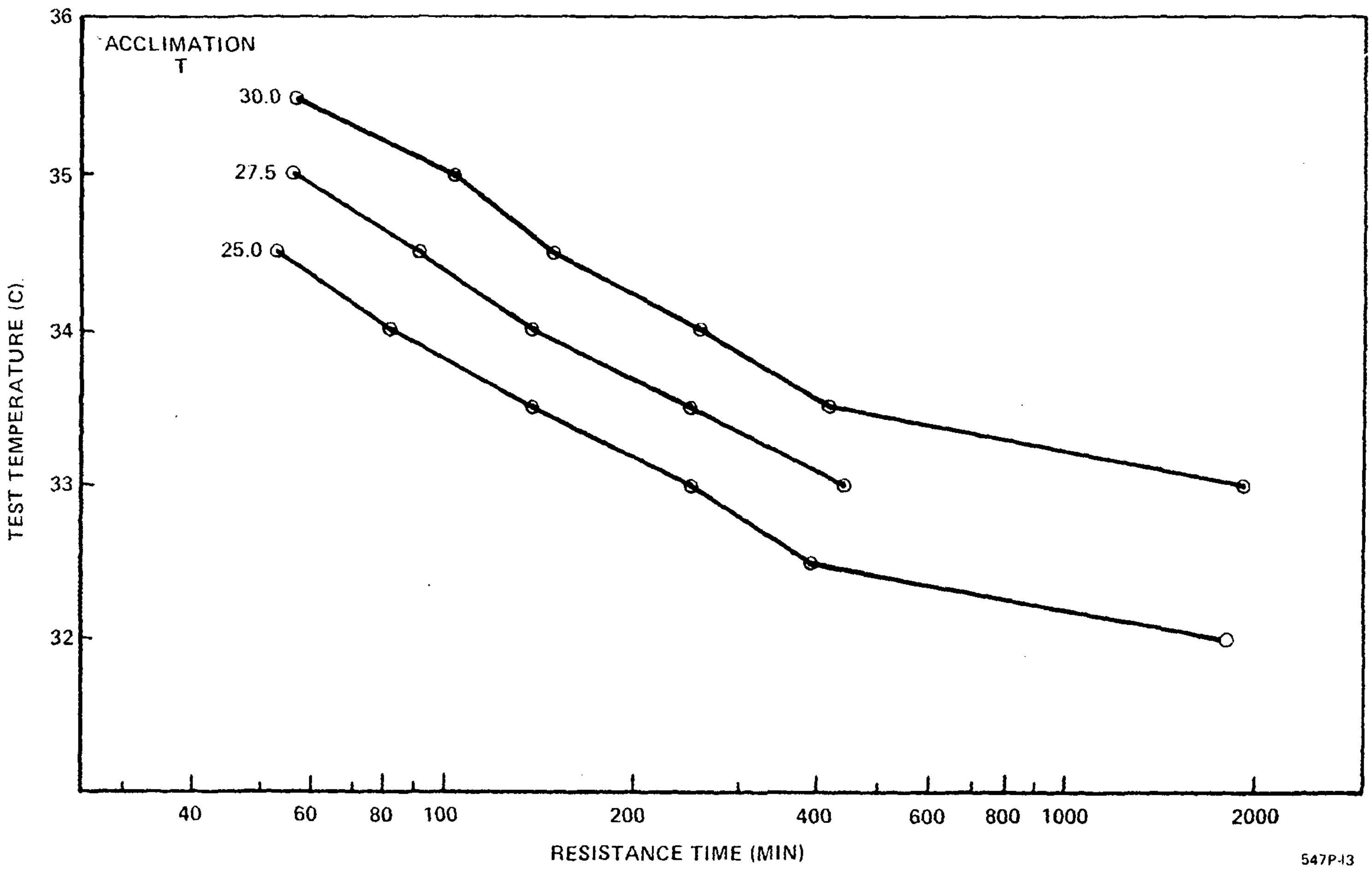


Figure A-1. Median resistance times (time to 50 percent mortality) for juvenile northern pike acclimated to 25°, 27.5°, and 30° C (adapted from Scott, 1964).

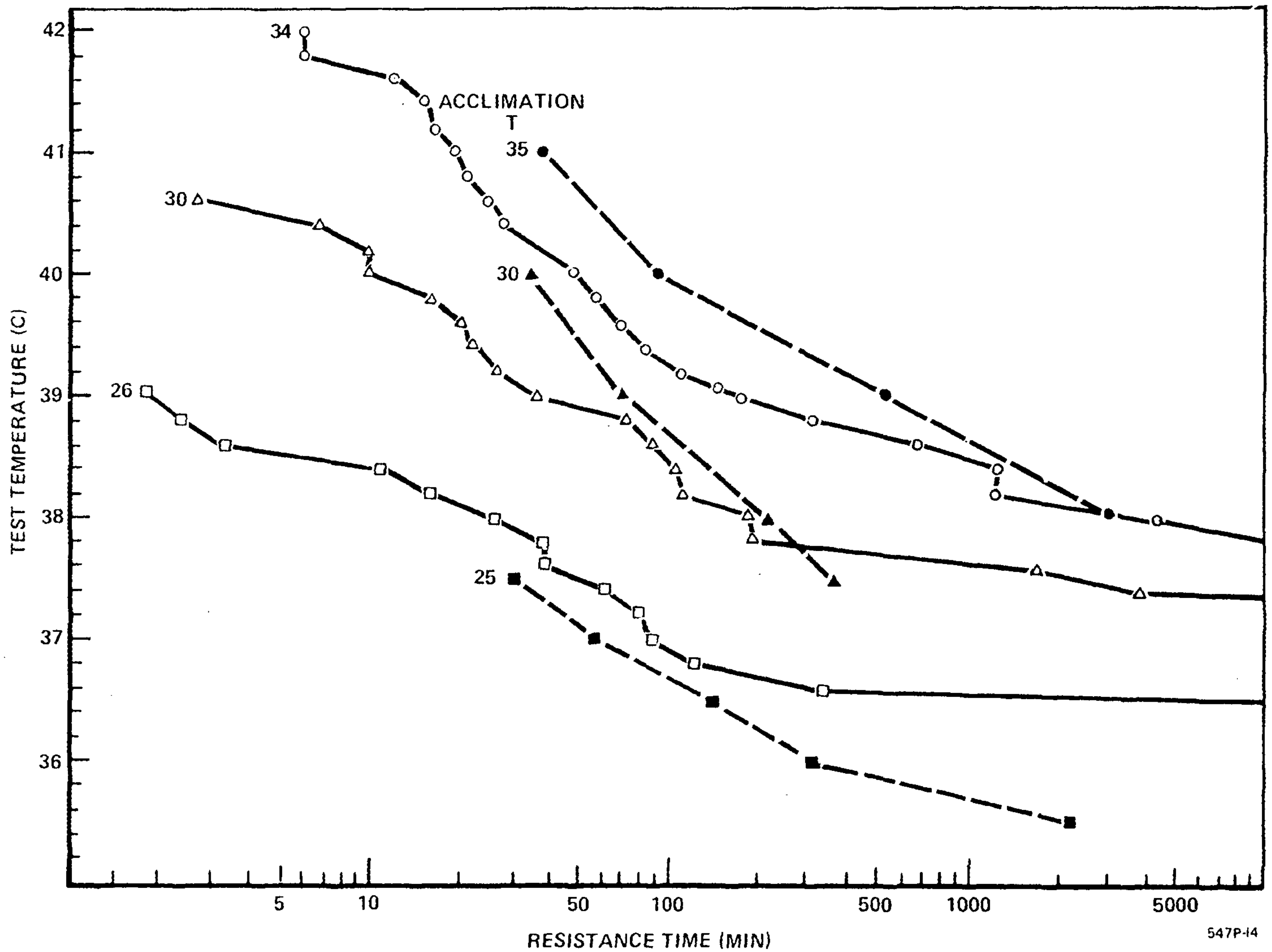


Figure A-2. Median resistance times (time to 50 percent mortality) for juvenile channel catfish from state fish hatcheries in Lonoke (open symbols) and Centerton (closed symbols), Arkansas at acclimation temperatures of 25° to 35° C (adapted from Allen and Strawn, 1968).

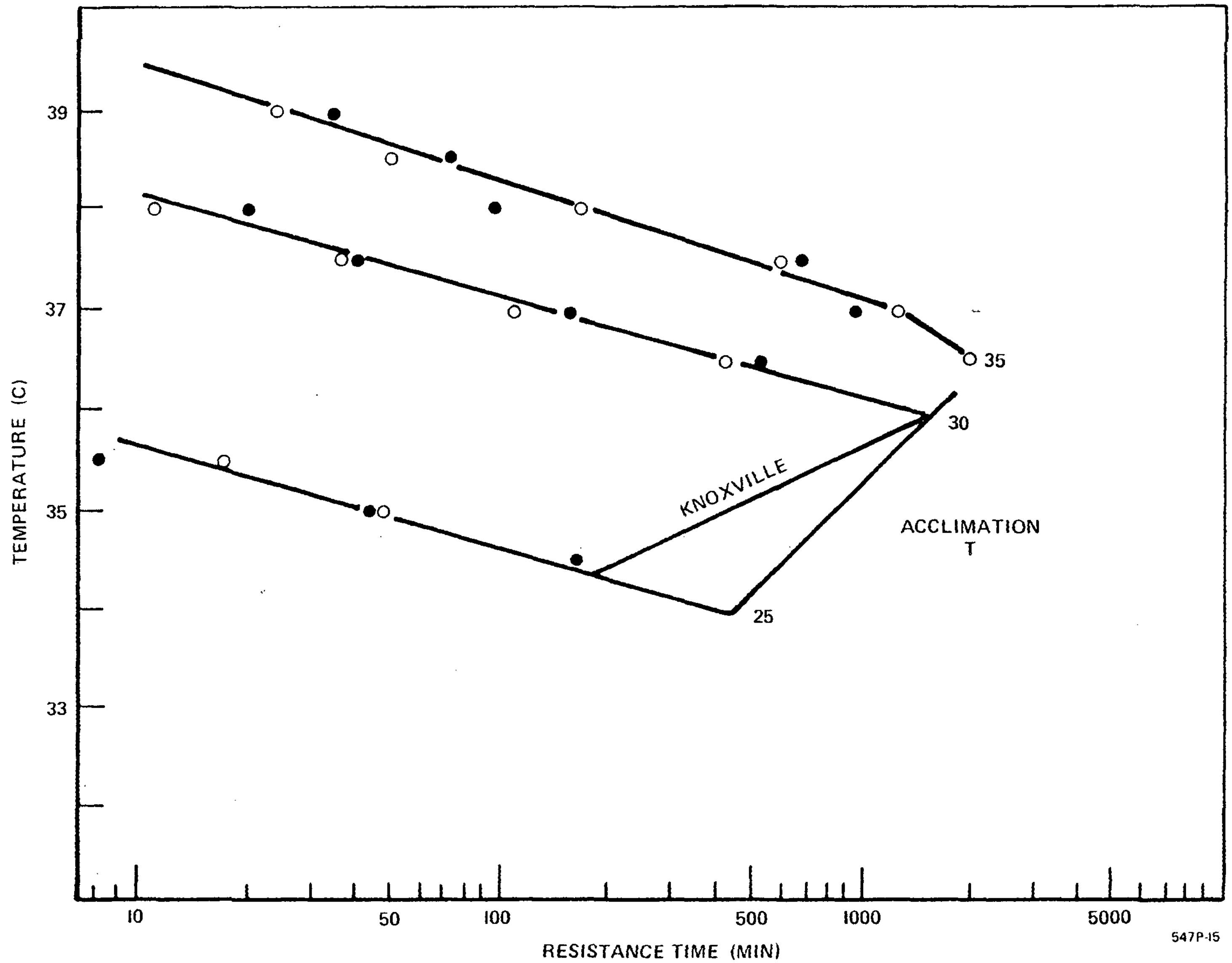
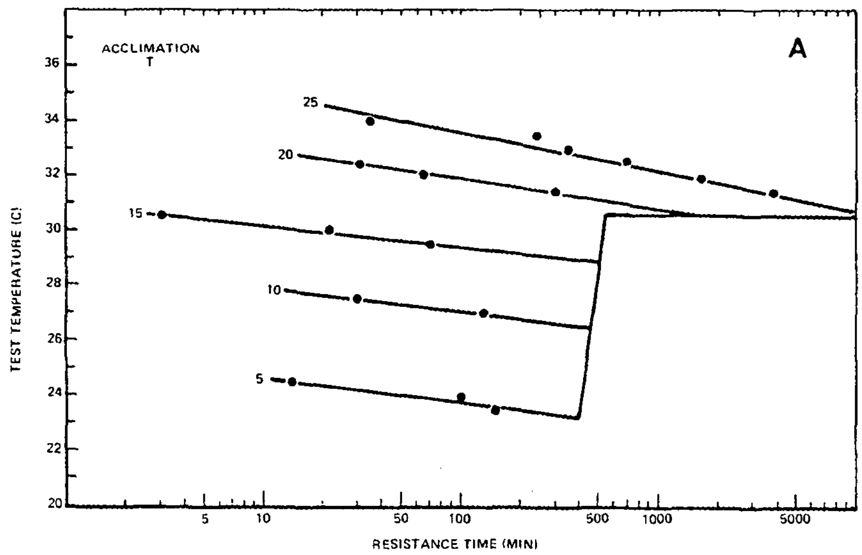


Figure A-3. Median resistance times (time to 50 percent mortality) of gizzard shad from Put-in-Bay, Ohio (closed symbols) and Knoxville, Tennessee (open symbols), for fish acclimated to 25°, 30°, and 35°C (adapted from Hart, 1952).



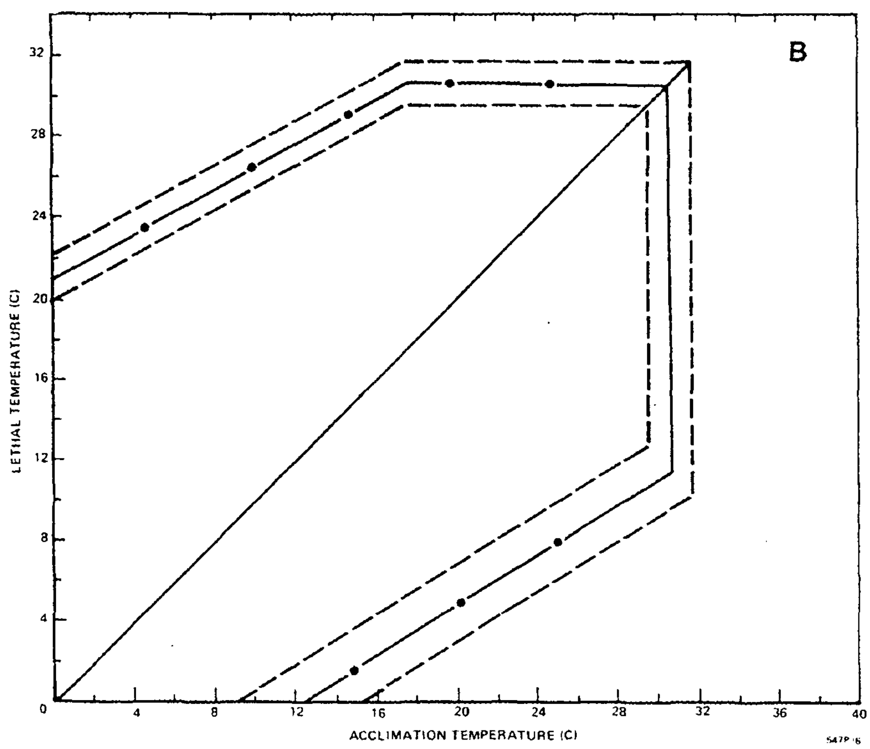


Figure A-4. A. Median resistance times (time to 50 percent mortality) for emerald shiners acclimated to temperatures from 5°to 25°C (adapted from Hart, 1947).

B. Median thermal tolerance polygon for emerald shiners. The dashed lines represent 10 percent (outer) and 90 percent (inner) survival (adapted from Hart, 1947).

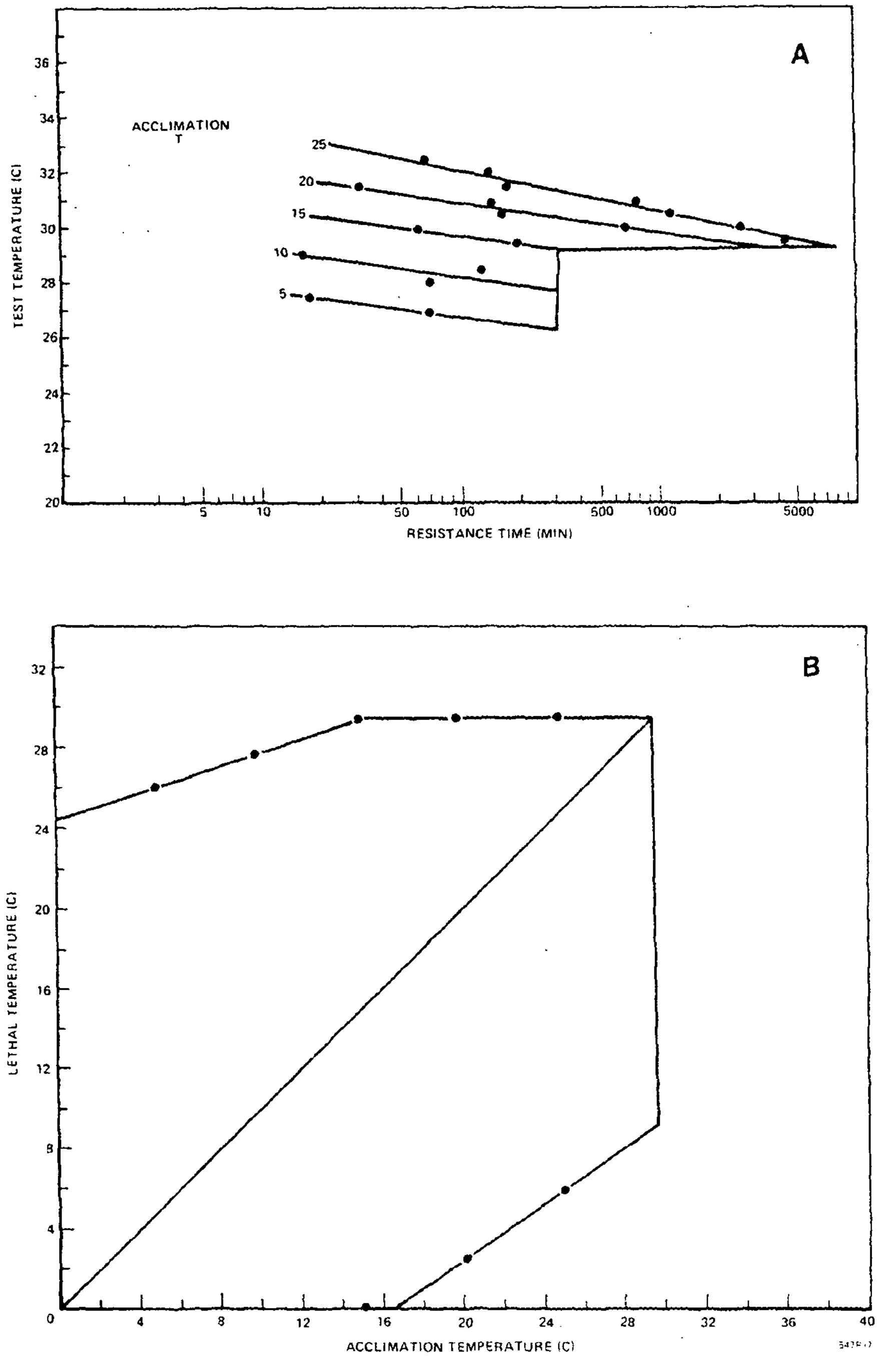


Figure A-5. A. Median resistance times (time to 50 percent mortality) for white suckers acclimated to temperatures from 5° to 25°C (adapted from Hart, 1947).

B. Median thermal tolerance polygon for the white sucker (adapted from Hart, 1947).

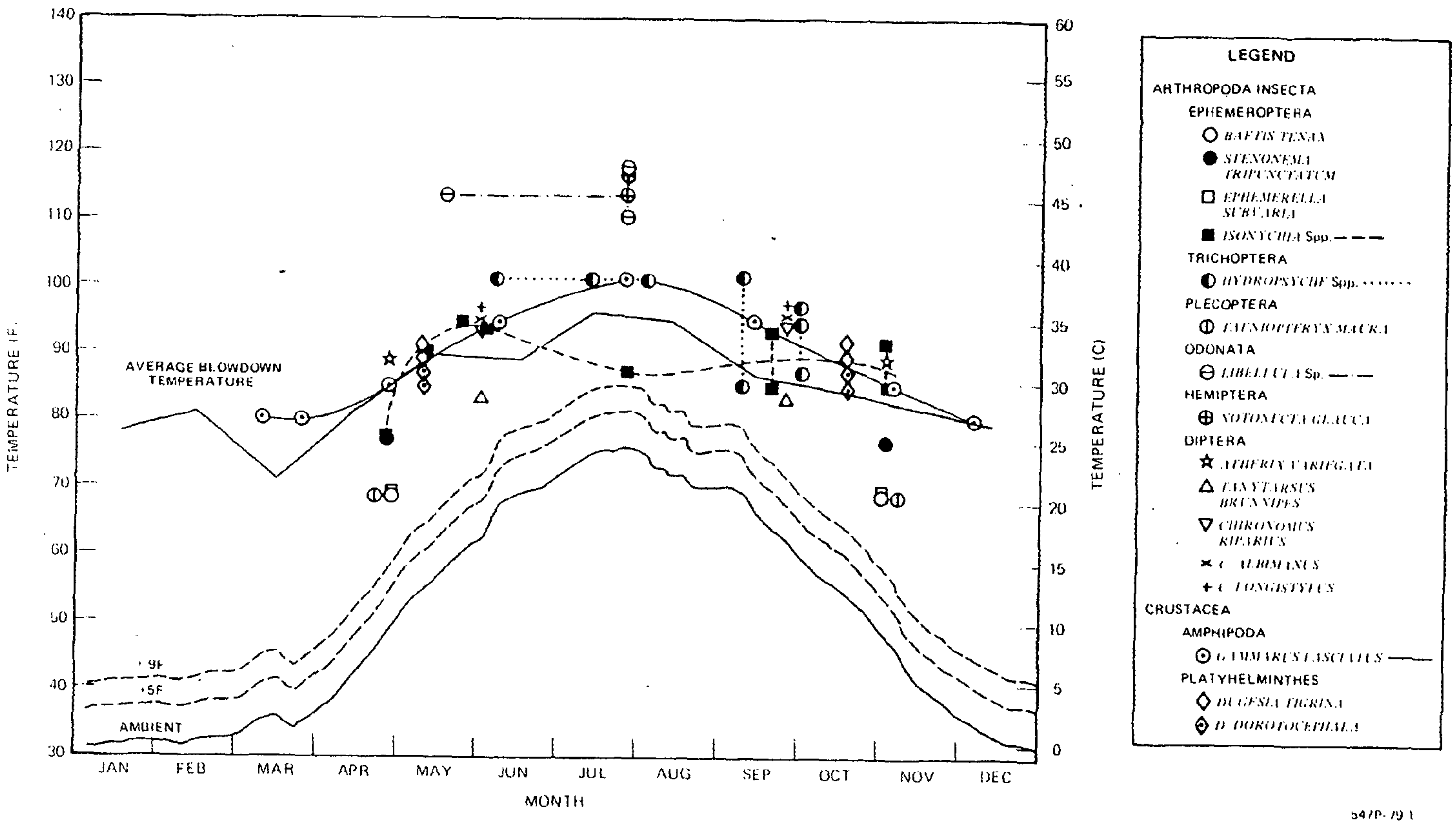


Figure A-6. Thermal tolerances of macroinvertebrates collected near PINGP (from Table A-28).

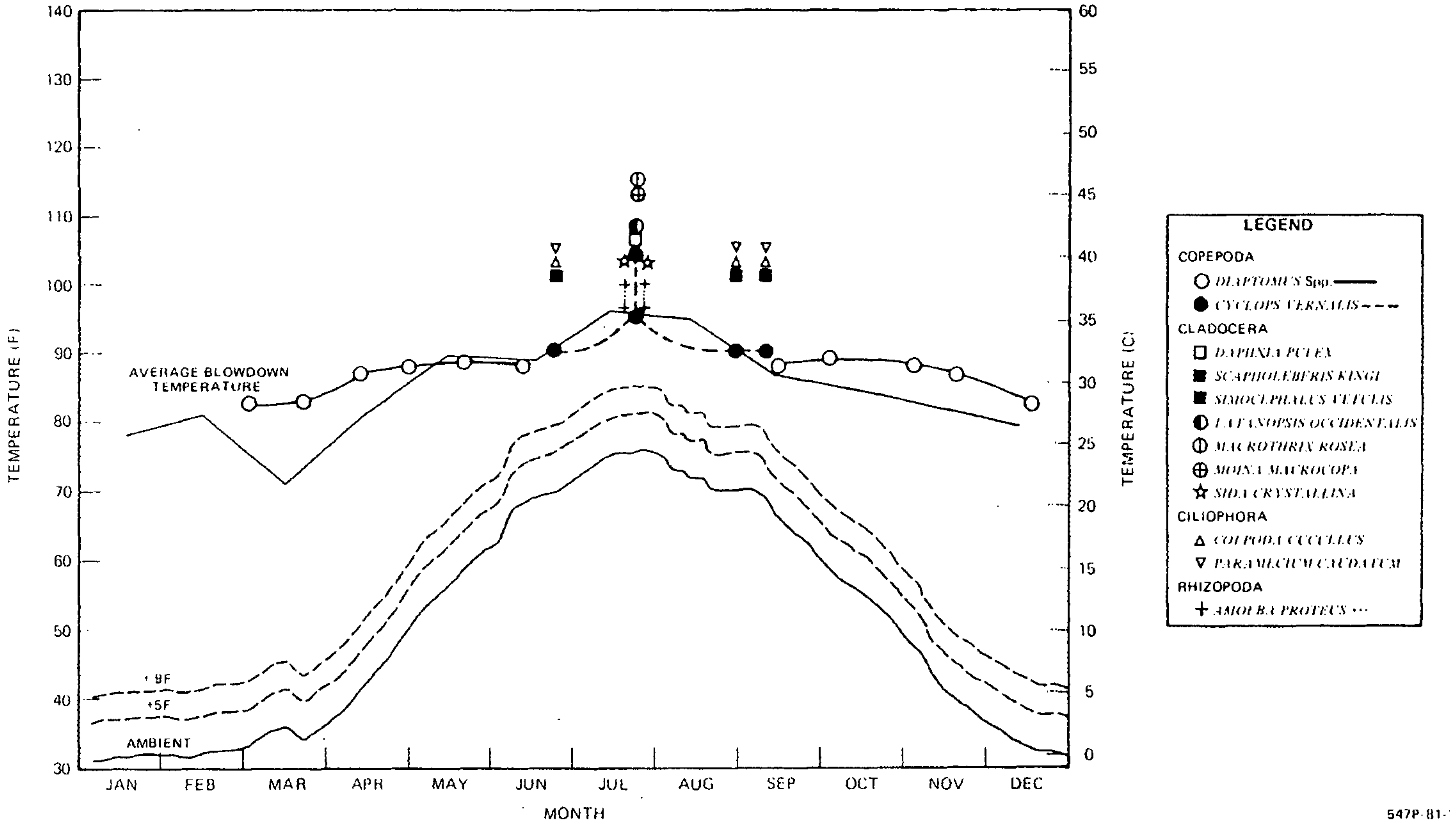


Figure A-7. Thermal tolerances for zooplankton collected near PINGP (information derived from Table A-31).

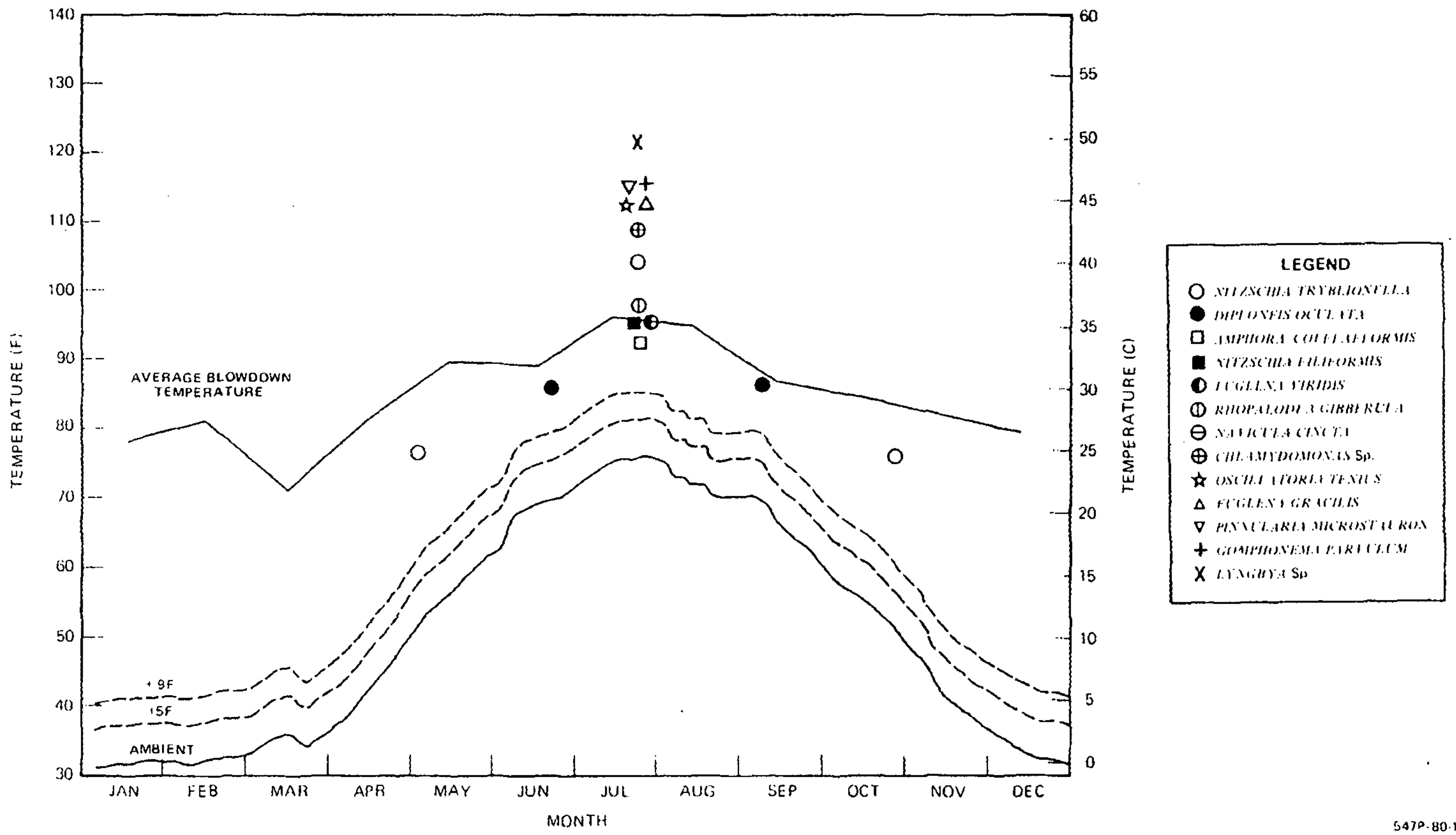


Figure A-8. Thermal tolerances of phytoplankton collected near PINGP, 1969 through 1976 (information derived from Table A-33).

APPENDIX B

DETAILS OF NON-FISHERIES STATISTICAL ANALYSES

LIST OF TABLES

Introduction

This appendix presents raw data and the statistical methods of the reanalyses that were used in determining PINGP discharge impacts upon non-fisheries biota. The raw data were taken from 1973-1976 Annual Reports and unpublished reports for 1977 of the Environmental Monitoring and Ecological Studies Program for the Prairie Island Nuclear Generating Plant (PINGP). Station and month code numbers were substituted for HDR station numbers and months (as shown in the appropriate raw data tables). The statistical analyses were done using: (a) the *Biomedical Computer Programs* (BMDP), edited by W. J. Dixon, (b) the *Statistical Analysis System* (SAS-76), developed by Barr et al., and (c) the *General Statistics Pac,* by Hewlett Packard. A complete listing of the various statistical analyses used is given in Table 1, and a brief description is given below.

Treatment of Missing Values

Most of the variables had several missing values and this was a major problem in the statistical analysis. A missing value in the data was represented by a decimal point in the SAS-76 programs, whereas a missing value code of -1.0 was used for the BMDP programs. The SAS-76 programs handle missing values by omitting them in calculating the result (Barr et al., 1976). In the BMDP package, some programs such as Stepwise Regression, t-Test, T^2 Routine, and Frequency Count Routine, complete the analysis using the remaining variables for that case; other programs omit the entire case (Dixon, 1975). To the extent possible, programs utilizing maximum available data were used.

Table B-1. *Table summarizing statistical analysis of the data.*

PARAMETER	DATA USED			BRIEF DESCRIPTION OF STATISTICAL PROCEDURES USED	COMPUTER PROGRAM USED	REFERENCES	PAGE
	HDR STATION NUMBERS	YEARS	NUMBER OF REPLICATES				
1. All complete data sets for phytoplankton density, Zooplankton density, Macroinvertebrate (dredge) and Macroinvertebrate (artificial substrate) densities.	6, 10, 12, 18, 21, 25, 27	1975-1976	—	Histogram plots and general data description for real numbers which showed that the data was not normally distributed	BMDP2D (Frequency Count Routine) of the BioMedical Computer Programs	Dixon, W. J., ed., 1975. *BMDP: Biomedical Computer Programs*, Los Angeles, CA, Univ. Calif. Press	77
2. Same as above using *log transformed* data				The log transformation of the data which showed a more normal distribution	BMDP2D (Frequency Count Routine) of the BioMedical Computer Programs	Dixon, 1975	81
3. Phytoplankton Density (No./ml).	6, 9, 14, 19, 27	1973-76	2 obs/month	Two-way Analysis of Variance on log transformed data and Duncan's Multiple Range Test	GLM Procedure of the SAS-76 Package	Barr, A. J. et al., 1976. *A User's Guide to SAS-76* and *SAS Supplemental Library User's Guide*, Raleigh, NC, SAS Institute.	85
4. Phytoplankton Density (No./ml).	6, 9, 14, 19, 27	Preop= 1973 Op= 1975-76	2 obs/month	Crossed and Nested Factor Analysis using log-transformed preoperational data (1973) and operational data (1975-76)	GLM Procedure of the SAS-76 Package	Barr, A. J. et al., 1976	95
5. Phytoplankton Density (No./ml).	intake (14) and discharge (19)	May to Oct 1975-76	—	Paired t-Test on log transformed data.	Hewlett-Packard General Statistics Package	Hewlett-Packard, 1975	19
6. Phytoplankton Density (No./ml).	10, 27	May to Oct 1975-76	—	Paired t-Test on log transformed data	Hewlett-Packard General Statistics Package	Hewlett-Packard, 1975	20
7. Phytoplankton Biovolume (mg/l)	6, 9, 14, 19, 27	Mar-July 1976 and May-Oct 1975	2 obs/month	Two-way Analysis of Variance using real numbers and Duncan's Multiple Range Test	GLM Procedure of the SAS-76 Package	Barr, A. J. et al., 1976	105
8. Phytoplankton Production: Chlorophyll *a* (ppb)	Intake (14) Discharge (19)	May-Oct 1975	22 obs/sample	Paired t-Test	Hewlett-Packard General Statistics Package	Hewlett-Packard, 1975	23
9. Phytoplankton Type I Productivity (ppm O_2/hr.)	6, 10, 14, 19, 27	Apr-Nov 1976 May-Oct 1975	3 obs/month for Stns 6, 10 and 1 ob/month for 14, 19, and 27	Two-way Analysis of Variance using real numbers and Duncan's Multiple Range Test	GLM Procedure of SAS-76	Barr, A. J. et al., 1976	111

Table B-1. (Continued).

PARAMETER	DATA USED			BRIEF DESCRIPTION OF STATISTICAL PROCEDURES USED	COMPUTER PROGRAM USED	REFERENCES	PAGE
	HDR STATION NUMBERS	YEARS	NUMBER OF REPLICATES				
10. Phytoplankton Type III Productivity (ppm O_2/hr.)	Intake (14) Discharge (19)	9 days in Fall 1976	4/day	Two-way Analysis of Variance using real numbers and Duncan's Multiple Range Test	GLM Procedure of SAS-76	Barr, A. J. et al., 1976	118
11. Phytoplankton Species Diversity (Shannon-Weaver Index)	6, 9, 14, 19, 27	Mar-July 1976 and May-Oct 1975	2 obs/month	Two-way Analysis of Variance using real numbers and Duncan's Multiple Range Test	GLM Procedure of SAS-76	Barr, A. J. et al., 1976	125
12. Periphyton total abundance (no./cm^2)	13, 20, 25	1975-75	2 obs/month	Two-way Analysis of Variance and Duncan's Multiple Range Test on log transformed data	GLM Procedure of SAS-76	Barr, A. J. et al., 1976	131
13. Periphyton Productivity: Chlorophyll *a*	13, 20, 25	1975-76	2 obs/month	Two-way Analysis of Variance and Duncan's Multiple Range Test	GLM Procedure of of SAS-76	Barr, A. J. et al., 1976	138
14. Periphyton Productivity: Phaeophytin *a*	13, 20, 25	1975-76	2 obs/month	Two-way Analysis of Variance and Duncan's Multiple Range Test	GLM Procedure of SAS-76	Barr, A. J. et al., 1976	145
15. Periphyton: Species Diversity (Shannon-Weaver Index)	13, 20, 25	1975-76	2 obs/month	Two-way Analysis of Variance and Duncan's Multiple Range Test	GLM Procedure of SAS-76	Barr, A. J. et al., 1976	152
16. Zooplankton total density (no./ml.)	6, 10, 12, 18, 21, 25, 27	1975-76	1 obs/month	Two-way Analysis of Variance on log transformed data and Duncan's Multiple Range Test	GLM Procedure of SAS-76	Barr, A. J. et al., 1976	158
17. Zooplankton Total Density (no./ml)	Intake (12) and Discharge (21)	May-Oct 1975-76	—	Paired t-Test on log transformed data	Hewlett-Packard General Statistics Package	Hewlett-Packard, 1975	34
18. Zooplankton Total Density (no./ml)	10 and 27	May-Oct 1975-76	—	Paired t-Test on log transformed data	Hewlett-Packard General Statistics Package	Hewlett-Packard, 1975	35
19. Zooplankton: Rotifer Density (no./ml)	Intake (12) and Discharge (21)	May-Oct 1975-76	—	Paired t-Test on log transformed data	Hewlett-Packard General Statistics Package	Hewlett-Packard, 1975	36

Table B-1. (Continued).

PARAMETER	DATA USED			BRIEF DESCRIPTION OF STATISTICAL PROCEDURES USED	COMPUTER PROGRAM USED	REFERENCES	PAGE
	HDR STATION NUMBERS	YEARS	NUMBER OF REPLICATES				
20. Zooplankton: Rotifer Density (no./ml)	10 and 27	May-Oct 1975-76	—	Paired t-Test on log transformed data	Hewlett-Packard General Statistics Package	Hewlett-Packard, 1975	37
21. Zooplankton: Crustacea Density (no./ml)	Intake (12) and Discharge (21)	May-Oct 1975-76	—	Paired t-Test on log transformed data	Hewlett-Packard General Statistics Package	Hewlett-Packard, 1975	38
22. Zooplankton: Crustacea Density (no./ml)	10 and 27	May-Oct 1975-76	—	Paired t-Test on log transformed data	Hewlett-Packard General Statistics Package	Hewlett-Packard, 1975	39
23. Zooplankton Species Diversity (Shannon-Weaver Index)	6, 10, 12 18, 21, 25, 27	1975-76	1/month	Two-way Analysis of Variance using real numbers and Duncan's Multiple Range Test	GLM Procedure of SAS-76	Barr, A. J. et al., 1976	164
24. Macroinvertebrate total density: collected by dredge methods (no./m^2)	6, 10, 12, 18, 21, 25, 27	Mar-Dec 1975 and 1976	1/month	Two-way Analysis of Variance on log transformed data and Duncan's Multiple Range Test	GLM Procedure of SAS-76	Barr, A. J. et al., 1976	170
25. Macroinvertebrate Density (dredge)	Intake (12) and discharge (21)	May-Oct 1975-76	—	Paired t-Test on log transformed data	Hewlett-Packard General statistics Package	Hewlett-Packard, 1975	44
26. Macroinvertebrate Density (dredge)	Intake (12) and discharge (21)	May-Oct 1975-76	—	Paired t-Test on log transformed data	Hewlett-Packard General statistics Package	Hewlett-Packard, 1975	45
27. Macroinvertebrate (dredge): species diversity (Shannon Weaver Index)	6, 10, 12, 18, 21, 25	Jan, Feb, Apr, May, Jun, Aug, Sept, Nov, Dec 1976 and Mar, July, Sept, Oct, Dec 1975	1 ob/month	Two-way Analysis of Variance and Duncan's Multiple Range Test	GLM Procedure of SAS-76	Barr, A. J. et al., 1976	175
28. Macroinvertebrates total density: collected by Artificial Substrate Methods (no./m^2)	6, 10, 12, 18, 21, 25	Feb-Dec 1975 Feb-Nov 1976	1 ob/month	Two-way Analysis of Variance and Duncan's Multiple Range Test	GLM Procedure of SAS-76	Barr, A. J. et al., 1976	179

Table B-1. (Continued).

PARAMETER	DATA USED			BRIEF DESCRIPTION OF STATISTICAL PROCEDURES USED	COMPUTER PROGRAM USED	REFERENCES	PAGE
	HDR STATION NUMBERS	YEARS	NUMBER OF REPLICATES				
29. Macroinvertebrate Density (artificial substrates)	Intake (12) and Discharge (21)	May-Oct 1975-76	—	Paired t-Test on log transformed data	Hewlett-Packard General Statistics Package	Hewlett-Packard, 1975	49
30. Macroinvertebrate (artificial substrates): Species diversity (Shannon Weaver Index)	6, 10, 12, 18, 21, 25	June-Dec 1976 July-Dec 1975	1 ob/month	Two-way Analysis of Variance and Duncan's Multiple Range Test	GLM Procedure of SAS-76	Barr, A. J. et al., 1976	184
31. Biological variables: Phytoplankton Density Zooplankton Density, Rotifera Density Crustacea density, Macroinvertebrate (dredge) and Macroinvertebrate (Art. Sub.) densities with Orthophosphate, filterable residues, ammonia, nitrite, nitrate, diss. O_2	6, 9, 14, 19, 27 6, 10, 12, 18, 21, 25, 27 6, 10, 12, 18, 21, 25	1975-76	—	Stepwise multiple regression analysis for each log transformed biological variables with selected water quality variables. Phytoplankton with surface water quality values, zooplankton, Rotifera, and Crustacea with averages of top and bottom values. Macroinvertebrate (dredge) with bottom values. Macroinvertebrate (art. Sub.) with top values.	BMDP2R: Stepwise Regression	Barr, A. J. et al., 1976	189

Logarithmic Transformation

It has been customary in dealing with data on biological densities to apply the logarithmic transformation to the observations (Barnes, 1972). This has the effect of reducing nonnormality and stabilizing the variance thus satisfying two of the basic assumptions of the analysis of variance (Scheffe, 1959). A comparison of the histogram plots of the original data as well as the transformed data was done on some of the variables to further check visually that the transformed data is more nearly normal.

Since several of the observations had values of zero, and log of zero is undefined, the logarithm of 1 plus the observation was used instead (Barnes, 1972). This has the effect of replacing a zero value with a zero and a missing value (-1.0) by a missing value (Dixon, 1975).

Two-way Analysis of Variance

This was used to test for differences between the effects of the various (s) stations and the various (m) months (or dates). Each observation (Y) is classified by two characteristics, the (i^{th}) station ($i = 1,\ldots,s$) and the (j^{th}) month ($j = 1,\ldots,m$) (or date) that it was measured. The usual linear model can be written as:

$$Y_{ij} = \mu + \alpha_i + \beta_j + e_{ij}$$

When there are replicates, as we considered them in the case of phytoplankton where density measurements were taken twice a month, the model involving interaction was used, namely,

$$Y_{ij} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + e_{ij}$$

where

Y_{ij} = observation at the i^{th} station in the j^{th} month

μ = general mean

α_i = effect due to i^{th} station, $i = 1,\ldots,s$

β_j = effect due to j^{th} month, $j = 1,\ldots,m$

$(\alpha\beta)_{ij}$ = interaction

e_{ij} = error

To compare the station effects, we formulate the null hypothesis

$$H_0: \alpha_1 = \alpha_2 = \cdots = \alpha_s$$

which says that the stations are not different. To test the hypothesis H_0 against the alternative hypothesis which says at least two of these α values are different, the two-way analysis of variance was used. Similar null and alternate hypotheses are formulated for the month (or date) effects β or the interaction effects. The computer printout gives us the value of the test statistic F and the probability (P-value) that the computed F-value is exceeded under the null hypothesis. If this P-value is $< \alpha$ (where α is a preassigned level of significance), then the null hypothesis should be rejected. If it is $\geq \alpha$ then we do not have enough evidence to reject the null hypothesis of equality of the effects.

For example, the two-way analysis of variance for phytoplankton biovolume gives a station P-value of 0.3625 (see printout No. 7, pg. B-118. This implies that there is a 36 percent chance that the null hypothesis is correct. Since the level of significance is commonly set at $\alpha = 0.05$, and the observed P-value is much larger than 0.05, we accept the null hypothesis, which is that the mean biovolumes at the seven stations tested are not significantly different. Duncan's Multiple Range Test was done in each case to group stations that were alike (i.e., with means that were not significantly distinguished) into subgroups.

Statistical Power Analysis for the Analysis of Variance

Analysis of variance, as explained above, is a procedure for detecting significant differences in the time means of the populations being considered. Just as there is a possibility of rejecting a correct null hypothesis (the so-called Type I Error), there is a chance of accepting a null hypothesis that is incorrect (the so-called Type II Error), i.e., concluding that the means are not different even when they are. We control the former error by choosing a small level of significance α, which in our analysis was taken to be the usual 0.05. The other error though equally important is often not considered in most statistical analyses since one often uses test procedures that minimize the latter risk. Nevertheless, it is pertinent to ask how much Type II Error is involved in the particular procedure or equivalently how likely our test procedure is in detecting significant differences in the means when they are indeed present. This probability of detecting significant differences when present is often referred to as the "power" of the test and depends on the: (a) sample sizes involved (power increases with sample size), (b) level of significance α for the test (power increases with α), and (c) size of the differences (called "effect size") in the true mean values. The last of these components is related to the heuristic idea that the population means that are close to each other are more difficult to distinguish from the null hypothesis of equality than the means that are very far from equal. A more detailed discussion of some of these concepts is given in Cohen (1977).

Effect size is indicated by an index "f" which is a measure of how different the true means are (under the null hypothesis $f \equiv 0$). In view of the absence of any specific information as to the alternative, we use the conventional levels proposed by Cohen (1977, §8.2.3).

$f = .10$ for small variability

$f = .25$ for medium variability

$f = .40$ for large variability

To calculate the power of the procedure we need,

f = effect sizes

a = level of significance of the test

k = number of populations being compared

$u = k - 1$

n' = number of observations taken from each population adjusted using the formula:

$$n' = \left(\frac{\text{error degrees of freedom in F-statistic}}{k} + 1\right)$$

The results of the power analysis are presented in Table 2. For example, for the first variable, phytoplankton density, analysis of variance was done using five stations. When comparing station means: $k = 5$; $u = (k - 1) = 4$; and using the error degrees of freedom given in computer printout No. 3, page B-85, $n' = \frac{123}{5} + 1 = 25$; and $\alpha = 0.05$. Using the power tables in Cohen (1977) for the three effect sizes, $f = 0.10$, 0.25, and 0.40, the probability of detecting a small, medium, or large variability in the station means is 0.12, 0.60, and 0.96 respectively. Thus, there is a poor chance of detecting small differences in the station means, a fair chance of detecting medium differences, and an excellent chance of finding large differences.

t-Tests

To confirm and clarify the results of the two-way analysis of variance procedures, single variable paired t-Tests were used. The idea of a multivariate test, such as the Hotelling's T^2 was abandoned because of scanty data. A paired t-Test was considered appropriate as the measurements from the stations were taken on the same day and the data sets may be considered to be related. Two pairs of stations were chosen for comparison. The nearfield stations compared were the intake (HDR Station No. 14) and the discharge (HDR Station No. 19). The farfield stations were one upriver station (HDR Station No. 10) and one downriver station (HDR Station No. 27). The biological variables used were densities of phytoplankton, zooplankton, rotifera, crustacea, macroinvertebrates (collected by dredge methods), macroinvertebrates (collected by artificial substrate methods), and phytoplankton production, measured as chlorophyll *a*. The last was included because data for this parameter were available for intake and discharge stations only and a two-way analysis of variance was irrelevant. A usable data set with no missing values (May to October, 1975 to 1976) was selected for all the t-Tests.

Table B-2. Statistical power calculations for the analysis of variance.

BIOTIC CATEGORY	SOURCE	K	DEGREES OF FREEDOM	NUMBER OF REPLICATES	TOTAL NUMBER OF OBS USED	Error n' = —— − 1 K	FOR α = 0.05 (LEVEL OF SIGNIFICANCE) SMALL f = .10	MEDIUM f = .25	LARGE f = .40	
1. Phytoplankton (log) Density	Station Month Error	5 37	4 (U) 36 (U) 123	2/cell 2/cell	277	26 4	0.12 0.08	0.60 0.21	0.96 0.62	Extrapolated
2. Phytoplankton (log) Crossed and Nested Factor Model	Opstat year—(Opstat) Station Month Error	2 2 5 24	1 1 4 (U) 23 (U) 85	2/cell	199	43 43 18 5	0.09 0.07	0.43 0.24	0.86 0.64	
3. Phytoplankton Type I Productivity (unequal cells)	Date Station Error	35 5	34 4	3/cell for Stn 1 3/cell for Stn 2 1/cell for Stns 3, 4 279	314	9 56	0.10 0.23	0.60 0.93	> 0.995 > 0.995	
4. Phytoplankton Type III Productivity	Station Days Error	2 9	1 8 54		72	28 7	0.06 0.07	0.46 0.31	0.84 0.53	
5. Phytoplankton (Biovolume)	Station Month Error	5 11	4 10 53		108	12 6	0.08 0.07	0.28 0.19	0.66 0.50	
6. Phytoplankton (Species Diversity)	Station Month Error	5 11	4 10 53		108	12 6	0.08 0.07	0.28 0.19	0.66 0.50	
7. Periphyton Density (Log)	Station Months Error	3 23	2 22 46		104	16 3	0.08 0.06	0.31 0.13	0.67 0.32	
8. Periphyton Chlorophyll a	Station Month Error	3 22	2 21 45		102	16 3	0.08 0.06	0.31 0.13	0.67 0.32	
10. Periphyton (Species Diversity)	Station Month Error	3 15	2 14 34		77	12 3	0.07 0.06	0.23 0.11	0.53 0.25	
11. Zooplankton (Density) Log	Station Month Error	7 24	6 23 123	1	153	19 6	0.11 0.08	0.53 0.30	0.94 0.76	
12. Zooplankton (Species Diversity)	Station Month Error	7 24	6 23 116	1	146	18 6	0.07 0.08	0.23 0.30	0.61 0.76	
13. Macrophyton (Dredge) Density	Station Month Error	7 17	6 16 85	1	106	13 6	0.09 0.07	0.36 0.23	0.80 0.61	
14. Macrophyton (Artificial Substrate) Density	Station Month Error	6 22	5 21 67	1	94	12 4	0.08 0.07	0.31 0.13	0.71 0.49	
15. Macrophyton (Artificial Substrate Species Diversity	Station Month Error	6 11	5 10 36		52	7 4	0.07 0.06	0.18 0.13	0.42 0.30	
16. Macrophyton (Dredge) Species Diversity	Station Month Error	6 14	5 13 59		78	11 3	0.08 0.07	0.28 0.19	0.66 0.50	

Stepwise Regression

This was done to study the relationship between each biological variable (dependent variable, y) with all the water quality variables (independent variables, x_i). The water quality measurements were taken for both surface (top) as well as bottom so appropriate values were used for each log transformed biotic variable. For phytoplankton density (dependent variable), the surface water quality values were used as independent variables, while for zooplankton, rotifera, and crustacea densities, the average of top and bottom values were used. Macroinvertebrate density (collected by dredge methods) was paired with the bottom values while macroinvertebrate density (by artificial substrates) was paired with top values. The regression model can be written as

$$Y_j = \beta_0 + \beta_1 X_{(1)j} + \cdots + \beta_i X_{(i)j} + \varepsilon$$

with $i = 1,\ldots,p$ for each $j = 1,\ldots,n$, where β is constant, ε is the error, Y_j is the j^{th} observed value of the dependent variable, and $x_{(i)j}$ is the j^{th} observed value of the i^{th} independent variable. The objective, then, of the selection procedures in the regression analysis is to determine the "best" subset of the p independent variables which yields a model of the form:

$$Y_j = \gamma_0 + \gamma_1 X_{(1)j} + \gamma_2 X_{(2)j} + \cdots + \gamma_i X_{(i)j} + \varepsilon$$

with $i = 1,\ldots,q$ for each $j = 1,\ldots,n$, where γ and ε are constants, and the independent variables X_i = 1 to q are a subset of the original set of X_i where i = 1 to p.

The "best" q independent variables selected from the p original variables may be determined in several ways, the most popular being the stepwise regression procedure. This procedure starts with no independent variables in the equation. The first variable added to the regression is the one most highly correlated (linearly) with the dependent variable. In addition, the correlation coefficient and its associated F statistic must be statistically significant at a predetermined probability level, such as $\alpha \leq 0.05$. The second step in the analysis is to select a second independent variable, is any of the remaining variables have an F larger than the F value specified. This procedure chooses the independent variable which is most correlated to the dependent variable, given that the variable included in step one is in the model. Moreover, the stepwise procedure "looks back" to see if any of the independent variables interact; for instance, the addition of one X_i might reduce the importance of another X_i to the point where it should be deleted. Hence, the stepwise procedure may add or delete variables at any step rather than just add variables. The stepwise procedure continues in this manner until either no further X_i values require entry or deletion from the equation, all variables are included in the equation, or the "tolerance values" for the remaining significant independent variables are less than a predetermined level. The R^2 values (coefficients of determination) obtained in the analyses indicate the fraction of the variability in the dependent parameter (Y) that is "explained" by the selected independent variables (X). For instance, an R^2 of 1.00 indicates that all Y variation is explained, whereas an R^2 of 0.00 indicates that none is explained.

RAW DATA TABLES*

(Tables 3-45)

*Except Tables 4, 5, 8, 16, 17, 18, 19, 20, 21, 24, 25, and 27 which also include computer printout.

Table B-3a. Phytoplankton densities for 1973.

HDR STATION NUMBER		6	9	19	27
STATION CODE[1]		1	2	4	5
MONTH CODE[1]	DATE	DENSITY PER ml			
3	March 12	846	821	—	826
	March 26	2,868	1,729	—	2,790
4	April 16	—	41,205	—	55,725
	April 30	32,250	—	—	40,650
5	May 14	21,375	24,450	—	—
	May 28	8,625	9,465	17,588	8,145
6	June 11	11,175	5,925	13,620	6,990
	June 25	7,755	6,945	11,040	5,790
7	July 9	8,880	4,800	9,180	5,250
	July 23	15,780	10,755	27,600	8,020
8	August 6	15,000	4,407	23,730	8,450
	August 27	7,770	9,690	12,690	5,100
9	September 10	10,560	5,640	22,590	6,300
	September 24	16,890	6,030	25,840	6,780
10	October 8	10,890	1,080	12,840	8,400
	October 22	4,050	4,770	5,760	3,480
11	November 5	2,625	4,710	3,870	3,480
	November 19	—	3,600	2,460	3,780

[1]As used on the computer printout.

Table B-3b. Phytoplankton densities for 1974.

HDR STATION NUMBER		6	9	14	19	27
STATION CODE[1]		1	2	3	4	5
MONTH CODE[1]	DATE	DENSITY PER ml				
13	January 21	261	252	—	—	471
15	March 11	1,470	1,965	—	1,770	2,010
16	April 8	23,700	54,840	—	23,460	19,830
	April 22	1,566	4,647	—	15,810	9,360
17	May 6	21,330	16,920	—	28,620	20,610
	May 20	15,870	10,065	—	19,665	12,690
18	June 17	5,610	3,606	—	8,265	5,940
19	July 1	7,710	8,085	10,830	12,840	8,550
	July 17	17,400	3,120	10,365	10,290	3,450
	July 29	16,050	4,410	19,350	26,070	12,525
20	August 12	7,350	4,455	10,665	10,980	7,245
	August 26	17,265	11,325	11,550	7,125	4,725
21	September 9	23,025	5,355	21,480	24,540	12,825
	September 23	8,745	2,205	4,515	42,780	1,920
22	October 7	31,260	7,665	40,710	18,990	21,750
	October 21	10,200	13,050	19,230	19,800	14,460
23	November 4	5,590	4,275	6,870	—	5,625
	November 18	3,990	3,870	13,170	12,330	2,160
24	December 2	3,300	2,775	4,140	4,185	4,050
	December 16	1,561	805	3,034	1,840	643
	December 30	1,637	—	336	2,835	—

[1]As used in the computer printout.

Table B-3c. Phytoplankton densities for 1975.

HDR STATION NUMBER		6	9	14	19	27
STATION CODE[1]		1	2	3	4	5
MONTH CODE[1]	DATE	DENSITY PER ml				
29	May 7	10,590	14,640	12,660	15,000	18,990
	May 21	14,190	22,590	14,490	17,610	11,670
30	June 4	14,460	12,300	19,860	24,540	11,880
	June 18	9,960	12,780	17,910	17,850	9,480
31	July 1	1,883	2,032	6,945	868	1,391
	July 16	4,839	4,513	4,299	846	5,912
32	August 12	11,265	2,905	5,625	8,985	5,655
	August 26	5,265	12,300	18,480	20,550	10,890
33	September 10	7,995	13,500	8,310	7,425	14,850
	September 24	11,910	12,960	10,650	10,065	10,530
34	October 8	25,440	13,830	22,260	18,120	11,670
	October 22	18,840	9,030	21,030	48,780	10,830
35	November 19	6,420	5,250	—	13,980	—
36	December 17	—	—	2,475	2,670	—
	December 31	—	—	990	885	—

[1]As used in the computer printout.

Table B-3d. Phytoplankton densities for 1976.

HDR STATION NUMBER		6	9	14	19	27
STATION CODE[1]		1	2	3	4	5
MONTH CODE[1]	DATE	DENSITY PER ml				
38	February 12	—	—	20	17	—
39	March 10	—	135	869	135	473
	March 24	953	696	535	1,285	1,312
40	April 6	5,145	2,289	2,835	3,105	4,350
	April 21	15,570	12,420	13,170	25,800	18,300
41	May 5	23,820	23,490	22,500	25,470	20,100
	May 19	17,280	11,310	17,940	12,690	13,890
42	June 1	15,540	5,310	19,410	17,670	4,695
	June 16	25,560	36,810	35,340	37,500	30,240
43	July 1	58,970	24,600	7,290	77,850	28,680
	July 14	—	—	56,925	44,400	39,540
	July 28	19,650	25,125	—	—	29,175
44	August 11	25,800	—	38,925	—	—
	August 25	—	30,060	—	—	—
45	September 22	39,525	18,300	32,175	—	—
46	October 6	—	50,400	50,700	—	—
	October 20	—	—	35,550	—	—
47	November 4	—	—	—	—	64,950

[1]As used on the computer printout.

Table B-4. Phytoplankton density (Log transformed), 1975-76.

PAIRED t-TEST		
SAMPLE NUMBER	INTAKE	DISCHARGE
1	3.6330	2.9270
2	4.2660	4.3130
3	3.9190	3.8700
4	4.3470	4.2580
5	1.3010	1.2300
6	3.4520	3.4920
7	4.2540	4.1030
8	4.5480	4.5740

t-Test

1) H0: MU(X)-MU(Y) = 0

H1 : MU(X)-MU(Y) > 0

t Value = 0.482

DF = 7

t(0.950, 7) = 1.895

Do not reject H0 at 0.05 level of significance

t = 0.4820, DF = 7

Prob t > 0.4820 = 0.3223

Table B-5. Phytoplankton density (Log transformed), 1975-76.

PAIRED t-TEST		
SAMPLE NUMBER	UPRIVER HDR STATION # 10	DOWNRIVER HDR STATION #27
1	4.1650	4.1850
2	4.1060	4.0280
3	3.6540	3.5620
4	3.4630	3.9170
5	4.1300	4.1030
6	4.1410	4.0510
7	2.1300	2.6750
8	3.3580	3.6380
9	4.0530	4.1430
10	4.5660	4.4800

t-Test

1) HO: MU(X)-MU(Y) = 0

H1: MU(X)-MU(Y) < 0

t value = -0.424

DF = 9

t (0.950, 9) = 1.833

Do not reject HO at 0.05 level of significance

t = -0.4237, DF = 9

Prob t > -0.4237 = 0.3409

Table B-6. Phytoplankton Type I productivity.

HDR STATION NUMBER		6			10			14	21	27
STATION CODE[1]		1			2			3	4	5
MONTH CODE[1]	DATE	PRODUCTIVITY (ppm O_2/hr)								
	1976									
1	April 1	-0.14	0.02	-0.01	0.03	0.03	0.03	0.12	0.07	0.03
2	April 8	0.02	0.21	0.16	-0.02	0.06	0.05	0.30	-0.02	0.16
3	April 26	0.17	0.28	0.35	0.32	0.40	0.39	0.60	0.22	0.38
4	May 6	0.64	0.75	0.78	0.57	0.49	0.66	0.87	0.14	0.70
5	May 14	0.66	0.92	0.88	0.76	0.88	0.88	0.92	0.18	0.86
6	May 22	0.47	0.60	0.59	0.45	0.39	0.45	0.48	0.30	0.41
7	May 27	0.78	0.29	0.36	0.63	0.76	0.54	0.69	0.28	0.49
8	June 4	0.84	0.62	0.67	0.82	0.69	0.69	0.93	0.03	0.92
9	June 14	-0.06	0.53	0.85	0.32	0.23	0.56	1.08	0.54	0.37
10	June 25	1.23	1.15	1.42	0.23	0.40	0.57	1.87	0.88	—
11	July 2	0.71	0.83	1.27	1.28	0.88	0.92	1.04	1.08	0.93
12	July 8	1.06	0.88	0.68	0.86	1.24	1.10	1.61	0.17	0.80
13	July 22	1.14	1.05	1.08	1.16	1.50	1.23	1.34	0.54	1.20
14	July 29	0.60	1.06	1.32	1.03	0.51	0.36	0.97	0.28	0.83
15	August 27	1.02	1.23	1.30	0.68	1.47	1.00	0.96	0.66	0.49
16	September 9	1.03	1.09	0.87	0.92	0.87	0.50	1.70	1.19	1.00
17	September 24	0.86	0.96	1.04	0.67	1.04	0.96	0.54	0.46	0.72
18	October 7	0.36	0.54	0.80	0.39	0.80	0.30	0.16	0.13	0.45
19	October 22	0.80	1.17	0.96	0.71	0.96	0.68	1.37	1.08	0.95
20	November 10	0.22	0.43	0.54	—	0.50	0.54	0.54	0.21	0.40
	1975									
21	May 26	0.33	0.28	0.42	0.35	0.27	0.27	0.36	0.27	0.19
22	June 2	0.13	0.09	0.15	0.15	0.21	0.11	0.15	0.09	0.15
23	June 23	-0.06	-0.07	-0.05	0.16	0.26	0.26	1.00	0.23	0.26
24	June 30	0.06	0.05	0.18	0.07	0.13	0.13	0.33	0.27	0.12
25	July 21	-0.20	-0.01	0.08	0.02	0.12	0.17	0.46	0.05	0.15
26	August 8	-0.99	-0.99	-0.37	0.03	0.10	0.24	0.10	0.00	0.18
27	August 11	0.04	-0.10	0.06	0.06	0.12	0.13	0.42	0.15	0.11
28	August 18	0.21	0.27	0.17	0.19	0.18	0.12	0.17	0.08	0.16
29	August 25	0.05	0.41	0.21	0.04	0.08	0.07	0.28	0.19	0.20
30	September 4	0.24	0.20	-0.06	0.10	0.17	0.07	0.23	0.08	0.15
31	September 8	0.04	0.29	0.28	0.13	0.18	0.24	0.47	0.08	0.31
32	September 22	0.20	0.36	0.36	0.25	0.23	0.12	0.98	0.34	0.29
33	September 29	-0.02	0.23	0.05	0.11	0.09	0.08	0.34	0.08	0.15
34	October 7	-0.08	0.27	0.08	0.10	0.14	0.16	0.16	0.00	0.22
35	October 20	0.01	0.09	0.50	0.14	0.16	0.11	0.34	0.23	0.33

[1]As used on the computer printout.

Table B-7. Phytoplankton Biovolume (mg/liter).

HDR STATION NUMBER		6	10	14	21	27
STATION CODE[1]		1	2	3	5	7
MONTH CODE[1]	DATE	(mg/liter)				
	1976					
3	March	— 2.16	0.16 3.76	0.42 0.53	0.06 0.81	0.22 3.64
4	April	1.99 10.24	2.15 7.15	1.67 7.38	1.50 12.01	1.81 8.12
5	May	19.27 14.08	17.50 8.42	11.99 20.48	17.03 13.03	12.42 12.84
6	June	19.24 42.05	9.75 52.44	49.94 52.05	47.11 55.16	16.22 56.55
7	July	49.87 29.71	18.34 31.08	6.88 48.60	61.01 33.76	23.40 33.62
	1975					
17	May	5.30 8.29	6.41 11.01	— 6.65	5.49 8.87	9.78 5.74
18	June	9.00 7.87	9.25 10.43	15.72 13.19	10.44 12.07	11.88 7.08
19	July	2.51 4.01	2.53 4.56	4.92 3.49	0.98 0.88	1.72 4.18
20	August	11.52 3.08	3.76 12.92	6.06 17.25	9.08 23.18	5.06 10.29
21	September	9.06 7.82	16.07 7.41	8.26 9.15	6.51 7.93	12.87 7.12
22	October	12.94 8.43	12.33 3.96	13.18 8.74	12.48 18.61	7.74 9.98

[1]As used in computer printout.

Table B-8. Phytoplankton production: Chlorophyll *a* (ppb).

PAIRED t-TEST		
SAMPLE NUMBER	INTAKE	DISCHARGE
1	40	40
2	49	38
3	54	48
4	43	28
5	50	30
6	30	30
7	38	38
8	23	10
9	50	25
10	54	26
11	75	40
12	110	30
13	55	32
14	85	61
15	60	45
16	75	45
17	60	32
18	85	60
19	60	52
20	80	47
21	45	25
22	125	48

t -Test:

2) HO: ABS(MU(X)-MU(Y)) = 0
   H1: ABS(MU(X)-MU(Y)) # 0

   t Value = 1.133
   DF = 21

   t(0.975, 21) = 2.080

   Do not reject H0 at 0.05 level of significance.

t = 1.1327, DF = 21

PROB t > 1.1327 = 0.1350

Table B-9. Phytoplankton—species diversity.

HDR STATION NUMBER		6	10	14	21	27
STATION CODE[1]		1	2	3	5	7
MONTH CODE[1]	MONTH	SHANNON-WEAVER INDEX				
	1976					
3	March	— 3.75	2.95 4.12	2.79 3.61	2.18 3.65	2.67 3.27
4	April	1.31 1.96	2.28 2.20	1.36 1.63	1.43 1.09	1.71 1.58
5	May	2.35 2.83	2.34 3.49	2.10 3.01	2.59 2.95	2.57 3.14
6	June	4.42 3.87	4.18 3.40	3.75 2.98	3.82 2.89	3.47 3.66
7	July	2.99 3.78	3.05 3.69	2.84 3.17	2.45 3.00	2.93 2.31
	1975					
17	May	1.51 2.48	1.32 2.34	— 2.43	1.02 2.15	1.55 2.25
18	June	3.01 3.21	2.85 3.07	3.14 2.51	2.96 2.27	3.67 2.17
19	July	4.19 3.37	3.45 3.32	3.29 3.26	3.55 4.21	3.53 3.43
20	August	3.84 3.02	3.90 3.50	2.98 3.00	3.41 2.87	3.87 3.17
21	September	3.59 3.02	3.75 3.07	3.27 3.35	2.90 3.47	3.52 3.00
22	October	2.52 2.47	2.88 2.30	2.37 2.44	2.43 1.54	2.74 3.02

[1]As used on the computer printout.

Table B-10. Phytoplankton: Type III productivity analysis (P=PSg-R) in ppm O_2/hr for intake and discharge (1976).

DATE CODE	INTAKE	DISCHARGE	DATE CODE	INTAKE	DISCHARGE
1	1.00	0.9	6	1.33	0.5
	1.35	0.7		1.0	0.35
	1.57	0.55		1.05	0.3
	0.85	0.65		0.8	0.6
2	0.85	0.1	7	0.9	0.15
	0.4	0.2		0.5	0.5
	0.9	0.1		1.1	0.1
	0.7	0.15		0.9	0.15
3	0.7	0.6	8	0.8	0.4
	0.4	0.4		0.8	0.4
	0.7	0.4		1.0	0.3
	0.6	0.4		0.5	0.4
4	0.85	0.4	9	0.6	0.4
	1.10	0.3		0.7	0.45
	0.6	0.2		0.75	0.4
	1.1	0.25		1.1	0.3
5	0.8	0.1			
	1.0	0.2			
	1.0	0.15			
	1.0	0.1			

Table B-11a. Periphyton density, 1976.

HDR STATION NUMBER		13	20	25
STATION CODE[1]		3	5	6
MONTH CODE[1]	DATE	DENSITY/cm^2		
1	January 14	—	67,636	2,424
	January 28	—	688,152	485
2	February 12	—	97,970	3,584
	February 25	—	90,968	56,209
3	March 10	—	1,821,879	6,162
	March 24	—	2,929,954	—
4	April 6	—	405,809	—
	April 21	—	1,031,068	—
5	May 5	—	170,279	—
	May 19	1,119,725	380,232	1,124,381
6	June 1	573,854	284,587	690,488
	June 16	198,278	107,297	247,261
7	July 14	415,232	247,272	368,576
	July 28	578,524	95,641	179,620
8	August 11	272,928	447,886	284,593
	August 25	27,991	359,245	312,589
9	September 8	265,932	209,946	513,207
	September 22	494,544	797,805	205,281
10	October 6	220,443	415,230	387,237
	October 20	88,641	737,152	108,471
11	November 4	5,261	12,725	93,307
	November 17	—	312,588	56,566
12	December 15	—	72,892	19,957
	December 30	—	60,646	26,934

[1]As used in computer printout.

Table B-11b. Periphyton density (1975).

HDR STATION NUMBER		13	20	25
STATION CODE[1]		3	5	6
MONTH CODE[1]	DATE	DENSITY/cm^2		
13	January 13	NS	51,313	594
	January 27	NS	310,245	2,464
14	February 10	NS	100,885	1,182
	February 24	NS	265,924	41,318
15	March 26	NS	2,262,806	59,705
16	April	NS	NS	NS
17	May 21	919,103	998,418	—
18	June 4	1,408,982	524,865	667,160
	June 18	1,313,337	807,128	1,255,017
19	July 16	557,518	228,595	737,151
	July 30	856,111	401,224	753,476
20	August 12	923,773	181,945	797,803
	August 26	352,232	69,975	657,825
21	September 10	727,814	825,793	895,779
	September 24	1,077,734	494,540	410,558
22	October 8	1,082,393	559,858	419,884
	October 22	629,839	919,099	1,185,044
23	November 19	1,194,370	632,166	592,512
24	December 17	—	942,428	124,094
	December 31	—	18,659	—

[1]As used in computer printout.

Table B-12a. Periphyton chlorophyll *a* concentration (1976).

HDR STATION NUMBER		13	20	25
STATION CODE[1]		3	5	6
MONTH CODE[1]	DATE	CONCENTRATION (μg/cm²)		
1	January 14	—	0.64	0.05
	January 28	—	1.59	0.04
2	February 12	—	3.24	0.12
	February 25	—	5.70	0.19
3	March 10	—	11.97	0.12
	March 24	—	13.97	—
5	May 5	—	2.85	—
	May 19	6.63	3.37	3.62
6	June 1	4.47	4.34	8.37
	June 16	3.93	4.26	4.08
7	July 1	4.15	1.49	3.02
	July 14	5.88	3.27	1.78
8	August 11	2.50	2.00	4.42
	August 25	3.00	3.10	3.60
9	September 8	2.38	1.90	3.29
	September 22	2.69	2.93	5.13
10	October 6	4.92	2.42	2.83
	October 20	1.58	2.43	1.36
11	November 4	0.16	1.87	1.26
	November 17	—	2.29	0.51
12	December 15	—	1.00	0.27
	December 30	—	0.64	0.62

[1]As used in the computer printout.

Table B-12b. Periphyton chlorophyll *a* concentration (1975).

HDR STATION NUMBER		13	20	25
STATION CODE[1]		3	5	6
MONTH CODE[1]	DATE	CONCENTRATION (μg/cm^2)		
13	January 13	—	0.36	0.04
	January 27	—	2.20	0.05
14	February 10	—	1.01	0.06
	February 24	—	1.53	5.27
15	March 26	—	9.37	0.58
17	May 21	4.02	7.30	—
18	June 4	6.66	3.38	2.21
	June 18	7.15	3.29	6.16
19	July 1	7.43	4.52	9.75
	July 16	4.09	5.65	4.51
20	August 12	4.72	2.94	5.70
	August 26	7.07	7.03	9.84
21	September 10	6.06	5.52	11.57
	September 24	9.30	3.76	3.64
22	October 8	8.51	6.59	6.80
	October 22	6.65	11.84	12.52
23	November 19[2]	3.48	2.08	4.76
24	December 17[2]	—	3.15	0.58
	December 31	—	0.17	—

[1]As used in the computer printout.

[2]4-week incubation periods.

Table B-13a. Periphyton—phaeophytin *a* concentration (1976).

HDR STATION NUMBER		25	13	21
STATION CODE[1]		6	3	5
MONTH CODE[1]	DATE	CONCENTRATION (µg/cm²)		
1	January 14	0.00	—	0.05
	January 28	0.01	—	0.05
2	February 12	0.02	—	0.45
	February 25	0.04	—	0.08
3	March 10	0.02	—	0.27
	March 24	—	—	0.66
5	May 5	—	—	0.56
	May 19	0.22	0.01	0.33
6	June 1	2.24	0.95	1.49
	June 16	6.04	2.33	4.23
7	July 1	2.79	1.44	1.31
	July 14	1.30	4.66	2.27
8	August 11	1.73	0.71	3.43
	August 25	2.41	1.08	2.08
9	September 8	1.97	1.76	3.90
	September 22	2.37	1.34	1.64
10	October 6	2.58	4.40	3.04
	October 20	1.07	0.42	1.90
11	November 4	0.88	0.06	0.84
	November 17	0.13	—	1.23
12	December 15	0.12	—	1.25
	December 30	0.05	—	0.62

[1]As used on the computer printout.

Table B-13b. Periphyton—phaeophytin *a* concentration (1975).

HDR STATION NUMBER		25	13	21
STATION CODE[1]		6	3	5
MONTH CODE[1]	DATE	CONCENTRATION (μg/cm^2)		
13	January 13	0.03	—	0.10
	January 27	0.01	—	0.11
14	February 10	0.00	—	0.00
	February 24	0.21	—	0.00
15	March 10	—	—	—
	March 26	0.00	—	0.24
16	April 9	—	—	—
	April 23	—	—	—
17	May 7	—	—	—
	May 21	—	0.60	1.90
18	June 4	0.17	0.42	0.48
	June 18	0.16	0.37	0.35
19	July 1	0.22	0.32	0.70
	July 16	1.01	0.92	0.92
20	August 12	3.74	1.01	1.18
	August 26	0.98	0.86	0.96
21	September 10	0.36	0.86	0.61
	September 24	1.05	0.71	0.46
22	October 8	0.62	1.32	0.97
	October 22	0.86	0.12	1.73
23	November 19[2]	0.12	0.08	0.42
24	December 17[2]	0.02	—	0.28

[1]As used on the computer printout.

[2]4-week incubation periods.

Table B-14. Periphyton—species diversity.

HDR STATION NUMBER		13	21	25
STATION CODE[1]		3	5	6
MONTH CODE[1]	MONTH	SHANNON-WEAVER INDEX		
	1976			
5	May	— 2.54	3.70 3.50	— 3.70
6	June	3.02 3.16	3.19 3.27	3.65 3.45
7	July	2.96 1.96	2.59 2.12	2.61 2.94
8	August	2.13 2.08	2.55 2.39	2.26 2.43
9	September	2.38 2.41	2.25 2.78	2.03 2.25
10	October	2.67 2.95	2.83 2.70	2.74 2.21
11	November	2.74 —	2.80 1.94	2.97 1.32
	1975			
17	May	3.62	2.61	—
18	June	4.04 3.53	3.00 3.10	2.90 3.12
19	July	3.78 3.75	3.49 3.78	3.15 2.18
20	August	2.13 3.82	3.34 3.26	3.27 3.38
21	September	3.88 3.18	3.50 3.50	2.16 2.61
22	October	3.52 2.38	3.03 2.21	3.74 3.18
23	November	3.74	4.11	3.82
24	December	— —	4.13 3.11	2.72 —

[1]As used on the computer printout.

Table B-15a. Zooplankton—total densities for 1975.

HDR STATION NUMBER		6	10	12	18	21	25	27
STATION CODE[1]		1	2	3	4	5	6	7
MONTH CODE[1]	DATE	DENSITY (Number/ℓ)						
1	January 15	16.2	—	14.1	11.2	23.4	104.2	—
2	February 18	5.7	—	7.9	7.5	4.0	11.7	—
3	March 11	28.0	8.4	11.4	14.4	11.3	23.4	302.0
4	April 15	12.8	22.9	8.9	11.2	15.8	12.2	18.9
5	May 20	35.8	14.3	28.7	15.3	27.0	17.5	10.2
6	June 24	31.3	30.1	75.3	40.0	55.0	53.9	48.7
7	July 30	358.9	231.0	263.6	398.6	234.4	242.2	350.4
9	September 2	91.6	198.6	143.0	91.3	56.8	82.5	111.1
	September 16	91.1	328.3	127.9	75.1	125.7	137.0	262.8
10	October 14	213.9	106.5	124.8	72.5	133.1	123.0	144.8
11	November 25	75.8	51.7	81.1	64.8	91.7	97.3	74.6
12	December 19	—	—	—	28.2	36.4	46.5	—

[1]As used on the computer printout.

Table B-15b. Zooplankton—total densities for 1976.

HDR STATION NUMBER		6	10	12	18	21	25	27
STATION CODE[1]		1	2	3	4	5	6	7
MONTH CODE[1]	MONTH	DENSITY (Number/ℓ)						
13	January	19.1	N.S.	30.7	9.1	15.2	16.2	N.S.
14	February	16.2	N.S.	13.5	9.2	10.2	11.8	N.S.
15	March	28.0	34.3	240.2	56.7	27.2	19.8	30.0
16	April	91.2	45.8	82.9	29.2	57.7	63.3	32.3
17	May	938.2	802.4	790.0	360.1	626.1	638.3	878.7
18	June	810.0	948.9	547.8	282.1	385.7	329.8	632.3
19	July	576.4	739.9	818.2	576.2	536.8	744.1	703.0
20	August	851.0	870.0	560.3	521.7	529.0	542.3	638.9
21	September	463.7	609.5	444.9	340.0	765.4	446.8	650.8
22	October	500.5	312.0	363.5	336.8	445.8	284.1	398.2
23	November	N.S.	57.7	115.9	108.8	137.2	96.4	33.0
24	December	135.3	N.S.	169.9	69.2	191.1	206.7	N.S.

[1]As used on the computer printout.

Table B-16. Zooplankton total density (Log transformed) 1975-76.

SAMPLE NUMBER	INTAKE	DISCHARGE
1	2.4210	2.3700
2	2.1550	1.7540
3	2.1070	2.1070
4	2.0960	2.1240
5	1.9090	1.9620
6	1.4870	1.1810
7	1.1300	1.0080
8	1.9180	1.7610
9	2.8970	2.7960
10	2.7380	2.5860
11	2.7480	2.7230
12	2.6480	2.8840
13	2.5600	2.6590
14	2.0640	2.1370

t-Test

1) H0: MU(X)-MU(Y) = 0

H1 : MU(X)-MU(Y) > 0

t value = 0.356

DF = 13

t (0.950, 13) = 1.771

Do not reject H0 at 0.05
level of significance

t = 0.3564, DF = 13

Prob t > 0.3564 = 0.3636

Table B-17. Zooplankton total density (Log transformed) 1975-76.

PAIRED t-TEST		
SAMPLE NUMBER	UPRIVER HDR STATION #10	DOWNRIVER HDR STATION #27
1	1.1550	1.0080
2	1.4780	1.6870
3	2,3630	2.5440
4	2.5160	2.4190
5	2.0270	2.1600
6	1.7130	1.8720
7	1.5350	1.4770
8	1.6600	1.5090
9	2.9040	2.9430
10	2.9770	2.8000
11	2.8990	2.8460
12	2.9390	2.8050
13	2.7850	2.8134
14	2.4940	2.6000
15	1.7610	1.5180

t-Test

1) HO: MU(X)-MU(Y) = 0

   H1: MU(X)-MU(Y) > 0

   t value = 0.093

   DF = 14

   t (0.950, 14) = 1.761

   Do not reject HO at 0.05 level of significance

t = 0.0934, DF = 14

Prob t > 0.0934 = 0.4635

Table B-18. Zooplankton: Rotifer density (Log transformed), 1975-76.

SAMPLE NUMBER	INTAKE	DISCHARGE
1	2.2480	2.2300
2	1.9780	1.4930
3	2.0280	1.6530
4	2.0040	2.0610
5	1.7430	1.7590
6	1.2090	0.6360
7	0.3980	0.5220
8	1.5750	1.4400
9	2.8490	2.7470
10	2.3400	2.2010
11	2.5760	2.6320
12	2.4700	2.8370
13	2.4610	2.5350
14	2.0030	2.0820

t-Test

1) H0: MU(X)-MU(Y) = 0

H1: MU(X)-MU(Y) > 0

t value = 0.296

DF = 13

t (0.950, 13) = 1.771

Do not reject H0 at 0.05 level of significance

t = 0.2959, DF = 13

Prob t > 0.2959 = 0.3860

Table B-19. Zooplankton: Rotifer density (Log transformed), 1975-76.

PAIRED t-TEST		
SAMPLE NUMBER	UPRIVER HDR STATION #10	DOWNRIVER HDR STATION #27
1	0.8260	0.7710
2	1.1730	1.4310
3	2.3030	2.4840
4	2.3380	2.3840
5	1.9570	2.1020
6	1.6020	1.7420
7	0.8550	0.7800
8	1.3420	1.1590
9	2.8650	2.9080
10	2.7290	2.5230
11	2.7720	2.6810
12	2.7900	2.6560
13	2.6480	2.6790
14	2.3340	2.3240
15	1.6650	1.2920

t-Test

1) H0: MU(X)-MU(Y) = 0

H1: MU(X)-MU(Y) > 0

t value = 0.113

DF = 14

t (0.950, 14) = 1.761

Do not reject H0 at 0.05
level of significance

t = 0.1131, DF = 14

Prob t > 0.1131 = 0.4558

Table B-20. Zooplankton: Crustacea density (Log transformed) 1975-76.

PAIRED t-TEST		
SAMPLE NUMBER	INTAKE	DISCHARGE
1	1.9100	1.9630
2	1.6530	1.3540
3	1.2940	1.6350
4	1.3580	1.1960
5	1.3760	1.2640
6	1.1370	0.3850
7	0.4190	0.2040
8	1.0190	0.9270
9	1.3730	1.4830
10	1.8320	1.6560
11	2.2640	2.0000
12	2.1740	1.8880
13	1.8690	2.0510
14	1.1770	1.2010

t-Test

1) H0: MU(X)-MU(Y) = 0

H1: MU(X)-MU(Y) > 0

t value = 0.447

DF = 13

T (0.950, 13) = 1.771

Do not reject H0 at 0.05 level of significance

t = 0.4469, DF = 13

Prob t > 0.4469 = 0.3311

Table B-21. Zooplankton: Crustacea density (Log transformed) 1975-76.

PAIRED t-TEST		
SAMPLE NUMBER	UPRIVER HDR STATION #10	DOWNRIVER HDR STATION #27
1	0.8260	0.5680
2	0.8860	1.0080
3	1.4750	1.6430
4	1.6180	1.2690
5	1.1640	1.2120
6	0.8190	1.2090
7	0.6530	0.5900
8	0.6300	0.5050
9	1.1630	1.1430
10	1.8340	1.8220
11	2.3050	2.3470
12	2.4040	2.2670
13	2.2160	2.2370
14	1.9810	2.1000
15	1.0520	1.1250

t-Test

1) H0: MU(X)-MU(Y) = 0

H1: MU(X)-MU(Y) < 0

t value = -0.007

DF = 14

t (0.950, 14) = 1.761

Do not reject H0 at 0.05 level of significance

t = -0.0071, DF = 14

Prob t > -0.0071 = 0.4972

Table B-22. Zooplankton—species diversity.

HDR STATION NUMBER		6	10	12	18	21	25	27
STATION CODE[1]		1	2	3	4	5	6	7
MONTH CODE[1]	MONTH	SHANNON-WEAVER INDEX						
	1976							
1	January	2.74	—	2.33	2.87	2.89	—	—
2	February	2.73	—	2.93	3.14	2.94	—	—
3	March	2.97	3.00	1.98	2.25	3.09	2.83	2.84
4	April	3.13	3.26	3.19	3.04	3.41	3.20	3.23
5	May	1.93	2.00	2.01	2.05	2.34	1.95	1.88
6	June	2.07	2.28	2.11	2.42	2.17	2.41	2.47
7	July	2.43	2.18	2.13	2.48	2.43	2.26	2.65
8	August	2.25	2.34	2.45	2.32	2.23	2.43	2.68
9	September	2.17	1.71	2.33	1.94	1.65	1.84	1.77
10	October	2.08	2.04	1.44	1.86	1.74	2.08	2.08
11	November	—	2.24	2.11	1.86	2.18	2.60	2.70
12	December	1.07	—	0.89	0.66	0.71	—	—
	1975							
13	January	3.39	—	2.66	2.57	2.36	—	—
14	February	1.96	—	1.93	2.04	2.14	—	—
15	March	3.04	3.12	3.63	0.10	2.60	—	0.10
16	April	3.47	2.15	2.53	2.31	1.80	1.67	2.37
17	May	2.09	2.98	1.90	2.64	2.29	3.10	3.00
18	June	2.53	2.81	2.45	2.79	2.70	2.47	2.37
19	July	2.74	2.39	3.02	2.69	2.71	2.46	2.20
20	August	3.31	2.66	3.16	3.43	3.34	3.09	2.74
21	September	2.46	1.15	1.76	2.90	3.13	1.10	0.98
22	October	1.15	1.28	1.17	2.68	1.17	1.97	1.44
23	November	1.90	2.15	2.22	1.82	2.61	2.38	2.41
24	December	—	—	—	2.76	2.75	—	—

[1]As used on the computer printout.

Table B-23a. Total macroinvertebrate density collected by Petersen dredge methods (1975).

HDR STATION NUMBER		6	10	12	21	25	27
STATION CODE[1]		1	2	3	5	6	7
MONTH CODE[1]	MONTH	DENSITY (Number/m^2)					
3	March	11,589.5	—	11,230.7	4,099.9	6,499.8	—
7	July	392.4	439.2	205.2	864.0	396.0	734.4
9	September	457.2	540.0	136.8	903.6	374.4	140.4
10	October	226.8	212.4	273.6	309.6	108.0	10.8
12	December	—	504.0	212.4	25.2	518.4	64.8

[1]As used on the computer printout.

Table B-23b. Total macroinvertebrate density collected by Petersen dredge methods (1976).

HDR STATION NUMBER		6	10	12	21	25	27
STATION CODE[1]		1	2	3	5	6	7
MONTH CODE[1]	MONTH	DENSITY (Number/m^2)					
13	January	644.4	—	378.0	925.2	932.4	—
14	February	604.8	1,713.6	1,724.4	482.4	842.4	6,296.4
16	April	1,018.8	1,328.3	1,260.0	356.4	543.6	—
17	May	1,245.1	1,033.4	746.3	2,106.2	258.3	1,532.1
18	June	1,194.8	3,189.8	1,930.4	10,078.9	1,776.1	2,389.7
20	August	566.9	1,955.5	5,938.3	2,178.0	943.7	5,131.0
21	September	886.3	2,178.0	3,484.0	3,695.7	1,001.1	7,997.8
23	November	5,192.0	6,171.5	5,873.3	5,292.4	6,053.1	6,978.8
24	December	2,601.4	—	6,971.6	3,979.2	8,173.7	—

[1]As used on the computer printout.

Table B-23c. Total macroinvertebrate density collected by Petersen dredge methods (1977).

HDR STATION NUMBER		6	10	12	21	25	27
STATION CODE[1]		1	2	3	5	6	7
MONTH CODE[1]	DATE	DENSITY (Number/m^2)					
25	January 24	1,397.85	—	8,630.81	1,157.71	1,340.50	—
28	April 18	3,949.82	4,465.95	6,186.37	3,473.11	3,860.21	4,200.71
29	May 31	3,240.14	—	7,218.62	4,939.06	4,810.03	15,505.37

[1]As used on the computer printout.

Table B-24. Macroinvertebrate density (Log transformed) collected by dredge methods, 1975-76.

PAIRED t-TEST		
SAMPLE NUMBER	INTAKE	DISCHARGE
1	2.3120	2.9360
2	2.1360	2.9560
3	2.4370	2.4910
4	2.5770	2.9660
5	3.2360	2.6320
6	3.1000	2.5520
7	2.8730	3.3230
8	3.2850	4.0030
9	3.7730	3.3380
10	3.5420	3.5670
11	3.7680	3.7230

t-Test

1) H0: MU(X)-MU(Y) = 0

H1: MU(X)-MU(Y) < 0

t value = -0.258

DF = 10

t (0.950, 10) = 1.812

Do not reject H0 at 0.05 level of significance

t = -0.2581, DF = 10

Prob t < -0.2581 = 0.4008

Table B-25. Macroinvertebrate density (Log transformed) collected by dredge methods, 1975-76.

PAIRED t-TEST		
SAMPLE NUMBER	UPRIVER HDR STATION #10	DOWNRIVER HDR STATION #27
1	2.7320	2.1470
2	2.3270	1.0330
3	3.0140	3.1850
4	3.5040	3.3780
5	3.2910	3.7100
6	3.3380	3.9030
7	3.7900	3.8440

t-Test

1) H0: MU(X)-MU(Y) = 0

H1: MU(X)-MU(Y) > 0

t value = 0.177

DF = 6

t (0.950, 6) = 1.943

Do not reject H0 at 0.05 level of significance

t = 0.1773, DF = 6

Prob t > 0.1773 = 0.4326

Table B-26a. Total macroinvertebrate density collected by artificial substrate method (1975).

HDR STATION NUMBER		6	10	12	21	25
STATION CODE[1]		1	2	3	5	6
MONTH CODE[1]	MONTH	DENSITY (Number/m^2)				
2	February	0	—	0	5.4	0
3	March	0	—	5.4	745.2	48.6
4	April	—	—	—	10,492.2	0
5	May	—	—	—	847.8	—
7	July	7,214.4	—	3,607.2	3,342.6	—
8	August	7,797.6	7,214.4	4,439.7	40,282.4	6,480.0
9	September	5,540.5	5,947.9	3,223.6	16,415.8	9,169.4
11	November	—	22,164.3	37,432.8	60,177.6	194,839.9
12	December	—	—	—	24,422.2	526.5

[1]As used on the computer printout.

Table B-26b. Total macroinvertebrate density collected by artificial substrate sampler (1976).

HDR STATION NUMBER		6	10	12	21	25
STATION CODE[1]		1	2	3	5	6
MONTH CODE[1]	MONTH	DENSITY (Number/m^2)				
14	February	—	—	—	4,250	65
15	March	—	—	—	14,966	14
16	April	—	—	—	2,967	—
18	June	18,565	—	37,940	28,988	22,583
19	July	23,227	9,559	28,197	52,925	31,994
20	August	14,524	—	32,191	69,284	29,314
22	October	13,270	36,084	20,880	38,065	26,986
23	November	27	417	514	13,536	7,500

[1]As used on the computer printout.

Table B-26c. Total macroinvertebrate density collected by Hester Dendy multiplate sampler (1977).

HDR STATION NUMBER		6	10	12	21	25
STATION CODE[1]		1	2	3	5	6
MONTH CODE[1]	DATE	DENSITY (Number/m^2)				
25	January 5	—	—	10.75	723.12	852.15
26	February 15	5.38	—	83.33	908.60	247.31
27	March 29	1,196.24	—	1,666.66	—	717.74
29	May 10	4,698.92	13,948.89	4,575.26	18,787.61	20,508.04

[1]As used on the computer printout.

Table B-27. Macroinvertebrate density (Log transformed) collected by artificial substrate methods, May-Oct, 1975-76.

PAIRED t-TEST		
SAMPLE NUMBER	INTAKE	DISCHARGE
1	3.5570	3.5240
2	3.6470	4.6050
3	3.5080	4.2150
4	4.5730	4.7790
5	4.5790	4.4620
6	4.5070	4.8400
7	4.3190	4.5800
8	2,7100	4.1310

t-Test

1) H0: MU(X)-MU(Y) = 0

H1: MU(X)-MU(Y) < 0

t value = -0.890

DF = 7

t (0.950, 7) = 1.895

Do not reject H0 at 0.05 level of significance

t = -0.8898, DF = 7

Prob t > -0.8898 = 0.2016

Table B-28. Macroinvertebrate diversity (dredge).

HDR STATION NUMBER		6	10	12	18	21	25	27
STATION CODE[1]		1	2	3	4	5	6	7
MONTH CODE[1]	MONTH	SHANNON-WEAVER INDEX						
	1976							
1	January	1.68	—	1.43	0.00	0.54	1.47	—
2	February	2.01	1.54	1.37	0.00	0.94	1.96	1.34
4	April	2.53	1.68	2.19	0.58	1.80	2.51	—
5	May	1.53	1.72	1.89	1.53	1.89	2.20	1.62
6	June	1.86	2.10	1.86	1.32	0.21	1.12	2.17
8	August	1.61	2.25	1.02	1.49	1.13	1.70	1.05
9	September	1.74	1.11	0.74	0.54	0.28	1.12	0.55
11	November	0.95	1.01	0.60	0.17	0.35	0.29	0.35
12	December	0.86	—	0.88	0.35	0.52	0.20	—
	1975							
15	March	1.68	—	1.40	0.00	1.07	1.52	—
19	July	2.07	1.95	1.42	0.95	0.12	0.45	—
21	September	1.46	2.58	2.23	0.59	0.28	2.21	—
22	October	2.26	2.41	2.97	—	0.09	2.77	—
24	December	—	2.24	2.22	—	1.15	2.04	—

[1]As used on the computer printout.

Table B-29. Macroinvertebrate diversity (artificial substrates).

HDR STATION NUMBER		6	10	12	18	21	25
STATION CODE[1]		1	2	3	4	5	6
MONTH CODE[1]	DATE	SHANNON-WEAVER INDEX					
	1976						
6	June	1.10	—	0.98	0.75	1.30	1.39
7	July	1.38	2.29	1.26	0.53	1.09	1.14
8	August	0.89	—	1.23	1.01	1.10	1.19
10	October	0.73	0.97	1.04	0.32	1.26	0.52
11	November	0.75	1.32	0.81	0.41	0.49	0.06
	1975						
19	July	2.07	—	1.96	1.72	2.65	—
20	August	—	2.19	1.47	0.29	1.40	1.78
21	September	1.46	2.65	1.68	0.06	1.54	2.55
22	October	2.26	—	—	—	—	—
23	November	—	0.76	0.22	0.03	0.57	0.11
24	December	—	—	—	0.54	0.97	1.86

[1]As used on the computer printout.

Table B-30. Data used in stepwise regression I biological variables HDR Station #6 for 1975.

MONTH	DENSITY (Number/ml)					
	1 PHYTOPLANKTON (PHYTOPLA)[1]	2 ZOOPLANKTON (ZOOP)[1]	3 ROTIFERA (ROTIF)[1]	4 CRUSTACEA (CRUSTAC)[1]	5 MACROINVERTEBRATE[2] (MACROD)[1]	6 MACROINVERTEBRATE[3] (MACROAS)[1]
January	—	16.2	7.5	7.5	—	—
February	—	5.7	2.0	3.7	—	0.0
March	—	28.0	0.7	26.6	11,589.5	0.0
April	—	12.8	2.3	9.4	—	—
May	10,590	35.8	30.6	4.9	—	—
June	9,960	31.8	21.7	3.4	—	—
July	4,839	358.9	278.6	75.8	392.4	7,214.4
August	11,265	—	—	—		7,797.6
September	7,995	91.1	53.1	20.5	457.2	5,540.5
October	25,440	213.9	191.7	19.0	226.8	—
November	6,420	75.8	52.4	20.9	—	—
December	—	—	—	—	—	—

[1]Abbreviation as used in the computer printout.

[2]Collected by dredge methods.

[3]Collected by artificial substrate.

Table B-31. II Water quality variables.

MONTH	PHOSPHORUS ORTHOPHOSPHATE		FILTERABLE RESIDUE		AMMONIA NITROGEN		NITRITE NITROGEN	
	B (ORTHOB)[1] 9	T (ORTHOT)[1] 10	B (FRESB)[1] 11	T (FREST)[1] 12	B (AMMONIAB)[1] 13	T (AMMONIAT)[1] 14	B (NITRITEB)[1] 15	T (NITRITET)[1] 16
January	0.14	0.17	241	233	0.59	0.63	0.008	0.006
February	0.14	0.17	256	243	1.06	1.06	0.008	0.008
March	0.14	0.16	249	254	0.85	0.82	0.009	0.009
April	0.08	0.08	219	251	0.45	0.42	0.027	0.028
May	0.02	0.01	270	289	<0.01	<0.01	0.021	0.022
June	0.10	0.10	144	127	0.19	0.15	0.036	0.037
July	0.19	0.07	232	224	0.17	0.22	0.029	0.031
August	0.07	0.10	194	195	0.19	0.34	0.028	0.030
September	0.07	0.07	203	203	0.19	0.19	0.028	0.030
October	0.04	0.06	224	224	0.09	0.25	0.020	0.020
November	0.07	0.10	203	203	0.32	0.37	0.010	0.010

[1]Abbreviation as used in the computer printout.

B = bottom; T = top

Table B-31. (Continued).

MONTH	NITRATE NITROGEN		CONDUCTIVITY		DISSOLVED OXYGEN		WATER TEMPERATURE	
	B (NITRATEB)[1] 17	T (NITRATET)[1] 18	B (CONDUCTB)[1] 19	T (CONDUCTT)[1] 20	B (DISOXB)[1] 21	T (DISOXT)[1] 22	B (TEMPB)[1] 23	T (TEMPT)[1] 24
January	0.69	0.50	200	235	—	—	0.3	0.4
February	0.60	0.54	250	240	0.30	9.85	0.0	0.0
March	0.81	0.75	205	210	3.50	12.40	0.0	1.0
April	3.45	3.61	255	260	1.75	11.95	4.7	4.5
May	1.39	1.18	380	380	7.74	7.79	19.7	19.0
June	4.30	4.20	370	380	3.79	8.37	24.4	24.0
July	0.60	0.67	270	270	6.16	6.07	25.4	25.5
August	0.60	0.45	320	320	8.89	7.24	22.4	21.4
September	0.26	0.25	290	305	9.68	8.69	17.4	16.6
October	0.45	0.39	305	310	12.31	10.15	16.4	14.6
November	1.60	0.28	230	230	12.65	12.33	0.8	1.0

[1]Abbreviation as used in the computer printout.

B = bottom; T = top

Table B-32. Data used in stepwise regression (biological variables), Sturgeon Lake, HDR Station No. 6 (1976).

MONTH	DENSITY (Number/ml)					
	1 PHYTOPLANKTON (PHYTOPLA)[1]	2 ZOOPLANKTON (ZOOP)[1]	3 ROTIFERA (ROTIF)[1]	4 CRUSTACEA (CRUSTAC)[1]	5 MACROINVERTEBRATE[2] (MACROD)[1]	6 MACROINVERTEBRATE[3] (MACROAS)[1]
January	—	19.10	9.53	3.40	644.4	—
February	—	16.20	3.90	2.16	604.8	—
March	953	28.00	7.97	3.67	—	—
April	5,145	91.20	42.80	9.13	1,018.8	—
May	23,820	938.20	895.07	8.87	1,245.1	—
June	25,560	810.00	378.07	98.60	1,194.8	18,565
July	19,650	576.40	323.92	252.24	—	23,227
August	25,800	851.00	640.84	210.17	566.9	14,524
September	39,525	463.70	312.76	150.99	886.3	—
October	—	500.50	324.34	176.11	—	13,270
December	—	135.31	130.11	5.21	2,601.4	—

[1]Abbreviation as used in the computer printout.

[2]Collected by dredge methods.

[3]Collected by artificial substrate.

Table B-33. II Environmental variables (water quality).

MONTH	PHOSPHORUS ORTHOPHOSPHATE		FILTERABLE RESIDUE		AMMONIA NITROGEN		NITRITE NITROGEN	
	B (ORTHOB)[1] 9	T (ORTHOT)[1] 10	B (FRESB)[1] 11	T (FREST)[1] 12	B (AMMONIAB)[1] 13	T (AMMONIAT)[1] 14	B (NITRITEB)[1] 15	T (NITRITET)[1] 16
January	0.19	0.19	309	253	0.79	0.84	0.008	0.007
February	0.18	0.16	268	252	0.83	0.75	0.010	0.012
March	0.15	0.11	267	268	0.77	0.82	0.017	0.017
April	0.04	0.03	206	205	0.05	0.01	0.013	0.014
May	0.00	0.00	185	171	0.02	0.02	0.005	0.004
June	0.06	0.06	219	210	0.12	0.02	0.005	0.001
July	0.09	0.09	196	198	0.01	0.00	0.003	0.003
August	0.06	0.04	221	221	0.00	0.00	0.003	0.004
September	0.03	0.05	219	231	0.00	0.02	0.004	0.014
October	0.00	0.00	216	213	0.00	0.03	0.200	0.160
December	0.22	0.22	298	289	1.60	1.80	0.019	0.018

[1]Abbreviation as used in the computer printout.

B = bottom; T = top

Table B-33. (Continued).

MONTH	NITRATE NITROGEN		CONDUCTIVITY		DISSOLVED OXYGEN		WATER TEMPERATURE	
	B (NITRATEB)[1] 17	T (NITRATET)[1] 18	B (CONDUCTB)[1] 19	T (CONDUCTT)[1] 20	B (DISOXB)[1] 21	T (DISOXT)[1] 22	B (TEMPB)[1] 23	T (TEMPT)[1] 24
January	1.00	0.69	220	225	8.6	9.0	0.3	0.0
Febuary	0.54	0.48	250	230	9.5	8.6	0.5	0.1
March	0.82	0.82	260	260	12.6	12.0	1.5	0.8
April	0.72	0.68	240	245	11.6	11.9	9.9	9.6
May	0.37	0.26	315	315	9.4	12.2	15.5	17.0
June	0.01	0.06	360	360	8.9	8.7	23.7	24.0
July	0.28	0.26	360	370	8.8	9.7	24.5	27.5
August	0.59	0.42	350	355	7.1	8.8	22.4	23.2
September	0.07	0.00	325	325	9.1	9.1	20.5	21.0
October	0.15	0.08	325	320	14.2	14.2	14.1	13.4
December	0.42	0.72	260	265	9.4	9.3	0.8	0.1

[1]Abbreviation as used in the computer printout.

B = bottom; T = top

Table B-34. Data used in stepwise regression (biological variables), HDR Station Nos. 9 and 10 (1976).

MONTH	DENSITY (Number/ml)					
	1 PHYTOPLANKTON (PHYTOPLA)[1]	2 ZOOPLANKTON (ZOOP)[1]	3 ROTIFERA (ROTIF)[1]	4 CRUSTACEA (CRUSTAC)[1]	5 MACROINVERTEBRATE[2] (MACROD)[1]	6 MACROINVERTEBRATE[3] (MACROAS)[1]
March	135	34.3	7.17	4.50	—	—
April	2,280	45.8	21.97	4.27	1,328.3	—
May	11,310	802.4	733.97	14.57	1,033.4	—
June	36,810	948.9	535.83	68.33	3,189.8	—
July	—	793.9	592.07	201.84	—	9,559
August	—	870.0	616.86	253.81	1,955.5	—
September	—	609.5	444.92	164.52	2,178.0	—
October	50,400	312.0	216.14	95.73	—	36,084
November	—	57.7	46.33	11.28	6,171.5	417

[1]Abbreviation as used in the computer printout.

[2]Collected by dredge methods.

[3]Collected by artificial substrate.

Table B-35. II Environmental variables (water quality) HDR Stations 9 and 10, 1976.

MONTH	PHOSPHORUS ORTHOPHOSPHATE		FILTERABLE RESIDUE		AMMONIA NITROGEN		NITRITE NITROGEN	
	B (ORTHOB)[1] 9	T (ORTHOT)[1] 10	B (FRESB)[1] 11	T (FREST)[1] 12	B (AMMONIAB)[1] 13	T (AMMONIAT)[1] 14	B (NITRITEB)[1] 15	T (NITRITET)[1] 16
March	0.12	0.12	276	274	0.71	0.75	0.019	0.019
April	0.04	0.04	149	171	0.06	0.04	0.010	0.010
May	0.00	0.00	161	163	0.05	0.04	0.009	0.009
June	0.05	0.07	225	222	0.05	0.03	0.034	0.037
July	0.05	0.02	196	189	0.00	0.00	0.004	0.003
August	0.01	0.02	217	202	0.00	0.00	0.025	0.006
September	0.01	0.05	270	255	0.10	0.15	0.143	0.145
October	0.00	0.00	222	228	0.00	0.00	0.230	0.220
November	0.23	0.20	250	246	0.97	0.97	0.018	0.018

[1]Abbreviation as used in the computer printout.

B = bottom; T = top

Table B-35. (Continued)

MONTH	NITRATE NITROGEN		CONDUCTIVITY		DISSOLVED OXYGEN		WATER TEMPERATURE	
	B (NITRATEB)[1] 17	T (NITRATET)[1] 18	B (CONDUCTB)[1] 19	T (CONDUCTT)[1] 20	B (DISOXB)[1] 21	T (DISOXT)[1] 22	B (TEMPB)[1] 23	T (TEMPT)[1] 24
March	0.91	0.87	280	270	12.0	11.7	2.2	1.8
April	0.66	0.63	200	200	11.2	11.2	9.0	8.8
May	0.31	0.23	290	280	10.0	10.2	15.5	15.5
June	0.17	0.14	355	360	9.5	9.4	23.0	23.0
July	0.09	0.07	330	320	10.1	10.8	25.0	25.2
August	0.51	0.31	340	330	9.0	9.6	23.3	23.7
September	0.31	0.32	380	375	8.7	8.5	20.8	20.0
October	0.56	0.00	345	330	12.1	12.3	14.0	14.0
November	0.32	0.32	315	310	15.4	16.0	2.6	2.6

[1]Abbreviation as used in computer printout.

B = bottom; T = top

Table B-36. Data used in stepwise regression (biological variables), HDR Station Nos. 12, 13, and 14 (1975).

MONTH	DENSITY (Number/ml)					
	1 PHYTOPLANKTON (PHYTOPLA)[1]	2 ZOOPLANKTON (ZOOP)[1]	3 ROTIFERA (ROTIF)[1]	4 CRUSTACEA (CRUSTAC)[1]	5 MACROINVERTEBRATE[2] (MACROD)[1]	6 MACROINVERTEBRATE[3] (MACROAS)[1]
March	—	11.4	3.6	7.4	11,230.7	5.4
May	14,490	28.7	19.1	8.7	—	—
June	17,910	75.3	48.2	20.6	—	—
July	4,299	263.6	177.1	81.4	205.2	3,607.2
August	18,480	143.0	95.2	45.0	—	4,439.7
September	8,310	127.9	106.8	19.7	136.8	3,223.6
October	22,260	124.8	100.9	22.8	273.6	—
November	—	81.1	55.4	23.8	—	37,432.8

[1]Abbreviation as used in the computer printout.

[2]Collected by dredge methods.

[3]Collected by artificial substrate.

Table B-37. II Environmental variables (water quality), HDR Stations 12, 13, and 14 for 1975.

MONTH	PHOSPHORUS ORTHOPHOSPHATE		FILTERABLE RESIDUE		AMMONIA NITROGEN		NITRITE NITROGEN	
	B (ORTHOB)[1] 9	T (ORTHOT)[1] 10	B (FRESB)[1] 11	T (FREST)[1] 12	B (AMMONIAB)[1] 13	T (AMMONIAB)[1] 14	B (NITRITEB)[1] 15	T (NITRITET)[1] 16
March	0.18	0.18	247	247	0.95	0.92	0.010	0.008
May	0.03	0.02	272	284	0.02	0.01	0.025	0.025
June	0.06	0.07	142	149	0.09	0.07	0.030	0.033
July	0.11	0.10	235	240	0.31	0.26	0.037	0.035
August	0.08	0.08	205	205	0.15	0.09	0.033	0.030
September	0.07	0.06	236	219	0.09	0.03	0.021	0.024
October	0.04	0.02	208	213	0.10	<0.01	0.021	0.020
November	0.08	0.08	186	192	0.40	0.35	0.010	0.010

[1]Abbreviation as used in the computer printout.

B = bottom; T = top

Table B-37 (Continued).

MONTH	NITRATE NITROGEN		CONDUCTIVITY		DISSOLVED OXYGEN		WATER TEMPERATURE	
	B (NITRATEB)[1] 17	T (NITRATET)[1] 18	B (CONDUCTB)[1] 19	T (CONDUCTT)[1] 20	B (DISOXB)[1] 21	T (DISOXT)[1] 22	B (TEMPB)[1] 23	T (TEMPT)[1] 24
March	0.75	0.78	215	205	10.93	—	0.3	0.0
May	1.26	1.10	380	380	7.80	8.08	19.8	19.9
June	4.20	4.50	430	420	10.50	9.92	24.4	24.4
July	0.81	0.64	340	340	5.87	5.80	24.7	25.3
August	0.56	0.54	320	325	8.02	8.04	22.1	28.8
September	0.17	0.22	295	320	9.50	9.04	17.4	26.0
October	0.45	0.39	320	300	10.25	11.31	15.6	16.2
November	6.20	0.03	230	230	13.01	12.93	0.9	0.8

[1]Abbreviation as used in the computer printout.

B = bottom; T = top

Table B-38. Data used in stepwise regression (biological variables), HDR Station Nos. 12, 13, and 14 (1976).

MONTH	DENSITY (Number/ml)					
	1 PHYTOPLANKTON (PHYTOPLA)[1]	2 ZOOPLANKTON (ZOOP)[1]	3 ROTIFERA (ROTIF)[1]	4 CRUSTACEA (CRUSTAC)[1]	5 MACROINVERTEBRATE[2] (MACROD)[1]	6 MACROINVERTEBRATE[3] (MACROAS)[1]
January	—	30.7	16.17	13.73	378.0	—
February	20	13.5	2.50	2.63	1,724.4	—
March	869	240.2	40.90	16.16	—	—
April	2,835	82.9	37.63	10.46	1,260.0	—
May	17,940	790.0	706.60	23.64	746.3	—
June	35,340	547.8	219.03	68.00	1,930.4	37,940
July	56,925	818.2	660.33	157.84	—	28,197
August	38,925	560.3	376.54	183.75	5,938.3	32,191
September	—	444.9	295.31	149.54	3,484.0	—
October	50,700	363.5	289.12	74.07	—	20,880
November	—	115.9	100.82	15.04	5,873.3	514
December	—	169.9	165.78	4.09	6,971.6	—

[1]Abbreviation as used in the computer printout.

[2]Collected by dredge methods

[3]Collected by artificial substrate.

Table B-39. II Environmental variables (water quality), HDR Stations 12, 13, and 14 (intake) for 1976.

MONTH	PHOSPHORUS ORTHOPHOSPHATE		FILTERABLE RESIDUE		AMMONIA NITROGEN		NITRITE NITROGEN	
	B (ORTHOB)[1] 9	T (ORTHOT)[1] 10	B (FRESB)[1] 11	T (FREST)[1] 12	B (AMMONIAB)[1] 13	T (AMMONIAT)[1] 14	B (NITRITEB)[1] 15	T (NITRITET)[1] 16
January	—	0.16	—	262	—	0.73	—	0.021
February	0.18	0.18	275	272	0.86	0.87	0.011	0.010
March	0.11	0.14	254	233	0.70	0.72	0.018	0.017
April	0.02	0.03	218	211	0.01	0.01	0.016	0.016
May	0.00	0.00	172	169	0.01	0.01	0.003	0.003
June	0.09	0.05	240	225	0.08	0.19	0.028	0.002
July	0.08	0.10	203	217	0.04	0.07	0.003	0.007
August	0.05	0.04	220	230	0.00	0.02	0.004	0.012
September	0.05	0.08	226	241	0.04	0.19	0.010	0.054
October	0.00	0.00	212	212	0.02	0.03	0.155	0.130
November	0.07	0.08	229	226	0.08	0.10	0.022	0.022
December	0.22	0.21	296	284	1.40	1.60	0.054	0.022

[1]Abbreviation as used in the computer printout.

B = bottom; T = top

LEGEND FOR TABLES 5-1 THROUGH 5-5

Q_p = plant blowdown flow, cfs

Q_i = plant intake, cfs

Q_r = river flow, cfs

Q_{36} = flow through channel 36, cfs, Figure 4-1

Q_{42} = flow through channel 42, cfs, Figure 4-1

Q_{26} = flow through channel 26, cfs, Figure 4-1

T_p = plant discharge temperature, degrees F

T_a = ambient temperature, degrees F

ΔT = temperature rise at Barney's Point

Ws and Wd = wind speed and its corresponding direction

Table 5-1 - 1975 Monthly Typical Discharge Conditions

Item Month	Qp (cfs) (1)	Qi (cfs)	Qr (cfs) (2)	Ws (mph)	Wd	Q36 (cfs)	Q42 (cfs)	Q26 (cfs)	Tp °F (3)	Ta °F (4)	Tp-Ta °F	ΔT °F (5)
Jan.	150	-175	7995	0	-	1037	-793	-209	75.0	32.5	42.5	8.4
Feb.	263	-289	8691	0	-	1127	-859	-232	73.9	33.1	40.8	9.0
Mar.	255	-281	9944	5	S	1256	-967	-254	72.1	35.0	37.1	8.0
Apr.	388	-414	45860	5	S	5904	-4372	-1497	79.3	40.1	39.2	4.5
May	591	-618	65220	5	S	8406	-6211	-2160	86.9	61.1	25.8	2.8
June	302	-326	36200	5	S	4655	-3455	-1165	92.5	69.5	23.0	2.9
July	735	-761	38010	5	S	4889	-3627	-1227	91.8	77.8	14.0	2.5
Aug.	509	-541	11790	5	S	1499	-1142	-322	89.4	76.0	13.4	3.6
Sept.	343	-378	10950	5	S	1389	-1063	-291	83.6	64.6	19.0	4.4
Oct.	230	-265	10070	5	S	1273	-979	-259	81.5	55.8	25.7	5.4
Nov.	154	-190	12570	5	S	1600	-1215	-350	76.7	44.2	32.5	5.8
Dec.	149	-175	12561	0	-	1622	-1222	-365	80.5	32.9	47.6	8.5

(1) Weighted Monthly Average - Prairie Island Environmental Event Log
(2) Monthly Average Daily Flow - U.S.G.S. Flow Data at Prescott, Wisconsin
(3) Cooling Tower Performance Curve
(4) Monthly Average Maximum Inlet Temperature - Red Wing Generating Plant
(5) Temperature Rise at Barney's Point

Item Month	Q (cfs) (1)	Qi (cfs)	Qr (cfs) (2)	Ws (mph)	Wd	Q36 (cfs)	Q42 (cfs)	Q26 (cfs)	Tp °F (3)	Ta °F (4)	Tp-Ta °F	ΔT °F (6)
Jan.	136	-169	9066	0	-	1175	-895	-245	74.6	32.2	42.4	8.1
Feb.	169	-199	9987	0	-	1293	-982	-276	82.3	34.4	47.9	9.3
Mar.	149	-176	21190	5	S	2715	-2030	-650	71.5	37.0	34.5	5.0
Apr.	150	-182	43070	5	S	5543	-4108	-1401	76.1	51.1	25.0	2.3
May	142	-176	11030	5	S	1399	-1070	-294	82.2	61.7	20.5	3.8
June	485	-518	6883	5	S	842	-667	-141	85.7	73.7	12.0	3.5
July	1011	-1044	5323	5	S	624	-507	-82	86.5	79.3	7.2	3.1
Aug.	816	-847	3636	5	S	370	-336	1	87.3	77.6	9.7	3.7
Sept.	209	-240	3002	5	S	273	-272	33	83.2	67.2	16.0	3.6
Oct.	182	-212	3556(5)	5	S	358	-328	5	80.8	52.6	28.2	6.2
Nov.	147	-180	3949(5)	5	S	418	-368	-15	71.1	37.7	33.4	7.0
Dec.	150	-183	3329(5)	0	-	434	-339	-61	73.4	33.0	40.4	8.4

(1) Weighted Monthly Average - Prairie Island Environmental Event Log
(2) Monthly Average Daily Flow - U.S.G.S. Flow Data at Prescott, Wisconsin
(3) Cooling Tower Performance Curve
(4) Monthly Average Maximum Inlet Temperature - Red Wing Generating Plant
(5) Flow at Lock & Dam No. 3
(6) Temperature Rise at Barney's Point

Table 5-3 - 1975 Monthly treme Discharge Conditions

Item Month	Qp (cfs) (1)	Qi (cfs)	Qr (cfs) (2)	Ws (mph) (3)	Wd (4)	Q36 (cfs)	Q42 (cfs)	Q26 (cfs)	Tp °F (5)	Ta °F (6)	Tp-Ta °F	ΔT °F (8)
Jan.	150	-180	5900	0	-	767	-591	-141	87.0	32.0(7)	55.0	11.[illegible]
Feb.	420	-446	8680	0	-	1125	-858	-232	76.1	34.0(7)	42.1	11.0
Mar.	410	-434	10100	3	E	1267	-995	-237	76.3	39.0	37.3	9.4
Apr.	490	-511	33600	5	S	4319	-3208	-1076	80.5	40.0	40.5	6.4
May	1190	-1213	38400	4	SE	4940	-3664	-1242	87.1	69.0	18.1	4.6
June	695	-716	38300	7	SE	4927	-3654	-1238	96.5	69.0	27.5	4.8
July	1200	-1225	58500	10	NW	7449	-5556	-1856	94.3	80.0	14.3	2.7
Aug.	1000	-1036	10000	7(4)	SE(4)	1245	-977	-233	88.5	78.0	10.5	4.4
Sept.	655	-690	12100	4(4)	NE(4)	1544	-1185	-324	87.6	72.0	15.6	4.[illegible]
Oct.	533	-567	10300	4	SE	1285	-1006	-245	84.8	60.0	24.8	7.0
Nov.	296	-332	10400	6	SW	1344	-1012	-297	87.3	52.0	35.3	7.[illegible]
Dec.	150	-182	14100	0	-	1817	-1363	-418	87.5	35.0(7)	52.5	9.[illegible]

(1) Maximum Average Daily Blowdown - Prairie Island Environmental Event Log
(2) U.S.G.S. Flow Data at Prescott, Wisconsin
(3) Prairie Island Meteorology Station
(4) Minneapolis Airport Weather Station
(5) Cooling Tower Performance Curves
(6) Maximum Daily Inlet Temperature - Red Wing Generating Plant
(7) Assumed Case
(8) Temperature Rise at Barney's Point

[illegible]

Item Month	Qp (cfs) (1)	Qi (cfs)	Qr (cfs) (2)	Ws (mph) (3)	Wd (3)	Q36 (cfs)	Q42 (cfs)	Q26 (cfs)	Tp °F (4)	Ta °F (5)	Tp-Ta °F	ΔT °F (9)
Jan.	173	-209	8790	0	-	1139	-869	-236	76.8	32.0	44.8	8.9
Feb.	317	-353	8560	0	-	1110	-847	-228	75.7	33.0	42.7	10.0
Mar.	206	-242	14400	7	SSE	1841	-1397	-409	77.3	33.0	44.3	8.1
Apr.	153	-189	39800	10	W	5138	-3801	-1302	85.0	52.0	33.0	3.2
May	205	-241	11500	4	NE	1466	-1129	-302	83.5	60.0	23.5	4.6
June	1137	-1170	6440	10(6)	SSW(6)	843	-543	265	87.5	75.0	12.5	5.7
July	1190	-1219	4430	8(6)	N(6)	599	-535	-28	90.8	78.0	12.8	6.2
Aug.	1245	-1269	3890	6	NE	435	-413	13	92.7	77.0	15.7	7.6
Sept.	472	-508	3230	6	E	236	-336	135	83.5	76.0	7.5	2.2
Oct.	367	-397	3132(8)	4	W	463	-299	-129	88.0	56.0	32.0	8.1
Nov.	147	-181	4140(8)	0	-	539	-419	-85	76.1	33.0(7)	43.1	9.0
Dec.	150	-180	3107(8)	0	-	406	-317	-54	81.0	32.0(7)	49.0	10.2

(1) Maximum Average Daily Blowdown - Prairie Island Environmental Event Log
(2) U.S.G.S. Flow Data at Prescott, Wisconsin
(3) Prairie Island Meteorology Station
(4) Cooling Tower Performance Curves
(5) Maximum Daily Inlet Temperature - Red Wing Generating Plant
(6) Minneapolis Airport Weather Station
(7) Assumed Worst Case
(8) Flow at Lock & Dam No. 3
(9) Temperature Rise at Barney's Point

Table 5-5 - Proposed Monthly Extreme Discharge Conditions

Item Month	Qp (cfs) (1)	Qi (cfs)	Qr (cfs) (2)	Ws (mph)	Wd	Q36 (cfs)	Q42 (cfs)	Q26 (cfs)	Tp °F (3)	Ta °F (4)	Tp-Ta °F	ΔT °F (6)
Jan.	150	-175	3699	0	-	482	-375	-72	85.0	32.0(5)	53.0	11.1
Feb.	150	-175	3780	0	-	493	-384	-74	85.0	32.0(5)	53.0	11.0
Mar.	150	-175	4279	10	S	-31	-204	270	85.0	32.0(5)	53.0	11.0
Apr.	150	-185	7623	10	S	710	-654	-21	85.0	65.0	20.0	4.2
May	600	-629	8475	10	S	856	-744	-78	87.3	73.0	14.3	4.6
June	800 1386	-829 -1410	6431	10	S	483	-527	80	90.4 88.5	79.0	11.4 9.5	4.4 5.0
July	1384	-1410	4299	10	S	-25	-209	268	91.5	83.0	8.5	3.9
Aug.	1381	-1410	3390	10	S	-334	-1	357	91.7	85.0	6.7	2.7
Sept.	500	-532	3680	10	S	-231	-63	328	90.0	78.0	12.0	3.1
Oct.	300	-333	4010	10	S	-121	-141	296	86.4	70.0	16.4	3.7
Nov.	150	-180	4243	10	S	-43	-195	274	85.0	32.0(5)	53.0	10.9
Dec.	150	-175	3787	0	-	494	-384	-75	85.0	32.0(5)	53.0	11.0

(1) Expected Maximum Blowdown for Future Operation with Existing Systems
(2) Seven-day, 10-year Low Flow - U.S.G.S. Flow Data at Prescott, Wisconsin (1928-1976)
(3) Cooling Tower Performance Curves 85.0°F Winter for Ice Control
(4) Maximum Inlet Temperature - Red Wing Generating Plant (unless noted)
(5) Minimum Inlet Temperature
(6) Temperature Rise at Barney's Point

Table 5-6 - Heat Recirculation Rate at Intake Structure

Month	1975 Typical	1976 Typical	1975 Extreme	1976 Extreme	Proposed Extreme
January	8.6	7.8	10.2	8.3	12.4
February	9.4	7.6	11.4	10.2	12.3
March	8.7	3.9	10.4	6.1	15.9
April	1.8	1.4	3.5	1.6	10.2
May	1.1	6.9	6.4	7.2	15.8
June	2.4	14.6	3.7	27.3	23.5 36.0
July	4.0	27.9	3.2	31.1	44.0
August	10.4	27.3	18.7	35.5	51.0
September	9.1	15.3	11.8	19.8	27.6
October	8.3	14.0	11.8	16.8	20.4
November	6.3	12.8	8.8	11.9	16.0
December	6.3	12.8	5.7	13.1	12.3

NOTE: Heat recirculation rate at the intake structure is expressed as the percentage of heat effluent at the discharge structure.

Table 5-7 - Surface Water Temperatu.e Rise Along Centerline of Heat Plume

Month	1975 Typical Operating Conditions						1976 Typical Operating Conditions					
	Barney's Point	1000 ft	2000 ft	3000 ft	4000 ft	5000 ft	Barney's Point	1000 ft	2000 ft	3000 ft	4000 ft	500(
Jan.	8.4	5.2	4.2	3.8	3.6	3.4	8.1	5.0	4.1	3.8	3.5	3.
Feb.	9.0	5.5	4.5	4.1	3.8	3.7	9.3	5.7	4.7	4.2	4.0	3.
Mar.	8.0	4.9	4.0	3.7	3.5	3.3	5.0	3.1	2.5	2.3	2.2	2.
Apr.	4.5	2.8	2.2	2.1	2.0	1.9	2.3	1.4	1.2	1.1	1.0	0.
May	2.8	1.7	1.4	1.3	1.2	1.1	3.8	2.3	2.0	1.8	1.7	1.
June	2.9	1.8	1.5	1.4	1.3	1.2	3.5	2.1	1.8	1.6	1.5	1.
July	2.5	1.5	1.3	1.2	1.1	1.0	3.1	1.9	1.6	1.4	1.3	1.
Aug.	3.6	2.2	1.8	1.7	1.6	1.5	3.7	2.2	1.8	1.7	1.6	1.
Sept.	4.4	2.7	2.2	2.0	1.9	1.8	3.6	2.2	1.8	1.7	1.5	1.
Oct.	5.4	3.3	2.7	2.4	2.3	2.2	6.2	3.8	3.0	2.8	2.6	2.
Nov.	5.8	3.6	2.9	2.7	2.5	2.4	7.0	4.3	3.4	3.1	2.9	2.
Dec.	8.5	5.2	4.3	3.9	3.7	3.5	8.4	5.1	4.1	3.8	3.5	3.

Table 5-8 - Surface Water Temperature Rise Along Centerline of Heat Plume

Month	1975 Extreme Operating Conditions						1976 Extreme Operating Conditions					
	Barney's Point	1000 ft	2000 ft	3000 ft	4000 ft	5000 ft	Barney's Point	1000 ft	2000 ft	3000 ft	4000 ft	5000
Jan.	11.3	6.9	5.7	5.1	4.8	4.6	8.9	5.5	4.4	4.1	3.8	3.
Feb.	11.0	6.8	5.5	5.0	4.7	4.5	10.0	6.1	5.0	4.6	4.3	4.
Mar.	9.4	5.8	4.7	4.3	4.1	3.9	8.1	5.0	4.1	3.7	3.5	3.
Apr.	6.4	4.0	3.2	2.9	2.8	2.7	3.2	2.0	1.6	1.5	1.4	1.
May	4.6	2.8	2.3	2.2	2.0	1.9	4.6	2.8	2.3	2.1	2.0	1.
June	4.8	3.0	2.4	2.2	2.1	2.0	5.7	3.5	2.8	2.6	2.4	2.
July	2.7	1.7	1.4	1.3	1.2	1.1	6.2	3.8	3.1	2.8	2.6	2.
Aug.	4.4	2.7	2.2	2.1	1.9	1.8	7.6	4.6	3.8	3.4	3.2	3.
Sept.	4.7	2.9	2.4	2.1	2.0	1.9	2.2	1.3	1.1	1.0	0.9	0.
Oct.	7.0	4.3	3.5	3.2	3.0	2.9	8.1	4.9	3.9	3.6	3.3	3.
Nov.	7.8	4.8	3.9	3.6	3.4	3.2	9.0	5.5	4.4	4.0	3.8	3.
Dec.	9.0	5.6	4.6	4.2	3.9	3.7	10.2	6.2	4.9	4.5	4.2	4.

Table 5-9 - Surface Water Temperature Rise Along Centerline of Heat Plume

	Barney's Point	Proposed Extreme Operating Conditions 1000 ft	2000 ft	3000 ft	4000 ft	5000 ft
Jan.	11.1	6.7	5.5	4.9	4.6	4.4
Feb.	11.0	6.7	5.4	4.9	4.6	4.4
Mar.	11.0	6.7	5.4	4.9	4.6	4.4
Apr.	4.2	2.6	2.1	1.9	1.8	1.7
May	4.6	2.8	2.3	2.1	2.0	1.9
June	4.4	2.7	2.2	2.0	1.9	1.8
	5.0	3.1	2.5	2.3	2.1	2.0
July	3.9	2.4	2.0	1.8	1.6	1.5
Aug.(1)						
Sept.	3.1	1.9	1.5	1.4	1.3	1.2
Oct.	3.7	2.3	1.8	1.7	1.6	1.5
Nov.	10.9	6.6	5.4	4.9	4.6	4.4
Dec.	11.0	6.7	5.4	4.9	4.6	4.4

(1) See Section 5.2.

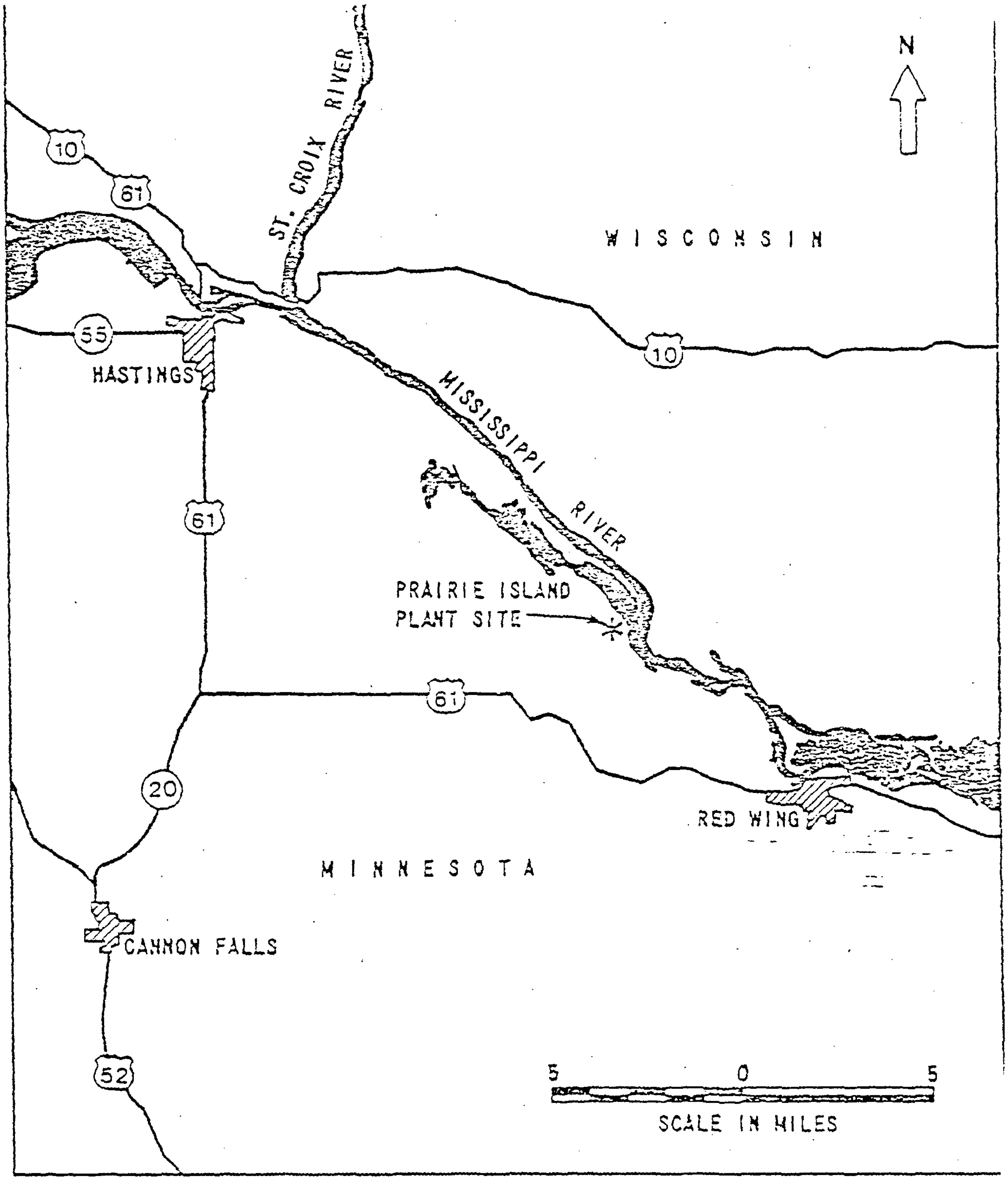


FIGURE 3-1
LOCATION MAP
THERMAL DISCHARGE ANALYSIS
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

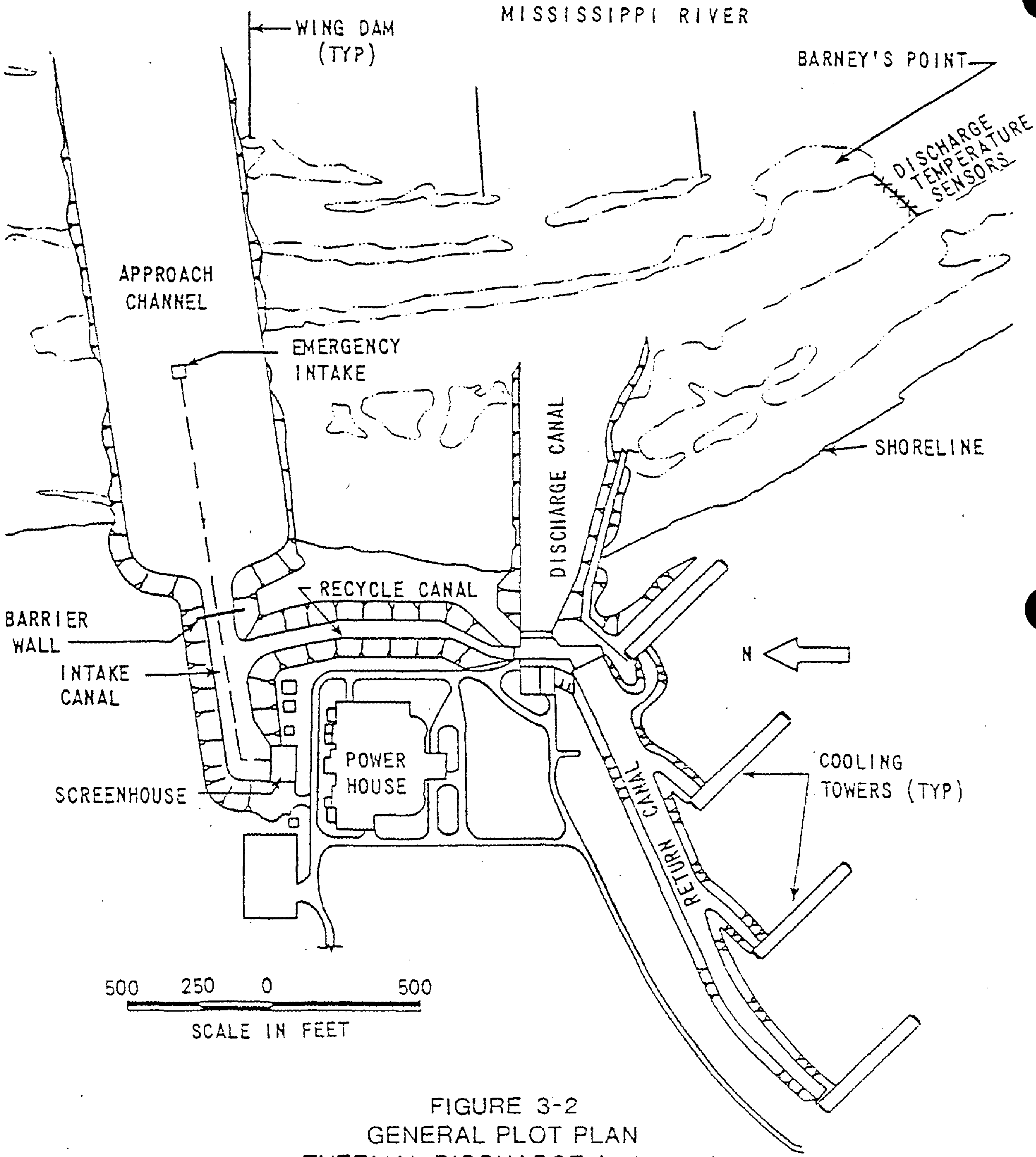


FIGURE 3-2
GENERAL PLOT PLAN
THERMAL DISCHARGE ANALYSIS
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

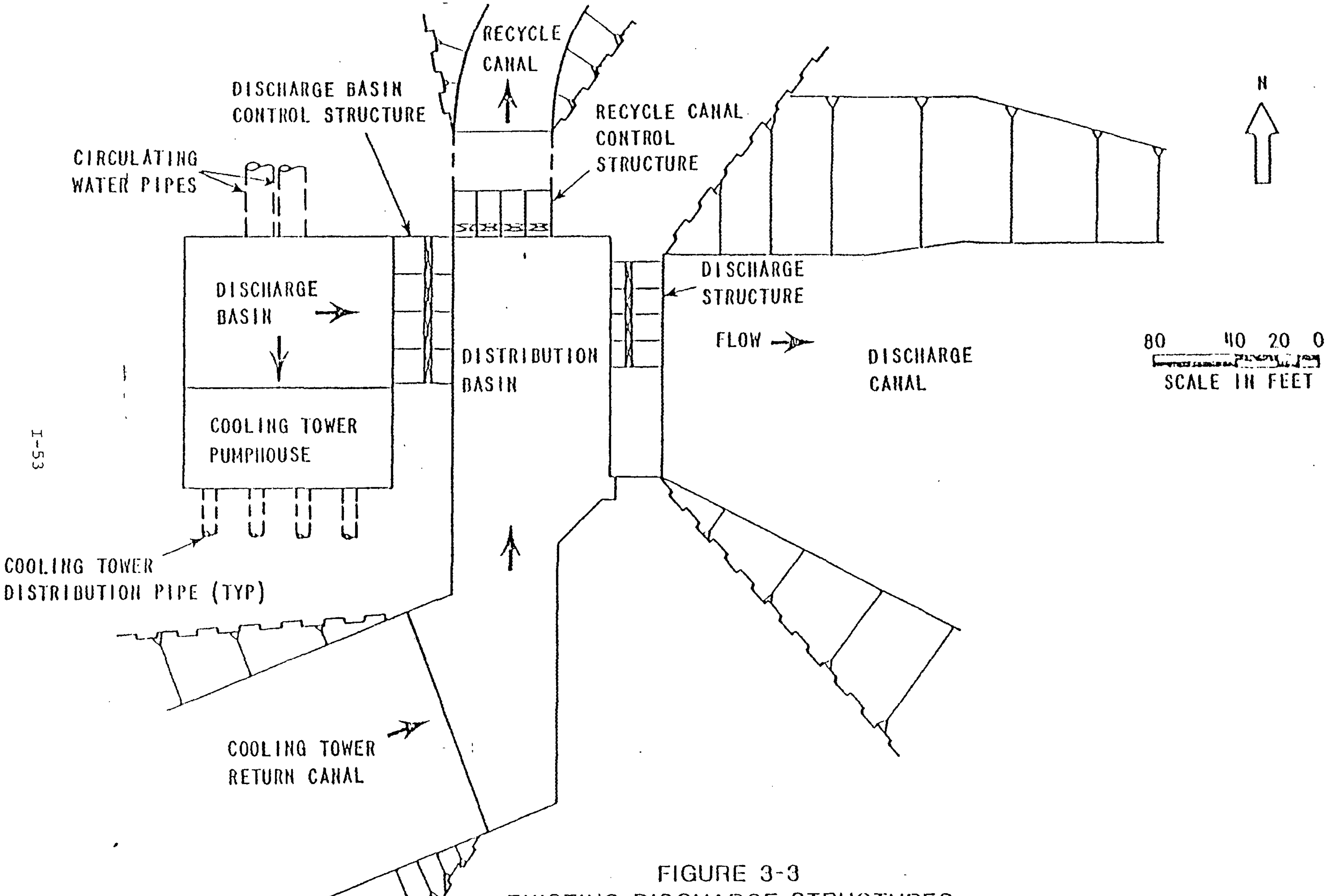


FIGURE 3-3
EXISTING DISCHARGE STRUCTURES
THERMAL DISCHARGE ANALYSIS
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

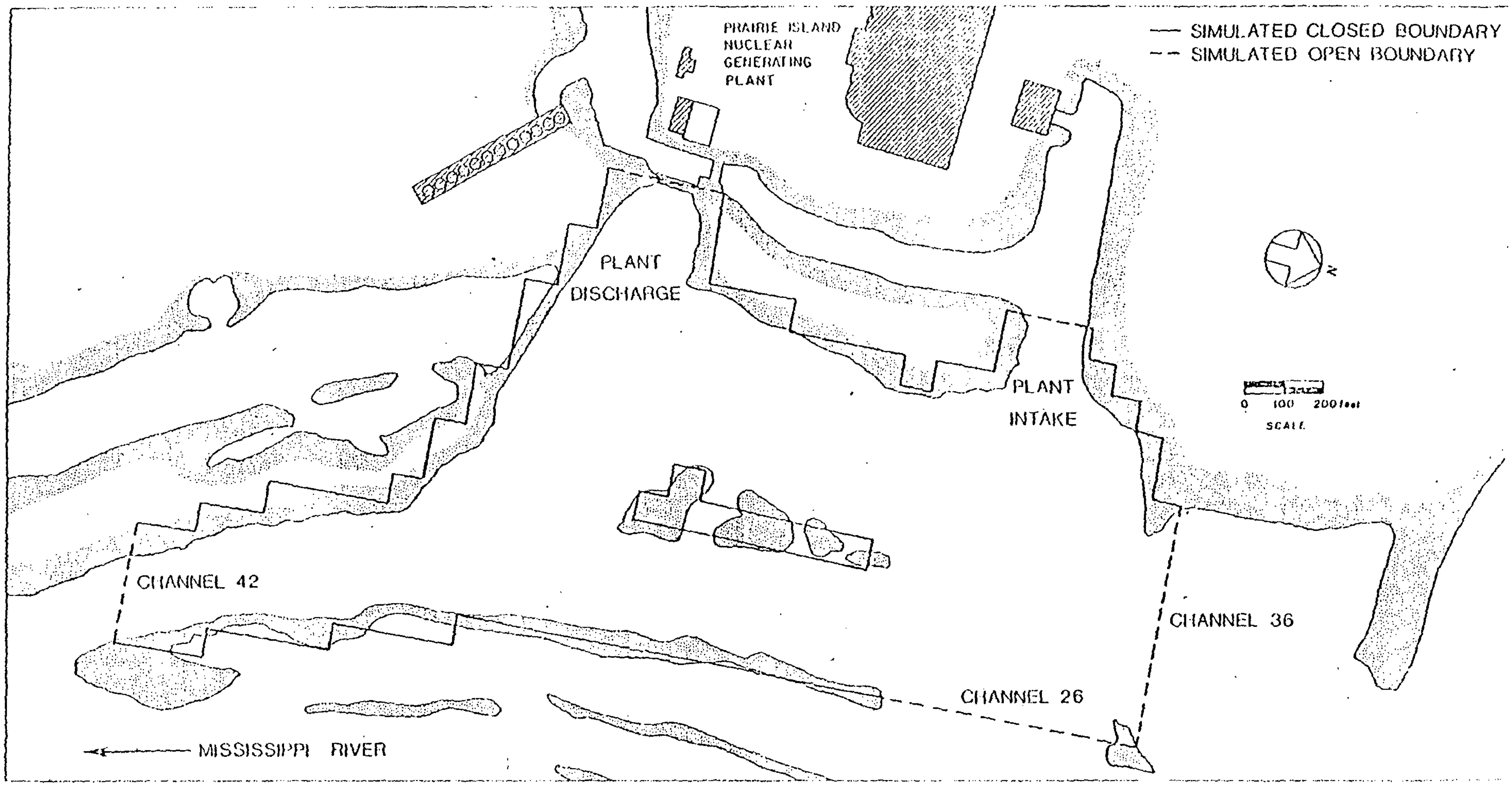


FIGURE 4-1

SITE VICINITY LAYOUT
THERMAL DISCHARGE ANALYSIS
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

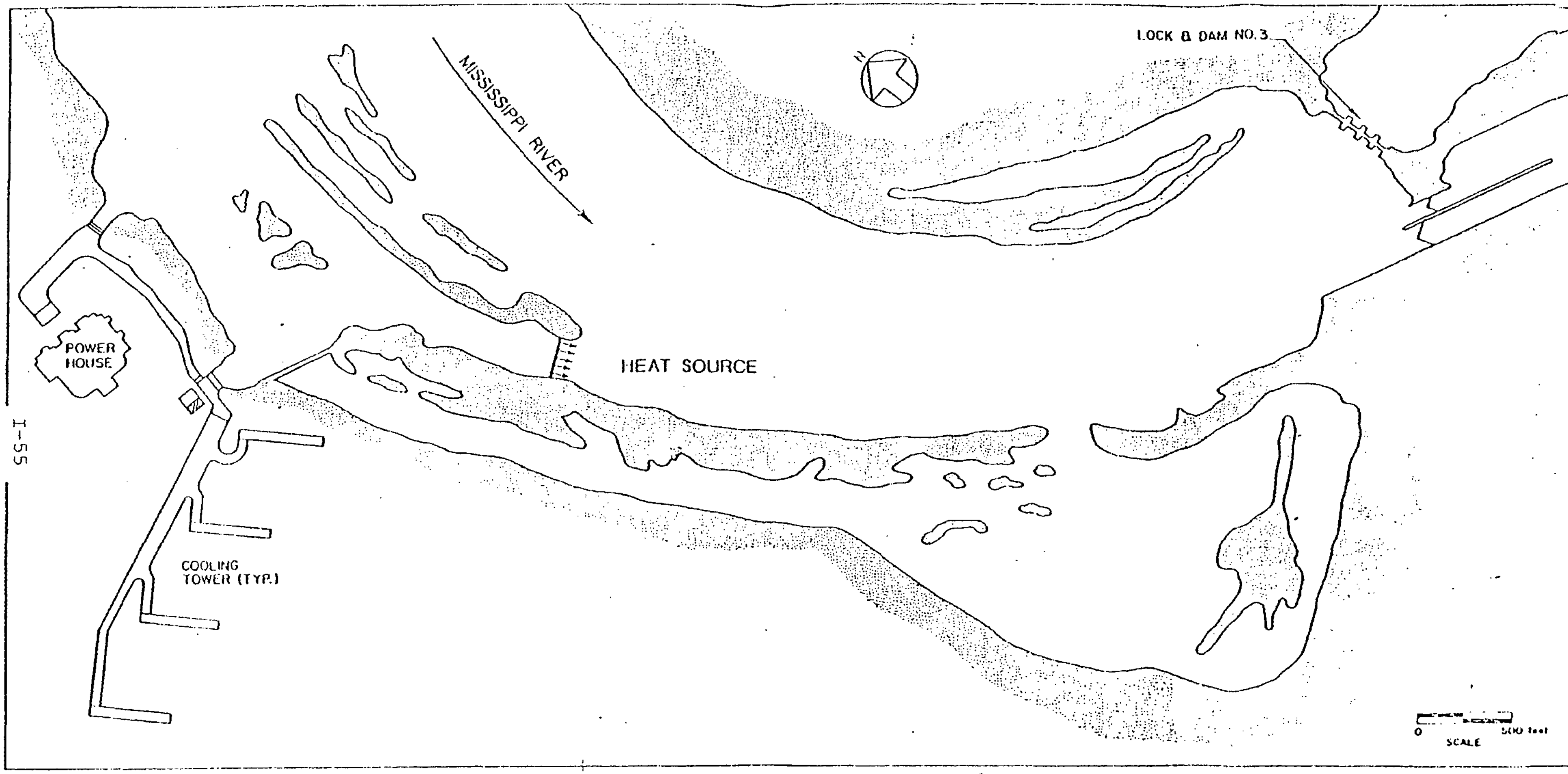


FIGURE 4-2

MISSISSIPPI RIVER LAYOUT
THERMAL DISCHARGE ANALYSIS
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

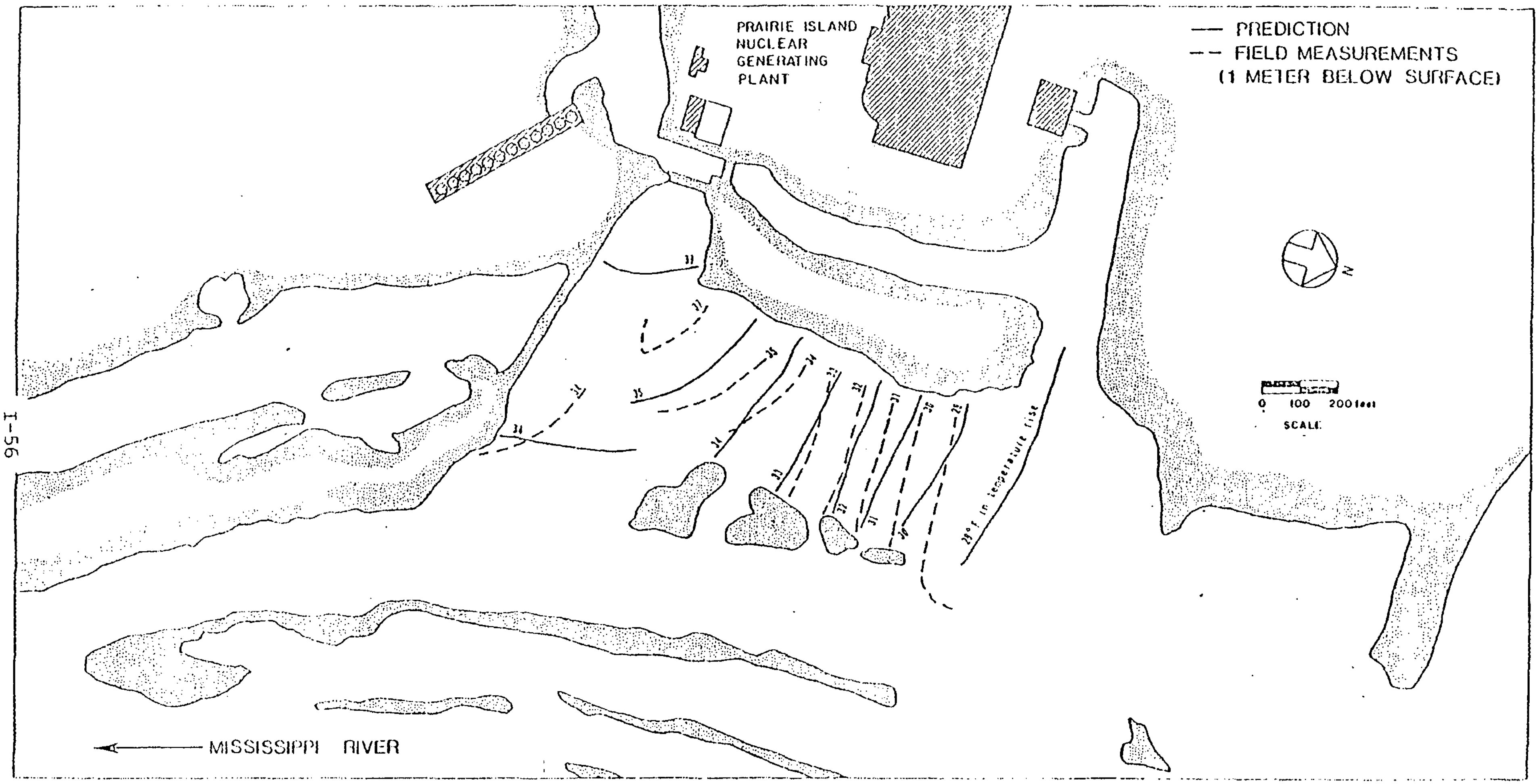
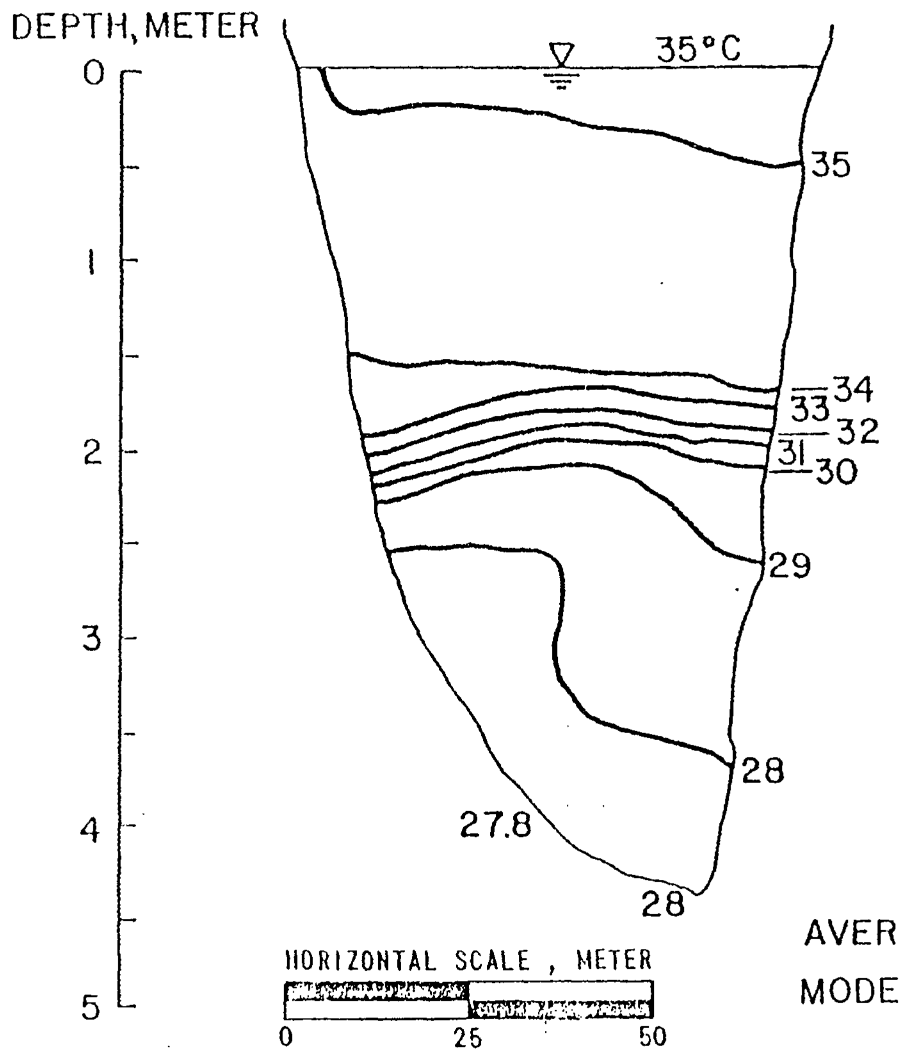


FIGURE 4-3

COMPARISON BETWEEN PREDICTED AND MEASURED ISOTHERMAL LINES, AUGUST 1, 1975
THERMAL DISCHARGE ANALYSIS
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY



(1) TEMP. °C	(2) AREA %	(3) TEMP. RISE °F	(4) WEIGHT (2) X (3)
35			
	9.2	14.0	1.3
35			
	37.3	13.1	4.9
34			
	4.4	11.3	0.5
33			
	3.1	9.5	0.3
32			
	2.1	7.7	0.2
31			
	2.8	5.9	0.2
30			
	5.0	4.1	0.2
29			
	20.3	2.3	0.5
28			
	15.9	1.4	0.2
28			

AVERAGE FIELD TEMPERATURE RISE = 8.3 °F

MODEL PREDICTED TEMPERATURE RISE = 8.1 °F

FIGURE 4-4
TOTAL HEAT RELEASED INTO MAIN CHANNEL OF MISSISSIPPI RIVER
THERMAL DISCHARGE ANALYSIS
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

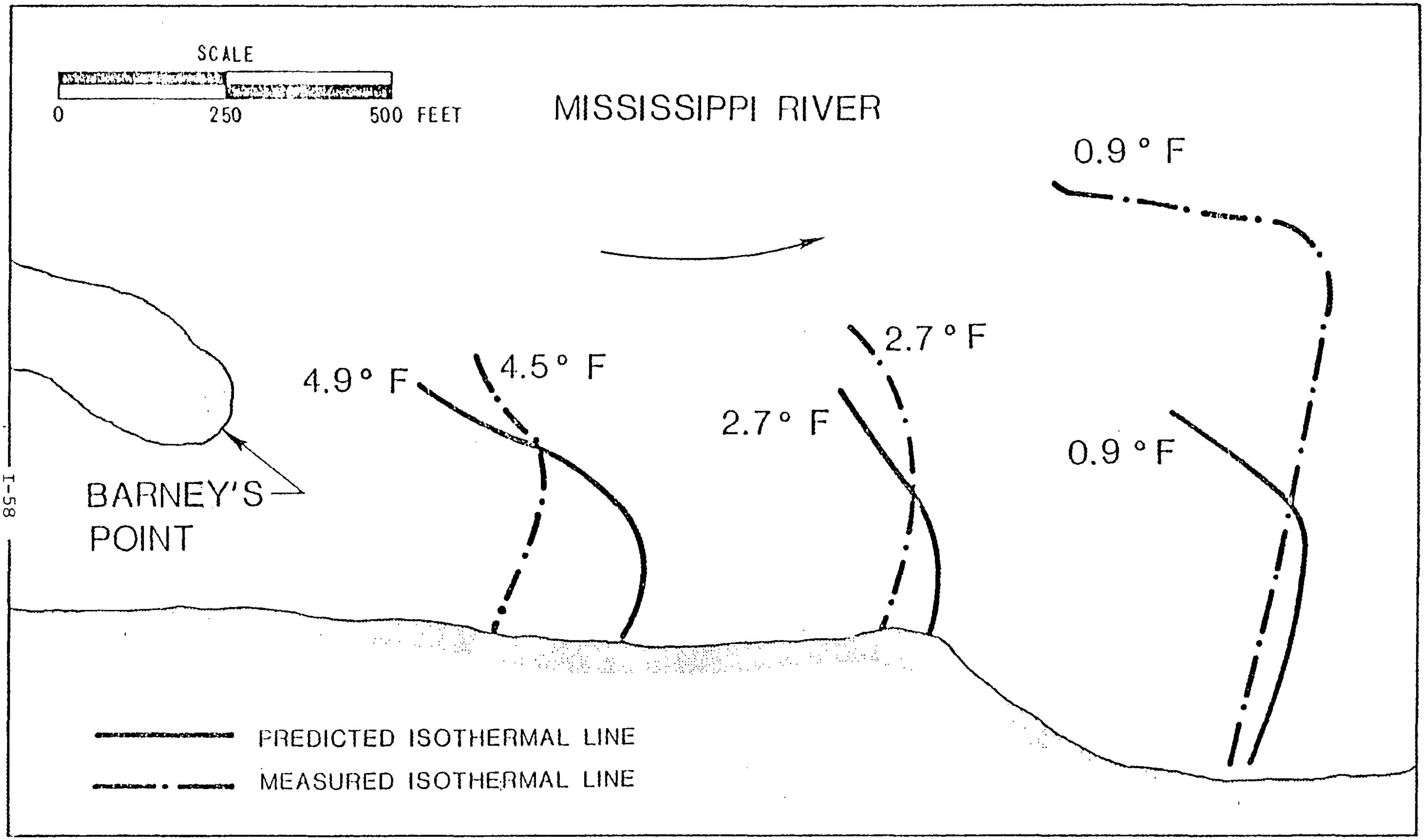


FIGURE 4-5
COMPARISON BETWEEN PREDICTED AND MEASURED
ISOTHERMAL LINES, SEPTEMBER 5, 1975
THERMAL DISCHARGE ANALYSIS
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

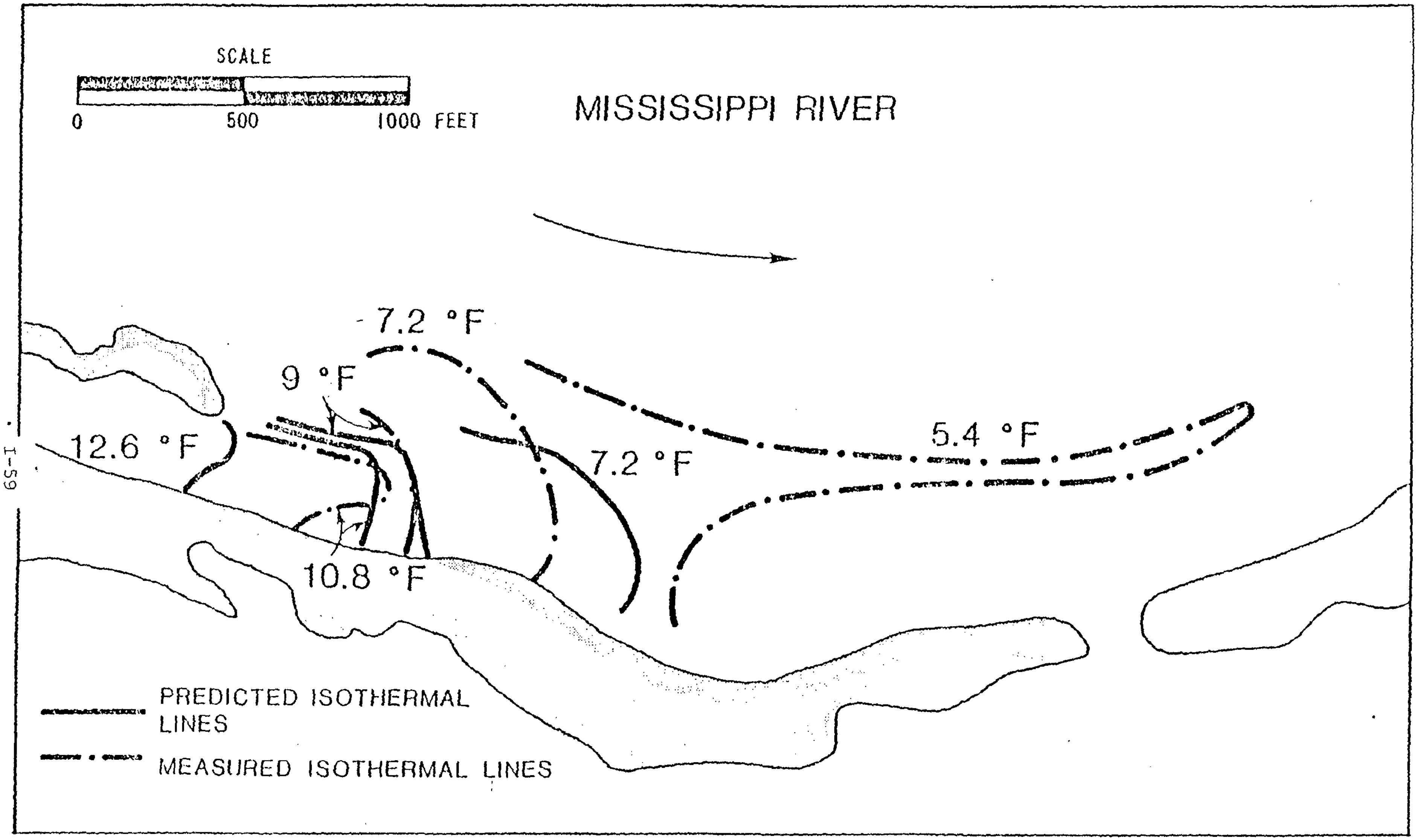


FIGURE 4-6
COMPARISON BETWEEN PREDICTED AND MEASURED
ISOTHERMAL LINES, AUGUST 1, 1975
THERMAL DISCHARGE ANALYSIS
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

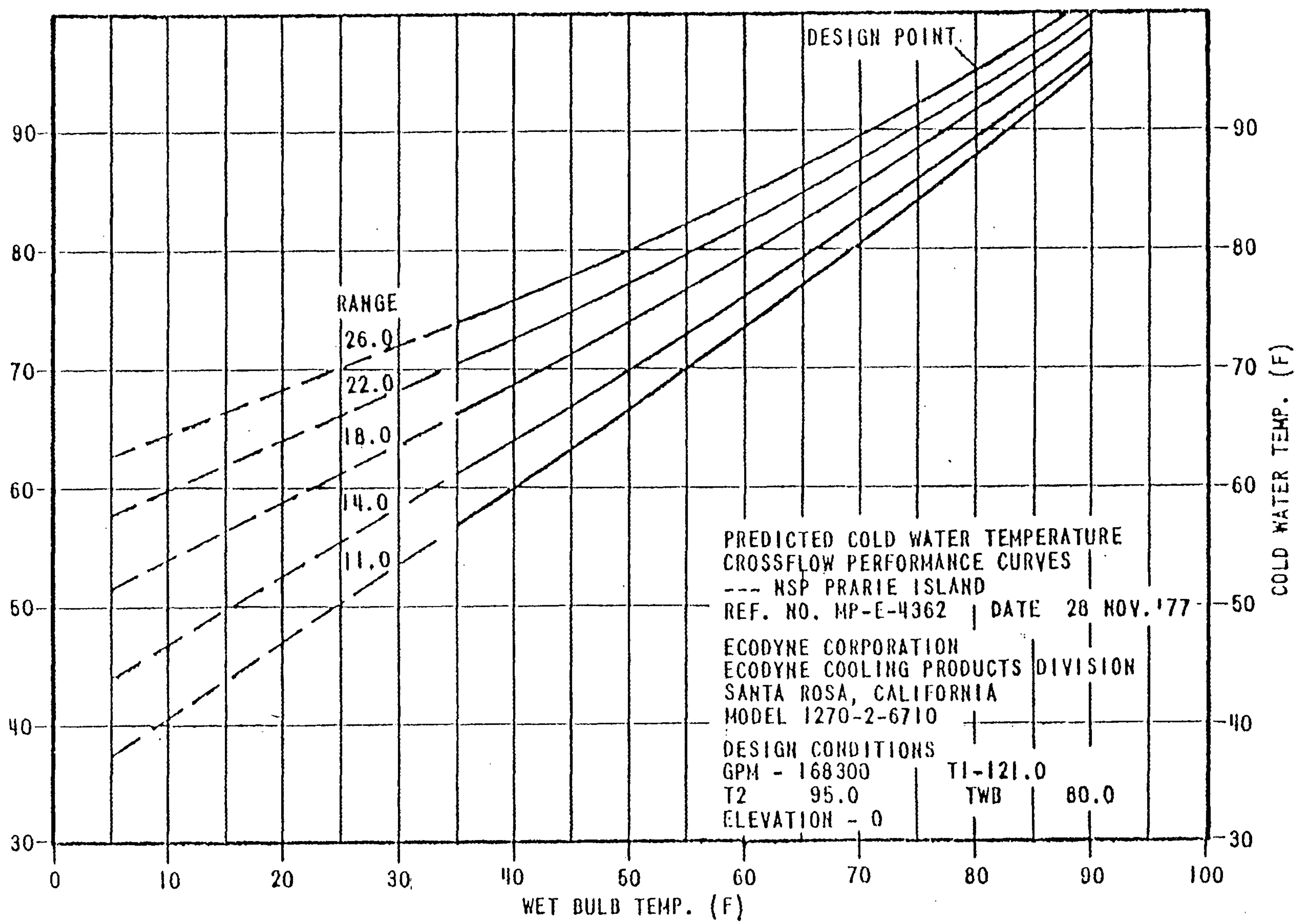


FIGURE 4-7

COOLING TOWER PERFORMANCE CURVE

THERMAL DISCHARGE ANALYSIS
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

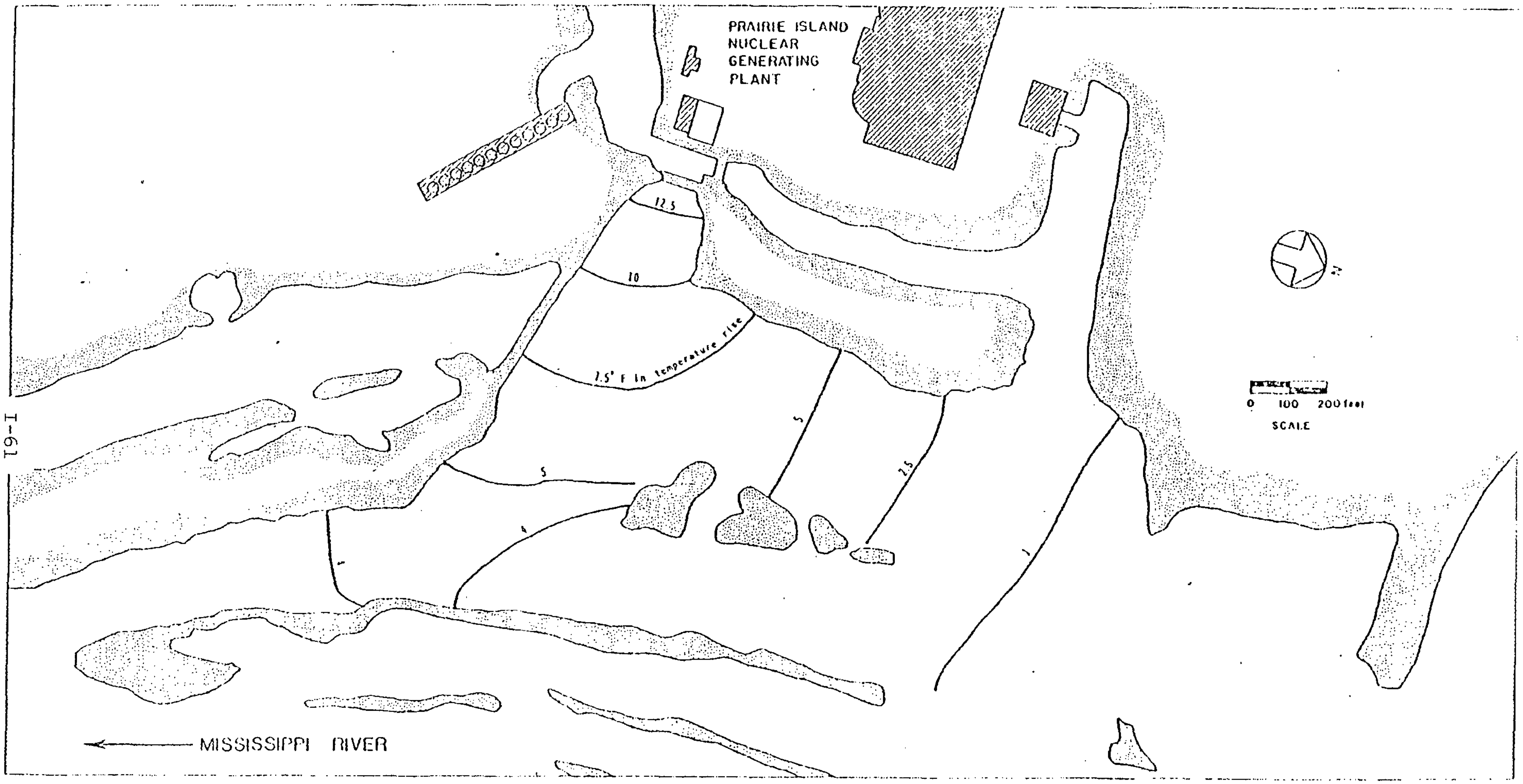


FIGURE 5-1

PREDICTED ISOTHERMAL CONFIGURATIONS IN SITE VICINITY AUGUST, 1975 TYPICAL CONDITION
THERMAL DISCHARGE ANALYSIS
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

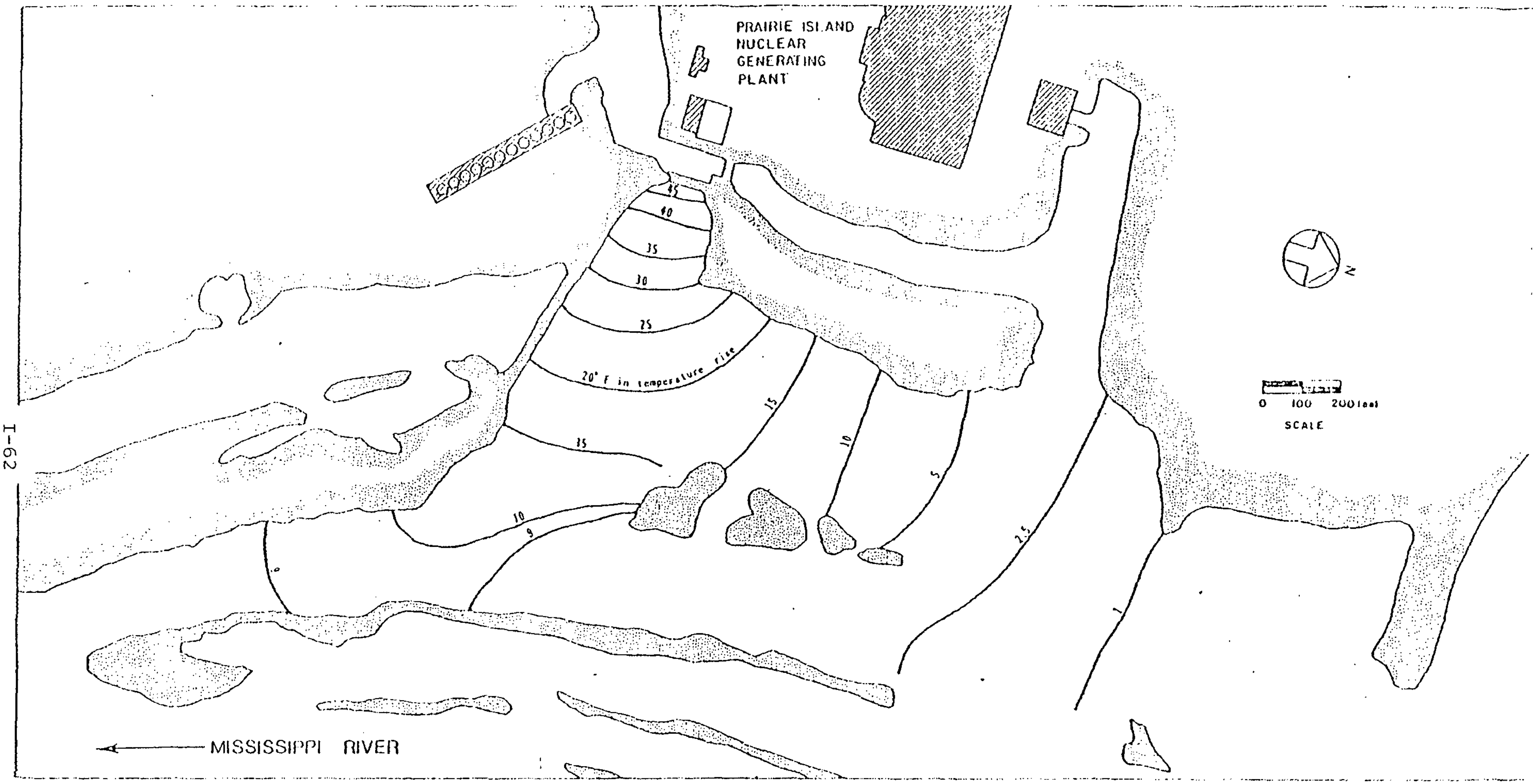


FIGURE 5-2

PREDICTED ISOTHERMAL CONFIGURATIONS IN SITE VICINITY DECEMBER, 1975 TYPICAL CONDITION
THERMAL DISCHARGE ANALYSIS
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

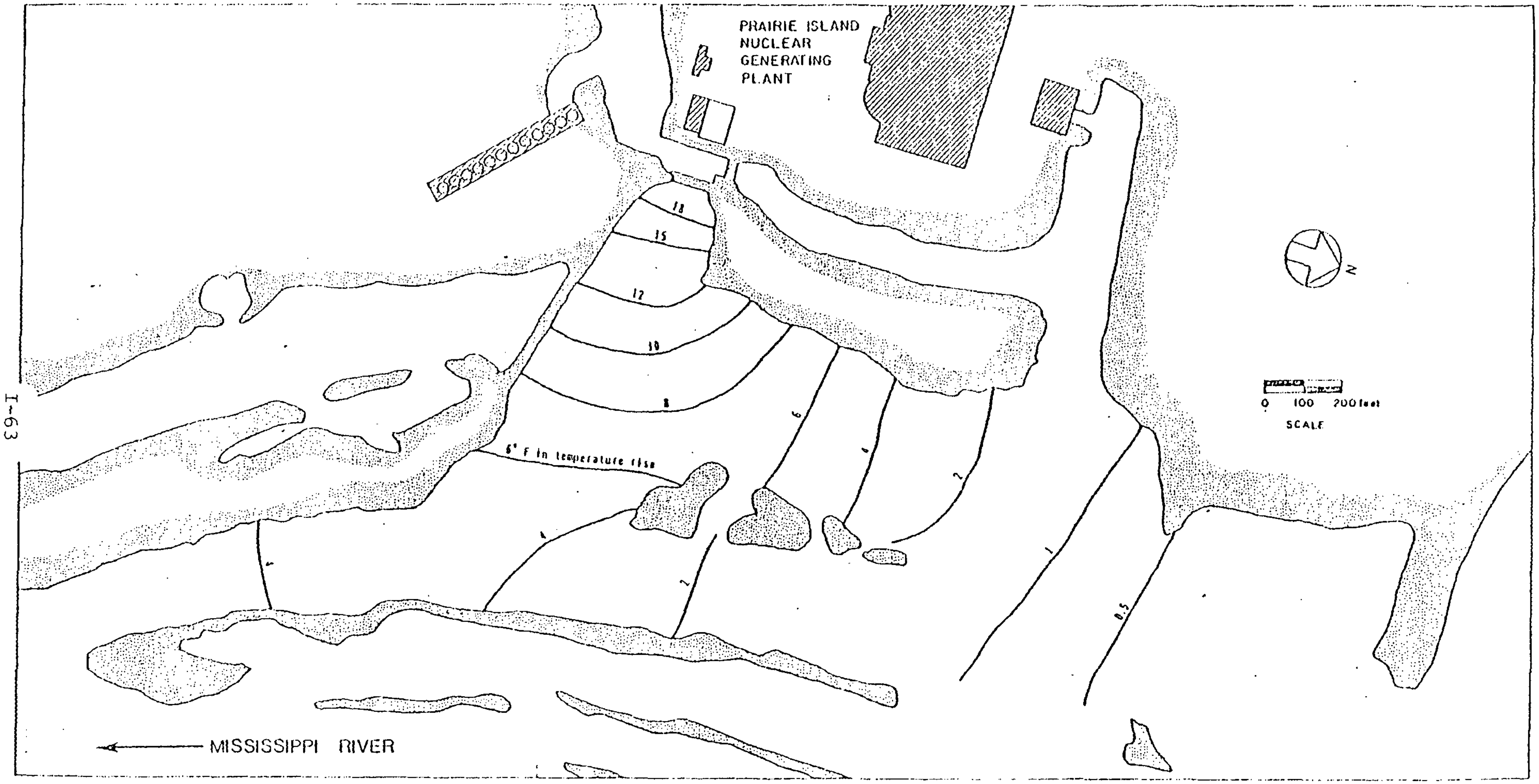


FIGURE 5-3
PREDICTED ISOTHERMAL CONFIGURATIONS IN SITE VICINITY MAY, 1976 TYPICAL CONDITION
THERMAL DISCHARGE ANALYSIS
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

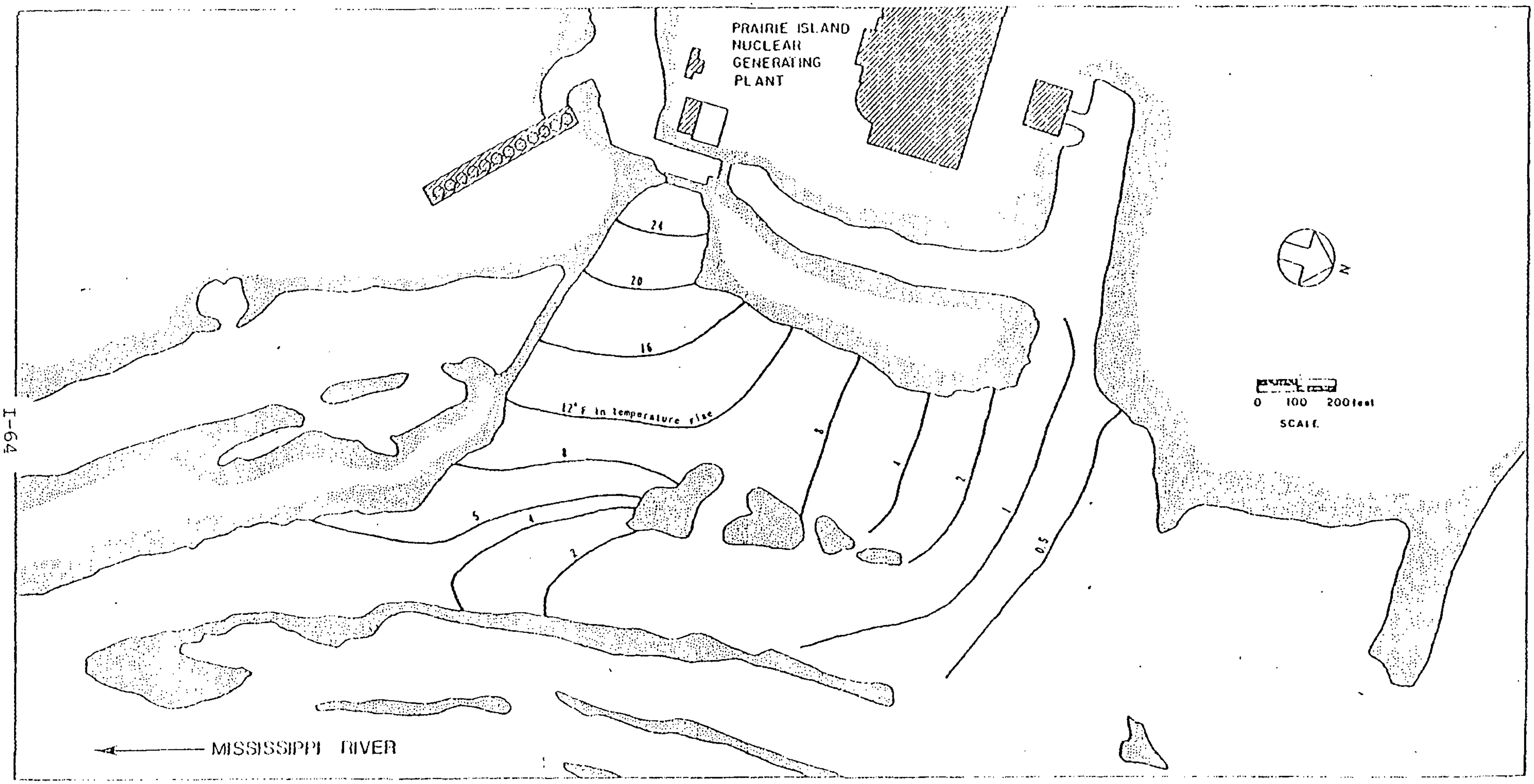


FIGURE 5-4

PREDICTED ISOTHERMAL CONFIGURATIONS IN SITE VICINITY JUNE, 1975 EXTREME CONDITION
THERMAL DISCHARGE ANALYSIS
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

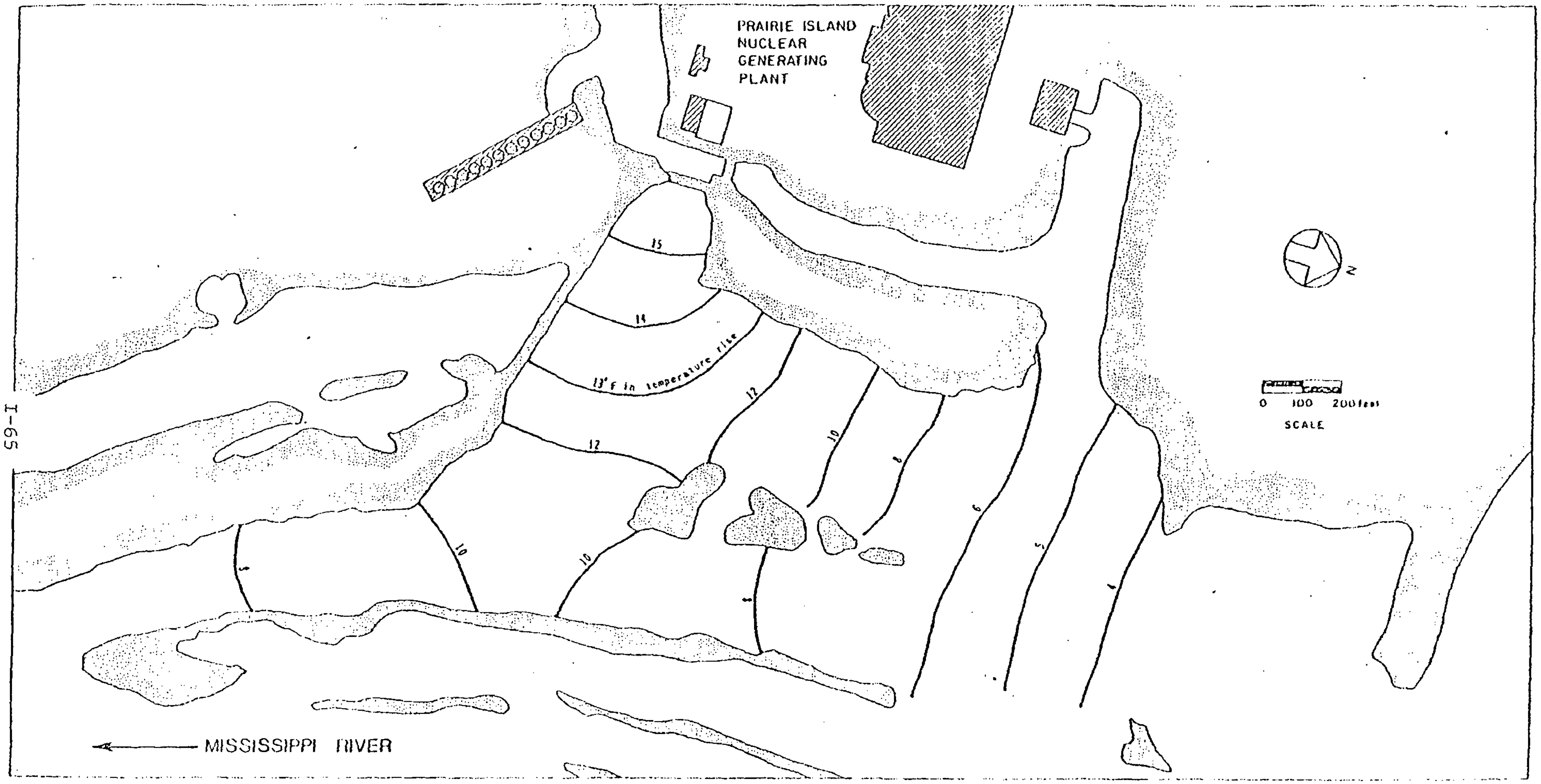


FIGURE 5-5

PREDICTED ISOTHERMAL CONFIGURATIONS IN SITE VICINITY AUGUST, 1976 EXTREME CONDITION
THERMAL DISCHARGE ANALYSIS
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

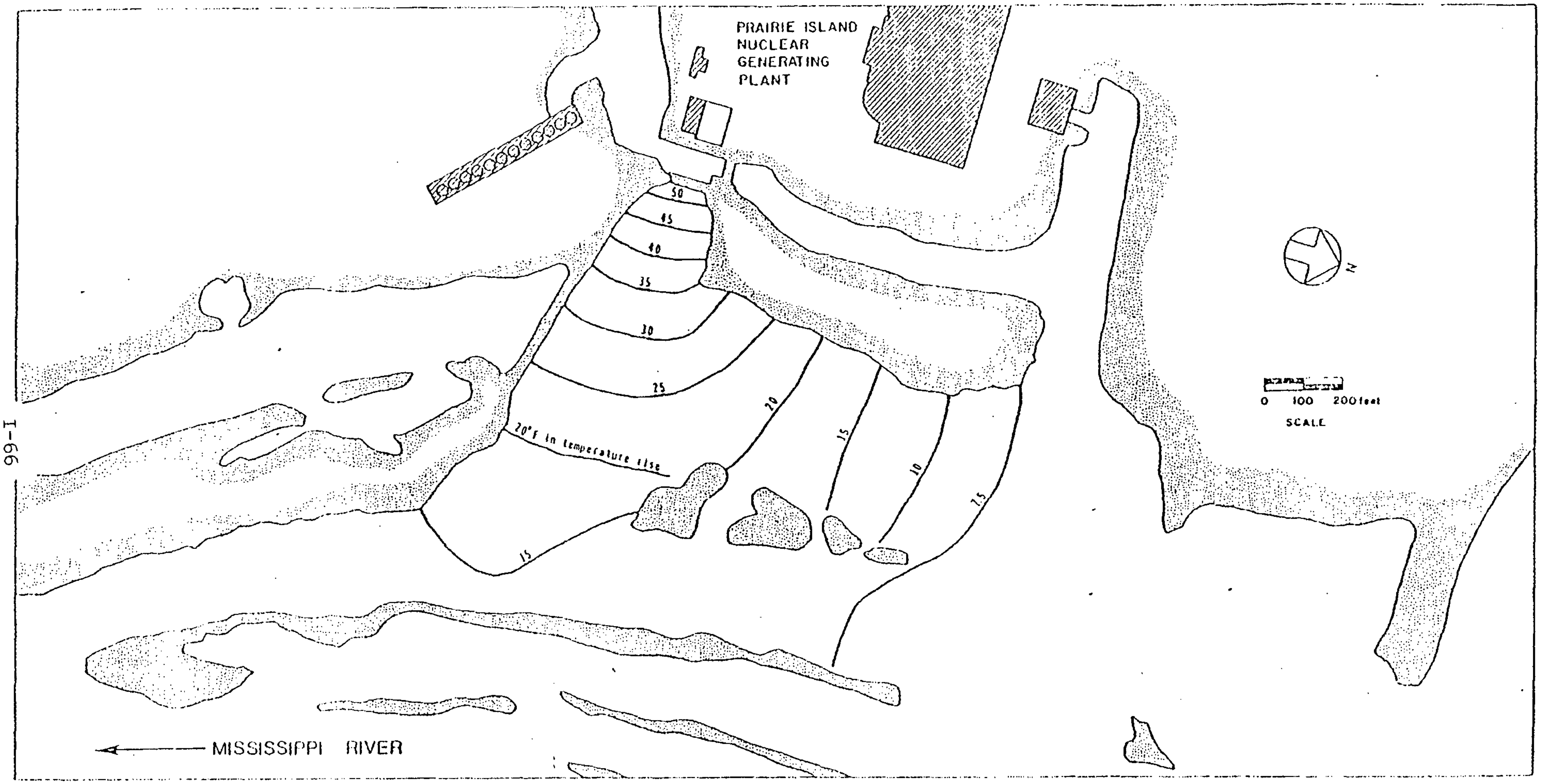


FIGURE 5-6

PREDICTED ISOTHERMAL CONFIGURATIONS IN SITE VICINITY JANUARY PROP. EXTREME CONDITION
THERMAL DISCHARGE ANALYSIS
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

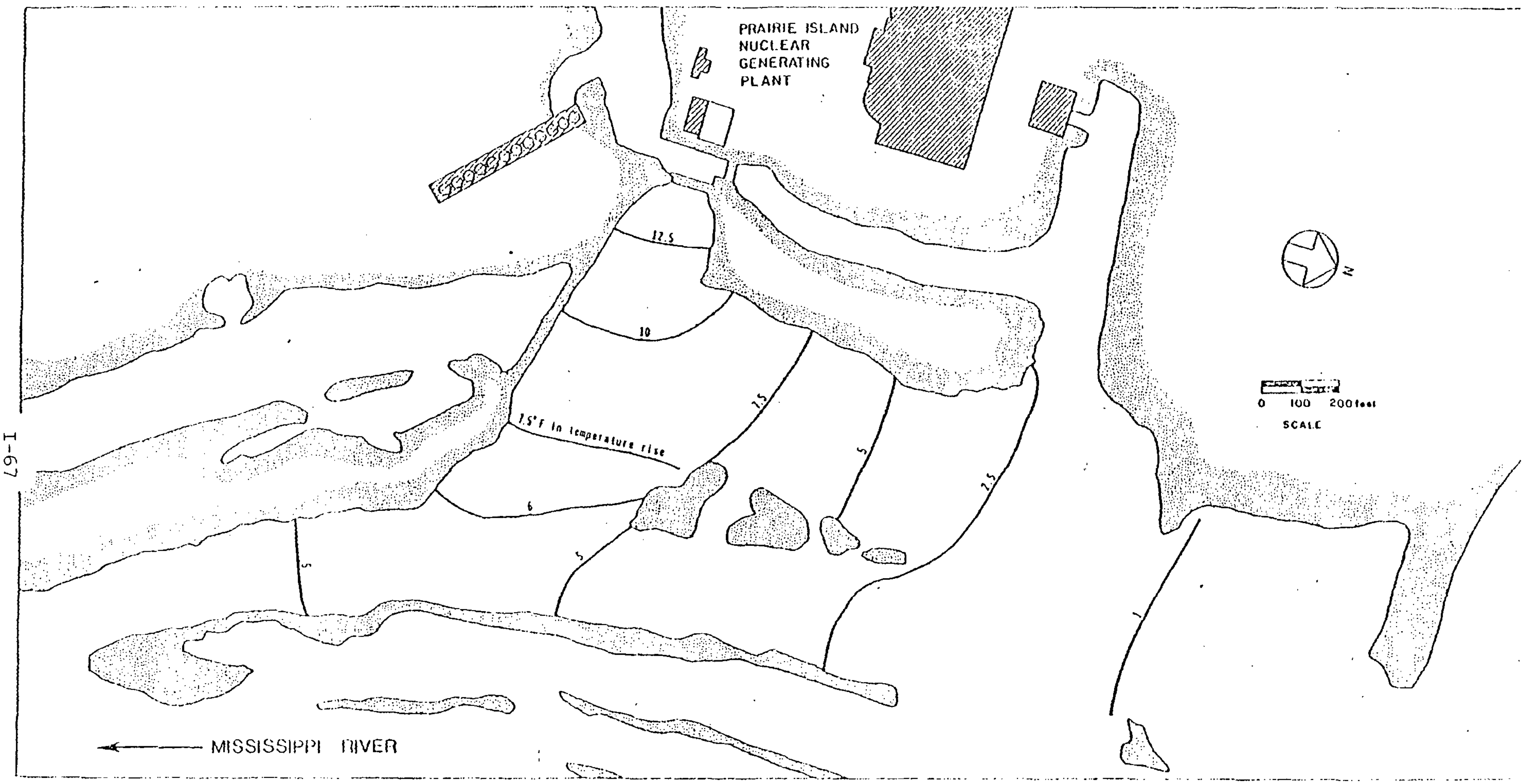


FIGURE 5-7

PREDICTED ISOTHERMAL CONFIGURATIONS IN SITE VICINITY MAY PROP. EXTREME CONDITION
THERMAL DISCHARGE ANALYSIS
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

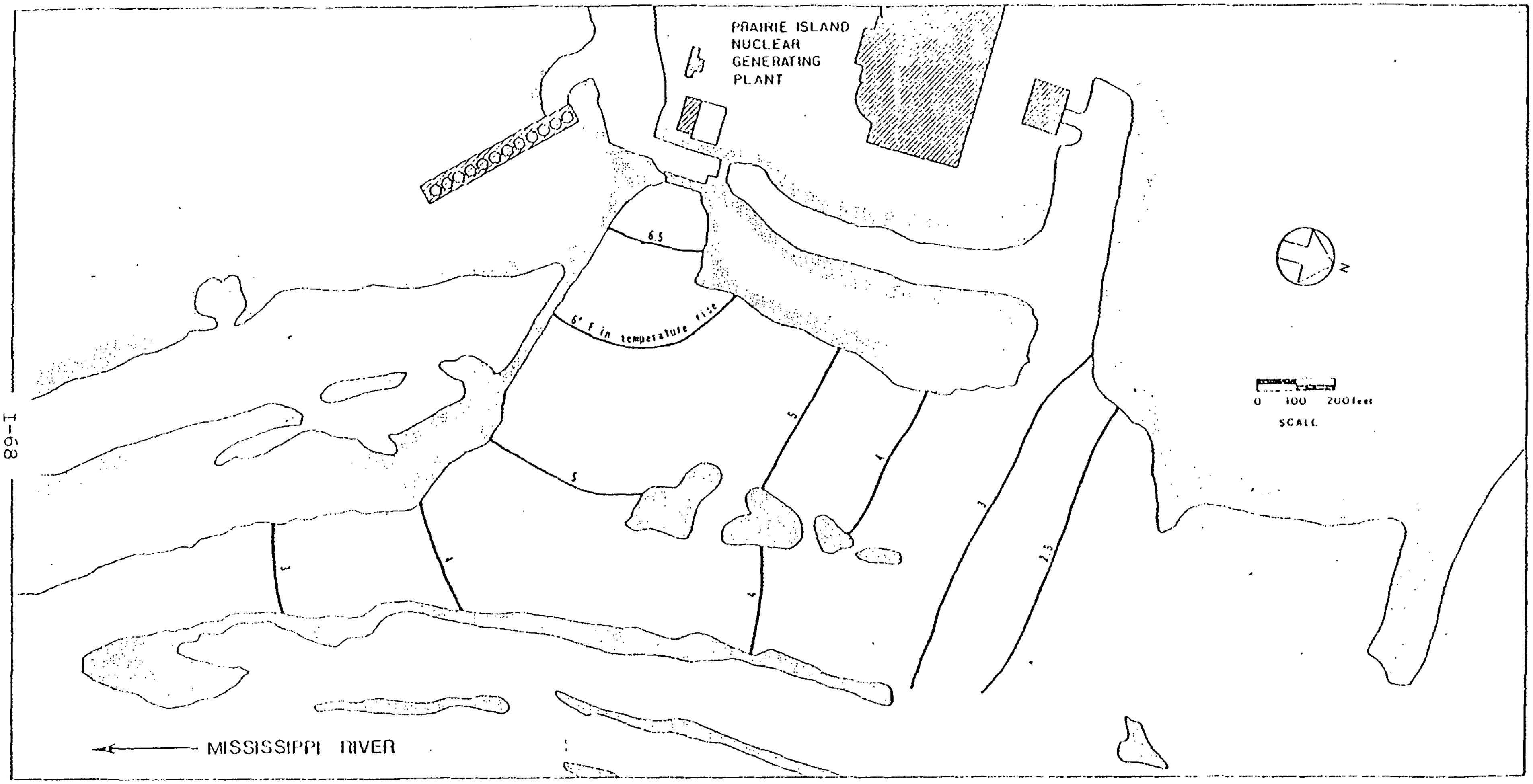


FIGURE 5-8

PREDICTED ISOTHERMAL CONFIGURATIONS IN SITE VICINITY AUGUST PROP. EXTREME CONDITION
THERMAL DISCHARGE ANALYSIS
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

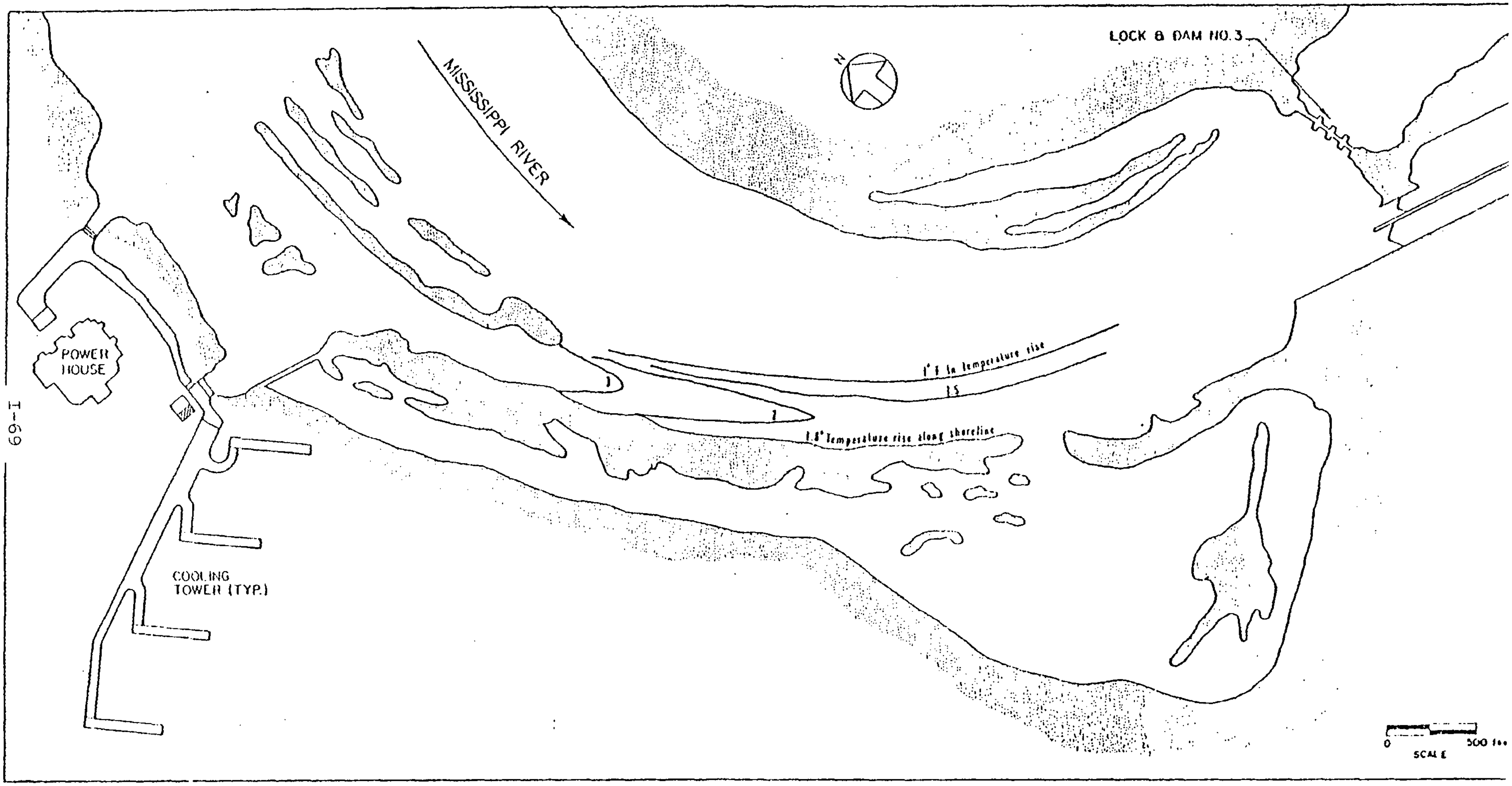


FIGURE 5-9

PREDICTED ISOTHERMAL CONFIGURATIONS IN MISSISSIPPI RIVER AUGUST, 1975 TYPICAL CONDITION
THERMAL DISCHARGE ANALYSIS
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

Revised 4/28/78

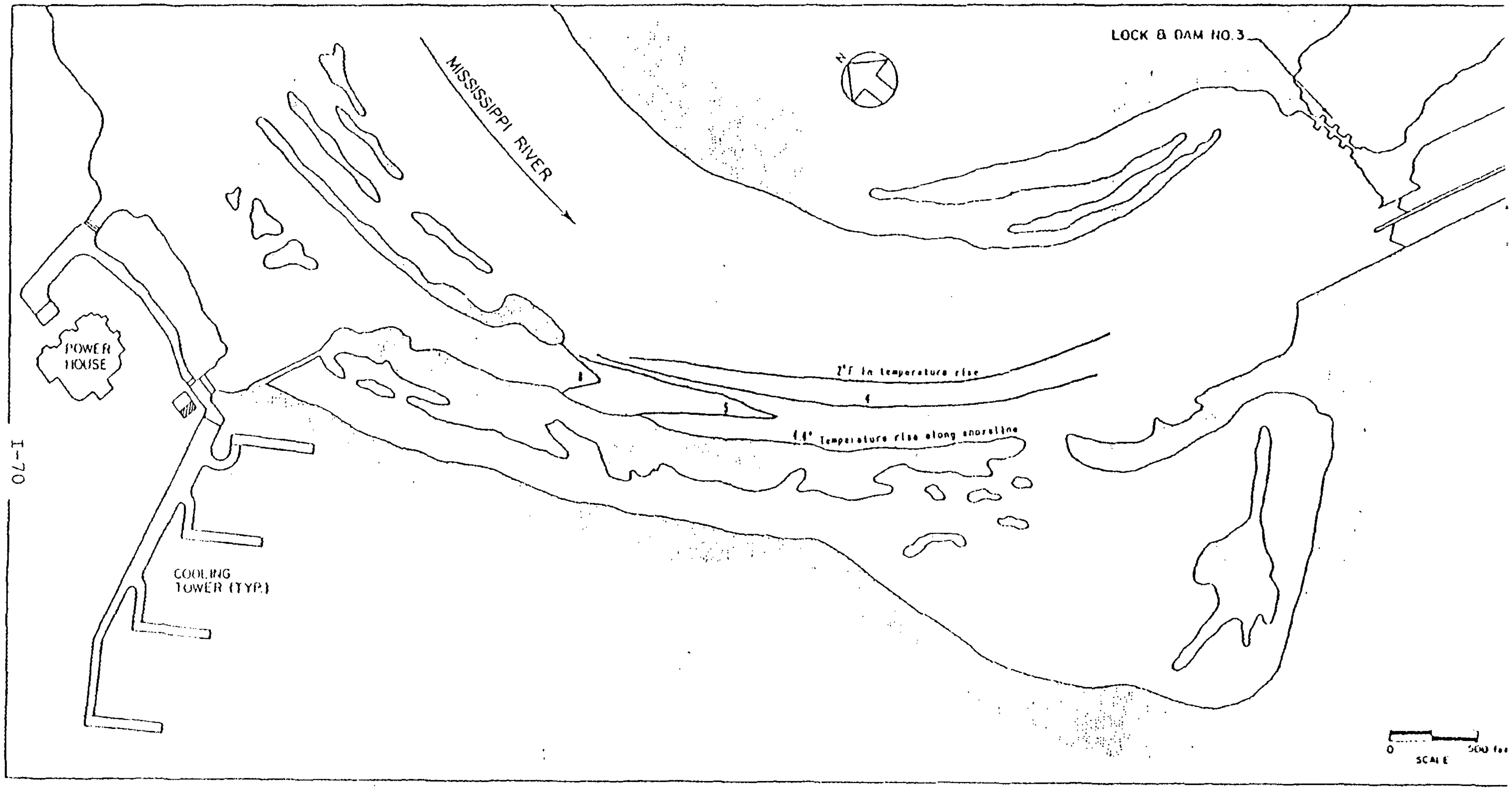


FIGURE 5-10

PREDICTED ISOTHERMAL CONFIGURATIONS IN MISSISSIPPI RIVER DEC. '75 TYPICAL CONDITION

THERMAL DISCHARGE ANALYSIS

PRAIRIE ISLAND NUCLEAR GENERATING PLANT

NORTHERN STATES POWER COMPANY

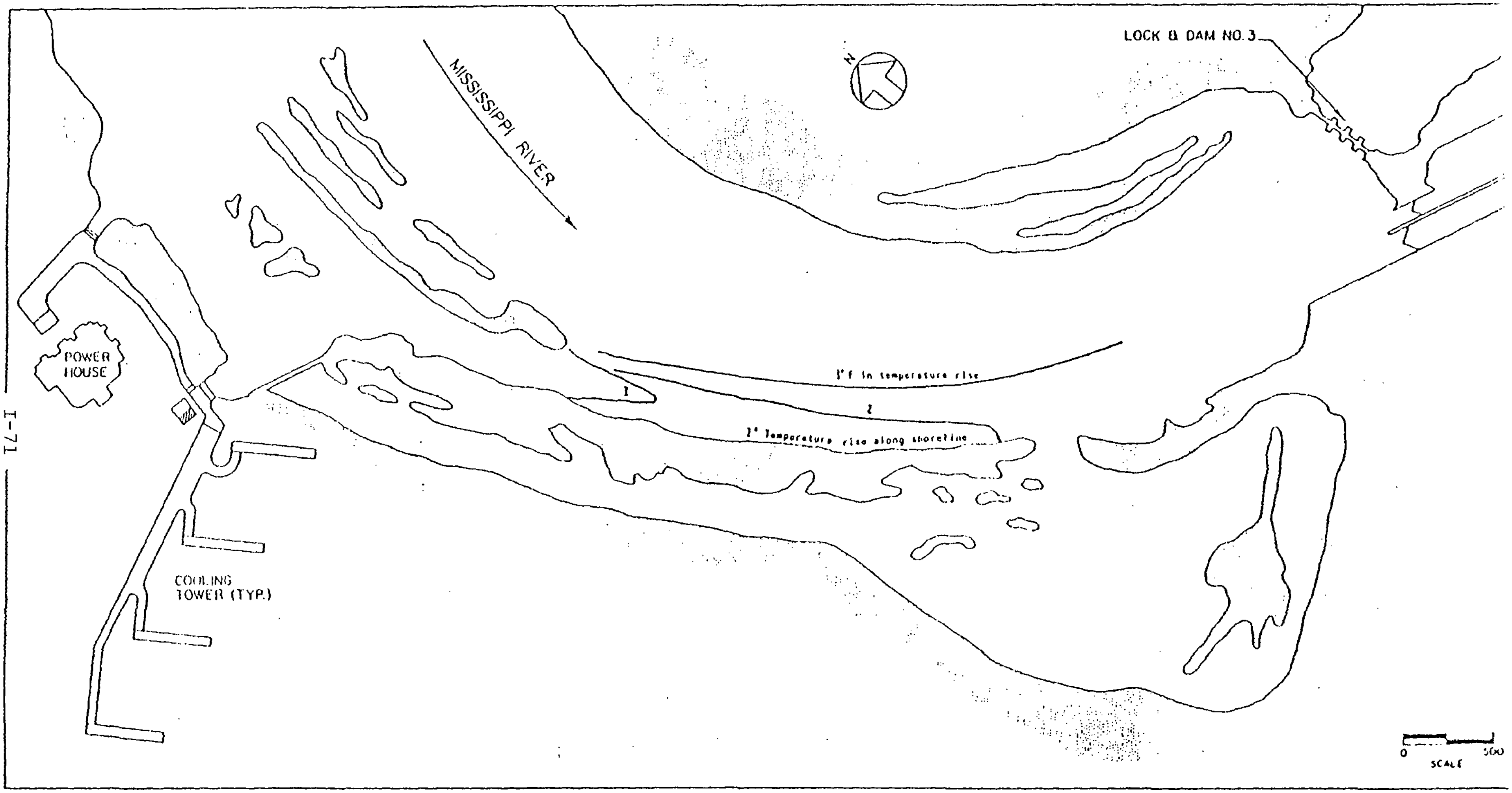


FIGURE 5-11

PREDICTED ISOTHERMAL CONFIGURATIONS IN MISSISSIPPI RIVER MAY '76 TYPICAL CONDITION
THERMAL DISCHARGE ANALYSIS
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

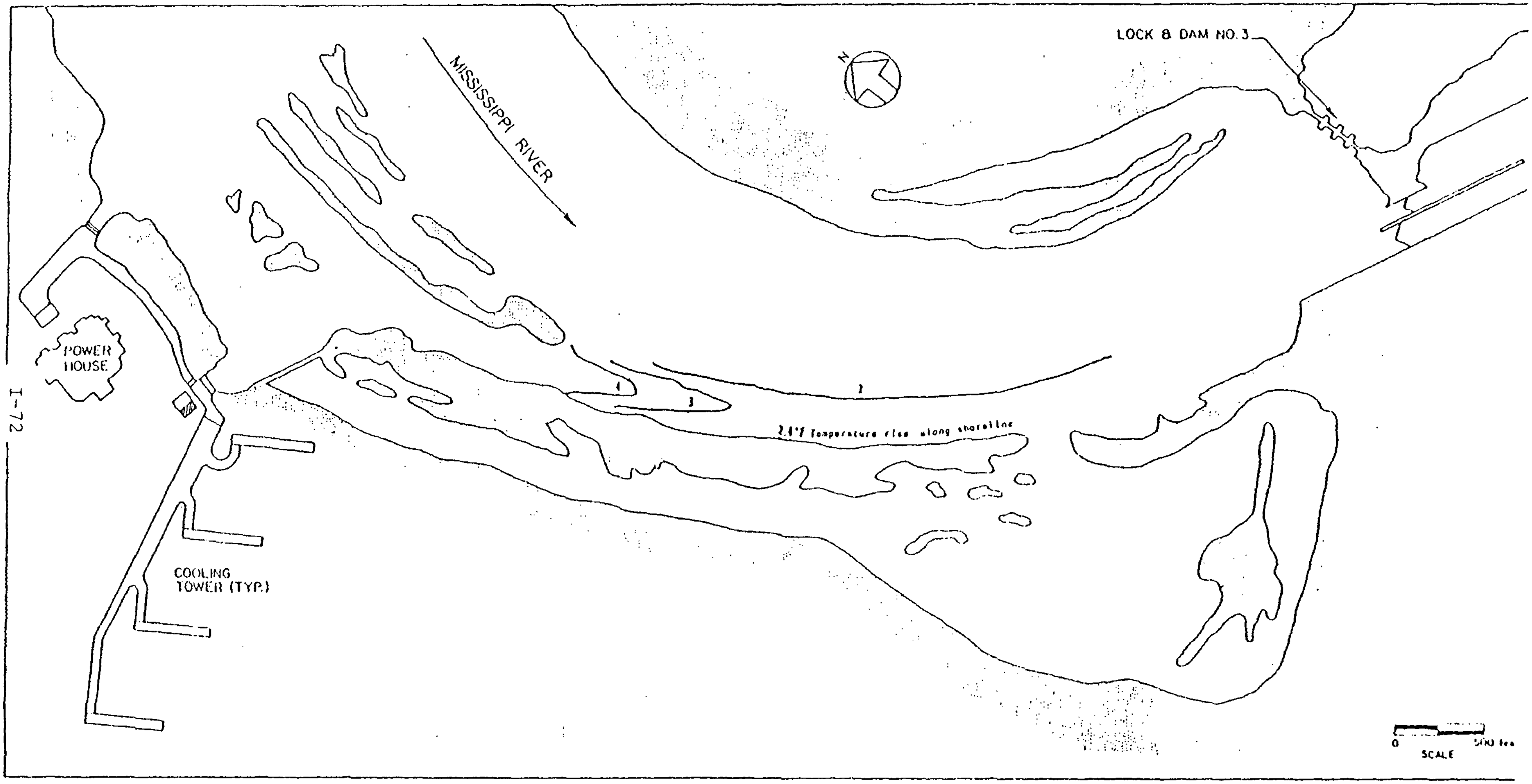


FIGURE 5-12

PREDICTED ISOTHERMAL CONFIGURATIONS IN MISSISSIPPI RIVER JUNE, 1975 EXTREME CONDITION
THERMAL DISCHARGE ANALYSIS
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

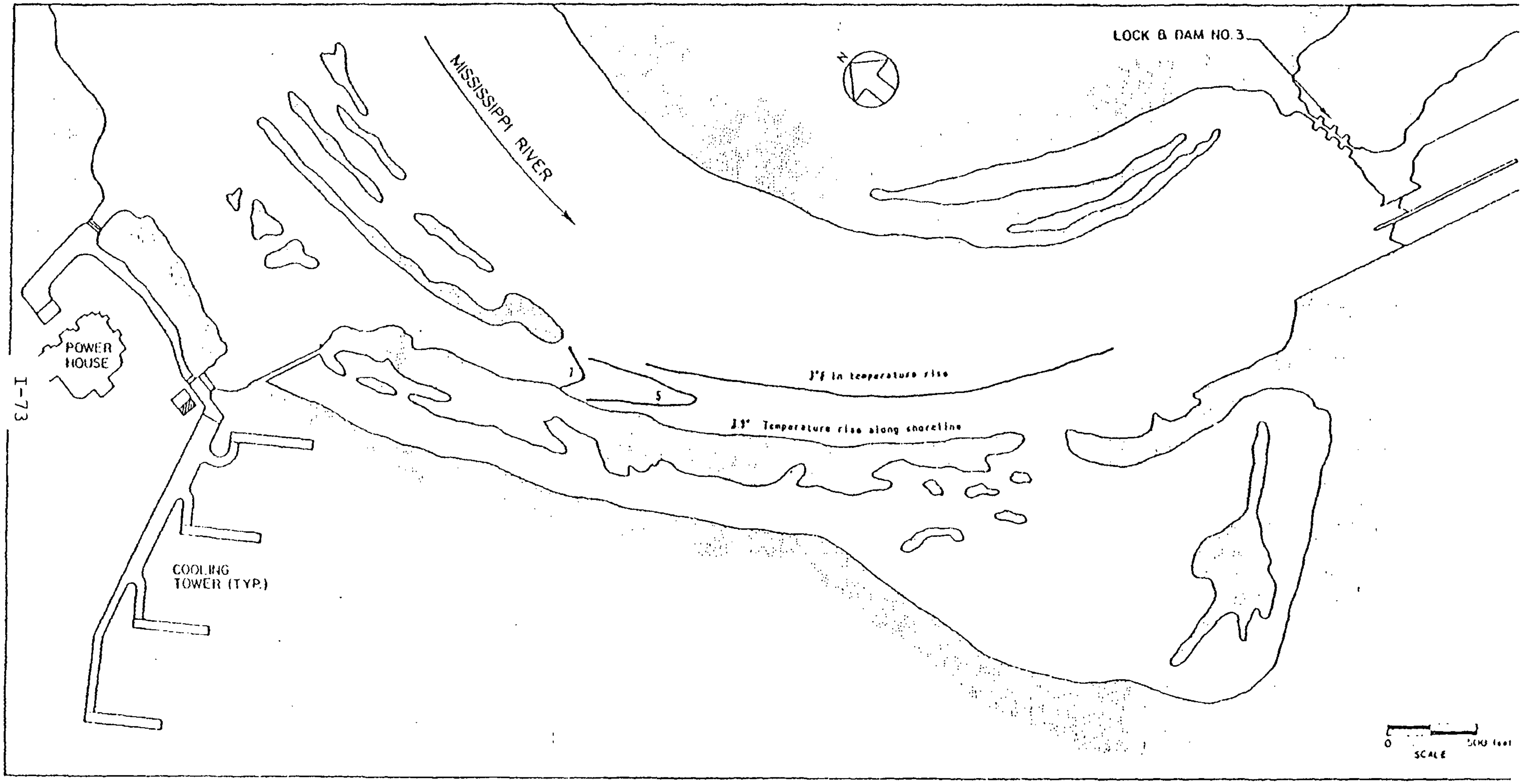


FIGURE 5-13
PREDICTED ISOTHERMAL CONFIGURATIONS IN MISSISSIPPI RIVER AUG. '76 EXTREME CONDITION
THERMAL DISCHARGE ANALYSIS
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

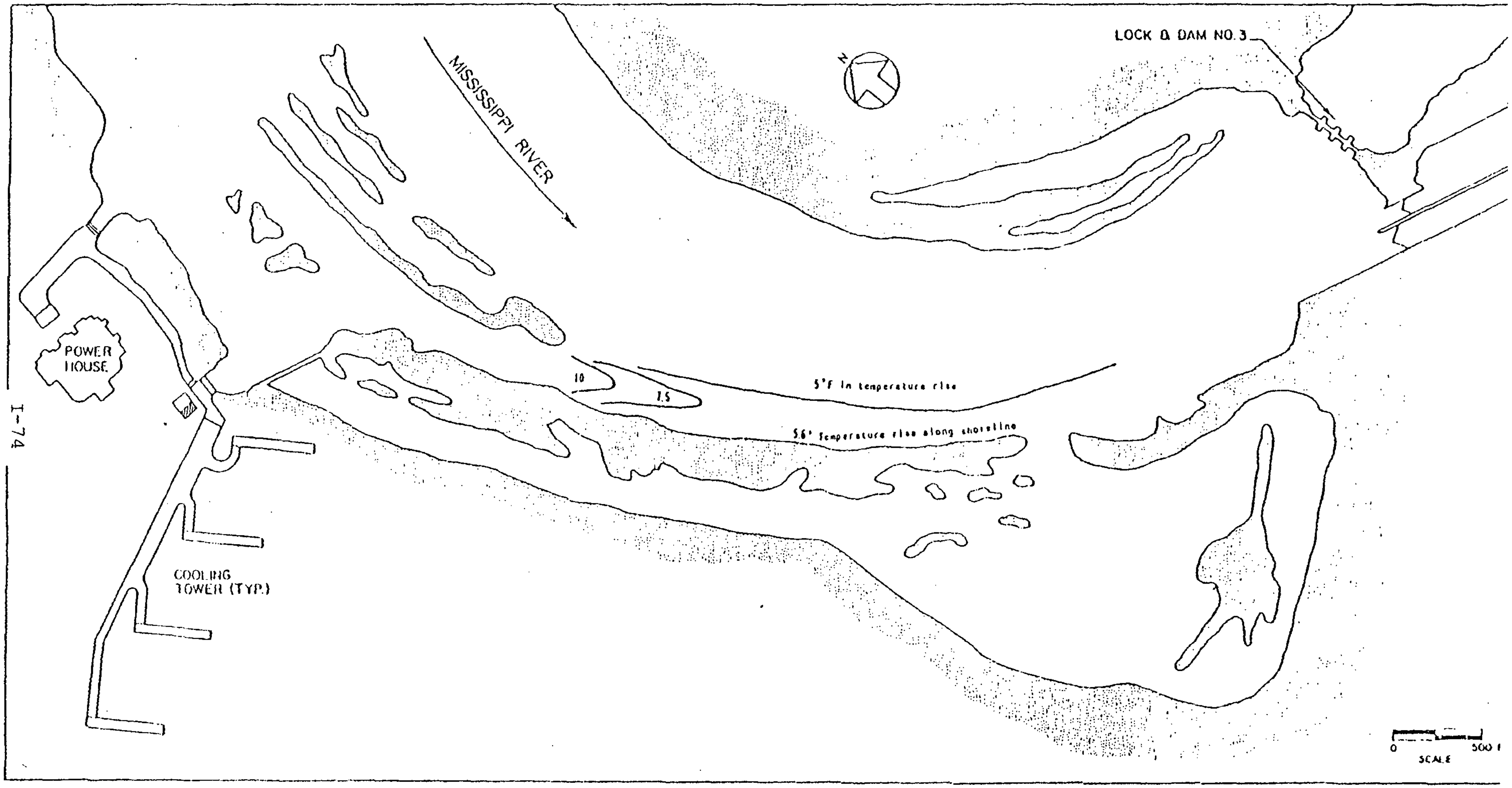


FIGURE 5-14

PREDICTED ISOTHERMAL CONFIGURATIONS IN MISSISSIPPI RIVER JAN. PROP. EXTREME CONDITION
THERMAL DISCHARGE ANALYSIS
PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NORTHERN STATES POWER COMPANY

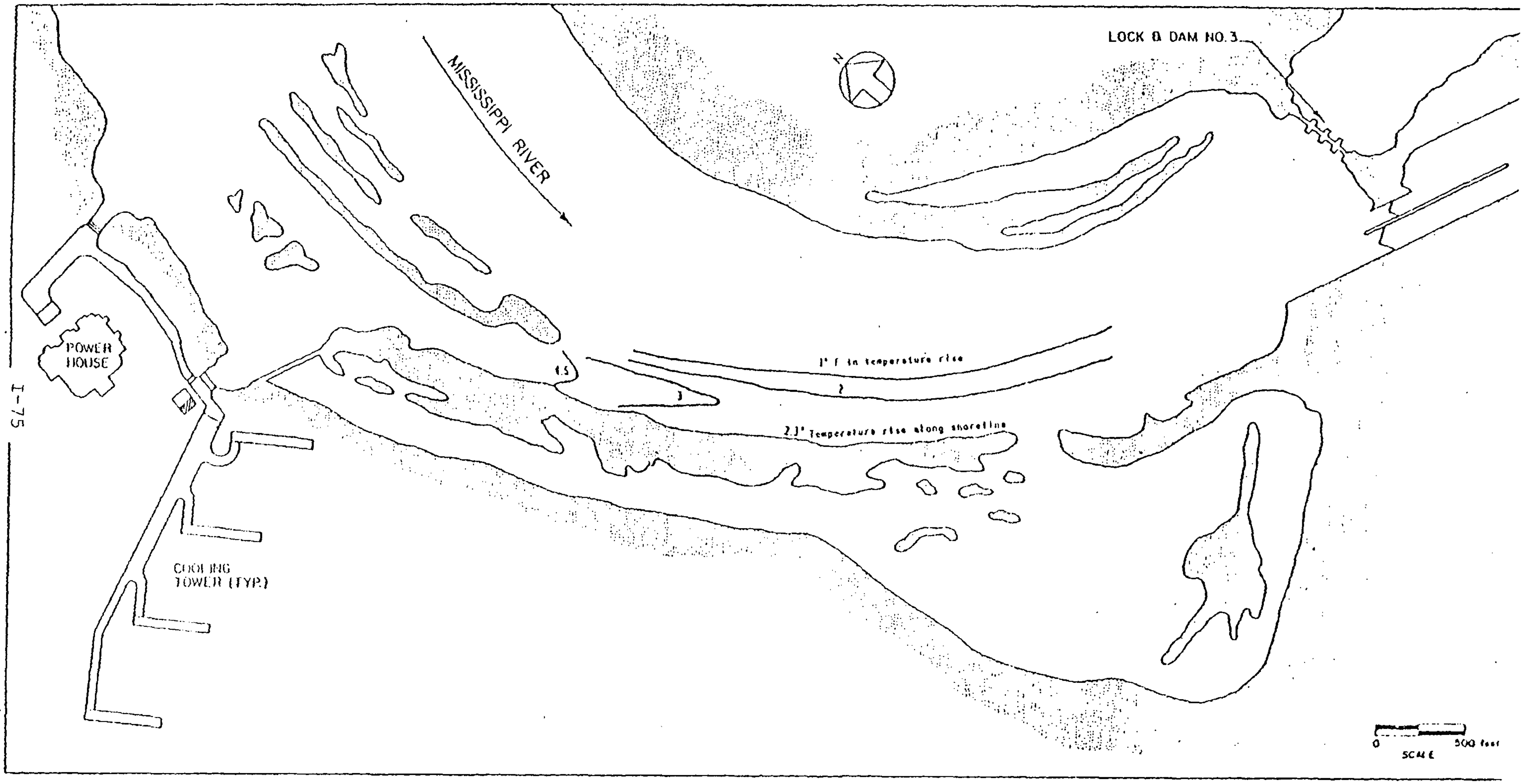


FIGURE 5-15

PREDICTED ISOTHERMAL CONFIGURATIONS IN MISSISSIPPI RIVER MAY PROP. EXTREME CONDITION

THERMAL DISCHARGE ANALYSIS

PRAIRIE ISLAND NUCLEAR GENERATING PLANT

NORTHERN STATES POWER COMPANY

APPENDIX A

Pertinent entries from the Prairie Island Environmental Event Log have been transcribed to a computer file maintained at Northern States Power Company's general office and are reproduced in the following table. Columns 1 through 5 in the table represent an entry in the Environmental Event Log sheet which occurred each time plant blowdown flow was changed. Entries by column numbers are described as follows:

Column 1: the month, day and year of the records

Column 2: time of the day at which the entry was made

Column 3: blowdown flow

Column 4: condenser inlet temperature

Column 5: river temperature measured at the sensors located in the plant intake canal on the river site of the skimmer wall

Column 6: river temperatures measured at Red Wing Steam Plant

Column 7: river temperatures measured at Lock & Dam No. 3

Column 8: wet bulb temperature measured at Twin Cities Airport

Column 9: number of cooling towers in operation

Column 10: plant discharge temperature

Column 11: evaporation rate

Column 12: monthly average temperature at Red Wing

Column 13: monthly average discharge temperature

Column 14: monthly average blowdown rate

Column 15: monthly average evaporation

MODAYR	TIME	BLOW DOWN	COND TEMP	RIVER TEMPS PI	RW	LD3	WET BULB	TW	DISCH TEMP	EVAP	MONTHLY AVE RIVR	DISCH	B DN	EVAP
2 175	0	185	******	33.0	33.0	33.8	12.0	3	9999.0	10.0				
21275	1300	185	72.3	32.1	32.0	33.8	7.0	3	75.7	31.1				
21275	1400	200	68.1	32.1	32.0	33.8	4.0	3	74.2	27.3				
21275	1500	255	******	****	32.0	33.8	4.0	3	9999.0	27.3				
21275	1651	260	65.0	32.1	32.0	33.8	2.0	3	74.8	21.8				
21375	1434	150	57.0	32.1	32.0	34.7	5.0	3	73.8	11.6				
21575	1540	244	65.0	32.1	33.0	35.6	25.0	3	73.8	23.3				
21575	2025	280	61.0	32.1	33.0	35.6	24.0	3	70.9	21.6				
21575	2100	350	65.0	32.1	33.0	35.6	24.0	3	73.6	23.5				
21675	200	150	64.4	32.1	33.0	35.6	23.0	3	73.1	23.5				
21675	330	244	74.2	32.2	33.0	35.6	23.0	3	79.2	28.9				
21775	830	330	72.0	32.1	33.0	35.6	27.0	3	78.4	26.8				
21775	1050	410	67.1	32.1	33.0	35.6	28.0	3	75.5	23.8				
21975	30	300	62.7	32.1	33.0	35.6	7.0	3	73.2	20.8				
21975	1230	374	62.0	32.1	33.0	35.6	20.0	3	71.0	23.0				
21975	1430	340	66.0	32.1	33.0	35.6	22.0	3	74.0	24.5				
22075	30	374	58.5	32.0	34.0	35.6	15.0	3	70.6	18.5				
22075	440	420	61.7	32.0	34.0	35.6	7.0	3	73.2	19.4				
22275	114	140	60.0	32.0	34.0	35.6	32.0	3	71.5	19.3				
22275	1300	330	67.0	32.0	34.0	35.6	27.0	3	75.3	24.0				
22275	1915	400	62.5	32.0	34.0	35.6	25.0	3	72.1	22.1				
22375	400	150	54.7	32.1	34.0	35.6	24.0	3	67.6	17.3				
22375	610	330	69.7	32.1	34.0	35.6	20.0	3	75.9	27.0				
22375	1830	420	69.0	32.2	34.0	35.6	24.0	3	76.1	25.7				
22575	1415	328	64.0	32.3	34.0	38.3	29.0	4	68.6	29.3				
22675	541	420	66.0	32.0	33.0	36.5	19.0	4	69.2	31.3				
22675	1813	330	64.1	32.5	33.0	36.5	20.0	4	68.9	29.1				
22775	615	420	65.7	32.4	33.0	35.6	13.0	4	71.2	28.1				
22775	830	330	60.0	32.4	33.0	35.6	15.0	4	70.6	20.7				
22775	1345	295	69.0	32.7	33.0	35.6	26.0	4	70.6	33.8				
											32.1	73.9	263.1	26.4
3 175	500	330	63.0	32.2	33.0	35.6	4.0	4	74.2	19.8				
3 175	630	360	60.9	32.2	33.0	35.6	4.0	4	74.2	16.8				
3 175	230	295	67.0	32.3	33.0	35.6	7.0	4	73.2	27.1				
3 375	309	230	60.8	32.2	33.0	34.7	4.0	4	74.2	16.6				
3 475	1330	295	66.1	32.1	32.0	35.6	17.0	4	69.9	30.5				
3 875	1518	150	62.1	32.8	34.0	35.6	15.0	4	70.6	23.8				
31775	620	225	65.0	33.0	36.0	41.0	28.0	4	69.0	30.3				
31775	1130	295	72.0	33.0	36.0	41.0	35.0	4	74.0	33.2				
31775	1415	325	71.0	33.0	36.0	41.0	37.0	4	73.9	31.9				
31775	1700	503	65.4	36.3	36.0	41.0	35.0	4	70.6	28.5				
31775	1815	405	69.8	35.0	36.0	41.0	35.0	4	72.8	31.6				
31775	1928	456	68.2	34.9	36.0	41.0	35.0	4	72.0	30.5				
31775	2028	397	78.1	35.6	36.0	41.0	35.0	4	76.7	36.0				
31875	200	490	72.5	45.0	37.0	40.1	34.0	4	74.0	33.9				
31875	500	410	70.4	44.9	37.0	40.1	34.0	4	72.9	32.4				
31875	625	442	70.3	42.2	37.0	40.1	34.0	4	72.9	32.3				
31875	1002	9999	74.0	39.9	37.0	40.1	35.0	4	75.0	34.7				
31875	1030	442	68.9	37.5	37.0	40.1	35.0	4	9999.0	34.7				
31875	1935	270	60.0	37.0	37.0	40.1	29.0	4	66.4	26.7				
31975	130	195	60.0	33.9	38.0	40.1	27.0	3	70.7	20.5				
31975	306	245	60.2	33.8	38.0	40.1	26.0	3	70.7	20.8				

MODAYR	TIME	BLOW DOWN	COND TEMP	RIVER TEMPS PI	RW	LD3	WET BULB	TW	DISCH TEMP	EVAP	MONTHLY AVE RIVR	DISCH	B DN	EVAP
31975	900	325	******	34.0	38.0	40.1	31.0	3	9999.0	20.8				
31975	1600	410	70.0	34.2	38.0	40.1	37.0	3	78.7	23.4				
32175	1950	285	64.0	35.1	39.0	41.0	35.0	3	74.6	20.7				
32175	2335	150	63.0	34.8	39.0	41.0	35.0	3	73.9	20.1				
32275	810	168	64.6	35.1	39.0	40.1	30.0	3	74.2	22.1				
32275	850	180	67.9	35.2	39.0	40.1	30.0	3	76.3	23.8				
32375	820	225	68.3	34.7	38.0	40.1	30.0	3	76.6	24.1				
32375	1120	165	62.3	34.3	38.0	40.1	30.0	3	72.7	20.9				
32375	1340	150	68.5	34.2	38.0	40.1	31.0	3	76.8	23.9				
32575	845	245	75.0	32.7	36.0	37.4	11.0	3	77.9	31.9				
32675	1100	335	72.0	32.8	35.0	36.5	17.0	3	76.9	28.9				
32975	1230	410	60.0	32.7	34.0	36.5	20.0	3	69.7	22.0				
32975	1306	335	60.0	32.8	34.0	36.5	20.0	3	69.7	22.0				
											33.5	72.1	255.1	26.0
4 675	1000	410	69.1	34.3	37.0	41.0	27.0	3	70.3	34.3				
41575	50	490	64.0	41.4	40.0	45.5	36.0	3	74.8	20.4				
41575	325	410	60.5	41.5	40.0	45.5	35.0	3	72.3	18.9				
41775	330	490	74.0	43.9	40.0	44.6	42.0	3	82.1	24.2				
42475	1900	9999	70.0	42.3	43.0	45.5	47.0	3	80.5	20.8				
42575	1415	9999	65.7	42.6	44.0	47.3	51.0	3	9999.0	20.8				
42875	1000	9999	60.0	42.8	45.0	47.3	43.0	3	9999.0	20.8				
51175	1600	270	86.0	44.1	57.0	60.8	57.0	3	9999.0	20.8				
											41.1	79.3	388.2	25.6
51175	2000	340	88.0	44.1	57.0	60.8	49.0	3	83.1	36.0				
51375	1800	9999	79.0	44.0	60.0	63.5	53.0	3	87.1	24.3				
51575	1605	490	87.6	61.8	62.0	62.6	50.0	3	9999.0	24.3				
51575	1800	655	88.0	61.9	62.0	62.6	50.0	3	91.3	31.2				
51775	1705	735	88.0	65.5	64.0	65.3	61.0	3	93.7	27.7				
51975	1300	900	86.0	66.0	66.0	68.9	71.0	3	95.2	22.6				
52175	1148	750	78.0	68.0	69.0	71.6	69.0	3	90.2	18.3				
52175	1405	720	80.0	68.7	69.0	71.6	70.0	3	91.7	19.1				
52375	1350	900	81.0	71.0	70.0	72.5	66.0	3	91.1	21.3				
52475	1105	1025	73.0	69.6	70.0	73.4	62.0	3	85.6	17.7				
52575	1035	1105	75.0	70.2	70.0	74.3	71.0	3	89.2	15.4				
52575	1325	1150	76.0	71.3	70.0	74.3	71.0	3	89.8	16.0				
52575	1725	1190	70.2	72.6	70.0	74.3	61.0	3	9999.0	16.0				
52775	930	980	70.0	68.4	69.0	73.4	52.0	3	81.6	19.3				
52775	1145	947	78.3	69.0	69.0	73.4	55.0	3	87.1	23.3				
52975	1200	897	75.5	65.7	68.0	70.7	56.0	3	85.7	21.2				
52975	1300	858	75.0	65.6	68.0	70.7	56.0	3	85.5	20.9				
52975	1415	775	75.4	65.7	68.0	70.7	57.0	3	85.9	20.8				
52975	1800	695	81.8	65.8	68.0	70.7	59.0	3	89.9	24.3				
											57.8	86.9	591.1	27.2
6 175	1800	300	76.0	69.2	67.0	70.7	54.0	3	77.5	33.9				
6 175	2000	150	79.1	69.3	67.0	70.7	50.0	3	86.5	25.3				
6 375	2030	347	85.0	70.8	67.0	70.7	57.0	3	91.2	27.0				
6 475	836	325	79.3	68.3	68.0	70.7	62.0	3	89.2	21.6				
6 475	1015	250	80.5	68.1	68.0	70.7	62.0	3	89.9	22.4				
6 575	945	190	85.5	68.0	68.0	70.7	56.0	3	91.3	27.7				
6 575	1620	150	86.5	69.5	68.0	70.7	57.0	3	92.0	28.1				
61675	1630	327	86.0	67.2	64.0	68.9	61.0	3	92.7	26.4				
61675	1910	490	85.7	68.9	64.0	68.9	64.0	3	93.3	25.1				

MODAYR	TIME	BLOW DOWN	COND TEMP	RIVER TEMPS PI	RW	LD3	WET BULB	TW	DISCH TEMP	EVAP	MONTHLY AVE RIVR	DISCH	B·DN	EVAP
61675	2000	650	86.7	69.9	64.0	68.9	63.0	3	93.5	26.1				
61675	2120	737	88.4	69.7	64.0	68.9	63.0	3	94.4	27.3				
61675	2210	695	87.4	70.5	64.0	68.9	63.0	3	93.9	26.6				
61875	1749	615	80.2	67.2	66.0	69.8	62.0	3	89.7	22.2				
61875	2013	450	77.8	67.6	66.0	69.8	60.0	3	87.9	21.4				
61975	417	520	84.0	67.4	69.0	71.6	62.0	3	91.8	24.7				
61975	800	695	85.3	66.9	69.0	71.6	67.0	3	93.8	23.7				
61975	1310	760	86.2	68.3	69.0	71.6	75.0	3	96.5	21.1				
61975	2115	654	86.2	71.9	69.0	71.6	73.0	3	95.9	21.9				
62075	1630	735	89.7	72.7	71.0	74.3	78.0	3	99.1	22.4				
62175	1050	700	85.3	71.7	73.0	75.2	74.0	3	95.7	20.9				
62175	1445	780	87.2	73.8	73.0	75.2	67.0	3	94.8	25.1				
62275	135	470	87.0	74.2	73.0	75.2	65.0	3	94.2	25.6				
62275	300	350	85.0	73.9	73.0	75.2	65.0	3	93.1	24.3				
62275	320	330	83.0	73.7	73.0	75.2	65.0	3	92.0	23.0				
62275	522	255	83.5	73.0	73.0	75.2	67.0	3	92.8	22.6				
62275	800	410	87.3	72.2	73.0	75.2	66.0	3	94.6	25.5				
62275	1200	374	84.7	72.7	73.0	75.2	68.0	3	93.7	23.0				
62275	1720	410	87.0	75.0	73.0	75.2	68.0	3	94.9	24.6				
62375	730	325	84.5	73.1	74.0	76.1	64.0	3	92.6	24.3				
62375	846	410	86.8	72.6	74.0	76.1	68.0	3	94.8	24.4				
62375	1015	370	85.8	73.5	74.0	76.1	68.0	3	94.3	23.7				
62475	910	353	85.0	74.0	74.0	77.0	70.0	3	94.4	22.3				
62475	1207	370	87.5	74.8	74.0	77.0	71.0	3	96.0	23.7				
62575	630	490	85.0	75.6	75.0	77.0	67.0	3	93.6	23.5				
62575	730	565	84.0	75.3	75.0	77.0	67.0	3	93.1	22.9				
62575	750	820	83.7	75.3	75.0	77.0	70.0	3	93.7	21.5				
62575	1215	410	79.3	76.0	75.0	77.0	73.0	3	92.2	17.3				
62575	1300	330	83.9	75.4	75.0	77.0	73.0	3	94.7	20.4				
62575	1440	363	87.3	76.1	75.0	77.0	74.0	3	96.8	22.3				
62575	1535	410	87.3	76.6	75.0	77.0	74.0	3	96.8	22.3				
62575	1745	455	87.7	77.6	75.0	77.0	74.0	3	97.0	22.6				
62575	2030	530	86.6	78.2	75.0	77.0	71.0	3	95.6	23.0				
62675	415	435	85.0	76.3	75.0	77.9	69.0	3	94.1	22.8				
62675	515	205	84.0	75.9	75.0	77.9	68.0	3	93.3	22.5				
62675	630	150	83.0	75.7	75.0	77.9	68.0	3	92.7	21.9				
											71.3	92.5	301.9	24.2
7 675	1053	150	81.3	81.0	80.0	82.4	73.0	3	83.0	33.7				
7 775	1350	325	88.7	80.2	80.0	83.3	72.0	3	96.9	24.1				
7 775	1400	420	88.7	80.2	80.0	83.3	72.0	3	96.9	24.1				
7 775	1415	575	89.4	80.4	80.0	83.3	72.0	3	97.3	24.6				
7 775	1430	795	89.3	80.5	80.0	83.3	72.0	3	97.2	24.5				
7 775	2036	820	86.2	81.7	80.0	83.3	72.0	3	95.6	22.3				
7 775	2100	900	86.5	81.7	80.0	83.3	72.0	3	95.8	22.6				
7 775	2250	1140	86.5	81.6	80.0	83.3	72.0	3	95.8	22.6				
7 875	130	1228	86.7	81.3	80.0	82.4	66.0	3	94.3	25.1				
7 875	2130	1167	84.4	79.5	80.0	82.4	59.0	3	91.3	26.0				
7 975	205	1105	84.8	78.5	78.0	80.6	57.0	3	91.1	26.9				
71075	25	1022	83.7	76.5	76.0	78.8	55.0	3	90.1	26.8				
71075	210	940	84.0	76.0	76.0	78.8	51.0	3	89.4	28.2				
71075	1630	910	84.3	75.0	76.0	78.8	59.0	3	91.3	25.9				
71175	530	060	84.0	73.6	75.0	77.9	53.0	3	89.8	27.6				

MODAYR	TIME	BLOW DOWN	COND TEMP	RIVER TEMPS PI	RW	LD3	WET BULB	TW	DISCH TEMP	EVAP	MONTHLY AVE RIVR	DISCH	B DN	EVAP
71175	1610	840	84.0	73.7	75.0	77.9	61.0	3	91.6	25.0				
71275	315	735	84.5	73.0	74.0	76.1	49.0	3	89.3	29.1				
71275	440	650	86.0	73.0	74.0	76.1	51.0	3	90.5	29.5				
71275	1843	694	87.0	72.5	74.0	76.1	57.0	3	92.3	28.4				
71375	430	330	85.2	70.7	73.0	75.2	52.0	3	90.3	28.7				
71375	950	410	87.7	70.2	73.0	75.2	55.0	3	92.2	29.5				
71475	330	575	86.0	70.0	72.0	76.1	53.0	3	90.9	28.9				
71475	530	540	86.1	69.4	72.0	76.1	54.0	3	91.2	28.7				
71475	1210	640	88.0	69.4	72.0	76.1	68.0	3	95.4	25.3				
71475	1430	730	88.1	70.9	72.0	76.1	70.0	3	96.0	24.5				
71575	610	655	84.0	73.2	74.0	77.9	62.0	3	91.8	24.7				
71575	1015	820	86.9	72.4	74.0	77.9	68.0	3	94.9	24.5				
71575	1150	777	83.5	72.7	74.0	77.9	73.0	3	94.5	20.1				
71675	35	820	86.0	76.0	76.0	79.7	69.0	3	94.7	23.5				
71675	458	735	85.9	74.7	76.0	79.7	68.0	3	94.3	23.8				
71675	1040	780	85.3	73.5	76.0	79.7	76.0	3	96.3	20.0				
71675	1535	840	87.8	77.0	76.0	79.7	76.0	3	97.6	21.8				
71675	1824	900	88.2	78.0	76.0	79.7	74.0	3	97.2	22.9				
71775	700	1065	84.4	76.3	78.0	80.6	68.0	3	93.5	22.8				
71775	730	1020	83.4	76.2	78.0	80.6	68.0	3	93.0	22.2				
71775	800	980	85.6	76.0	78.0	80.6	72.0	3	95.3	21.9				
71775	1050	900	85.7	75.9	78.0	80.6	75.0	3	96.2	20.7				
71775	1230	940	87.8	76.1	78.0	80.6	75.0	3	97.3	22.2				
71775	1330	980	86.8	76.4	78.0	80.6	75.0	3	96.8	21.5				
71775	1405	940	87.9	76.6	78.0	80.6	74.0	3	97.1	22.7				
71775	1924	1014	89.8	78.5	78.0	80.6	74.0	3	98.0	24.1				
71875	1115	980	85.3	76.6	78.0	81.5	75.0	3	96.0	20.5				
71875	2140	1055	85.5	79.6	78.0	81.5	73.0	3	95.6	21.4				
71975	15	1020	84.9	79.8	79.0	81.5	69.0	3	94.1	22.7				
71975	230	940	83.8	79.3	79.0	81.5	66.0	3	92.7	23.1				
71975	330	890	84.0	79.1	79.0	81.5	66.0	3	92.8	23.3				
71975	410	820	83.7	79.0	79.0	81.5	66.0	3	92.6	23.1				
71975	455	780	84.5	78.8	79.0	81.5	66.0	3	93.1	23.6				
71975	935	738	87.5	78.0	79.0	81.5	68.0	3	95.2	24.9				
71975	1730	820	87.3	79.4	79.0	81.5	65.0	3	94.3	25.8				
71975	1820	910	88.5	79.9	79.0	81.5	65.0	3	95.0	26.7				
71975	1950	940	87.9	79.7	79.0	81.5	63.0	3	94.2	27.0				
72075	618	900	86.4	78.0	79.0	81.5	61.0	3	92.9	26.6				
72075	840	875	83.7	77.5	79.0	81.5	63.0	3	91.9	24.1				
72075	1650	930	86.8	78.4	79.0	81.5	65.0	3	94.1	25.5				
72175	728	960	84.2	77.4	79.0	81.5	60.0	3	91.5	25.5				
72175	2350	980	88.1	79.1	79.0	61.5	68.0	3	95.5	25.3				
72275	1700	1060	86.4	79.4	79.0	83.3	71.0	3	95.5	22.9				
72375	1155	980	83.3	77.9	79.0	81.5	71.0	3	93.8	20.8				
72475	510	900	84.1	77.5	78.0	80.6	60.0	3	91.4	25.4				
72575	445	860	84.6	76.4	77.0	80.6	57.0	3	91.0	26.8				
72675	1120	980	86.5	76.5	77.0	81.5	69.0	3	94.9	23.8				
72675	1415	940	82.0	77.1	77.0	81.5	72.0	3	93.4	19.5				
72675	1630	860	85.9	77.3	77.0	81.5	72.0	3	95.5	22.1				
72875	55	820	86.7	79.7	79.0	82.4	65.0	3	94.0	25.4				
72875	730	920	85.6	78.7	79.0	82.4	62.0	3	92.7	25.7				
72875	1615	950	88.2	80.1	79.0	82.4	71.0	3	96.4	24.2				

MODAYR	TIME	BLOW DOWN	COND TEMP	RIVER TEMPS PI	RW	LD3	WET BULB	TW	DISCH TEMP	EVAP	MONTHLY AVE RIVR	DISCH	B DN	EVAP
72975	1330	980	87.3	81.0	80.0	83.3	74.0	3	96.8	22.3				
72975	1700	1065	88.8	81.2	80.0	83.3	76.0	3	98.1	22.5				
73075	2120	980	84.8	82.0	81.0	83.3	72.0	3	94.9	21.4				
73075	2230	900	84.6	81.7	81.0	83.3	72.0	3	94.8	21.2				
73175	115	860	84.9	81.3	81.0	83.3	71.0	3	94.7	21.9				
73175	1940	940	87.2	82.3	81.0	83.3	74.0	3	96.7	22.2				
											78.0	91.8	735.3	26.2
8 175	440	1022	87.0	81.9	82.0	83.3	70.0	4	76.7	36.0				
8 175	515	1063	86.7	81.9	82.0	83.3	70.0	4	89.9	31.4				
8 175	600	1105	86.3	81.7	82.0	83.3	70.0	4	89`.8	31.0				
8 175	2010	1180	88.0	82.7	82.0	83.3	69.0	4	90.0	33.1				
8 175	2200	980	84.1	82.2	82.0	83.3	69.0	4	88.6	29.6				
8 275	345	940	83.6	81.1	82.0	83.3	66.0	4	87.3	30.7				
8 275	435	900	83.8	80.9	82.0	83.3	65.0	4	87.1	31.3				
8 275	545	860	83.5	80.8	82.0	83.3	65.0	4	87.0	31.1				
8 275	1820	980	88.0	81.0	82.0	83.3	65.0	4	88.7	35.1				
8 275	1945	.900	86.0	81.0	82.0	83.3	64.0	4	87.6	33.7				
8 275	2120	860	85.3	.81.0	82.0	83.3	64.0	4	87.4	33.1				
8 375	330	820	85.5	80.1	81.0	84.2	62.0	4	86.8	34.2				
8 375	530	780	85.7	79.8	81.0	84.2	60.0	4	86.2	35.3				
8 375	945	740	89.0	79.2	81.0	84.2	65.0	4	89.0	36.0				
8 375	1300	780	88.6	79.9	81.0	84.2	70.0	4	90.6	33.2				
8 475	1300	820	90.6	81.8	80.0	85.1	69.0	4	90.9	35.6				
8 575	255	580	86.3	80.9	80.0	84.2	61.0	4	86.7	35.4				
8 575	330	820	85.3	80.9	80.0	84.2	61.0	4	86.4	34.5				
8 575	425	740	84.4	80.8	80.0	84.2	61.0	4	86.0	33.7				
8 575	535	700	84.8	80.3	80.0	84.2	62.0	4	86.5	33.6				
8 575	1230	820	88.5	83.5	80.0	84.2	66.0	4	89.2	35.1				
8 575	1830	820	89.5	81.5	80.0	84.2	63.0	4	88.6	36.0				
8 675	1500	1140	90.1	78.3	78.0	82.4	62.0	4	88.5	36.0				
8 675	1615	1320	87.0	78.5	78.0	82.4	62.0	4	87.3	35.6				
8 775	310	1050	83.3	82.1	77.0	80.6	53.0	4	83.2	36.0				
8 775	315	980	83.3	81.9	77.0	80.6	53.0	4	83.2	36.0				
8 775	440	820	83.8	81.9	77.0	80.6	54.0	4	83.7	36.0				
8 775	1345	980	89.4	78.1	77.0	80.6	65.0	4	89.2	36.0				
8 775	2045	940	86.8	78.9	77.0	80.6	59.0	4	86.3	36.0				
8 975	315	840	85.9	80.5	.77.0	80.6	63.0	3	93.1	25.6				
8 975	505	655	85.2	79.8	77.0	80.6	63.0	3	92.7	25.1				
8 975	600	490	85.0	79.3	77.0	80.6	63.0	3	92.6	25.0				
8 975	1345	535	87.7	76.9	77.0	80.6	71,.0	3	96.1	23.8				
81075	1000	410	84.4	78.2	77.0	80.6	64'.0	3	92.5	24.2				
81075	1010	575	85.6	81.0	77.0	80.6	64.0	3	93.2	25.0				
81075	1950	410	82.5	81.0	77.0	80.6	61.0	3	90.8	24.1				
81075	2100	510	85.9	81.0	77.0	80.6	61.0	3	92.6	26.3				
81175	5	410	83.1	79.8	78.0	80.6	60.0	3	90.8	24.8				
81175	150	330	83.2	79.4	78.0	80.6	59.0	3	90.7	25.2				
81175	315	160	83.1	79.0	78.0	80.6	59.0	3	90.6	25.2				
81175	450	150	84.1	78.8	78.0	80.6	60.0	3	91.4	25.4				
81175	1710	188	88.7	79.9	78.0	80.6	71.0	3	96.6	24.5				
81375	310	150	85.1	77.3	77.0	79.7	57.0	3	91.3	27.1				
81575	600	245	90.1	76.4	77.0	79.7	62.0	3	95.1	28.8				
81575	1430	150	86.1	77.8	77.0	79.7	66.0	3	94.0	24.7				

MODAYR	TIME	BLOW DOWN	COND TEMP	RIVER TEMPS PI	RW	LD3	WET BULB	TW	DISCH TEMP	EVAP	MONTHLY AVE RIVR	DISCH	B DN	EVAP
81775	1330	188	88.8	74.6	76.0	77.9	57.0	4	86.4	36.0				
81775	1405	328	90.1	74.7	76.0	77.9	59.0	4	87.5	36.0				
81775	1430	410	88.5	74.6	76.0	77.9	59.0	4	86.9	36.0				
81875	1145	408	89.7	73.9	75.0	77.0	59.0	4	87.3	36.0				
81875	1325	531	89.0	73.7	75.0	77.0	59.0	4	87.1	36.0				
81975	0	450	83.5	76.1	75.0	******	58.0	4	84.7	34.4				
81975	230	325	81.0	75.6	75.0	******	56.0	4	83.1	33.0				
81975	920	439	88.5	73.4	75.0	******	59.0	4	86.9	36.0				
81975	1050	408	90.7	73.5	75.0	******	67.0	4	90.3	36.0				
81975	1430	652	90.0	74.2	75.0	******	67.0	4	90.0	36.0				
82075	1200	735	87.9	75.6	74.0	76.1	72.0	4	91.1	31.4				
82075	1330	820	87.8	74.1	74.0	76.1	72.0	4	91.1	31.3				
82075	2105	330	90.0	73.3	74.0	76.1	74.0	4	92.6	32.3				
82175	530	410	87.3	73.3	75.0	77.0	73.0	4	91.3	30.3				
82175	1210	490	88.1	76.0	75.0	77.0	71.0	4	90.8	32.1				
82175	1745	410	85.0	75.1	75.0	77.0	72.0	4	90.1	28.7				
82375	30	328	84.4	73.3	73.0	76.1	64.0	4	87.0	32.3				
82375	1230	410	87.5	73.5	73.0	76.1	77.0	4	92.9	28.3				
82375	1310	490	87.3	73.5	73.0	76.1	77.0	4	92.8	28.1				
82475	1315	576	87.4	76.2	74.0	77.0	77.0	4	92.8	28.2				
82475	1440	660	87.9	77.9	74.0	77.0	79.0	4	93.8	27.4				
82475	1540	740	87.9	80.0	74.0	77.0	79.0	4	93.8	27.4				
82475	2230	660	85.1	78.3	74.0	77.0	68.0	4	88.6	31.0				
82575	215	572	83.9	77.2	74.0	77.0	58.0	4	84.8	34.7				
82575	435	490	84.6	76.6	74.0	77.0	53.0	4	83.7	36.0				
82575	550	415	84.5	76.3	74.0	77.0	53.0	4	83.7	36.0				
82575	725	325	81.6	75.9	74.0	77.0	53.0	4	82.5	34.7				
82575	2020	246	85.7	75.0	74.0	77.0	56.0	4	85.0	36.0				
82575	2125	170	86.4	74.9	74.0	77.0	56.0	4	85.3	36.0				
82675	115	150	85.7	74.1	73.0	76.1	56.0	4	85.0	36.0				
82675	1235	325	88.8	72.6	73.0	76.1	59.0	4	87.0	36.0				
82675	1410	245	84.6	72.6	73.0	76.1	61.0	4	86.1	33.9				
82675	1600	160	83.6	72.4	73.0	76.1	61.0	4	85.7	33.0				
82675	2350	150	84.8	71.7	73.0	76.1	57.0	4	84.9	35.9				
82775	1120	230	86.0	70.6	72.0	74.3	64.0	4	87.6	33.7				
82775	2220	150	84.8	72.7	72.0	74.3	64.0	4	87.2	32.6				
82875	600	230	89.2	72.1	72.0	74.3	66.0	4	89.4	35.8				
82875	730	310	87.8	72.0	72.0	74.3	66.0	4	88.9	34.5				
82875	925	395	87.1	72.0	72.0	74.3	69.0	4	89.7	32.3				
82875	1230	490	86.6	73.1	72.0	74.3	72.0	4	90.7	30.2				
82975	2200	320	84.3	74.2	72.0	75.2	65.0	4	87.3	31.7				
82975	235	150	84.3	73.8	72.0	75.2	64.0	4	87.0	32.2				
82975	910	410	86.9	72.4	72.0	75.2	65.0	4	88.3	34.1				
82975	1030	325	84.8	72.2	72.0	75.2	65.0	4	87.5	32.2				
82975	1508	490	89.5	74.5	72.0	75.2	68.0	4	90.2	35.1				
82975	1523	660	88.5	74.7	72.0	75.2	68.0	4	89.8	34.2				
83075	400	490	82.0	73.3	72.0	74.3	62.0	4	85.4	31.2				
83075	1205	570	87.4	71.3	72.0	74.3	63.0	4	87.8	35.5				
83175	45	490	83.7	73.1	72.0	74.3	59.0	4	85.1	34.1				
83175	145	410	83.8	72.7	72.0	74.3	57.0	4	84.5	35.0				
83175	310	330	84.5	72.8	72.0	74.3	57.0	4	84.8	35.6				
83175	945	410	89.4	71.2	72.0	74.3	62.0	4	88.2	36.0				

MODAYR	TIME	BLOW DOWN	COND TEMP	RIVER TEMPS PI	RW	LD3	WET BULB	TW	DISCH TEMP	EVAP	MONTHLY AVE RIVR	DISCH	B DN	EVAP
83175	1030	490	90.2	71.3	72.0	74.3	62.0	4	88.5	36.0				
83175	1300	570	89.4	72.3	72.0	74.3	66.0	4	89.5	35.9				
											76.6	89.4	509.0	32.0
9 175	1741	655	91.0	73.5	72.0	75.2	65.0	4	77.3	36.0				
9 275	710	570	83.5	75.3	72.0	75.2	55.0	4	83.9	35.6				
9 275	1130	655	86.8	72.9	72.0	75.2	63.0	4	87.6	34.9				
9 375	500	570	84.4	72.8	72.0	75.2	56.0	4	84.5	35.9				
9 375	1230	490	84.6	71.2	72.0	75.2	62.0	4	86.4	33.4				
9 375	1350	570	86.6	71.2	72.0	75.2	62.0	4	87.2	35.2				
9 475	330	490	84.1	72.8	71.0	73.4	51.0	4	83.0	36.0				
9 475	430	370	84.0	72.5	71.0	73.4	51.0	4	82.9	36.0				
9 475	515	285	83.3	72.4	71.0	73.4	50.0	4	82.4	36.0				
9 475	750	490	86.2	72.4	71.0	73.4	59.0	4	86.1	36.0				
9 575	430	410	84.6	71.1	70.0	74.3	58.0	3	91.2	26.5				
9 575	845	490	87.4	71.1	70.0	74.3	57.0	3	92.5	28.7				
9 575	1251	530	87.0	71.1	70.0	74.3	61.0	3	93.2	27.0				
9 575	1820	480	86.1	71.1	70.0	74.3	55.0	3	91.4	28.4				
9 675	130	370	84.6	70.7	70.0	72.5	51.0	3	89.7	28.6				
9 675	415	310	84.0	70.7	70.0	72.5	48.0	3	88.8	29.1				
9 675	1000	480	87.9	70.7	70.0	72.5	56.0	3	92.5	29.3				
9 675	1120	400	83.7	70.7	70.0	72.5	58.0	3	90.7	25.9				
9 675	1330	440	87.3	70.7	70.0	72.5	58.0	3	92.6	28.3				
9 775	245	410	84.5	71.6	69.0	72.5	58.0	4	85.1	35.2				
9 775	950	455	88.0	71.6	69.0	72.5	55.0	4	85.6	36.0				
9 875	10	240	83.2	71.6	69.0	73.4	50.0	4	82.4	36.0				
9 875	635	330	85.0	69.6	69.0	73.4	46.0	4	82.0	36.0				
9 875	900	410	87.1	69.6	69.0	73.4	52.0	4	84.4	36.0				
9 875	1545	480	87.0	69.6	69.0	73.4	54.0	4	84.9	36.0				
9 875	1645	9999	73.6	69.6	69.0	73.4	52.0	4	78.9	28.3				
9 975	10	330	73.5	69.6	68.0	******	46.0	4	9999.0	28.3				
9 975	300	245	83.4	74.2	68.0	******	44.0	4	80.9	36.0				
9 975	345	150	83.5	74.2	68.0	******	44.0	4	80.9	36.0				
9 975	830	195	87.2	74.2	68.0	******	52.0	4	84.4	36.0				
9 975	910	240	88.2	74.2	68.0	******	52.0	4	84.8	36.0				
9 975	930	320	88.4	74.2	68.0	******	52.0	4	84.9	36.0				
9 975	1155	410	88.0	74.2	68.0	******	59.0	4	86.7	36.0				
91075	106	285	82.9	70.6	68.0	******	57.0	4	84.2	34.2				
91075	900	375	86.4	70.6	68.0	******	65.0	4	88.1	33.6				
91075	1130	410	87.8	70.6	68.0	******	69.0	4	89.9	33.0				
91075	1200	480	87.1	70.6	68.0	******	69.0	4	89.7	32.3				
91175	200	370	84.4	68.3	68.0	******	57.0	4	84.8	35.5				
91175	400	285	83.8	68.2	68.0	******	57.0	4	84.5	35.0				
91175	1320	490	86.0	66.5	68.0	******	51.0	4	83.7	36.0				
91175	1405	285	85.9	66.5	68.0	******	50.0	4	83.4	36.0				
91175	2230	205	84.0	65.9	68.0	******	41.0	4	80.4	36.0				
91275	815	160	83.4	63.8	65.0	******	44.0	4	80.9	36.0				
91275	1300	330	85.5	63.5	65.0	******	46.0	4	82.2	36.0				
91275	1315	410	86.6	63.5	65.0	******	46.0	4	82.6	36.0				
91275	1425	160	87.1	63.4	65.0	******	47.0	4	83.0	36.0				
91275	1630	245	88.4	63.4	65.0	******	47.0	4	83.5	36.0				
91375	400	150	83.0	62.6	65.0	******	36.0	4	78.8	36.0				
91375	800	295	89.4	61.7	65.0	******	46.0	4	83.6	36.0				

Chapter 4

NSP-1981a

NSP

Northern States Power Company

414 Nicollet Mall
Minneapolis, Minnesota 55401
Telephone (612) 330-5500

July 24, 1981

Don L. Kriens
Enforcement Section
Division of Water Quality
Minnesota Pollution Control Agency
1935 West County Road B-2
Roseville, MN 55113

Prairie Island Nuclear Generating Plant
Chlorination of Circulating Water to Remove Parasitic Amoeba

Analyses of the circulating water system at the Prairie Island Nuclear Generating Plant have confirmed the continued presence of the parasitic amoeba, Naeglaria Fowleri. Population densities are such that it has been determined necessary to again treat the system to control the amoeba. The purpose of this letter is to secure MPCA approval for an alteration in the mode of plant operation and the addition of chemicals to the Prairie Island circulating water system.

The proposed treatment plan will utilize chlorination and subsequent dechlorination prior to discharge of water from the system. It is planned to conduct the treatment in the same manner as that performed at Prairie Island on August 28, 1980. The specifics of that procedure are contained in our letter to the MPCA dated August 19, 1980 in which we requested authorization to conduct the treatment.

We are requesting your written authorization to conduct the test for a one-day period, tentatively set for September 2, 1981. We will again coordinate our efforts with the Minnesota Department of Natural Resources to attempt to remove fish from the recirculation canal prior to treatment.

Please contact me at (612) 330-6894 if additional information is required.

R D Clough, Administrator
Operating Permits

FILE
ERAD RECORD CENTER

RDC:jz

cc: Russ Frazier - MN Dept of Health
Howard Krosch - MN Dept of Natural Resources

bcc: G M Kuhl
L J Micienzi
J M Pappenfus
R W Steurnagel
E C Ward
E L Watzl

PINGP-040

Chapter 4

NSP 1981b

Prairie Island Modification/Intake Des. General

NSP

Northern States Power Company

414 Nicollet Mall
Minneapolis, Minnesota 55401
Telephone (612) 330-5500

October 14, 1981

Don Kriens
Division of Water Quality
Minnesota Pollution Control Agency
1935 West County Road B2
Roseville, Minnesota 55113

PRAIRIE ISLAND NUCLEAR GENERATING PLANT
Circulating Water Chlorination-Dechlorination
Pathogenic Amoeba (Naegleria fowleria) Control Program

As requested in your letter of August 3, 1981 we are submitting the results of the Prairie Island circulating water chlorination-dechlorination conducted last month to reduce the population of pathogenic Naegleria.

Also enclosed is an NSP Testing Lab Report on the procedure and a summary addressing the "Chlorine Effects on Resident Fisheries Population." A final report on the amoeba will be included in the annual Environmental Report for Prairie Island.

If you have any questions concerning this information, please contact Bob Clough at 330-6894.

W E Jensen
Senior Consultant
Regulatory Service

ah

enclosure

cc: R D Clough

bcc: L W Eberley
J M Pappenfus
R W Steuernagel
E C Ward
E L Watzl

Analysis of data prior to and after chlorination in 1981 reveals a pattern similar to that seen in previous years. Thus pathogenic Naeglaria could be detected in 1 and 10 ml samples of cooling tower and intake water prior to chlorination. After chlorination pathogenic Naegleria could not be detected in 1, 10 or 100 ml samples of water from either the intake or cooling tower canal.

Prairie Island Plant

Before Chlorination: 1981

Site	Temp. (C°)	Date	Type/Vol. sample	Amoebic outgrowth at 45°C	Flagel.	Appearance	Path.
Cooling Tower	30	8/10	H_2O - 100ml	Pos.	NT	NA	NA
Cooling Tower	30	8/10	H_2O - 100ml	Pos.	NT	NA	NA
Cooling Tower	30	8/10	H_2O - 100ml	Pos.	NT	NA	NA
Cooling Tower	30	8/10	H_2O - 100ml	Pos.	NT	NA	NA
Cooling Tower	30	8/10	H_2O - 10ml	Pos.	Pos.	P	Pos.
Cooling Tower	30	8/10	H_2O - 10ml	Pos.	Pos.	P/NP	Neg.
Cooling Tower	30	8/10	H_2O - 10ml	Pos.	Pos.	NP	NT
Cooling Tower	30	8/10	H_2O - 10ml	Pos.	Pos.	NP	NT
Cooling Tower	30	8/10	H_2O - 1ml	Pos.	Pos.	P	Pos.
Cooling Tower	30	8/10	H_2O - 1ml	Neg.	NA	NA	NA
Cooling Tower	30	8/10	H_2O - 1ml	Pos.	NT	NN	NT
Cooling Tower	30	8/10	H_2O - 1ml	Pos.	NT	NN	NT
Cooling Tower	30	8/10	H_2O - 1ml	Neg.	NA	NA	NA
Cooling Tower	30	8/10	H_2O - 1ml	Pos.	NT	NN	NT
Cooling Tower	30	8/10	H_2O - 1ml	Neg.	NA	NA	NA
Cooling Tower	30	8/10	H_2O - 1ml	Neg.	NA	NA	NA
Cooling Tower	30	8/10	H_2O - 1ml	Neg.	NA	NA	NA
Cooling Tower	30	8/10	H_2O - 1ml	Neg.	NA	NA	NA

NT - Not tested

NA - Not applicable

NN - Not Naegleria

P - Pathogenic Naegleria

NP - Non-pathogenic Naegleria

Prevalence of Pathogenic Naegleria at the
Prairie Island Plant
Before Chlorination: 1981

Site	Temp.(C°)	Date	Type/Vol. sample	Amoebic outgrowth at 45°C	Flagel.	Appearance	Path.
Cooling Tower	35	8/31	H_2O - 100ml	Pos.	NT	P/NP	NA
Cooling Tower	35	8/31	H_2O - 100ml	Neg.	NT	NA	NA
Cooling Tower	35	8/31	H_2O - 100ml	Pos.	NT	P/NP	NA
Cooling Tower	35	8/31	H_2O - 10ml	Neg.	NA	NA	NA
Cooling Tower	35	8/31	H_2O - 10ml	Pos.	NT	NN	NT
Cooling Tower	35	8/31	H_2O - 10ml	Pos.	Pos.	P/NP	Pos.
Cooling Tower	35	8/31	H_2O - 10ml	Neg.	NA	NA	NA
Cooling Tower	35	8/31	H_2O - 10ml	Pos.	Pos.	P	Pos.
Cooling Tower	35	8/31	H_2O - 10ml	Pos.	NT	NN	NT
Cooling Tower	35	8/31	H_2O - 10ml	Pos.	NT	NN	NT
Cooling Tower	35	8/31	H_2O - 10ml	Neg.	NA	NA	NA
Cooling Tower	35	8/31	H_2O - 10ml	Pos.	NT	P/NP	NT
Cooling Tower	35	8/31	H_2O - 10ml	Pos.	NT	NN	NT
Cooling Tower	35	8/31	H_2O - 1ml	Neg.	NA	NA	NA
Cooling Tower	35	8/31	H_2O - 1ml	Pos.	Pos.	P	Pos.
Cooling Tower	35	8/31	H_2O - 1ml	Neg.	NA	NA	NA
Cooling Tower	35	8/31	H_2O - 1ml	Neg.	NA	NA	NA
Cooling Tower	35	8/31	H_2O - 1ml	Neg.	NA	NA	NA
Cooling Tower	35	8/31	H_2O - 1ml	Pos.	Neg.	NN/P	NT
Cooling Tower	35	8/31	H_2O - 1ml	Pos.	Neg.	NN/P	NT
Cooling Tower	35	8/31	H_2O - 1ml	Neg.	NA	NA	NT
Cooling Tower	35	8/31	H_2O - 1ml	Pos.	Neg.	NN/P	NT
Cooling Tower	35	8/31	H_2O - 1ml	Pos.	Neg.	NN/P	NT

NT - Not tested
NA - Not applicable
NN - Not Naegleria
P - Pathogenic Naegleria
NP - Non-pathogenic Naegleria

Presence of Pathogenic Naegleria at the
Prairie Island Plant
Before Chlorination: 1981

Site	Temp.(C°)	Date	Type/Vol. sample	Amoebic outgrowth at 45°C	Flagel.	Appearance	Path.
Intake	34	8/31	H_2O - 100ml	Pos.	NT	P	NT
Intake	34	8/31	H_2O - 100ml	Pos.	NT	P	NT
Intake	34	8/31	H_2O - 100ml	Pos.	NT	NN	NT
Intake	34	8/31	H_2O - 100ml	Pos.	NT	NN	NT
Intake	34	8/31	H_2O - 100ml	Pos.	NT	P/NP	NT
Intake	34	8/31	H_2O - 10ml	Pos.	NT	NN	NT
Intake	34	8/31	H_2O - 10ml	Pos.	NT	NN	NT
Intake	34	8/31	H_2O - 10ml	Pos.	NT	NN	NT
Intake	34	8/31	H_2O - 10ml	Pos.	NT	P	NT
Intake	34	8/31	H_2O - 10ml	Pos.	NT	P/NN	NT
Intake	34	8/31	H_2O - 10ml	Pos.	NT	NN	NT
Intake	34	8/31	H_2O - 10ml	Pos.	NT	NN	NT
Intake	34	8/31	H_2O - 10ml	Neg.	NT	NP	NA
Intake	34	8/31	H_2O - 10ml	Pos.	NT	P	NT
Intake	34	8/31	H_2O - 10ml	Pos.	NT	P/NN	NT
Intake	34	8/31	H_2O - 1ml	Pos.	Pos.	P	Pos.
Intake	34	8/31	H_2O - 1ml	Pos.	NT	NN	NT
Intake	34	8/31	H_2O - 1ml	Pos.	NT	NN	NT
Intake	34	8/31	H_2O - 1ml	Pos.	NT	NN	NT
Intake	34	8/31	H_2O - 1ml	Pos.	NT	NN	NT
Intake	34	8/31	H_2O - 1ml	Pos.	NT	NN	NT
Intake	34	8/31	H_2O - 1ml	Neg.	NA	NA	NA
Intake	34	8/31	H_2O - 1ml	Pos.	Pos.	P/NP	Neg.
Intake	34	8/31	H_2O - 1ml	Pos.	Pos.	P/NP/NN	NT
Intake	34	8/31	H_2O - 1ml	Pos.	Pos.	P/NP	Pos.

NT - Not tested
NA - Not applicable
NN - Not Naegleria
P - Pathogenic Naegleria
NP - Non-pathogenic Naegleria

Prevalence of Pathogenic Naegleria at the
Prairie Island Plant
After Chlorination: 1981

Site	Temp. (C°)	Date	Type/Vol. sample	Amoebic outgrowth at 45°C	Flagel.	Appearance	Path.
Cooling Tower	28	9/8	H_2O - 100ml	Pos.	NT	NN	NT
Cooling Tower	28	9/8	H_2O - 100ml	Pos.	NT	NN	NT
Cooling Tower	28	9/8	H_2O - 100ml	Pos.	Pos.	NP	Neg.
Cooling Tower	28	9/8	H_2O - 100ml	Pos.	NT	NN	NT
Cooling Tower	28	9/8	H_2O - 100ml	Pos.	NT	NN	NT
Cooling Tower	28	9/8	H_2O - 10ml	Pos.	NT	NN	NT
Cooling Tower	28	9/8	H_2O - 10ml	Pos.	Neg.	NN/P	NT
Cooling Tower	28	9/8	H_2O - 10ml	Pos.	NT	NN	NT
Cooling Tower	28	9/8	H_2O - 10ml	Pos.	NT	NN	NT
Cooling Tower	28	9/8	H_2O - 10ml	Pos.	Neg.	NN/P	NT
Cooling Tower	28	9/8	H_2O - 10ml	Neg.	NA	NA	NA
Cooling Tower	28	9/8	H_2O - 10ml	Pos.	Pos.	NP/P	Neg.
Cooling Tower	28	9/8	H_2O - 10ml	Pos.	NT	NN	NT
Cooling Tower	28	9/8	H_2O - 10ml	Pos.	NT	NN	NT
Cooling Tower	28	9/8	H_2O - 10ml	Pos.	NT	NN	NT
Cooling Tower	28	9/8	H_2O - 1ml	Pos.	NT	NN	NT
Cooling Tower	28	9/8	H_2O - 1ml	Pos.	NT	NN	NT
Cooling Tower	28	9/8	H_2O - 1ml	Pos.	Pos.	NP	Neg.
Cooling Tower	28	9/8	H_2O - 1ml	Pos.	NT	NN	NT
Cooling Tower	28	9/8	H_2O - 1ml	Pos.	NT	NN	NT
Cooling Tower	28	9/8	H_2O - 1ml	Pos.	NT	NN	NT
Cooling Tower	28	9/8	H_2O - 1ml	Pos.	Neg.	NN/NP	NT
Cooling Tower	28	9/8	H_2O - 1ml	Pos.	NT	NN	NT
Cooling Tower	28	9/8	H_2O - 1ml	Pos.	Pos.	NP	Neg.
Cooling Tower	28	9/8	H_2O - 1ml	Neg.	NA	NA	NA

NT - Not tested
NA - Not applicable
NN - Not Naegleria
P - Pathogenic Naegleria
NP - Non-pathogenic Naegleria

Provalence of Pathogenic Naegloria at the
Prairie Island Plant
After Chlorination: 1981

Site	Temp. (C°)	Date	Type/Vol. sample	Amoebic outgrowth at 45°C	Flagel.	Appearance	Path.
Intake	27	9/8	H_2O - 100ml	Neg..	NA	NA	NA
Intake	27	9/8	H_2O - 100ml	Pos.	NT	NN	NT
Intake	27	9/8	H_2O - 100ml	Neg.	NA	NA	NA
Intake	27	9/8	H_2O - 100ml	Pos.	NT	NN	NT
Intake	27	9/8	H_2O - 100ml	Pos.	Neg.	NN/NP	NT
Intake	27	9/8	H_2O - 10ml	Neg.	NA	NA	NA
Intake	27	9/8	H_2O - 10ml	Pos.	NT	NN	NT
Intake	27	9/8	H_2O - 10ml	Neg.	NA	NA	NA
Intake	27	9/8	H_2O - 10ml	Neg.	NA	NA	NA
Intake	27	9/8	H_2O - 10ml	Neg.	NA	NA	NA
Intake	27	9/8	H_2O - 10ml	Neg.	NA	NA	NA
Intake	27	9/8	H_2O - 10ml	Neg.	NA	NA	NA
Intake	27	9/8	H_2O - 10ml	Neg.	NA	NA	NA
Intake	27	9/8	H_2O - 10ml	Neg.	NA	NA	NA
Intake	27	9/8	H_2O - 10ml	Neg.	NA	NA	NA
Intake	27	9/8	H_2O - 1ml	Neg.	NA	NA	NA
Intake	27	9/8	H_2O - 1ml	Neg.	NA	NA	NA
Intake	27	9/8	H_2O - 1ml	Neg.	NA	NA	NA
Intake	27	9/8	H_2O - 1ml	Neg.	NA	NA	NA
Intake	27	9/8	H_2O - 1ml	Neg.	NA	NA	NA
Intake	27	9/8	H_2O - 1ml	Neg.	NA	NA	NA
Intake	27	9/8	H_2O - 1ml	Neg.	NA	NA	NA
Intake	27	9/8	H_2O - 1ml	Neg.	NA	NA	NA
Intake	27	9/8	H_2O - 1ml	Neg.	NA	NA	NA
Intake	27	9/8	H_2O - 1ml	Neg.	NA	NA	NA

NT - Not tested
NA - Not applicable
NN - Not Naegleria
P - Pathogenic Naegleria
NP - Non-pathogenic Naegleria

CHLORINE EFFECTS ON RESIDENT FISHERIES POPULATION

An estimated total of 28,095 fishes were lost during the September 1981 chlorination at Prairie Island. Table lists the total numbers and representative length frequency distributions for all fishes lost. Where possible, unmeasured fish were designated and recorded as young-of-the-year (yy) and juvenile or adult. When this was not possible fish not measured were recorded as "unmeasured".

Gizzard shad ans shiners comprised 77 percent of the total loss. Channel catfish comprised 16 percent; other game species encountered, in decreasing order of abundance were white bass, bluegill, green sunfish, crappie, walleye, and sauger. Collectively, game fish were less than four percent of all fishes lost.

To estimate the number of yy and juvenile lost the number of fish from three buckets were counted and th eaverage used to extrapolate the total numbers for all buckets (table). Adults were separated from the yy and juveniles and enumerated individually.

In an attempt to drive fish out of the plant circulating water system, one and one-quarter pounds of copper sulfate instant powder were added to the circulating water system each minute for two hours commencing at 0630 hours. Based upon the estimated volume of the circulating water system, the copper sulfate concentration was expected to approach one-half parts-per-million which should repel fish.

The total fish loss during the September 1981 chlorination was considerably less than the 162,448 fishes lost during the August 1980 chlorination. A number of explanations may be possible. The copper sulfate may have been successful, the fact that the two parts-per-million free chlorine was achieved for only about two hours may have prevented a total kill in the circulating water system. Although there is no way to adequately assess the effectiveness of the copper sulfate it is recommended that it be employed in any subsequent chlorination efforts at Prairie Island. The copper sulfate is relatively cheap and any fish chased from the system will not be lost.

Although the number of fish lost during the 1981 chlorination was substantially less than that of 1980, the relative composition of fish lost was quite similar. Gizzard shad, shiners, and carp collectively dominated the total with channel catfish comprising the next most abundant species. Other game fish comprised less than 13 and 4 percent of the total in 1980 and 1981 respectively.

[redacted]

[redacted]

[redacted]

TOTAL LENGTH (MM)	Longnose gar	Shortnose gar	American Eel	Gizzard Shad	Northern Pike	Carp	Silver Chub	Shiner SP.	Carpsucker SP.	Quillback
0-19										
20-39										
40-59				1						
60-79				6						
80-99				31						
100-119				19						
120-139				5		1	1			
140-159				1						
160-179						1				
180-199						1				
200-219	1					5				
220-239				1		3				
240-259				9		4				
260-279				7	1	3				
280-299	1			11		3				
300-319				4		2				
320-339						7				
340-359				1		3				1
360-379				1		4				
380-399						1				
400-419						1				1
420-439									1	
440-459						2				1
460-479			1			1				
480-499						2				
500-519						1				
520-539						1				
540-559						2				
560-579										
580-599		2				1				
600-619		1								
620-639		1				1				
640-659						2				
660-679						1				
680-699										
760-779						1				
800-819						1				
UNMEASURED								1551		
UNM. YY+Juv.				19998		11			11	
UNM ADULT				32		102			2	
TOTAL	2	4	1	20,127	1	168	1	1551	14	3

COMMENTS:

[redacted]

TOTAL LENGTH (MM)	River Carpsucker	Smallmouth Buffalo	Bigmouth buffalo	Shorthead redhorse	Black bullhead	Channel catfish	Tadpole Madtom	Flathead catfish	White bass	Green Sunfish
0-19										
20-39							1			
40-59										2
60-79						19	2			
80-99						6	2	12	10	5
100-119						8	1	25	19	9
120-139						18		11	14	5
140-159						10		1	5	3
160-179						6		2	5	
180-199						1			4	
200-219						1		1	14	
220-239					1				12	
240-259		1							6	
260-279				1					12	
280-299						1		1	3	
300-319	1	1				1			2	
320-339		4		2		4			5	
340-359		19				2				
360-379		8		2		7				
380-399		13		3		8				
400-419		8		6		8			1	
420-439	1	3		2		3		1		
440-459		3		6		5		2		
460-479		3				4		3		
480-499		1				3				
500-519		1				2		1		
520 539		1	1			1		1		
540-559								1		
560-579								1		
580-599										
600-619								1		
620-639						1		1		
640-659						1				
660-679								2		
680-699								2		
700-719								1		
720-739								1		
740-759								2		
840-859								1		
880-899								1		
UNMEASURED							33	464-1771		11
UNM. YY+Juv.						4015		55	363	
UNM ADULT		53	1	4		480		8	30	
TOTAL	2	119	2	26	1	4615	39	139	505	35

COMMENTS:

[redacted]

[redacted]

[redacted]

TOTAL LENGTH (MM)	Bluegill	Smallmouth bass	Croppie SP	Sauger	Walleye	Freshwater drum			
0-19									
20-39									
40-59	8								
60-79									
80-99			2						
100-119	14								
120-139	17		4						
140-159	8		9						
160-179	2		3			1			
180-199	6		2						
200-219	1		1	1		10			
220-239					1	5			
240-259		2		2	1	7			
260-279				3	1	12			
280-299				1	1	3			
300-319		1		2		8			
320-339				2		7			
340-359		1		1	2	7			
360-379					2	4			
380-399					1	2			
400-419				1	1	1			
420-439					4				
440-459					1				
460-479				1	2				
480-499				1					
500-519					1				
520-539					1	1			
540-559									
560-579									
580-599					1				
600-619									
620-639									
640-659									
660-679									
680-699									
UNMEASURED	239		11			154			
UNM. YY + Juv.									
UNM ADULT					1	151			
TOTAL	295	4	32	15	21	373		[illegible]	

COMMENTS:

NUMBER OF FISH COUNTED PER BUCKET DURING THE SEPTEMBER 1981 CHLORINATION

Gizzard Shad	608	597	613
Carp	0	1	0
Shiner sp	48	25	68
Carpsucker sp	0	0	1
Channel Catfish	105	133	127
Tadpole madtom	1	1	1
Flathead Catfish	1	2	2
White Bass	14	8	11
Green Sunfish	1	0	0
Bluegill	6	7	8
Crappie sp.	0	0	1
Freshwater drum	6	4	4
Total	790	778	836

Chapter 4

NSP-1983

PRAIRIE ISLAND
MN PCA
NPDES - GEN.
03500

NSP

Northern States Power Company

414 Nicollet Mall
Minneapolis, Minnesota 55401
Telephone (612) 330-5500

October 14, 1983

16

Howard Krosch
Division of Fish & Wildlife
MN Dept of Natural Resources
Centennial Office Building
St Paul, Minnesota 55155

Don L Kriens
Division of Waste Quality
MN Pollution Control Agency
1935 West County Road B2
Roseville, Minnesota 55113

File: PI NPDES
MN0004006

PRAIRIE ISLAND NUCLEAR GENERATING PLANT
Chlorination of Circulating Water System
Fish Loss Report

Enclosed, for your information, is a report on the fish loss due to chlorination of the circulating water system at the Prairie Island Nuclear Generating Plant in August, 1983.

Feel free to contact Glen Kuhl at the Prairie Island Environmental Lab at (612) 388-1121, extension 349, if you have any questions concerning this report.

W E Jensen
Senior Consultant
Regulatory Services

ah

enclosure

cc: G M Kuhl

Internal Correspondence

NSP

		Date	August 30, 1983
From	G. M. Kuhl Phycologist	Location	Prairie Island
To	S. F. Schmidt Admin Reg Compliance	Location	GO (2)

Subject FISH LOSS DUE TO CHLORINATION OF THE PINGP CIRCULATING WATER SYSTEM

An estimated total of 37,124 fish were killed during the chlorination of the circulating water system at PINGP on August 20, 1983. Tables 1 and 2 list representative length frequencies and totals for all species lost. When possible, unmeasured fish were designated as young-of-the-year (yy), juvenile, and adult. During instances where this was not possible fish not measured were recorded as "unmeasured".

Gizzard shad comprised 61.7% of the total loss with channel catfish representing 26.5% of the total. Other game fish in decreasing order of abundance, included white bass, crappie spp., bluegill, sauger and walleye. These species comprised 3.9% of the total fish loss.

Adult fish were separated from yy and juvenile fish, enumerated and measured individually (Table 1). Estimated numbers of yy and juvenile fish were based on the number of fish counted per bucket with this number extrapolated over all buckets (Table 2).

As in the 1981 chlorination, copper sulfate was used in an attempt to drive fish from the circulating water system prior to chlorination. In cooperation with a Minnesota Department of Natural Resources licensed applicator, copper sulfate was added on two occasions. On Friday, August 19, copper sulfate was added at a rate of two pounds per minute for 15 minutes to the new discharge canal while the plant was operating in open helper cycle. This provided adequate mixing and flow to hopefully drive fish from the canal. On Saturday, August 20, copper sulfate was added at a rate of three pounds per minute for 60 minutes to the remainder of the circulating water system. Based on calculations of the quantity of water in the system the application rates were expected to allow copper sulfate concentrations to reach 0.5 ppm, which should repel fish.

FORM 17-3467

Fish loss during the 1983 chlorination was slightly greater than the 28,095 lost during 1981 but considerably less than the 162,448 lost during the 1980 chlorination. Species composition was similar to previous years with gizzard shad and channel catfish being major contributors of fish loss.

G M Kuhl

G. M. Kuhl

sw

Minnesota Department of Natural Resources

500 Lafayette Road
St. Paul, Minnesota 55155-40__

August 10, 2007

James Holthaus, Project Manager
Nuclear Management Company
1717 Wakonade Drive East
Welch, MN 55089

RE: Prairie Island Nuclear Generating Plant Re-licensing and Environmental Review.

Dear Mr. Holthaus:

The Minnesota Department of Natural Resources (DNR) has reviewed the materials presented in the NEPA Issues Index for the Prairie Island Nuclear Generating Plant (PINGP) Environmental Report. The DNR requests additional emphasis or clarification on the following issues

Surface Water Quality, Hydrology and Use
The DNR recommends PINGP continue the periodic assessment of best management practices for control of bio-fouling which includes plant system infestations of zebra mussels. The DNR also recommends periodic assessment of plant chemicals for determining alternative products which do not contain aquatic nutrients or endocrine disrupting substances.

The DNR and Xcel have discussed a drawdown of Mississippi River Pool #3 sometime in the near future to improve habitat conditions. The DNR recommends the environmental report include an evaluation of the issues and impacts to PINGP intake and operations associated with summer drawdowns. This evaluation may already included in the NEAP Issues Index #13.

Terrestrial Resources
The DNR recommends routine review of herbicide product use for reducing aquatic or terrestrial toxicity or endocrine disruption.

The DNR recommends periodic assessment of best available technology for lighting effects on bird collision with structures including the communications tower at the PINGP site. This tower is approximately 340 feet in height and is placed within the floodplain of the nations most significant bird migration corridor.

The DNR requests a review of plant emissions of fugitive light and noise not essential for facility security or operations to minimize disturbance to surrounding residents, recreational users, and terrestrial wildlife.

Thank you for the opportunity to review the PINGP NEPA Issues Index. Please contact me with any questions regarding this letter.

Sincerely,

Matt Langan, Environmental Planner
Environmental Review Unit
Division of Ecological Resources
(651) 259-5115

c: Steve Colvin, Joe Kurcinka, Wayne Barstad, Tim Slagenhaft, Scot Johnson, Jack Enblom
D:\AA_OMBS\LEPGP\PINGP_NEPA_issuesIndexComments_081007.doc

MINNESOTA
MDH
DEPARTMENT OF HEALTH

Protecting, maintaining and improving the health of all Minnesotans

April 10, 2008

James J. Holthaus, PMP
Environmental Project Manager
Prairie Island Nuclear Generating Plant
1717 Wakonade Drive East
13-Plex (License Renewal)
Welch, MN 55089

Dear Mr. Holthaus:

I am writing in response to the letter of January 25, 2008 from Mike Wadley, Prairie Island Site Vice President, regarding the Nuclear Regulatory Commission license renewal for the Prairie Island Nuclear Generating Plant (PINGP). Mr. Wadley asked the Minnesota Department of Health (MDH) for help in determining whether there is any public health-related concerns from occurrence of thermophilic organisms in Mississippi River waters affected by the operations of the PINGP.

MDH does not monitor Mississippi River waters for occurrence of the organisms mentioned in the letter. Further, we have no information concerning possible exposures and health risks should these organisms be found in areas of the Mississippi affected by the PINGP discharge.

If MDH receives any information relevant to your query we will forward it to you. Please contact me if you have additional questions.

Sincerely,

John Linc Stine, Director
Environmental Health Division
P.O. Box 64975
St. Paul, Minnesota 55164-0975

January 25, 2008

Mr. John Linc Stine, Director
Environmental Health Division
Minnesota Department of Health
625 Robert Street
St. Paul, Minnesota 55164-0975

SUBJECT: Prairie Island Nuclear Generating Plant License Renewal
Request for Information on Thermophilic Microorganisms

Dear Mr. Stine:

Nuclear Management Company (NMC), acting on behalf of Northern States Power Company, a wholly-owned subsidiary of Xcel Energy, is preparing an application to the U.S. Nuclear Regulatory Commission (NRC) to renew the operating licenses for Prairie Island Nuclear Generating Plant (PINGP), which expire in 2013 (Unit 1) and 2014 (Unit 2). As part of the license renewal process, NRC requires license applicants to provide "...an assessment of the impact of the proposed action {license renewal} on public health from thermophilic organisms in the affected water." Organisms of concern include the enteric pathogens *Salmonella* and *Shigella*, the *Pseudomonas aeruginosa* bacterium, thermophilic Actinomycetes ("fungi"), the many species of *Legionella* bacteria, and pathogenic strains of the free-living *Naegleria* amoeba.

As part of the license renewal process, NMC is consulting with your office to determine whether there is any concern about the potential occurrence of these organisms in the Mississippi River at the location of PINGP. On June 14, 2007 your office indicated there were no concerns at that time. As stated in the September 7, 2007 letter from James Holthaus, we are currently seeking your input on any specific concerns the Department may have regarding thermophilic microorganisms. By contacting you, we hope to identify any issues that need to be addressed or any information your office may need to expedite the NRC consultation.

The PINGP site, located in Goodhue County, Minnesota, consists of 578 acres on the west bank of the Mississippi River (Figure 1), within the city limits of Red Wing, Minnesota. The Vermillion River lies just west of PINGP and flows into the Mississippi River approximately two miles downstream of Lock and Dam No. 3 (Figure 2). NRC regulations specify that if discharges are made to a small river with an average annual flow rate of less than 3.15×10^{12} cubic feet per year, the applicant must assess the public health impacts of the proposed action regarding potential proliferation of thermophilic microbiological organisms in the affected waters. As a component of its operation, PINGP discharges cooling water into the Mississippi River. The Mississippi River has an average flow of 5.8×10^{11} cubic feet per year in the vicinity of PINGP, conforming to the NRC definition for consideration as a small river. This issue is therefore applicable to PINGP license renewal and will be addressed in the Environmental Report.

To determine the ambient river water temperature, assess the plant's thermal output, and assure compliance with NPDES thermal discharge requirements, river water is monitored by PINGP at multiple locations. Temperatures are monitored in the main river channel (upstream), Sturgeon Lake (upstream), the plant intake structure, the discharge canal, and immediately downstream of Lock and Dam Number 3. The highest temperature at the station upstream of the plant intake structure during the period of 2000-2005 was 86.0°F in 2001 (August 8). The highest temperature measured over the same period downstream of the plant at the Lock and Dam Number 3 monitoring station was 86.4°F in 2001 (August 9). The highest daily maximum temperature measured at the plant's discharge canal from January 2003 through December 2004 was 99.0°F, recorded on July 28, 2003. The entire length of the discharge canal and adjoining portions of the Mississippi River are within the plant's exclusion zone, however, and there is no public access to these areas. Water at these temperatures could, in theory, allow limited survival of thermophilic microorganisms, but are well below the optimal temperature range for growth and reproduction of thermophilic microorganisms. Thermophilic bacteria generally occur at temperatures from 77°F to 176°F, with maximum growth at 122°F to 140°F. The probability of the presence of thermophilic microorganisms due to plant operations is low.

During the early 1980s, PINGP identified the presence of the parasitic amoeba *Naegleria* at high population densities within the plant's circulating water system. In cooperation with the Minnesota Pollution Control Agency and Minnesota Department of Natural Resources, PINGP conducted chlorination and subsequent dechlorination of the circulating water system in August 1980, September 1981, and August 1983. The chlorination processes were successful in controlling and reducing the populations of the organisms; however, the dechlorination process does impact the fish populations in the Mississippi River. Although the Minnesota Department of Health did not consider the presence of the organism to be a public health threat, it was recognized as an occupational health hazard and plant personnel were instructed to wear protective equipment when in contact with the circulating water system components. PINGP continues to periodically chlorinate the circulating water system to control microbiological organisms and zebra mussels in accordance with the NPDES permit requirements.

Given the thermal characteristics at the PINGP discharge and the fact that NMC periodically chlorinates the circulating water system, NMC does not expect PINGP operations to stimulate growth or reproduction of thermophilic microorganisms. Under certain circumstances, these organisms might be present in limited numbers in the station's discharge, but would not be expected in concentrations high enough to pose a threat to recreational users of the Mississippi River.

We appreciate your earlier response to general License Renewal Issues. We would appreciate a letter detailing any concerns you may have about thermophilic microorganisms in the area of PINGP or confirming NMC's conclusion that operation of PINGP over the license renewal term would not stimulate growth of thermophilic pathogens. NMC will include a copy of this letter and your response in the license renewal application that we submit to the NRC.

Please direct any requests for additional information, questions and your response to:

James J. Holthaus, PMP
Environmental Project Manager
Prairie Island Nuclear Generating Plant
1717 Wakonade Drive East
13 – Plex (License Renewal)
Welch, MN 55089
651-388-1121 ext 7268
James.holthaus@nmcco.com

Sincerely,

Mike Wadley

Mike Wadley
Prairie Island Site Vice President
Nuclear Management Company

Enclosures: Figure 1
Figure 2

Figure 1
PINGP Site Boundary

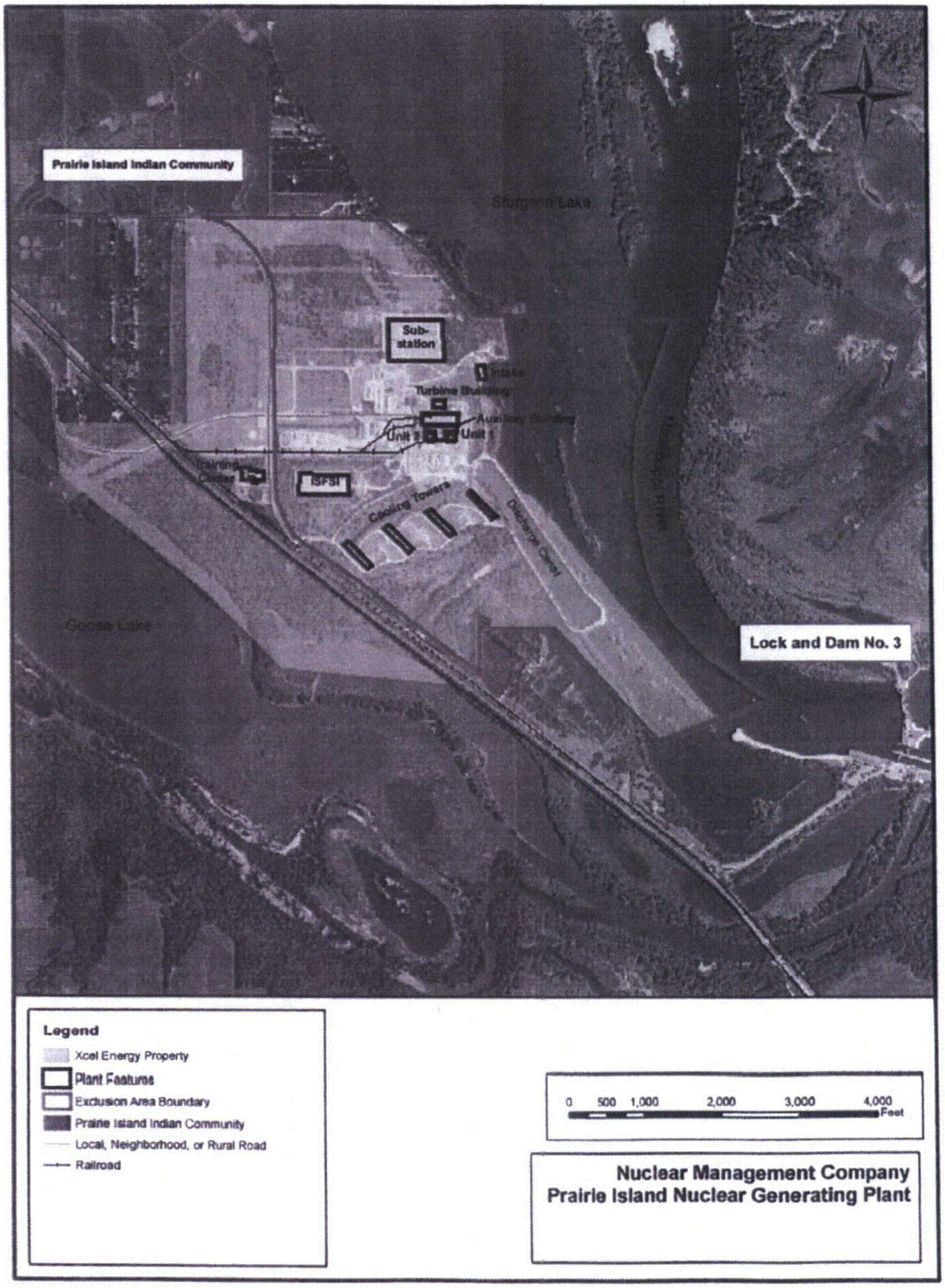
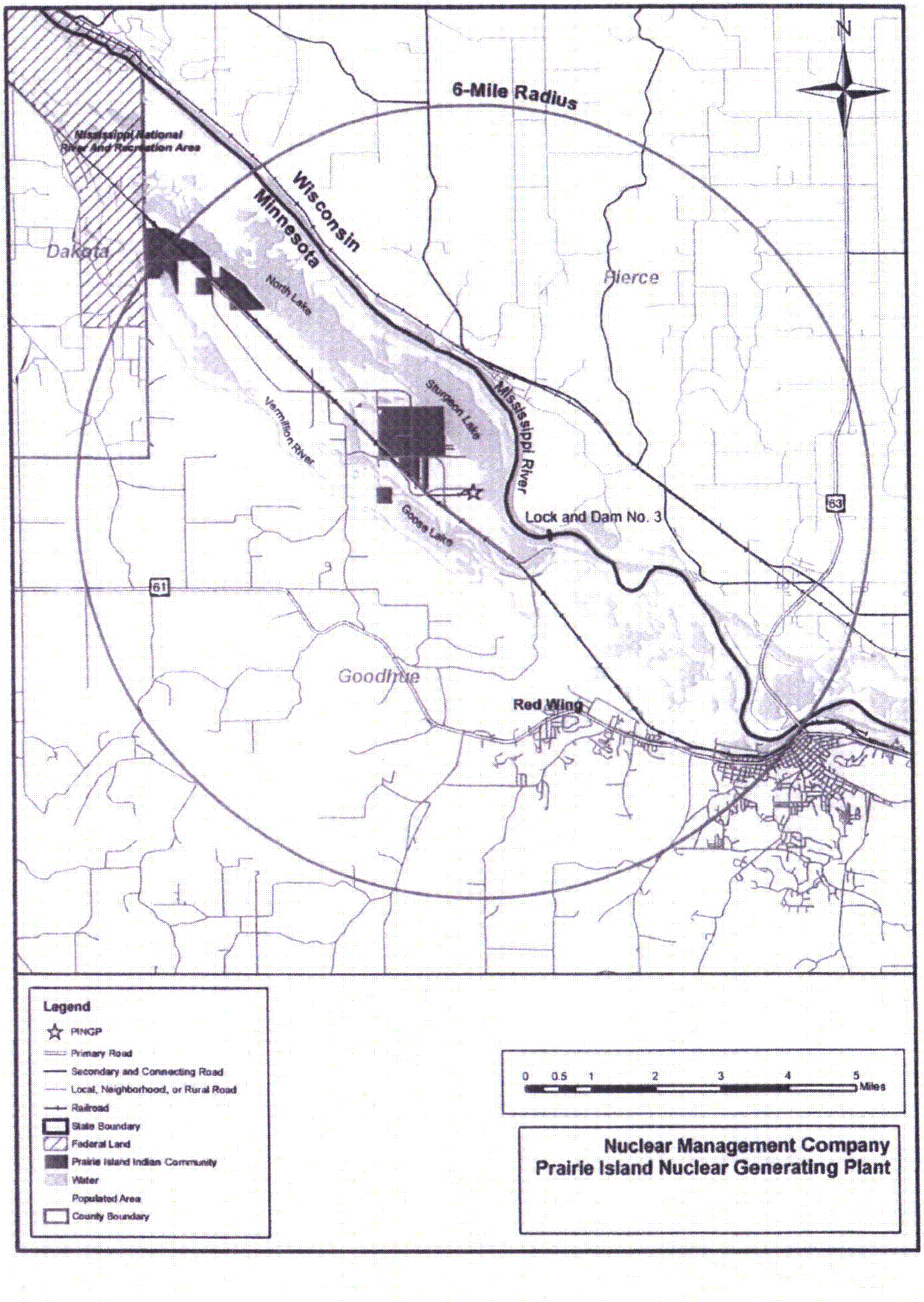


Figure 2
6-Mile Radius of PINGP



6-20-07

Issues for Prairie Island Nuclear Generating Plant License Renewal Project 404

1. Thermal effluent changes. I understand there will be a small increase in the output of the plant. The resulting change in the thermal discharge, especially during winter months, should be modeled to identify any changes to the existing thermal requirements and plume. This and any resulting environmental impacts should be contained in environmental review documents.

2. Environmental Drawdown of Pool 3. The Service and other agencies on the Upper Mississippi River are pursuing environmental drawdowns in the navigation pools to reestablish aquatic vegetation. Drawdowns (approximately 18 inches at the dam) were conducted in Pool 8 in 2001 and 2002, and in Pool 5 in 2005 and 2006. Dewatered areas (approximately 3,000 acres) successfully revegetated with submergent and emergent vegetation. We (Water Level Management Task Force comprised of the St. Paul District Corps of Engineers, Minnesota, Iowa and Wisconsin Departments of Natural Resources, Minnesota Pollution Control Agency, towing industry, public) are currently working on a drawdown proposal for Pool 6 in 2008 and are beginning discussions for other pools. Aquatic vegetation in Pool 3 has declined since inundation and we believe a similar drawdown would provide significant benefits to aquatic vegetation and habitat. We understand that the Upper Mississippi River is used for cooling of the Prairie Island Plant, and a critical issue determining the depth of the drawdown will be the depth and operational mode of the intake/discharge features. We are hopeful that future discussions between Northern States Power and the interagency Water Level Management Task Force will lead to a successful Pool 3 drawdown project. Because drawdowns will become a common management practice on the Upper Mississippi River to sustain aquatic vegetation, any changes to the infrastructure or operation of the Prairie Island Plant resulting from the proposed renewal project should take into account future drawdowns of Pool 3. 405

Thanks for the opportunity to comment!

Gary Wege
Fish & Wildlife Biologist
U.S. Fish & Wildlife Service
4101 East 80th Street
Bloomington, MN, 55425-1665
612-725-3548 ext. 207
Gary_Wege@fws.gov

Prairie Island Nuclear Generating Plant
Environmental Review Process
Agency Response Sheet

Agency Name: U.S. Fish & Wildlife Service

☒ Yes, we have information regarding environmental concerns or historic and archeological resources.

Please identify the information below, or state if there is an attachment:

Please see attachment

☐ Yes, we would like to meet with NMC individually at this time to discuss our concerns.

Contact Information:

☐ No, we do not have any comments or concerns at this time, however we may decide to comment later during the process.

Thank you for your feedback!

Mr. James Holthaus
Environmental Project Manager
PINGP License Renewal (13-Plex)
1717 Wakonade Drive East
Welch, MN 55089
651-388-1121 ext 7268
james.holthaus@nmcco.com

Committed to Nuclear Excellence

Xcel Energy

April 30, 2007

Robyn Thorson
Regional Director
U.S. Fish and Wildlife Service
BHW Federal Building
1 Federal Drive
Fort Snelling, MN 55111-4056

SUBJECT: Environmental Review for Prairie Island Nuclear Generating Plant License Renewal Project

Dear Robyn:

Nuclear Management Company (NMC) acting on behalf of Northern States Power Company, a Minnesota Corporation and wholly owned subsidiary of Xcel Energy, requests your input on the environmental review of the license renewal for the Prairie Island Nuclear Generating Plant (PINGP). Xcel Energy owns the Prairie Island nuclear generating facility, while NMC is responsible for plant operations. NMC is preparing an application for submittal to the U.S. Nuclear Regulatory Commission (NRC) to renew the operating licenses for the PINGP located in Goodhue County, Minnesota. The PINGP is currently licensed to generate electricity through 2013 for Unit 1 and 2014 for Unit 2. Successful renewal of these licenses would extend the PINGP operating licenses for an additional 20 years; i.e., until 2033 and 2034 for Units 1 and 2 respectively.

The NMC environmental review process assesses the NRC requirements for PINGP license renewal and evaluates environmental impacts or stakeholder issues associated with potential continued operations. Early participation by your agency ensures timely identification of issues and information for consideration in this process.

In addition to detailed safety reviews, the license renewal process involves a thorough review, both by NMC and the NRC, of potential environmental impacts in accordance with provisions of the National Environmental Policy Act (NEPA). The attached supplement provides an overview of the process and associated environmental review activities for PINGP. In brief, the NRC has prepared a generic environmental impact statement (GEIS) that addresses environmental impacts of license renewal based on its review of plants nationwide. A detailed environmental review for individual plants such as PINGP includes preparation of an Environmental Report by the applicant and a site-specific supplement to the GEIS prepared by the NRC. These documents must include impact assessments for site-specific environmental issues that were not resolved generically by the NRC in the GEIS. They also must identify any known "new and significant information," i.e., potentially significant environmental issues or impacts not recognized as such by the NRC in the GEIS, and the NRC's codified findings from the GEIS

(10 CFR 51.53). In accordance with NEPA, the NRC's process for developing the site-specific supplements to the GEIS includes substantial opportunity for participation by agencies and the public, including the opportunity to formally comment on the scope of the NRC's site-specific supplement and the adequacy of that document.

The PINGP License Renewal Environmental Review Team would appreciate your Agency's early and active participation in the license renewal environmental review process for PINGP. In the course of evaluating the requirements and developing the Environmental Report, applicants for a renewed operating license routinely consult with resource agencies. These consultations are undertaken to familiarize the agencies with the project, identify agency concerns, and obtain pertinent resource information, including any new and potentially significant information, as needed to ensure a complete and accurate application. We welcome any questions or concerns your agency has in regards to the environmental implications of renewing the PINGP's license and any information that your agency may consider to be potentially "new and significant." These efforts will help ensure that the Environmental Report we prepare is complete. In this regard, we would be pleased to meet with your agency representative(s) to discuss the PINGP license renewal environmental review in more detail. If you desire a meeting, please contact us as soon as possible to schedule. Time is of the essence as a prompt response will allow for a more thorough review.

NMC respectfully requests you respond to this request by returning the attached response form within 30 days of your receipt of this letter, regardless of whether your agency has identified any concerns or issues to be raised in the environmental report. Your response simply acknowledges you received this letter and indicates you either have no concerns at this time or have attached your concerns to the response form. This does not prohibit your agency from raising concerns or questions in the future, but it is extremely valuable to the public and stakeholder input process. If you have any questions or concerns about the environmental review, or would like to schedule a meeting to discuss your concerns please contact:

Mr. James Holthaus
Environmental Project Manager
651-388-1121 ext 7268
james.holthaus@nmcco.com

For your convenience, please find a response form as well as a self addressed, stamped envelope attached. Thank you on behalf of NMC and the PINGP License Renewal Environmental Review Team.

Sincerely,

Joel P. Sorensen for

Tom Palmisano
Site Vice President
Nuclear Management Company

Charlie Bomberger
General Manager, Nuclear Asset Management
Xcel Energy

Attachments

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
SIBLEY SQUARE AT MEARS PARK
190 FIFTH STREET EAST, SUITE 401
ST. PAUL MN 55101-1638

REC'D MAR 13 2008

March 11, 2008

Environmental and Economic Analysis Branch
Planning, Programs and Project Management Division

Mr. Mike Wadley
Prairie Island Site Vice President
Nuclear Management Company
Prairie Island Nuclear Generating Plant
1717 Wakonade Drive East
Welch, MN 55089

Dear Mr. Wadley:

In response to your March 3, 2008 letter to the U.S. Army Corps of Engineers, St. Paul District requesting information regarding the Federally endangered Higgins eye pearlymussel reintroduction program, we are sending documentation used in the decision making process to use Sturgeon Lake as a relocation site.

Seven documents are on the enclosed CD;

1) **2002clamchronicle.pdf.** Minnesota Department of Natural Resources. Specifically, page 4 - June 5th, reports results of a mussel survey at the Sturgeon Lake site (in part leading to the specific selection of this site - healthy existing mussel community, favorable habitat, zebra mussels nearly absent, etc...)

2) **DOI 2001 Higgins eye Federal Register Notice.pdf** and **DOI Higgins eye 2000 Federal Register Notice.pdf.** U.S. Fish and Wildlife public notice of the Higgins eye Relocation Plan.

3) **DPR notice of Availability.pdf.** Corps of Engineers public notice of availability of the Relocation Plan for Higgins eye.

4) **Higgins eye Final Relocation DPR July 2002.pdf.** Corps of Engineers, Final Definite Project Report and Environmental Assessment for Relocation Plan for the Endangered Higgins eye Pearlymussel. Note Section 7.2 Candidate Relocation Sites (page 22). Also note Appendix 6 – Distribution List for the DPR/EA and Public Notice.

5) **Higgins eye 2004 Recovery Plan.pdf.** Extensive information on Higgins eye historic and present distribution, ecology, life history, etc…

6). **Sec6Final_Report.pdf**. Minnesota Department of Natural Resources. Report (page 1 and 2) on the results of relocating Higgins eye to Pool 2 and 3 prior to the Corps' Relocation Plan implementation.

We have furnished a copy of the enclosed CD to the U.S Fish and Wildlife Service, Twin Cities Field Office as well. We recommend that you coordinate with USFWS concerning potential impacts to Higgins eye relating to Prairie Island Nuclear Generating Plant. If you have questions about the project, please call Mr. Dennis Anderson (Project Manager) at (651)-290-5272 or Mr. Dan Kelner (Biologist) at (651) 290-5277.

Sincerely,

Terry J. Birkenstock
Chief, Environmental and Economic
Analysis Branch

Copy w/ Enclosures sent to:

Mr. Tony Sullins
U.S. Fish and Wildlife Service
Twin Cities Field Office
4101 East 80th Street
Bloomington, Minnesota 55425

CLAM CHRONICLES

An account of activities associated with efforts to propagate and repatriate *Lampsilis higginsii* in the Mississippi River, Minnesota – Minnesota Department of Natural Resources (Mike Davis - Biologist)

2002 FIELD SEASON

May 9, 2002: On this day the *Lampsilis higginsii* listed in the table below were collected from the Pool 2 repatriation site at Hidden Falls and transported to the Genoa National Fish Hatchery to be used as a source of glochidia for infecting fish hosts.

ID #	Length	Gravid?	Used in fall '01?
657	71.4	x	
C128	58.6	x	
C132	70.0		x
DH87	63.9	x	
DH8	90.1	x	
DH32	79.1	x	
C58	78.4	x	x
DH2	89.2	x	
08	85.0	x	
C81	83.6		
C152	76.5	x	x
C84	57.0		x
C165	80.2	x	
C154	74.9	x	
C56	67.7	x	x
C41	70.0	x	
C97	64.5	x	
C183	76.0	x	
C13	59.3	x	x
C59	62.4	x	
C42	83.3	x	
DH19	89.5	male	

May 23, 2002 : *Lampsilis higginsii* adults from whom glochidia were harvested were returned to the Hidden Falls site. Later in the day, a cage at the Hudson propagation site was emptied and 37 juvenile *Lampsilis higginsii* ranging in length from 16.5mm to 28 mm were removed and placed into an adjacent cage.

May 29, 2002 : 20 cages containing 520 Walleye (*Stizostedion vitreum vitreum*) infected with *Lampsilis higginsii* glochidia were placed on the bottom of Lake Pepin at the Frontenac propagation site. An individual record for each cage was recorded.

UTM
15 T 0553350
4930739

May 30, 2002: 27 cages containing 804 largemouth bass (*Micropterus salmoides*) infected with *Lampsilis higginsii* glochidia were placed in Pool 1, Mississippi River about ½ mile upstream of Lock and Dam 1.

UTM
0484277
4974550

June 5, 2002: A survey for suitable sites to place propagation cages in Pool 3 led to choosing a site in Sturgeon Lake immediately downstream of the public access and about 50-60 meters offshore.
UTM
15 T 0529127
4941821

At this site one diver performed a 25-minute qualitative search to collect all live and dead mussels encountered. Results are in the table below. Species reported as dead were fresh and can be assumed to be living in the area.

Species	# found	Live/dead	#zebes
Obliquaria reflexa	54	L	0
Amblema plicata	31	L	0
Quadrula quadrula	18	L	0
Pyganodon grandis	5	L	0
Fusconaia flava	4	L	0
Quadrula pustulosa	4	L	0
Truncilla truncata	2	L	0
Potamilus alatus	1	D	1
Potamilus ohiensis	1	D	0
Total live mussels	**118**		**1**
CPUE (catch/minute)	**4.72**		

CPUE at this site indicates that mussels are fairly abundant. Physical conditions are favorable to cage placement in that this area. We did not observe recent accumulations of river bed load at this site. This is because it is near the outlet of Sturgeon Lake and bed load entering the Lake settles near the inlets upstream and on the opposite side, nearly one mile away. Also there is apparently current of adequate velocity to carry away fine sediments in that the bottom substrate at this site is gravel, sand and a thin layer of silt, similar to the propagation site in Lake Pepin. Depth range is 6-12 feet.

June 18, 2002. All cages at the Lake Pepin propagation site were opened to allow fish to escape. Four fish were preserved in ETOH for analysis of their gills at the Genoa National Fish Hatchery. Condition of the fish appeared to be good and gills of several examined with a hand lens appeared to be free of encysted glochidia. A single dead fish was observed and all cages had live fish present in them. All cages were closed after one hour.

June 19, 2002. Four of five cages placed at this site in 2001 were retrieved from the Mississippi River below Prescott, WI. These cages were nearly buried in sediments and the remaining cage, presumably buried, was not found. The table below summarizes what was collected from within each cage.

Cage #	*#higginsii*	Lengths (mm)	Other species found in cage
1	2 empty shells		*Utterbackia imbecillis* (1) *Corbicula sp* (3)
2	3	21,21,15	*Leptodea fragilis* (8)
3	1	17	*Arcidens confragosus* (1 - 28mm) *Utterbackia imbecillis* (42) *Potamilus alatus* (2) *Potamilus ohiensis* (1) *Corbicula sp.* (1)
4	5	33,32,23,28,27	*Utterbackia imbecillis* (13) *Potamilus alatus* (1) *Potamilus ohiensis* (2) *Pyganodon grandis* (1) *Leptodea fragilis* (15) *Corbicula sp.* (3)
Total	9 live, 2 dead		74

Lampsilis higginsii from these cages were taken to the propagation site in the St Croix River just upstream of the U. S. Highway 10 Bridge and placed into a cage there for grow-out. Two cages at this site were also retrieved for inspection. One is a small cage into which transformed juveniles from tanks at the Genoa National Fish Hatchery were placed in June of 2001. Three juvenile *Lampsilis higginsii* were removed from this cage (lengths 10,11,12 mm) and placed into a cage bearing tag number 48 along with a single *Pleurobema sintoxia* (17mm) also found within the cage.

One closed bottom cage was retrieved and all mussels removed. This cage contained the 3 *Lampsilis higginsii* and 1 *Ligumia recta* from the year 2000 effort in Lake Pepin. These mussels were measured and the *Lampsilis higginsii* found to be 32, 37, and 35 mm in length while the black sandshell was 53 mm long. 167 other *Lampsilis higginsi* were removed from this cage and transferred to cage #48 for grow-out. A random sample of lengths produced a range from 7 – 15 mm. Nine empty *Lampsilis higginsii* juvenile shells were found and have been accessioned into the collections of the James Ford Bell Museum of Natural History. About 20 small zebra mussels were found attached to the closed bottom cage. On the bottom of the small cage were attached about 3-dozen mudpuppy eggs.

<u>June 20, 2002</u>, At the Hudson propagation site 6 cages were brought to shore and searched. One cage had been placed for the purpose of rearing transformed animals from the Genoa National Fish Hatchery; it was empty. Two open bottom cages were removed from and the river and the bottom beneath them searched by hand for juvenile mussels. 15 juvenile *Lampsilis higginsii* were collected from beneath the cage whose bottom was about 2-3 cm above the riverbed. None were found beneath the other open bottom cage whose bottom was about 5 cm above the riverbed. This suggests that the lower cage may have offered greater protection from predators. The lengths of the 15 juveniles ranged from 19– 27mm and averaged 22.5 mm. All of these juveniles were moved to the cage propagation site in Lake Pepin for grow-out.

Three other cages at this site contained 63, 96 and 37 juvenile *Lampsilis higginsii,* or a total of 215 from the 2001 propagation effort. Lengths of these juveniles ranged from 17 – 31 mm. These were placed into a single cage and returned to the river bottom at this site for grow-out.

Eleven other Mussels of three Minnesota listed species were collected gravid from this site on this date and used to infect fish. *Ligumia recta, Pleurobema sintoxia, and Ellipsaria lineolata* propagation efforts are part of a "Bring Back the Natives" grant proposal to the National Fish and Wildlife Foundation.

June 24, 2002.
Two timed searches in Minnesota Slough, Pool 9 Mississippi River produced the following:

UTM (Near the upper end of Minnesota Slough)
0640660
4819083

An 8-minute spot search produced 132 mussels of 9 species resulting in a catch per unit effort of 16.5 mussels/minute. This is a very high CPUE and suggests high mussel abundance and the potential for additional species, including *Lampsilis higginsii,* to be found here if additional effort were expended. For example, if 60 minutes of search time were expended at this site it could be expected that nearly 1000 mussels would be collected.

Species	# individuals	L/D	Min length	Max length	zebes
Amblema plicata	81	L	28	107	0
Obliquaria reflexa	15	L	37	61	0
Quadrula quadrula	19	L	56	94	0
Pyganodon grandis	6	L	133	156	0
Fusconaia flava	4	L	34	64.5	0
Quadrula pustulosa	4	L	47.5	66	0
Quadrula nodulata	1	L	56		0
Truncilla truncata	1	L	31		0
Toxolasma parvus	1	L	22		0
TOTAL	132				0

UTM (outlet of Goose Lake)
0640861
4819187

A ten-minute spot dive produced 37 individuals of 7 species for a catch per unit effort of 3.7 mussels/minute. Over 4 hours of search time would be needed to collect 1000 mussels at this site.

Species	# individuals	L/D	Min length	Max length	Zebes
Amblema plicata	24	L	23	107	0
Fusconaia flava	6	L	25	65	0
Obliquaria reflexa	3	L	34.5	43	0
Quadrula quadrula	1	L	56		0
Quadrula pustulosa	1	L	26		0
Utterbackia imbecillis	1	L	57		0
Pyganodon grandis	1	L	120		0
Total	37				0

Minnesota Slough – across from New Albin public boat ramp: The bottom of the channel in this area is covered in old relic shells that included *Fusconaia ebena, Lampsilis teres,* and *Lampsilis higginsii,* but was predominately *Amblema plicata.* Few live mussels were found although it is difficult to search by feel for live mussels among all the old shells. Most were covered with zebra mussel byssal threads indicating recent, intense colonization. Additional searching in Minnesota Slough seems promising in that it has apparently provided excellent mussel habitat in the past and is vast in physical scale.

July 1, 2002
Cages # 49 was placed in Lake Pepin at the propagation site with 11 walleye and 3 yellow perch (*Perca falvascens*) infected with glochidia from *Ligumia recta.* Cage #50 also placed here with 12 walleye similarly infected.

July 9, 2002
152 *Elliptio dilatata* were collected for transplanting into upper Pool 2 from the mussel bed at the foot of Lake Pepin.

UTM
0571372
4918229

These individuals were stored in mesh bags until August 1, 2002 due to unexpected high water conditions at the transplant site. Several apparently gravid females were brought into the lab for further examination and found to have ovum present but no larvae. Zebra mussels have heavily colonized this site in the recent past. However, it appears that many of the zebra mussels died in late 2001 during the hot weather, although there were still live individuals attached to many of the native spikes.

August 1, 2002
An additional 76 *Elliptio dilatata* were collected from Lake Pepin. The stockpiled spikes were retrieved from the lake and all were taken to Pool 2 for transplanting. A site was picked along the left descending bank of the Mississippi just across from the old Ft Snelling State Park Interpretive Center and beneath the overhead power lines. Depth at

this site ranged from 6 – 12 feet, with depth increasing with distance from shore. Substrate was sand and rubble.

UTM
0486059
4971231

Nine individuals died during the wait for transplanting, a total of 220 live animals were placed into the substrate using a metal bar to create a cavity for them.

August 5, 2002
Picked up 19 *Quadrula metanevra* and 2 *Cyclonaias tuberculata* that were collected from the St Croix River near Franconia by Mark Hove. These animals were taken to the Genoa National Fish Hatchery to be used for infecting host fish.

August 6, 2002
Many of the mussels had aborted immature glochidia. 17 of the *Quadrula metanevra* no longer had any larvae in their gill chambers, the 2 remaining had immature glochidia present. The 2 *Cyclonaias tuberculata* had apparently aborted all their larvae.

August 13, 2002
A search for gravid mussels upstream of Franconia produced 2 *Ellipsaria lineolata,* 5 *Elliptio dilatata* and 2 *Actinonaias ligamentina* that appeared to be gravid. Four *Quadrula fragosa* (Federally Endangered) were collected incidentally to this effort, photographed, and immediately returned to the riverbed where they were found. Lengths and ages are shown in the table below.

Quadrula fragosa

Length (mm)	Age
58	5
60	6
55	4
47	4

Quadrula fragosa

Two *Cumberlandia monodonta* were also collected and returned to the river.

August 14, 2002
A collection of 146 *Elliptio dilatata* was made from the mussel bed at the foot of Lake Pepin.

UTM
0571370
4918230

Five were taken to Genoa National Fish Hatchery microscopic examination of their marsupial chamber contents.

August 15, 2002
Mussels collected on 8/13-14/02 were examined at the Genoa National Fish Hatchery and determined to have ovum in their gill chambers, not larvae. *Actinonaias ligamentina and Ellipsaria lineolata* were left at the hatchery to see if the ova were fertile and would mature into glochidia. The 5 *Elliptio dilatata* were retained for transfer to the Pool 2 transplant site.

Cage # 51 and 52 were placed at the Lake Pepin propagation site each containing 6 flathead catfish (*Pylodictis olivaris*) infected with glochidia from *Cyclonaias tuberculata* collected previously from the St Croix River near Franconia. Cage 53 was placed here also containing 28 tadpole madtoms (*Noturus gyrinus*) also infected with *Cyclonaias tuberculata.*

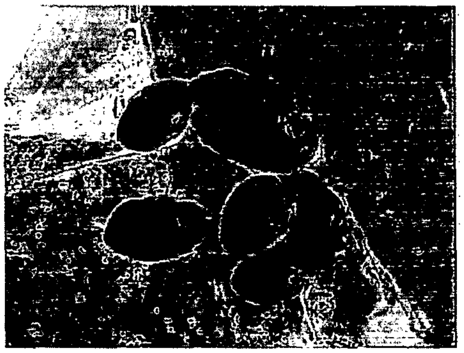
August 16, 2002
151 *Elliptio dilatata* were hand placed into the substrate at the Pool 2 transplant site bringing the total number of this species repatriated here to 371.

August 28, 2002
Cage # 54 containing 6 sauger (*Stizostedion canadense*) infected with *Ligumia recta,* cage 55 containing 6 walleye infected with *Ligumia recta* and cage 56 containing 3 sauger and 3 walleye infected with *Ligumia recta* were placed at the Lake Pepin propagation site. These fish were collected from Lake Pepin by the MN DNR Fisheries crew at Lake City during annual trawling.

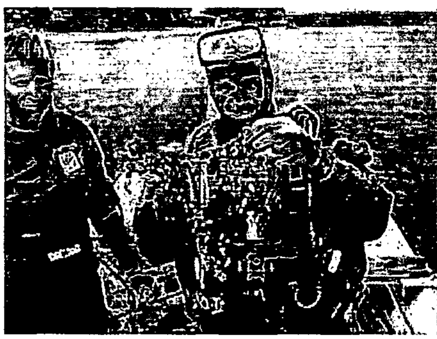
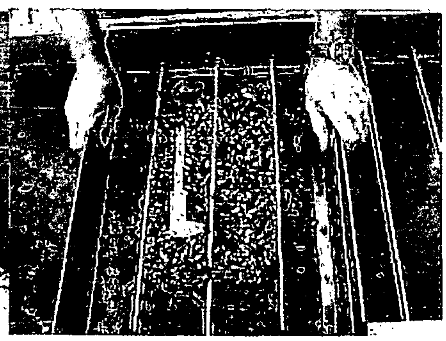
September 13, 2002
Cages 51-54 at the Lake Pepin propagation site were opened and fish released. Cages 49 and 50 were not located in the time allotted for this effort and will be retrieved in 2003. Cage 55 was left alone.

September 16, 2002
Cage #21 from the Pool 1 propagation site was raised and its contents checked. This was the only cage found that was not at least partially buried beneath bed load from the summer flooding.

Six juvenile *Lampsilis higginsii* were found that ranged in length from 15 –26 mm. In addition, 12 *Utterbackia imbecillis*, 11 *Corbicula sp.*, 7 *Leptodea fragilis*, and 3 *Potamilus alatus* juveniles were removed from the cage and placed into a second cage on site.


Pool 1 cage #21

<u>September 24, 2002</u>
Lake Pepin propagation cage site: eleven cages were lifted from the lake and emptied into a trough covered with a wire mesh. *Lampsilis higginsii* collected from these cages were consolidated and placed into two cages for continuing grow-out.

The table below summarizes what was found in each cage.

Cage #	# of *L. higginsii*	Fish remaining	Other species found	Min and Max Length (mm)
7	25	3 live walleye	1 *Corbicula sp*	10 -22
6	93	0	1 *Corbicula sp*	
8	11	0	1 *Corbicula sp.*, 1 *T. Parvus*	
18	6	1 dead LMB?	1 *L. fragilis*	10 – 18
5	41	1 dead Walleye	1 *T parvus*	9 - 20
4	70	2 live walleye	2 *Corbicula sp.*, 3 *T. parvus*, 1 *Utterbackia imbecillis*	
10	153	4 live walleye	None	9 – 22
12	70 (+ 15 from 2001)	0	5 *Corbicula sp.*, 1 *L. cardium*, 1 *L. fragilis*, 4 *U. imbecilis*, 1 O. *reflexa*	9 –22 (25 – 35)
9	38	1 dead walleye	none	9 –22
1	29	1 live walleye	none	
20	11	1 live, 2 dead walleye	2 *T. parvus*	
Total	547 (+ 15) = 562	11 live	25	9 - 22

Cage numbers 1 and 20 were placed back into the lake with all juveniles divided between them.

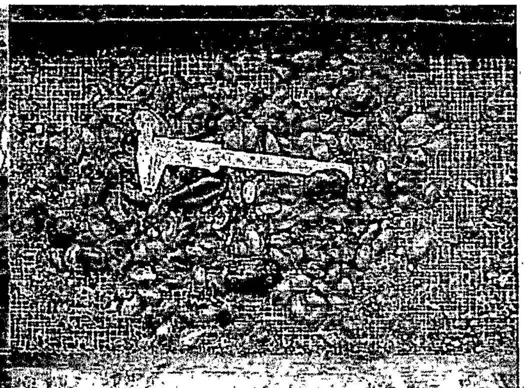
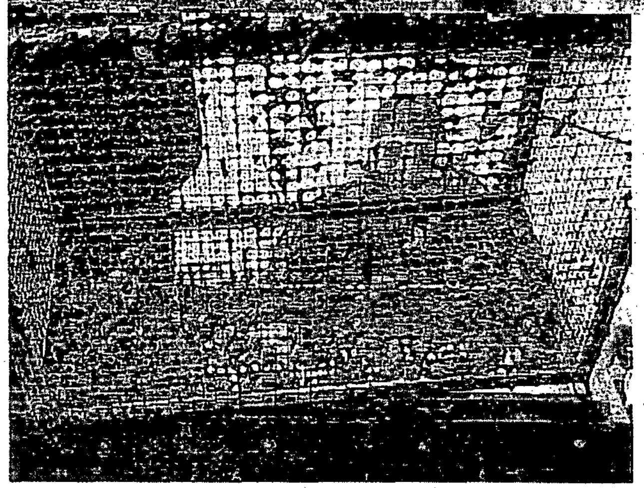
September 26, 2002

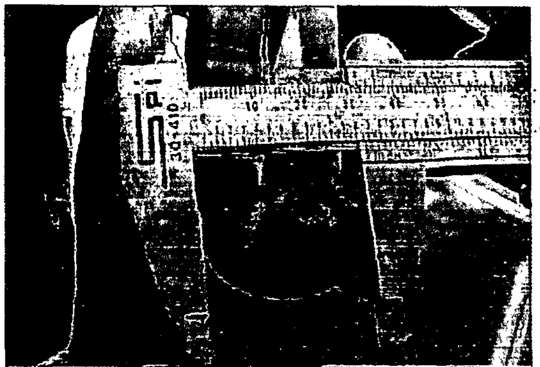
Four cages were retrieved and all juvenile mussels removed from the St. Croix River, Prescott, WI cage propagation site. All juvenile *Lampsilis higginsii* were placed back into two cages (#s 99 and 100) for grow-out. The table below summarizes the contents of each cage.

Cage	# of live *L. higginsii*	Other species found	Min-Max Length (mm)	# zebra mussels attached to juvenile *L. higginsii*
P1	7	3 A. plicata, 1 P. ohiensis, 1 E. dilatata, 1 T. parvus	20 –32	3
P2	4	none	26 - 38	9
P3	84	5 A. plicata, 2 T. parvus	18 -36	22

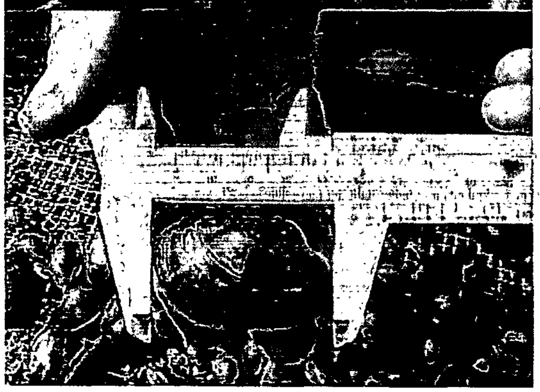
		1 P. sintoxia, 1 L. fragilis		
P4	37	2 A. plicata, 2 P. ohiensis	20 - 35	11
P100	185 + (8 dead) (previously consolidated cage)	5 A. plicata	20 - 42	30
Total 2001 juveniles	317	23		75

Three *Lampsilis higginsii* juveniles from the 2000 Lake Pepin propagation effort were recovered and measured. Average length had increased from 34.6 to 44.6 mm since June. A single *Ligumia recta* from the Lake Pepin effort in 2000 was also recovered and had grown from 53 to 66 mm. One juvenile *Arcidens confragosus*, was moved here from the below Prescott cage site in June, its length increased from 28 – 45 mm.

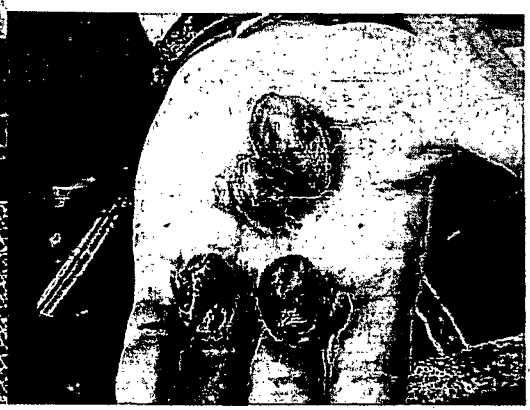






2000 higginsi - Sept 2001
Juvenile from Lake Pepin cage



2000 higginsi - Sept 2002
Juvenile from Lake Pepin cage

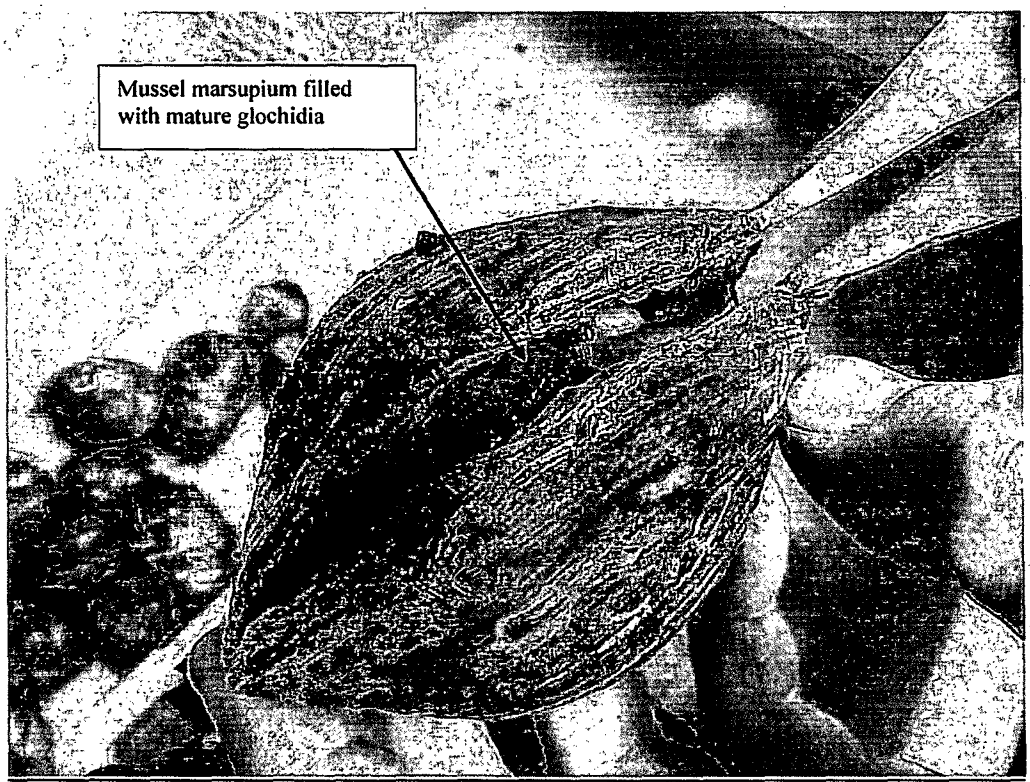


Adult *Lampsilis higginsii* relocation site, Pool 3

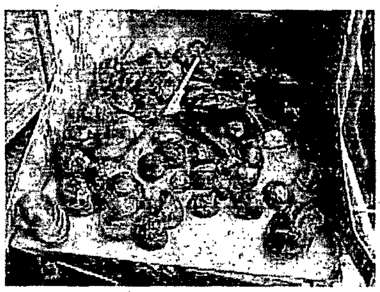
22 *Lampsilis higginsii* adults that were transferred here from Cassville, WI in September of 2000 were retrieved, measured and examined for reproductive status. The table below summarizes these findings. Note that the growth measurements indicate shrinking length, this may have been an error in reading the caliper used when the leading edge of the instrument was used to read the measurement instead of the zero mark. If this is indeed what happened, then the lengths reported in the table would be 5 mm larger and most negative growth would become positive.

Lampsilis higginsi moved from Cassville, WI to Upper pool 3, MN in September 2000							
	mussel #	gender	length 2000	length 2002	**growth in mm**		
	516	m	106	dead			
	517	m	89	87	-2		
	523	m	98	93	-5		
	526	m	102	98	-4		
	527	m	97	94	-3		
	528	m	81	86	5		
	529	m	89	84	-5		
	533	m	97	94	-3		
	538	m	91	87	-4		
	551	m	84	82	-2		
	556	m	91	82	-9		
	559	m	87	85	-2		
	574	f	69	72	3		
	592	m	74	75	1		
	596	m	86	84	-2		
	602	m		83			
	608	f		60			
	619	f		87			
	630	f		83			
	635	m		77			
	640	m		97			
	654	f		90			

Females collected on this date were gravid. A sample of glochidia was examined under a microscope and tested for viability with saline solution. All glochidia snapped shut, indicating that they were ready to clamp onto a fishes gills. Since it had been 2 full years since their removal from Cassville Slough in Pool 11, I assume that this means they have successfully fertilized eggs and developed these glochidia at this site.



In addition to the *Lampsilis higginsii*, we collected a number of other mussel species that had been transplanted here at the same time. All were found to be alive, no empty shells were found.

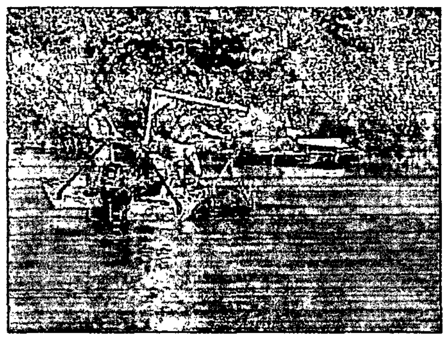


Species	# of individuals
Megalonaias nervosa	5
Ligumia recta	6
Pleurobema sintoxia	1
Obovaria olivaria	12
Ellipsaria lineolata	2
Quadrula metanevra	4

September 30, 2002

Pool 1 cage propagation site. Eight cages were retrieved and the contents sieved in search of juvenile *Lampsilis higginsii*. A single cage produced 2 juvenile *Lampsilis higginsii*; juvenile mussels representing nine other species populated the cages. One of these, *Utterbackia imbecillis*, was very abundant with as many as 56 individuals found in one cage. In total, 267 juvenile mussels (exclusive of *Lampsilis higginsii*) were found in these cages. The *Lampsilis higginsii* juveniles were taken to the Lake Pepin propagation site.

Cages at this site were nearly full of sand, silt and wood debris and were very difficult to retrieve. It was concluded that this was a poor site for propagation cages and will be abandoned in favor of more stable environments elsewhere. A winch and boom was used to lift the cages so that they could be taken into the boat for processing. After these 8 cages were processed it was determined that a suction dredge would be used to retrieve the remaining cages because they were buried almost entirely in the sand.



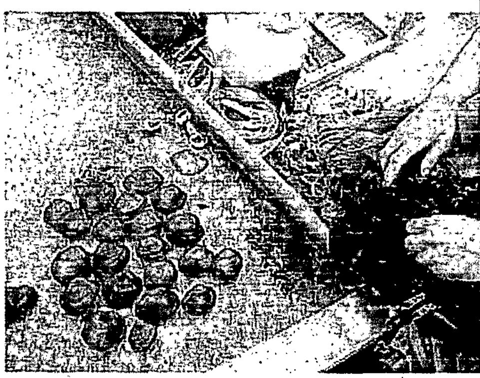
October 1, 2002

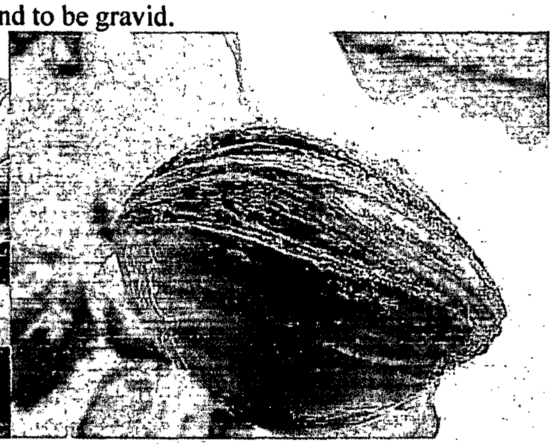
Pool 1 cage site: A 4" diameter hydraulic dredge was used to remove sand and detritus from in and around the buried cages so that a diver could carry them to the boat. Substrate that was delivered to the boat was forced through a ¼" mesh wire screen and any mussels removed. No *Lampsilis higginsii* were collected from the screen. An additional 6 cages were retrieved. Twelve cages remain buried in sand at the site.

Adult mussel transplant site at Hidden Falls, Pool 2: A collection of 21 *Lampsilis higginsii* were brought to the boat for examination and measuring. The table below presents the results of this effort.

Lampsilis higginsi moved from Cordova, IL to Pool 2, Hidden Falls MN in July 2001								
mussel #	gender	length 7/01	length 9/02	total growth	May-02	growth in '02	glochidia harvest?	gravid fall/02?
C102	F	79.8	84	**4.2**				
C112	F	58.4	63	**4.6**				
C13	F	59.7	60	**0.3**				
C152	F	75.3	76	**0.7**	76.5	**0.5**	fall '01 and spring '02	yes
C154	F	74.9	79	**4.1**	74.9	**-4.1**	spring '02	yes
C177	F	68	71	**3**				
C18	F	75.6	78	**2.4**				
C183	F	75.6	79	**3.4**	76	**-3**	spring '02	yes
C185	F	83.4	85	**1.6**				
C56	F	68.2	69	**0.8**	67.7	**-1.3**	fall '01 and spring '02	yes
C77	F	72.7	75	**2.3**				
C97	F	63.2	71	**7.8**				
DH12	F	76	92	**16**				
DH21	M	88.7	89	**0.3**				
DH23	M	83.6	87	**3.4**				
DH30	M	88.4	90	**1.6**				
DH38	F	79.2	80	**0.8**				
DH8	F	89.6	87	**-2.6**	90.1	**3.1**	spring '02	yes
DH87	F	61.6	70	**8.4**	63.9	**-6.1**	spring '02	yes

It was also noted that several of the *Lampsilis higginsii* appear to be growing in a peculiar way with exaggerated growth arrest lines and in-turning along the ventral margin of the shell. Otherwise they appeared to be in good health and about 1/3 of the females were examined for reproductive status and found to be gravid.





October 14, 2002

Eight *Megalonaias nervosa* were collected from among those transplanted into the Pool 3 site and 3 of these appeared to be gravid. It was hoped that these could be used to infect host fish that would then be placed into cages in Lake Pepin for the winter to see if juveniles could be successfully propagated and also to find out if fish can be successfully over wintered in a cage. We anticipate needing to do this in order to propagated *Quadrula fragosa* some day.

October 15, 2002

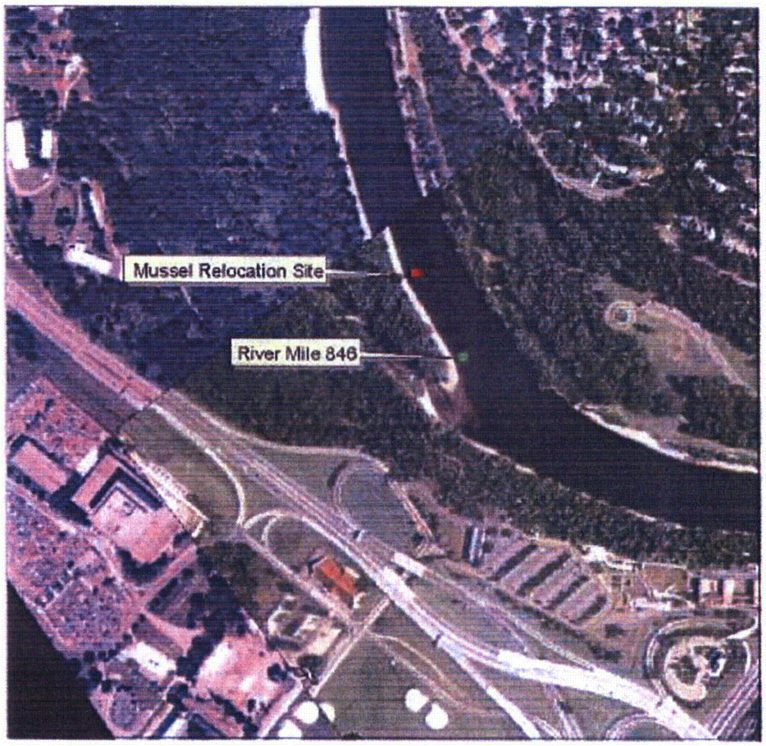
Three *Megalonaias nervosa* were taken to the Genoa National Fish Hatchery and the contents of their marsupia examined. All were found to contain undeveloped larvae, one female had completely aborted her marsupia. These females were all left at the hatchery in a tank in the hope that they might develop mature glochidia later in the fall.

Transplant site maps on following pages

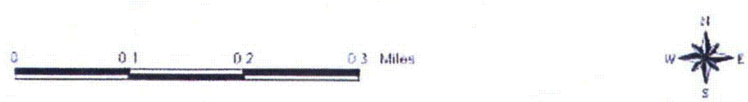
MISSISSIPPI RIVER MUSSEL RELOCATION SITE:

Across from Hidden Falls Park, River Mile 846.1

Latitude 44.8973 Longitude 93.1897
***L. higginsi* and State Listed Species**



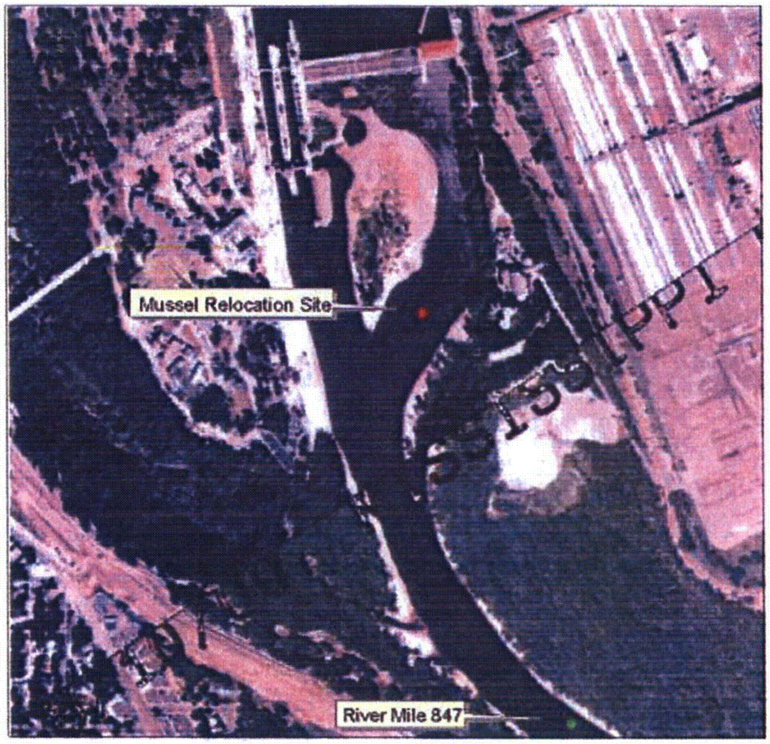
2000 Color Air Photo courtesy USGS--UMESC
Mussel Relocation Data provided by Dan Kelner, MN DNR
Map prepared by Jesse Kroese, NPS--MNRRA, 1/2/02



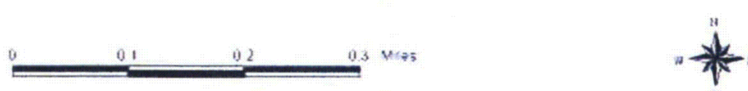
MISSISSIPPI RIVER MUSSEL RELOCATION SITE:

Below Ford Dam, River Mile 847.4

Latitude 44.9123 Longitude 93.1999
State Listed Species



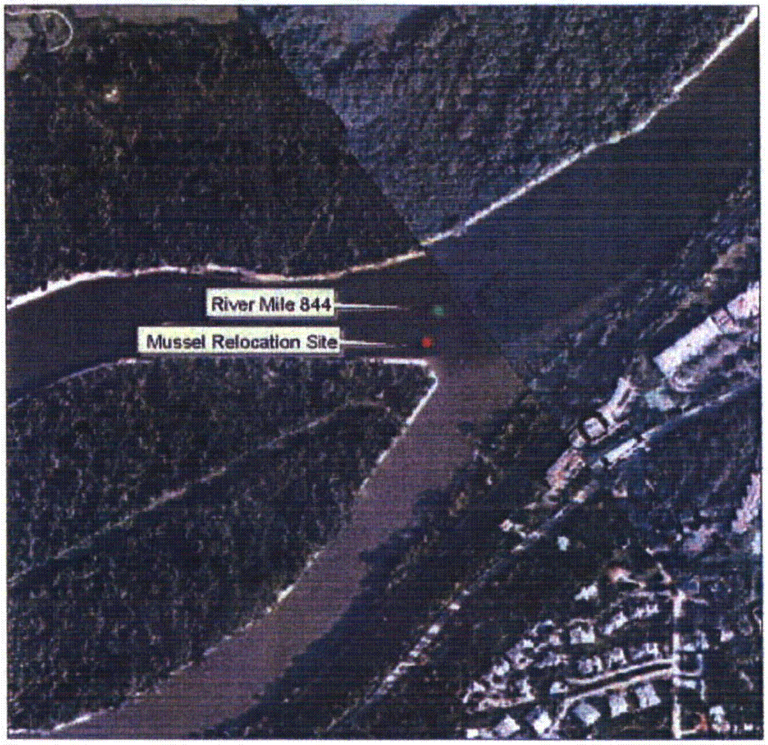
2000 Color Air Photo courtesy USGS- UMESC
Mussel Relocation Data provided by Dan Kelner, MN DNR
Map prepared by Jesse Kroese, NPS--MNRRA, 1/2/02



MISSISSIPPI RIVER MUSSEL RELOCATION SITE:

Below Pike Island, River Mile 844.0

Latitude 44.8970 Longitude 93.1507
State Listed Species



2000 Color Air Photo courtesy USGS-UMESC
Mussel Relocation Data provided by Dan Kelner, MN DNR
Map prepared by Jesse Kroese, NPS-MNRRA, 1/2/02

0 0.1 0.2 0.3 Miles

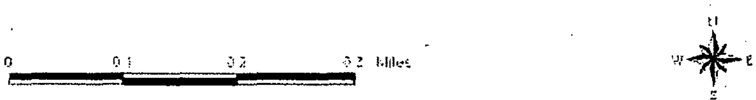
N W E S

MISSISSIPPI RIVER MUSSEL RELOCATION SITE:

Near Hastings, River Mile 813.0

Latitude 44.7492 Longitude 92.8334
L. higginsi and State Listed Species

2000 Air Photo courtesy Metropolitan Council
Mussel Relocation Data provided by Dan Kelner, MN DNR
Map prepared by Jesse Kreese, NPS–MNRRA, 1/2/02



[Federal Register: May 4, 2001 (Volume 66, Number 87)]
[Notices]
[Page 22593]
From the Federal Register Online via GPO Access [wais.access.gpo.gov]
[DOCID:fr04my01-117]

[[Page 22593]]

DEPARTMENT OF THE INTERIOR

Fish and Wildlife Service

Endangered and Threatened Species Permit Application

AGENCY: Fish and Wildlife Service, Interior.

ACTION: Notice of intent to amend endangered species recovery.

The following applicant has applied for an amended permit to conduct certain activities with endangered species. This notice is provided pursuant to section 10(c) of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531, et seq.).

Permit Number TE023308-2

Applicant: U.S. Fish and Wildlife Service, Twin Cities Field Office, Bloomington, Minnesota (Russ Peterson, Field Supervisor).

The applicant holds a permit to take (collect, hold in captivity, propagate, and release) endangered Higgins' eye pearlymussels (Lampsilis higginsi) from locations within their historic range in the States of Iowa, Minnesota, and Wisconsin. The applicant requests authorization to expand the geographical area permitted for reintroducing artificially propagated specimens into the wild to include all historical locations of the species, including mainstem and tributaries of the Upper Mississippi River including the Chippewa, St. Croix, Black and Wisconsin Rivers in Wisconsin; the Iowa, Cedar and Wapsipinicon Rivers in Iowa; the Illinois, Sangamon, and Rock Rivers in Illinois; and, the Minnesota River in Minnesota. This permit is for the enhancement of survival of the species in the wild to protect from zebra mussel (Dreissena polymorpha) infestation, in the interest of recovery.

Written data or comments should be submitted to the Regional Director, U.S. Fish and Wildlife Service, Ecological Services Operations, 1 Federal Drive, Fort Snelling, Minnesota 55111-4056, and must be received within 30 days of the date of this publication.

Documents and other information submitted with this application are available for review by any party who submits a written request for a copy of such documents to the following office within 30 days of the date of publication of this notice: U.S. Fish and Wildlife Service, Ecological Services Operations, 1 Federal Drive, Fort Snelling, Minnesota 55111-4056. Telephone: (612/713-5343); FAX: (612/713-5292).

Dated: April 20, 2001.

Charlie Wooley,

Assistant Regional Director, Ecological Services, Region 3, Fort Snelling, Minnesota.

[FR Doc. 01-11192 Filed 5-3-01; 8:45 am]

DEPARTMENT OF THE INTERIOR

Fish and Wildlife Service

Endangered and Threatened Species Permit Application

AGENCY: Fish and Wildlife Service, Interior.

ACTION: Notice of receipt of application.

The following applicant has applied for a permit to conduct certain activities with endangered species. This notice is provided pursuant to section 10(c) of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531, et seq.).

Permit Number TE023308-0

Applicant: U.S. Fish and Wildlife Service, Twin Cities Field Office, Bloomington, Minnesota (Russ Peterson, Field Supervisor)

The applicant requests a permit to take (collect, hold in captivity, propagate, and release) endangered Higgins' eye pearlymussels (Lampsilis higginsi) from locations within their historic range in the States of Iowa, Minnesota, and Wisconsin (St. Croix River, Upper Mississippi River, Chippewa River, and Wisconsin River). The applicant proposes to propagate captive mussels at: (1) The U.S. Fish and Wildlife Service's Genoa National Fish Hatchery; (2) a temporary facility at the Upper Mississippi River, Pools 1-4 (River Mile 853-787); (3) a temporary facility at the lower Chippewa River (RM 0-15); and (4) a temporary facility at the lower Wisconsin River (RM 0-15). The applicant proposes to subsequently relocate host fish infected with glochidia (resulting from propagation) to a temporary facility in the lower Bad Axe River adjacent to the Genoa NFH. Artificially propagated and temporarily held specimens will be reintroduced into the wild at the Upper Mississippi River, Lower Chippewa River, and lower Wisconsin River. The Field Supervisor, Twin Cities Field Office, proposes to serve as project manager including, but not limited to, designation of individuals who meet issuance criteria to work under this permit. This permit is proposed for the enhancement of survival of the species in the wild (protection from zebra mussel (Dreissena polymorpha) infestation, in the interest of recovery.)

Written data or comments should be submitted to the Regional Director, U.S. Fish and Wildlife Service, Ecological Services Operations, 1 Federal Drive, Fort Snelling, Minnesota 55111-4056, and must be received within 30 days of the date of this publication.

Documents and other information submitted with this application are available for review by any party who submits a written request for a copy of such documents to the following office within 30 days of the date of publication of this notice: U.S. Fish and Wildlife Service, Ecological Services Operations, 1 Federal Drive, Fort Snelling, Minnesota 55111-4056. Telephone: (612/713-5350); FAX: (612/713-5292).

Dated: February 24, 2000.

Stanley L. Smith,
Acting Assistant Regional Director, Ecological Services, Region 3, Fort Snelling, Minnesota.

US Army Corps of Engineers
St. Paul District

Notice of Availability

Relocation Plan for the Endangered Higgins' Eye Pearlymussel, Upper Mississippi River and Tributaries, Minnesota, Wisconsin, Iowa, and Illinois

Date: March 29, 2002

In Reply Refer to:
Environmental and Economic Analysis Branch

Project Proponent. St. Paul District, Corps of Engineers, 190 Fifth Street East, St. Paul, Minnesota 55101-1638

Project Background. This Notice of Availability describes a proposal to establish five new populations, through relocation, of the Federally-listed Endangered Higgins' eye pearlymussel (*Lampsilis higinnsii*). The Draft Definite Project Report and Environmental Assessment stems from the April 2000 USFWS final biological opinion report that said continued operation of the 9-Foot Navigation Channel project on the Upper Mississippi River System (UMRS) would likely jeopardize the continued existence of the Higgins' eye pearlymussel. Due to the upstream transport by commercial and recreational craft, zebra mussels are now found in the UMRS. The zebra mussels came from Europe and were introduced into North America by ships discharging their ballast water into the Great Lakes. The zebra mussels eventually got into the Illinois River through the Chicago Sanitary and Shipping Canal, and then the Mississippi River, by attaching themselves to other ships and boats coming out of the Illinois River. Zebra mussels have a significant adverse impact on Higgins' eye pearlymussel and other native freshwater mussels. The USFWS biological opinion listed a reasonable and prudent alternative (RPA) believed necessary to avoid jeopardy. "A Reasonable and Prudent Alternative (RPA) is for the Corps to (1) develop a Higgins' eye pearlymussel Relocation Action Plan and (2) to conduct a reconnaissance study to control zebra mussels in the UMR."

Project Authority. The River and Harbor Act of July 3, 1930, which authorizes the 9-foot channel navigation project on the Upper Mississippi River, provides federal authority for the project. Section 7(a)(2) of the 1973 Endangered Species Act (ESA) requires Federal agencies to insure that actions authorized, funded, or carried out by them are not likely to jeopardize the continued existence of endangered or threatened species. In addition, ESA establishes as Federal policy that "*all Federal departments and agencies shall seek to conserve endangered species and threatened species*." In keeping with this ESA requirement and policy, it is within the Federal Interest to implement the Biological Opinion's Reasonable and Prudent Alternative of conducting a Relocation Plan for Higgins' eye pearlymussel.

Project Purpose. The Relocation Plan objective is to establish a minimum of five new and viable populations (minimum of 500 individuals each) of Higgins' eye pearlymussel in areas of the UMRS and/or tributaries that have no or low levels of zebra mussel infestations.

Project Location. Attempts to establish new populations will occur at a minimum of 10 sites, to ensure that at least five new populations are established. The specific locations have not been determined, however the following potential areas have been identified: Rock and Kankakee Rivers in Illinois; Iowa, Cedar, Des Moines, Upper Iowa, Wapsipinicon, and Turkey Rivers in Iowa; Wisconsin, Chippewa, and Black Rivers in Wisconsin; from the head of navigation to Monticello, Minnesota, and pools 1 through upper 4 and pool 24 on the UMRS; and the first 30 miles of the St. Croix River above Taylors Falls, Minnesota.

Proposed Action. The Relocation Plan involves collecting adult Higgins' eye pearlymussels from areas heavily infested with zebra mussels, where survival of the Higgins' eye pearlymussel is in question, and cleaning and moving them to an area with no or low levels of zebra mussel infestation. Relocation efforts will also involve raising juvenile mussels on host fish species and at hatcheries, with subsequent stocking at selected relocation sites. A monitoring program to evaluate the long-term effectiveness of the relocation efforts is also part of the plan.

The Higgins' eye pearlymussel Relocation Plan is only one part of the overall effort. The Corps of Engineers is also undertaking, in a separate interrelated effort, a reconnaissance/feasibility study of long-term measures for controlling zebra mussels in the UMRS. Additional mussel work that is under way or will be planned and conducted over the next several years includes monitoring the health and status of Higgins' eye pearlymussel and other mussels; protecting existing Higgins' eye pearlymussel within Essential Habitat Areas; monitoring the abundance and distribution of zebra mussels; evaluating the opportunity for fish passage at locks and dams for fish species that are hosts of the Higgins' eye pearlymussel glochidia; a relocation plan for winged mapleleaf mussels; and public outreach on the threat to native mussels.

Alternatives. No Action: Under the No Action alternative, no Federal actions would be undertaken to relocate endangered mussels for the purpose of establishing new populations in areas with no or low levels of zebra mussel infestation. With the most probable future without action, zebra mussel densities on the main stem of the UMRS are expected to remain high, with some continued expansion into the tributaries. Higgins' eye pearlymussel may continue to exist in the more marginal secondary and essential habitat areas, which contain low to moderate numbers of zebra mussels, and in areas not infested with zebra mussels. However, until an effective zebra mussel management program is implemented on the UMRS, zebra mussels will continue to be the greatest threat to native mussels of the UMRS. The USFWS Biological Opinion concluded that continued operation and maintenance of the 9-Foot Channel Project for another fifty years would jeopardize the continued existence of Higgins' eye pearlymussel due to the indirect effect of zebra mussels.

Schedule. Some limited pilot efforts begin in 2000/1. Full project implementation will begin in May 2002. The Relocation Plan will take 10 years to fully implement. Monitoring of the newly established populations will continue after the 10-year establishment period.

Summary of Environmental Impacts. Implementation of the proposed relocation plan would have overall substantial benefits to Higgins' eye pearlymussel populations in general, although some mortality to individual Higgins' eye pearlymussel would be associated with these activities. Impacts on other natural resources would generally be minor. Relocation of Higgins' eye pearlymussel to tributaries is likely to be controversial because of restrictions on uses associated with endangered species. One of the factors that will be used in selecting the final relocation sites will be degree of local opposition, which should minimize socioeconomic impacts.

The proposed actions would cumulatively aid in the long-term preservation of Higgins' eye pearlymussel populations. Relocation of Higgins' eye pearlymussel would mitigate or reduce the impacts of zebra mussels on this endangered species.

Coordination. The Mussel Coordination Team (MCT), made up of 9 federal and state government agencies and 1 private non-profit entity, has been extensively involved in the development of the relocation plan and other on-going mussel related activities. The MCT members include the U.S. Army Corps of Engineers; the U.S. Fish and Wildlife Service; the U.S. Geological Survey; the National Park Service; the U.S. Coast Guard; the department of natural resources from the states of Minnesota, Wisconsin, Iowa and Illinois; and the Science Museum of Minnesota.

Who Should Reply? Any interested parties that may be affected by the proposed action are invited to submit to this office facts, arguments, or objections to the proposal within 30 days of this notice. These statements should bear upon the adequacy of plans and suitability of locations and should, if appropriate, suggest any changes considered desirable. Statements should indicate that they are in response to this notice of availability. All replies should be addressed to the District Engineer, St. Paul District, Corps of Engineers, ATTN: PM-E, 190 Fifth Street East, St. Paul, Minnesota 55101-1638. The Draft Definite Project Report/Environmental Assessment may be obtained electronically at http://www.mvp.usace.army.mil. Mr. Dennis Anderson, telephone number (651) 290-5272 and email dennis.d.anderson@mvp02.usace.army.mil, can be contacted for additional information or to obtain a hard copy of the Draft Definite Project Report and Environmental Assessment.

ROBERT T. BALL
Colonel, Corps of Engineers
District Engineer

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
190 FIFTH STREET EAST
ST. PAUL, MINNESOTA 55101-1638

OFFICIAL BUSINESS
CEMVP-PM-E

Anderson PM-E ____
Mose PM-E ____
Bankston OC____
DesHarnais DPM ____
O'Hara DD____
Ball DE ____

File name: DPR notice of availability

Dubuque Public Meeting

Dubuque
Mussel Meeting Sept. 2?

[illegible]	MUSBAC	[illegible], MN
Dennis Anderson	St. Paul District, Corps	St Paul, MN
BOB SCHIESL	CITY OF DBQ, ENGINEERING	
DAVE CZARNECKI	LORAS COLLEGE	DBQ
Larry Stone	Elkader, Ia	
Charles [illegible] | [illegible]	Dubuque, IA	
Shannon Ault	Bellevue	
[illegible] Peterson	Bellevue	
[illegible]	Dubuque	
Mindy [illegible]	Dubuque	

Prairie du Chien Public Meeting

Mussel Meeting Sign In
Prairie du Chien

Robin Graves	MWBAC	Winona
Lynn Gaede	USFWS	Genoa
Joe and June Olson		Guttenberg
Marian Havlik Malacologist Consultant		La Crosse
Don Valley		P.D.C.
Steve Kolbach		Marquette
Laurie Klosterboer		Elkader

Wabasha Public Meeting

Wabasha Kellogg Mussel Meeting

	[illegible]	[illegible]	Winona
	[illegible]	USFWS	[illegible]
	Doug Beisell		WABASHA
	Shari Beisell	realtor	Wabasha
	Dennis Anderson	Corps	St. Paul, MN
[illegible]@aol.com	Nicole Ward	student	Rochester
	MARY JOHNSON		Pepin
	Jane R. Smith		Pepin

Moline Public Meeting

SIGN-IN SHEET

NAME	ADDRESS
Dick & Bess Pierce	734-18 Avenue A Moline, IL 61265 309/764/55[illegible] Gemini@aol.com

APPENDIX 6

DISTRIBUTION LIST

List of elected officials, Federal, State, and local agencies, interest groups, media, individuals, and libraries that will receive a copy of the draft Definite Project Report/Environmental Assessment and/or Notice of Availability

NAME	POSITION	AGENCY	CITY	STATE	ZIPCODE
DON WARD	DIRECTOR	DEPT OF TRANSPORTATION	AMES	IA	50010
MARIA PEARSON		GOV'S LIAISON FOR INDIAN AFFAIRS	AMES	IA	50010
G. GENE JONES		DEPT OF TRANSPORTATION	AMES	IA	50010
MR. LES HOLLAND		IA DEPT OF TRANSPORTATION	AMES	IA	50010
CRAIG W. O'RILEY		DEPT OF TRANSPORTATION	AMES	IA	50010
MR BOB KRAUSE		IOWA DOT	AMES	IA	50010
	DIVISION ADMINISTRATOR	FEDERAL HIGHWAY ADMINISTRATION	AMES	IA	50010
JOEL BRINKMAYER	BRANCH MANAGER	STATE OF IOWA	AMES	IA	50010-0451
MR. BRAD BARRETT		OFFICE OF BRIDGES AND STRUCTURES	AMES	IA	50010-6915
MR. ROBERT L. HUMPHREY		STATE OF IOWA	AMES	IA	50010-6915
	CTRE	LIBRARY	AMES	IA	50010-8632
		DEPART OF COMMERCE	ANKENY	IA	50021
DON BRAZLTON		IA ASSN OF COUNTY CONSERVATION BOARDS	ANKENY	IA	50021-3052
DALE FAULKNER	BRANCH MANAGER	STATE OF IOWA	INDIANOLA	IA	50125-2802
MR. BILL BALLENTYNE	CHAIRMAN OF THE BOARD	COUNTY OF DECATUR	LEON	IA	50144-1647
HONORABLE T. R. THOMPSON, JR.	MAYOR & CITY COUNCIL	CITY HALL	MARSHALLTOWN	IA	50158
MR. ALLEN HILLEMAN	DIRECTOR	US DEPT OF AGRICULTURE	MARSHALLTOWN	IA	50158-4548
ROYCE J. FICHTNER	ENGINEER	COUNTY OF MARSHALL	MARSHALLTOWN	IA	50158-4906
MR ROBERT SUEPPEL	IOWA FIELD OFFICE	CONGRESSMAN BOSWELL	OSCEOLA	IA	50213
		PELLA CHAMBER OF COMMERCE	PELLA	IA	50219
MR. RICHARD JOHNSON	BRANCH MANAGER	STATE OF IOWA	WILLIAMS	IA	50271
MR. TODD R. HAGAN	PRINCIPAL	MADISON COUNTY ROADS DEPT	WINTERSET	IA	50273
	DIRECTOR	STATE OF IOWA	DES MOINES	IA	50306-9204
HONORABLE TOM HARKIN	UNITED STATES SENATOR		DES MOINES	IA	50309
MARK ACKELSON		IOWA NATURAL HERITAGE FOUNDATION	DES MOINES	IA	50309
BRENT HALLING		IOWA DEPT OF AGRI	DES MOINES	IA	50309
MR BOB RENAND	IOWA FIELD OFFICE	SENATOR GRASSLEY	DES MOINES	IA	50309
MR DICK VEGORS	MARKETING MANAGER	IOWA DEPT OF ECONOMIC DEVELOPMENT	DES MOINES	IA	50309
HONORABLE GREG GANSKE	REPRESENTATIVE IN CONGRESS		DES MOINES	IA	50309
MS DIANNE LIEPA	IOWA FIELD OFFICE	SENATOR HARKIN	DES MOINES	IA	50309
HONORABLE CHARLES E. GRASSLEY	UNITED STATES SENATOR		DES MOINES	IA	50309
MR. LEROY BROWN	BRANCH MANAGER	NATURAL RESOURCES CONSERVATION SERVICE	DES MOINES	IA	50309-2180
HONORABLE NEAL SMITH	REPRESENTATIVE IN CONGRESS		DES MOINES	IA	50309-3904
MR. JOHN BELLIZZI	BRANCH MANAGER	CITY OF DES MOINES	DES MOINES	IA	50309-4820
HONORABLE WILLIAM D. PALMER	UNITED STATES SENATOR		DES MOINES	IA	50317-7068
	DIRECTOR	IA DEPT OF SOIL CONSERVATION	DES MOINES	IA	50319
LYLE ASELL		IOWA DNR	DES MOINES	IA	50319
DARRELL MCALLISTER	BUREAU CHIEF	SURFACE & GROUNDWATER PROT BUREAU-DNR	DES MOINES	IA	50319
ALLEN STOKES	DIVN ADMIN	ENVIRONMENTAL PROTECTION	DES MOINES	IA	50319
ANDREW VARLEY		IOWA COMMERCE COMMISSION	DES MOINES	IA	50319
ARNOLD SOHN	CHIEF	PLANNING BUREAU - DNR	DES MOINES	IA	50319
DAN LINDQUIST	NAT RES ENGR	DEPT OF AGRICULTURE & LAND STEWARDSHIP	DES MOINES	IA	50319
MR. PAUL JOHNSON	DIRECTOR	DNR	DES MOINES	IA	50319
AL FARRIS	ADMINISTRATOR	DNR	DES MOINES	IA	50319
HONORABLE DALE M. COCHRAN	SECRETARY OF AGRICULTURE		DES MOINES	IA	50319
HAROLD HOMMES		IA DEPT OF AGRI & LAND STEWARDSHIP	DES MOINES	IA	50319
MARY JANE OLREY		IOWA DEPT OF AGRI	DES MOINES	IA	50319
PATTY JUDGE		IOWA DEPT OF AGRI	DES MOINES	IA	50319
J. EDWARD BROWN		STATE WATER COORDINATOR	DES MOINES	IA	50319
JACK RIESSEN	ENV PROG SUPV	DNR	DES MOINES	IA	50319
JIM BROWN	LEGISLATIVE LIAISON	DNR	DES MOINES	IA	50319
RALPH CHRISTIAN		BUREAU OF HISTORIC PRESERVATION	DES MOINES	IA	50319
MARION CONOVER		DNR	DES MOINES	IA	50319
HONORABLE SHELDON RITTMER	UNITED STATES SENATOR		DES MOINES	IA	50319
PATRICIA OHLERKING	DEPUTY STATE HISTORIC PRESERV. OFCR	BUREAU OF HISTORIC PRESERVATION	DES MOINES	IA	50319
MR. JEFFREY R. VONK	DIRECTOR	IOWA DNR	DES MOINES	IA	50319-0034
KEVIN SZCODRONSKI	MISSISSIPPI RIVER COORDINATOR	IA DNR	DES MOINES	IA	50319-0034
MR. GLENN BUSH	BRANCH MANAGER	US DEPT OF TRANSPORTATION	DES MOINES	IA	50321-2805
MR. JERRY BOOTH	BRANCH MANAGER	US DEPT OF AGRICULTURE	DES MOINES	IA	50322-7907
HONORABLE JIM NUSSLE	REPRESENTATIVE IN CONGRESS		MASON CITY	IA	50401
MR. JOSEPH MCLAUGHLIN	BRANCH MANAGER	US DEPT OF AGRICULTURE	MASON CITY	IA	50401-5615
MR. ROBERT BORTLE	BRANCH MANAGER	STATE OF IOWA	MASON CITY	IA	50402-0741
MR. ARNOLD JOHNSON	BRANCH MANAGER	STATE OF IOWA	BRITT	IA	50423-0187
MR. JIM WAHL	BRANCH MANAGER	STATE OF IOWA	CLEAR LAKE	IA	50428-1233
		US DEPT OF AGRICULTURE	GARNER	IA	50438-0040
MR. RANDALL J. WILL	BRANCH MANAGER	COUNTY OF FRANKLIN	HAMPTON	IA	50441-0118
HONORABLE TOM LATHAM	REPRESENTATIVE IN CONGRESS		FORT DODGE	IA	50501
MR. ROGER L. KEITH	COUNTY EXECUTIVE DIRECTOR	US DEPT OF AGRICULTURE	POCAHONTAS	IA	50574-0189
JAMES DUNHAM		PARK RECREATION & CEMETERY DEPT	WEBSTER CITY	IA	50595
		CENTRAL IOWA TOURISM REGION	WEBSTER CITY	IA	50595-0454
MR. BRIAN HOLT	EXECUTIVE DIRECTOR	HAMILTON COUNTY CONSERVATION BOARD	WEBSTER CITY	IA	50595-9799
MR. DENNIS EBERLE	DIRECTOR	US DEPT OF AGRICULTURE	ALLISON	IA	50602-0068
MR. LARRY SCHWAB	BRANCH MANAGER	STATE OF IOWA	ALLISON	IA	50602-0625
MR. STEVE LINDAMAN	PURCHASING	CITY OF CHARLES CITY	CHARLES CITY	IA	50616-2229
MR. JOHN BAHNSEN	BRANCH MANAGER	US DEPT OF AGRICULTURE	CHARLES CITY	IA	50616-3722

Holthaus, James J.

From:	Lovejoy, Tom A - DNR [Tom.Lovejoy@Wisconsin.gov]
Sent:	Friday, August 31, 2007 10:46 AM
To:	Holthaus, James J.
Cc:	Siebert, David R - DNR; Koslowsky, Shari - DNR; Benjamin, Ron - DNR; Sullivan, John F - DNR
Subject:	Prairie Island Nuclear Generating Plant (PINGP) Re-Licensing and Environmental Review
Attachments:	316b Guidance DNR 10_18_04.doc

By your June 19, 2007 letter to Dave Siebert you requested Wisconsin Department of Natural Resources (WDNR) input in preparation of environmental review documents associated with an application to Nuclear Regulatory Commission (NRC) for license renewal of the Prairie Island Nuclear Generating Plant.

Through various phone calls and emails WDNR subsequently alerted you that our contact for threatened and endangered resources information was Ms. Shari Koslowsky, (608) 261-4382 and that I would get back to you with any other scoping comments. This provides those additional comments.

1. Fish Impingement and Entrainment
We are concerned about the extent of fish and other aquatic organism mortality resulting from entrainment and impingement at cooling water intake structures. Will the plant comply with Clean Water Act 316(b) standards for minimizing adverse impacts? How? To assist in this regard attached is draft guidance to WDNR managers to determine if best available technology is being used.

<<316b Guidance DNR 10_18_04.doc>>

2. Pool drawdowns for habitat enhancement
We have in the past expressed interest in working with the Corps of Engineers and others in conducting water level drawdowns of 1-2' in Mississippi River Pool 3 for biological habitat enhancement purposes. We have heard there are PINGP concerns, such as for fire control or design limits of water intake structure(s), that may conflict with the idea of pool drawdowns. Please describe any such concerns and measures that could be employed to allow such pool drawdowns.

3. Thermal discharge effects
A. Biological resources
We are aware of past fish kills, particularly associated with effluent thermal mixing during winter cold water conditions, resulting from past plant operations. There is also a mussel bed adjacent to the plant. We are interested in minimizing adverse plant operational impacts to such resources. We understand that the entire river is used as the thermal mixing zone for determining compliance with MPCA discharge permits and believe a smaller portion of river flow along the Minnesota shoreline should be used to more accurately protect fish and aquatic life. Has the mussel bed been monitored above and below the plant to determine thermal discharge impacts? Are there other biological monitoring efforts underway or planned in effort to demonstrate little or no adverse thermal effects to biological communities? We know there have been some operational adjustments made in effort to eliminate/reduce the frequency or extent of fish kills. What are these measures and how successful have they been? What future measures are proposed? What opportunities will exist during the next license term to respond to new threats and issues as they appear?

B. Recreation opportunities
We have routinely received seasonal complaints from the ice fishing public that access to the upper 1/3 of Lake Pepin is adversely impacted by PINGP warm water discharges, resulting in delayed ice formation at winter's onset and more rapid ice deterioration before spring thaw. Efforts should be undertaken to document historic PINGP discharge effects on winter ice cover and usability of traditional ice fisherman access points. Measures to offset adverse effects should be identified and considered for future operations over the next NRC license term.

4. Zebra mussel control
Best management practices for control of biofouling from zebra mussels and other exotics continues to evolve. PINGP should have a plan in place calling for periodic reassessment of zebra mussel control methods in effort to assure that proven state-of-the-art control methods are in place while also minimizing toxicity to native biological resources.

Thanks you for the opportunity to comment. If you have questions or would like to discuss these issues in more detail please contact me at (715) 839-3747.

Guidance for Evaluating Cooling Water Intake Structures

[Implementing Chapter 283.31(6), Wis. Stats., and Section 316(b) of the Clean Water Act]

DRAFT - October 18, 2004

This guidance is intended to describe the information needed in order for the Department to evaluate the potential impacts of cooling water intake structures (CWIS) on their aquatic environment and to allow for the Department's determination of whether the best technology available (BTA) is being used (or proposed) to minimize adverse environmental impacts. Although this guidance provides general guidelines to follow, permits and regional staff responsible for decision making and water quality and fisheries biologists who best understand the area in question should be relied upon for more specific analyses of individual sites.

This document is intended solely as guidance, and does not contain any mandatory requirements except where requirements found in statute or administrative rule are referenced. This guidance does not establish or affect legal rights or obligations, and is not finally determinative of any of the issues addressed. This guidance does not create any rights enforceable by any party in litigation with the State of Wisconsin or the Department of Natural Resources. Any regulatory decisions made by the Department of Natural Resources in any matter addressed by this guidance will be made by applying the governing statutes and administrative rules to the relevant facts.

Best Technology Available For Minimizing Environmental Impact

Section 316(b) of the Clean Water Act and Chapter 283.31(6), Wis. Stats., require that the location, design, construction, and capacity of cooling water intake structures (CWIS) reflect the best technology available (BTA) for minimizing adverse environmental impact. In order to make decisions regarding whether a facility will meet these requirements, the Department will need sufficient information to determine whether technologies are the best available to minimize adverse environmental impact. In the case of existing facilities, this may be accomplished by providing reliable, quantitative estimates of damage that is occurring and projecting the long-range effect of such damage to the extent reasonably possible. In some cases, reliable estimates of future damage may be estimated through the use of historical data, pre-operational models, biological studies, and/or the operating experience of other facilities. However, historical data should be used carefully, and only in situations where source water and operating conditions are not believed to have changed significantly over time.

General guidance is provided in this document, outlining the development, conduct, and review of studies designed to determine and evaluate the potential for adverse environmental impact from a CWIS. This document is intended for use by Department staff who will need to decide whether the proposed (or existing) design, location, construction, and capacity of a CWIS reflects the best technology available (BTA) for minimizing adverse environmental impact, as well as the permittees who will have to provide the information needed to make these decisions. Staff should remember that environment-intake interactions are highly site-specific, and therefore BTA decisions should be made on a case-by-case basis. When deciding what is needed to evaluate an existing intake, data requirements should be based on the determination of the potential for adverse impact and the availability of relevant historical data. In limited instances, existing plants may have enough relevant historical data to make further studies unnecessary. Conversely, the process for evaluating new intakes and most existing intakes will probably be more extensive because of a lack of relevant historical data (because there is no historical data or because there have been significant changes in the environment since data was collected).

Background

In s. 316b, a cooling water intake structure (CWIS) is defined as the total physical structure and any associated constructed waterways used to direct water into the cooling system, where a major portion of the water is used for cooling. The CWIS extends from the point at which water is withdrawn, up to and including the intake pumps. A CWIS can cause adverse environmental impact by pulling large numbers of fish, shellfish, and other organisms or their eggs and larvae into a facility's cooling system. There, the organisms may be killed or injured by heat, physical stress, or by chemicals used within the system. Larger organisms may be killed or injured when they are trapped against screens at the front of the intake structure. Indirect impacts are also possible, such as the disruption of thermal regimes, the disruption of normal water flow, wetland or other upland disturbance (usually during construction), aesthetics, and/or noise.

The goal of s. 316(b) is to minimize impingement mortality and entrainment (IM&E) of organisms in the area around a CWIS. Entrainment is the taking in of organisms with the cooling water. The organisms involved are generally of smaller size and include phyto- and zooplankton, fish eggs and larvae, shellfish larvae, etc. As these entrained organisms pass through the system, they can be subjected to stressors such as mechanical damage due to contact with internal surfaces of pumps, pipes, and condensers; pressure damage due to passage through pumps; shear damage due to complex water flows; thermal damage due to elevated water temperatures; and toxicity due to the addition of chemicals to prevent condenser fouling and corrosion. Those organisms that do survive passage through the system may then experience delayed mortality after being returned to the receiving water.

Impingement (or entrapment) is the blocking of larger organisms by some type of physical barrier. For example, most CWIS include screening equipment (usually 3/8" mesh) installed in the cooling water flow to protect downstream equipment such as pumps and condensers from damage or clogging. Larger organisms, such as fish which enter the system and cannot pass through the screens, are trapped ahead of them. Eventually, if a fish cannot escape or is not removed, it will tire and become impinged on the screens. If impingement continues for long, the fish may suffocate when water currents prevent it's gill covers from opening. If the fish is impinged for a short period and removed, it may survive. However, it may lose its protective slime and/or scales through contact with screen surfaces or from the high pressure water jets designed to remove debris from the screens. Delayed mortality following impingement may approach 100 percent. For some species of fish, the intake may represent a double jeopardy situation where the same population will be subject to increased mortality through entrainment of eggs and larvae and additional mortality to juveniles and adults through impingement.

CWIS regulations do not specifically identify methods to reduce IM&E in each situation. Instead, these rules set basic performance standards and allow Department staff to decide what is BTA for each site-specific situation. Examples of existing technologies in use to reduce IM&E include fish diversion or avoidance systems designed to divert fish away from intakes; passive intake systems such as non-mechanical screens; mechanical screen systems that prevent organisms from entering the intake system; and fish return systems that transport live organisms away from the intake system.

316(b) Rulemaking History

EPA originally issued regulations to implement Section 316(b) of the Clean Water Act in 1976. Soon after, the U.S. Court of Appeals vacated the EPA rules, saying that the Agency had failed to comply with the publication provisions of the Administrative Procedure Act. Because of this, determinations of BTA for CWIS technologies have generally been governed by draft federal guidance ever since, and each state has had substantial discretion to determine what control requirements would satisfy the BTA criterion. For the most part, regulators have decided on a case-by-case basis whether CWIS technologies constitute BTA. Following an initial burst of activity in the mid 70's and early 80s, EPA has paid little attention to CWIS. In 1993, various environmental groups brought suit against EPA to compel the Agency to implement the requirements of s. 316(b). In order to settle the litigation, EPA entered into a consent decree in 1995 that required them to create regulations to implement s. 316(b) according to the following schedule:

Expected Timeline For New 316(b) Rules

- **Phase I (completed):** New facilities - final rules published December 2001
- **Phase II (completed):** Existing power generators withdrawing ≥50 MGD - final rules July 2004
- **Phase III (under development):** Other facilities, including power generators withdrawing <50 MGD; chemical mfg.; refineries; pulp & paper; steel, aluminum, copper and iron mfg. (proposed November '04; final by June '06)

Power plants are the largest users of cooling water in most cases and, to date, federal regulations have been directed primarily at this category. In December 2001, EPA published a final rule implementing section 316(b) that applies to new power generating and manufacturing facilities; final rules for existing power generating facilities were completed on July 9, 2004. However, EPA has proposed regulations covering other dischargers that have CWIS. These facilities will also need to show that their CWIS meet BTA standards in the near future.

Phase I: New Facilities. On December 18, 2001, EPA published a final rule implementing s. 316(b) that applies to new power plants and manufacturing facilities that withdraw water for cooling purposes. This rule for new facilities is referred to as "Phase I". According to this rule, a new facility is any "greenfield" or "stand-alone" facility that started construction after January 2002, has a design intake flow > 2 MGD, and uses at least 25% of the water that is withdrawn for cooling purposes. A greenfield facility is one that is constructed at a site where no other source is located, or that totally replaces the process or production equipment at an existing facility. A stand-alone facility is a new, separate facility that is constructed on property where an existing facility is located and whose processes are substantially independent of the existing facility at the same site (see 40 CFR Part 125.83 for the full, legal definitions of "new", "greenfield", and "stand alone" facilities).

The new facility rule establishes BTA, based on a two-track approach, for minimizing adverse environmental impact associated with the use of a CWIS. Based on size, Track I requires the permittee to select and implement design and construction technologies that will minimize IM&E. Based on the assumption that closed-cycle cooling systems cut cooling water usage by about 75-95% compared to once-through cooling systems, thereby reducing IM&E and other aquatic impacts by a similar percentage, Track I basically requires the use of wet, closed-cycle cooling systems with a maximum through-screen velocity of less than 0.5 feet per second (fps). Track II allows applicants to conduct site-specific studies to demonstrate that alternative measures will reduce IM&E to a level of reduction comparable to the level the facility would achieve if it used a closed-cycle cooling system and a through-screen velocity of 0.5 fps or less.

The new facility rule also includes alternative requirements that allow facilities to demonstrate that compliance costs associated with Tracks I and II would be unreasonable; or that air quality impacts, energy generation impacts ("energy penalties"), or other impacts not related to IM&E, could outweigh the additional IM&E effects and therefore justify an open loop system.

Phase II: Existing Power Plants. On July 9, 2004, EPA published a final rule implementing s. 316(b) that applies to existing power plants that withdraw ≥50 MGD cooling water. This rule, known as Phase II, establishes requirements applicable to the location, design, and capacity of CWIS at existing facilities. This rule defines an "existing facility" as one that commenced construction on or before January 17, 2002, and any modification of, or any addition of a unit at such a facility that does not meet the definition of a new facility at s.125.83. According to the Phase II rule, an existing facility can do one of the following to meet BTA requirements:

1) Demonstrate that technology in use reduces intake capacity to a level commensurate with the use of a closed-cycle, recirculating cooling system. (applies to all waterbody types)

2) Select and implement design and construction technologies, operational measures, and/or restoration measures that meet specified performance standards:

   a) For facilities with CWIS on a freshwater river or stream:
      i) If the intake flow is <5% of the annual mean flow, must reduce impingement mortality by 80-95%;
      ii) If the intake flow is ≥ 5% of the annual mean flow, must reduce impingement mortality by 80-95% and entrainment by 60-90%.

   b) For facilities with CWIS on a lake or reservoir other than the Great Lakes:
      i) Must reduce impingement mortality by 80-95%, and, if they expand their intake capacity, the increase in intake flow must not disrupt the natural thermal stratification or turnover pattern of the source water.

   c) For facilities with CWIS on a Great Lake:
      i) Must reduce impingement mortality by 80-95% and entrainment by 60-90%.

3) Demonstrate that the facility qualifies for a site-specific determination of BTA because its costs of compliance would be significantly greater than the environmental benefits of compliance with the performance standards.

4) Demonstrate that it has installed and properly operates and maintains a pre-approved technology. Only one technology is pre-approved at this time: submerged cylindrical wedgewire screen technology which treats the total CWIS flow. According to the rule, there are 5 conditions that must be met in order to use this technology to meet BTA standards: a) The CWIS is located in a freshwater river or stream; b) The CWIS is situated such that sufficient ambient counter currents exist to promote cleaning of the screen face; c) The through screen design intake velocity is 0.5 ft/s or less; d) The slot size is appropriate for the size of eggs, larvae, and juveniles of any fish and shellfish to be protected at the site; and e) The entire main condenser cooling water flow is directed through the technology (small flows totaling <2 MGD for auxiliary plant cooling uses are excluded). Sec. 125.99 of the rule also allows the Department to pre-approve other CWIS technologies, after providing public notice and an opportunity to comment on the request for approval of the technology.

The rule states that the baseline against which compliance with the performance standards mentioned above should be assessed is a shoreline intake with the capacity to support once-through cooling and no IM&E controls.

Phase III: Other CWIS Users. Many have assumed incorrectly that the requirements of s. 316(b) apply only to the power industry. While it is certainly the case that the primary focus in the past has been mostly on that industry sector, 316(b) applies broadly to any facility with a CWIS. Phase III of these regulations will, at a minimum, address power plants not covered by Phase II (e.g., those with design intake flows < 50 MGD) and other facilities that employ CWIS. Thus, the rulemaking that EPA has initiated could have major implications for other industrial sectors, including chemicals and allied products, primary metals, petroleum and coal products, and paper and allied products industries, and others. Under the court-ordered consent decree, EPA must propose Phase III regulations by November 1, 2004 and take final action on these regulations by June 1, 2006.

Wisconsin's Authority to Regulate CWIS

The Department's authority to regulate CWIS is directly tied to the issuance of a Wisconsin Pollutant Discharge Elimination System (WPDES) permit and can be found in Wis. Stats. Chapter 283.31(6):

> *"Any permit issued by the department under this chapter which by its terms limits the discharge of one or more pollutants into the waters of the state may require that the location, design, construction and capacity of water intake structures reflect the best technology available for minimizing adverse environmental impact."*

Since the mid 70's, the Department has used EPA guidance and best professional judgment to determine, on a case-by-case basis, whether CWIS technologies used by individual facilities constitute BTA. In order to make initial BTA determinations in the 1970's, power plants with a WPDES permit were required to provide site-specific information to estimate the number and weight of fish impinged or entrained by their CWIS.

Recent and future rule revisions at the federal level will mean that the Department must re-evaluate each CWIS at permit reissuance. In most cases, permittees with a CWIS should expect to demonstrate whether they meet BTA requirements described in s. 316(b) as a part of the permit application and reissuance process. To do this may require not only the assistance of CWIS technology experts, but also fishery biologists, impact assessment modelers, economists, and others (more details are provided throughout the rest of this guidance).

Where Does CWIS Review Fit Into the Permitting Process?

Phase I and II of the 316(b) regulations require that the regulations be implemented through WPDES permit applications and reissuances. (See page 7 for a discussion of proposed schedules.) When a new power plant has been proposed, the CWIS coordinator and permits staff will be expected to work closely with the Department's Project Manager and Regional Coordinator to ensure that permitting and review activities are smoothly integrated into the process mandated by the Power Plant Siting Law (s. 196.491(3), Wis. Stats.). (See "*Statutory Timelines and Agency Responsibilities for Approval of New Power Plants*" in Appendix 1). When a CWIS review is needed for an existing power plant or other facility, permits staff, basin engineers, fisheries staff, and the CWIS coordinator will work together to ensure that CWIS review activities are smoothly integrated into the permit application and reissuance process, where appropriate.

The WPDES Permit coordinator & Basin Engineer share the responsibility for:
- overall project (permit) coordination
- review of plans & study results
- drafting Environmental Assessment (EA) & Environmental Impact Statement (EIS) language (as needed)
- review of permit monitoring data
- determination of compliance with performance standards
- main point of contact for Environmental Analysis and Liaison Section, Public Service Commission, region/central office staff, and other programs
- attend meetings with permittee, as needed, to discuss performance standards and CWIS technologies

The CWIS coordinator is responsible for:
- maintaining CWIS guidance (this document) & standard permit language

- providing "expertise" in difficult or complex situations
- providing statewide perspective and checks for consistency
- assist permit coordinator with EA and EIS language (as needed)
- assist in the review of plans & study results
- attend meetings with permittee, as needed, to provide advice and expertise regarding performance standards and CWIS technologies

Fishery & water quality biologists and other staff will also need to be involved in certain aspects of each project. For example, knowledge of the local fisheries around the CWIS site will be very important when reviewing information related to physical waterbody data, expected (or existing) IM&E data and the potential for direct and indirect impacts to aquatic habitats.

In order for the CWIS review process to take place, whether for a new or existing facility, it will be necessary for the permittee to supply the information needed to determine whether the CWIS will meet BTA standards. Once this information is made available, the Department will have to determine which s. 316b performance standards apply and then review and approve plans, biological studies, source water information, and proposed technologies to decide if the proposed (or existing) CWIS will meet BTA criteria. Once the Department has determined whether the proposed (or existing) CWIS will meet applicable performance standards, the WPDES permit should be reissued with requirements describing how the permittee will demonstrate compliance with the standards. This usually includes monitoring of IM&E levels, maximum intake velocity, and visual or remote inspections of the CWIS to insure technologies are operating as designed.

Information Submittals for Existing (Phase II) Facilities

In order to make a BTA demonstration, certain information will be needed (required at 40 CFR Parts 9, 122, 123, 124, and 125, *National Pollutant Discharge Elimination System--Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities*). This information is summarized below. More detailed information is contained in the federal regulations.

Cooperation and open communication between the permittee and the Department during plan development and study implementation is essential and will ensure that everyone is in agreement as to the scope and details of work to be planned and completed. No formal approval of study plans should be necessary, however, staff will need to be aware of and in general agreement with study objectives, specific goals, and schedules for completion, to make sure that studies address all of the important environmental and operational concerns of all parties.

The Comprehensive Demonstration Study (CDS)

The purpose of the Comprehensive Demonstration Study (CDS) is to characterize impingement mortality and entrainment (IM&E), to describe the operation of each CWIS, and to confirm that the technologies, operational measures, and/or restoration measures selected and installed, or to be installed, at the facility reflect the best technology available (BTA) for minimizing adverse environmental impact.

The final CDS report should specify which compliance alternative(s) are planned to achieve BTA for minimizing adverse environmental impact. Facilities that intend to meet BTA requirements by reducing flow commensurate with a closed-cycle, recirculating system are not required to submit a CDS. Facilities that intend to meet BTA requirements by reducing their design intake through-screen velocity to $\leq$0.5 fps are required to submit a CDS only for the entrainment requirements, if applicable. Facilities with a capacity utilization rate <15%, withdraw <5% of the mean annual flow of a river, or withdraw cooling water from a lake or reservoir (other than the Great Lakes), are required to submit a CDS only for the impingement mortality requirements.

Facilities that intend to meet BTA requirements by installing a pre-approved technology need to submit only the Technology Installation and Operation Plan and the Verification Monitoring Plan described below. In the final

316(b) Phase II rule, only submerged cylindrical wedgewire screen technology was pre-approved, and only for facilities that withdraw cooling water from a river or stream. In order to demonstrate BTA through the use of submerged cylindrical wedgewire screen technology, the permittee must demonstrate that this technology has been/will be properly installed and properly operated and maintained. The facility must also meet the following conditions: (1) the CWIS is situated in the river such that sufficient ambient counter-currents exist to promote cleaning of the screen face; (2) the maximum through-screen design intake velocity ≤ 0.5 fps; (3) the slot size is appropriate for the size of eggs, larvae, and juveniles of all fish and shellfish to be protected at the site; and (4) the entire main condenser cooling water flow is directed through the technology.

Suggested Information Submittal Timelines. Phase I and II of the 316(b) regulations require that the regulations be implemented through WPDES permit applications and reissuances. Existing facilities whose permits expire on or after July 7, 2008, and new facilities must comply with 316(b) information submittal requirements with their application for an initial/reissued WPDES permit. Existing facilities whose permit expires before July 7, 2008, may request a schedule for submission of application materials that is as expeditious as practicable but does not exceed January 7, 2008, to provide sufficient time to perform the required information collection requirements. (This is the latest date that the Department may allow; staff are to use BPJ to determine how much time is needed.) Below is an example timeline that may be allowed for these facilities:

Task	Approximate Time Allowed	Suggested Due Date
Prepare RFP and select contractor	---	10/30/04
Prepare and submit PIC	8 weeks	12/31/04
State Review of PIC and Address Comments	60 days, 2 weeks	3/15/05
Complete baseline IM&E sampling	1 year	3/31/06
Analyze IM&E data and make adaptive management decisions on compliance (assumes May-Sep sampling)	3 months	6/30/06
Engage in site-specific studies appropriate to support compliance approach	1 year	6/30/07
Prepare and submit final CDS report	7 months	1/7/08*

*this is the final date allowed by the Phase II regulations and it cannot be extended.
Dates suggested at 10/12/04 DNR/Utilities meeting

The following is a summary of the information that should be included in a final CDS report, depending upon the compliance alternative selected:

1) Proposal for Information Collection (PIC)

As a first step in the process, the permittee should submit a proposal to the Department describing how they intend to demonstrate that their proposed (or existing) CWIS will meet BTA standards. This proposal should include a plan and schedule for the studies that will be conducted to provide the needed information to the Department. At a minimum, the PIC should include the following:

a) A description of the technologies, operational measures, and/or restoration measures to be evaluated;
b) A description of historical studies characterizing IM&E and the physical/biological conditions in the vicinity of the CWIS. If the permittee proposes to use existing data, a demonstration should be made of the extent to which the data are representative of current conditions and that the data were collected using appropriate QA/QC procedures;
c) A summary of any past or ongoing consultations with Federal, State, and Tribal fish and wildlife agencies relevant to this study and a copy of comments received as a result of such consultation;
d) A sampling plan for field studies proposed to ensure that sufficient data is available to develop a scientifically valid estimate of IM&E at the site. The plan should document all methods and QA/QC procedures for sampling and data analysis. Sampling and data analysis methods should be appropriate for a quantitative survey and take into account methods used in other studies performed in the source waterbody. A description of the study area (including the CWIS' area of influence) should be provided, along with taxonomic identifications of the biological assemblages (including all life stages of fish & shellfish) to the extent this is known in advance and relevant to plan development.

e) Any other information, where available, that would aid in the review of the plan.

The collection and analysis of information will be an iterative process and plans for information collection may change as new data needs are identified. While the PIC is only submitted once, the permittee should consult with the Department as appropriate after the PIC has been submitted, in order to ensure that the Department will have all of the information necessary to make decisions regarding whether the location, design, construction, and capacity of each CWIS reflects BTA for minimizing adverse environmental impact.

2) Source Waterbody Flow Information

The natural hydrology of the waterbody and its relationship to the cooling system are key factors in evaluating the potential of a CWIS to impinge and entrain organisms. Organisms most likely to be entrained are those present in the "hydraulic zone of influence" of the intake. Whether an organism will enter the zone of influence is determined by the behavior and motion of the organism and the flow of water around and into the CWIS. To determine how the behavior and motion of local organisms are influenced by the flows in and around the CWIS, it is necessary to identify the types of circulation dominant in the waterbody and to collect data related to currents and other relevant hydrological and physical parameters of the system (e.g., water current, speed and direction; wind speed and direction; tides/local water levels; temperature; water density).

The proximity of a primary spawning or nursery area to a CWIS can be an important influence on the entrainment potential for an individual species. Other factors also interact with proximity to determine susceptibility to entrainment. Predictive tools, such as computer models, may be useful in many cases for identification of the area of potential damage. The selection of the appropriate models and data collection schemes should be guided by the circulation regime and geomorphology of the waterbody. Field data collection and modeling should be done to determine the probability that a non-motile organism released from a given point in the flow field will be entrained into the CWIS.

At a minimum, the following information should be provided:

a) A narrative description and scaled drawings showing the physical configuration of all source waterbodies used by the facility, including areal dimensions, depths, temperature regimes, and other documentation that supports the determination of the waterbody type where each CWIS is located
b) identification and characterization of the source waterbody's hydrological and geomorphological features, as well as the methods used and the results of any physical studies to determine the CWIS' area of influence
c) locational maps

Facilities that withdraw cooling water from freshwater river or stream:

d) documentation showing the mean annual flow of the waterbody and any supporting documentation and engineering calculations that shows whether they are withdrawing less than or greater than 5 % of the mean annual flow. Representative historical data (from a period of time up to 10 years, if available) should be used to determine mean annual flow values.

Facilities that withdraw cooling water from a lake (other than the Great Lakes) or reservoir and propose to increase the facility's design intake flow:

e) a narrative description of the thermal stratification of the waterbody and any supporting documentation and engineering calculations showing that the increased total design intake flow will not disrupt the natural thermal stratification or turnover pattern (where present) of the source water in a way that adversely impacts fisheries.

3) Facility, Cooling System, and Cooling Water Intake Structure (CWIS) Information

Information will be needed to fully investigate the potential for organisms to become entrapped within the CWIS, impinged on parts of the CWIS, and/or entrained in the water circulated through the cooling water system. It will be necessary to describe the full range of potential physical, chemical, and biological impacts which could be encountered throughout the cooling system during a typical yearly operation cycle. The following information should be provided to adequately describe the CWIS and cooling water system:

a) Site Location and Layout
   i) Map showing locations of all existing and proposed CWIS, associated cooling water systems, and other pertinent information related to surrounding shore and water features in a 50-mile radius, including:
      (1) Latitude and longitude in degrees, minutes, and seconds for each CWIS;
      (2) Proximity of intake to effluent discharge(s), other permittees' discharges and water withdrawals
      (3) Proximity to areas of biological concern
   ii) Larger scale map w/topographic and hydrographic data depicting the specific location of the CWIS, including:
      (1) Topographic details, including existing site w/topographic features as changed by proposed CWIS
      (2) Hydrological features, including depth contours
      (3) Waterbody surface elevations (low and normal)
      (4) Waterbody boundaries & affected waterbody segment
      (5) Location and description of other CWIS in waterbody segment
      (6) Additional stresses on waterbody segment (e.g., existing/planned point sources; etc.)

b) CWIS and Cooling System Descriptions
   i) A flow distribution and water balance diagram that includes all sources of water to the facility, recirculating flows, and discharges
   ii) A narrative description of the operation of each cooling water system, the relationship to each CWIS, proportion of the design intake flow used in the system, number of days of the year the system is in operation, and seasonal changes in operation
   iii) A description of CWIS operation; identification of withdrawal type (once-through vs. recycled); type of intake structure (size, shape, configuration, orientation); location of CWIS with respect to cooling water system; location in water body (horizontal and vertical); depth of intake; distance from shoreline; configuration including canals and channels; capacity (volume withdrawn in gpm & MGD; design & actual intake flows); timing, duration, frequency of withdrawal; presence/absence of organism protection technologies (behavioral and physical), fish bypass and handling facilities; average and maximum through-screen and approach velocities; proportion of water withdrawn to the overall source water flow
   iv) CWIS Pump information, including: design details (location in structure, configuration of blades, housing); revolutions per minute; number, capacities, and planned operating schedule; pressure regimes in water subjected to pumping; velocity shear stresses in pumping; sites of potential turbulence and physical impacts
   v) Design and engineering calculations and supporting data to support the descriptions mentioned above, including engineering drawings of proposed CWIS and cooling system

c) Use of Cooling Water System Biocides and Ice Removal Technologies
   i) Location of introduction in system
   ii) Description and aquatic toxicity information for biocide(s) to be used
   iii) Concentrations of biocide in various parts of cooling water system and receiving waters
   iv) Location, amount, timing, and duration of recirculation water for deicing or tempering
   v) Maintenance procedures, use of heat treatment or deicing procedures

d) Thermal experience
   i) Water temperature in cooling system; temperature change during entrainment; duration of entrainment; resultant time-temperature experience of organisms subjected to entrainment
   ii) Annual ambient temperatures, thermal addition to cooling water of various operating capacities

e) Facility Data
   i) Age and expected lifetime
   ii) Capacity factor and percent of time at fractional loads
   iii) History of intake model

4) Impingement Mortality and/or Entrainment (IM&E) Characterization Study

The permittee should submit an IM&E Characterization Study whose purpose is to provide information to support the development of a calculation baseline and to characterize current and/or to estimate future potential for IM&E. In order to properly assess the potential for environmental impact from a CWIS, a one- to three-year biological survey may be necessary to establish the aquatic life present in the area. A one-year survey is usually of limited value, except in cases where substantial, relevant historical data can be presented to demonstrate that the intake has little potential for impact. In situations where an existing intake is being evaluated and relevant historical data is available which is still representative of current conditions, less data collection may be necessary. The type and extent of biological and other data needed in each case will be determined by the potential severity of adverse environmental impact.

Adverse aquatic environmental impacts will occur whenever there will be entrainment or impingement as a result of the operation of a CWIS. The critical question is the magnitude of those effects and the potential overall impact on aquatic populations and/or their habitat. Indirect impacts should also be considered, including: disruption of thermal regimes or normal water flow/circulation; wetland or other upland disturbance (especially during construction of a new CWIS); aesthetics; and noise. Studies designed to collect biological information should be designed on a case-by-case basis, recognizing the uniqueness of biota-site-structure interrelationships. Surveys should be designed to determine the spatial and temporal variability of each of the important components of the biota that may be damaged by the intake. Local DNR fish biologists and water quality specialists should be consulted when selecting appropriate sampling methods and monitoring program design.

When a new CWIS is being proposed, biological studies may be needed to determine the abundance and distribution of aquatic organisms in the vicinity of the proposed CWIS. Data from these studies should be used to predict the potential for impingement, entrainment, and other impacts due to the location, design, construction, and capacity of the proposed CWIS. The losses of aquatic life at an existing CWIS can be determined in most cases through the direct measurement of numbers, sizes and weights of organisms impinged and entrained (taking into account daily and seasonal variation). Impingement monitoring usually involves sampling impingement screens or catchment areas, counting the impinged fish, and extrapolating the count to an annual basis. Entrainment monitoring typically involves intercepting a small portion of the intake flow at a selected location in the facility, collecting organisms by sieving the water sample through nets or other collection devices, counting the collected organisms, and extrapolating the counts to an annual basis.

Since expected impacts will vary, each case is not expected to require the same level of study. A decision as to the appropriate number of years and type of data necessary should be worked out during drafting and review of the PIC. At a minimum, the study should include the following:

a) Taxonomic identification 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 each existing and/or proposed CWIS
   i) A list of species (or relevant taxa) for all life stages and their relative abundance in the vicinity of the CWIS;
   ii) Identification of the species and life stages that would be most susceptible to impingement and entrainment. Species evaluated should include the forage base as well as those most important in terms of significance to commercial and recreational fisheries;
   iii) Identification of all threatened, endangered, and other protected species that might be susceptible to impingement and entrainment at the CWIS
b) A characterization of the species noted above, including a description of the abundance and temporal and spatial characteristics in the vicinity of each CWIS, based on sufficient data to characterize annual, seasonal, and daily variations in IM&E (related to climate and weather differences, spawning, feeding and water column migration)
   i) Identification and evaluation of the primary period of reproduction, larval recruitment, and period of peak abundance for relevant taxa;
   ii) Data representative of the seasonal and daily activities (e.g., feeding and water column migration) of biological organisms in the vicinity of the cooling water intake structure;
   iii) Habitat preferences (e.g., depth, substrate)
   iv) Principal spawning (breeding) ground; Migratory pathways; Nursery or feeding areas
   v) Ability to detect and avoid currents; swimming speeds
   vi) Body size; Age/developmental stage
   vii) Physiological tolerances (e.g., temperature, dissolved oxygen)
   viii) Feeding habits
   ix) Reproductive strategy; Mode of egg and larval dispersal
   x) Generation time
   xi) Other functions critical during the life history

If the information requested above includes data collected using field studies, supporting documentation should include a description of all methods and quality assurance procedures for sampling, and data analysis including a description of the study area; taxonomic identification of sampled and evaluated biological assemblages (including all life stages of fish and shellfish); and sampling and data analysis methods. The sampling and/or data analysis methods used should be appropriate for a quantitative survey and based on consideration of methods used in other biological studies performed within the same source water body. The study area should include, at a minimum, the area of influence of the cooling water intake structure.

Once the occurrence and relative abundance of aquatic organisms at various life stages has been estimated, it will be necessary to determine the potential for their involvement with the CWIS. For example, some organisms may spend a portion of their life in the pelagic phase and be susceptible to entrainment; other migratory species may be in the vicinity of the CWIS for only short periods during the year. Often, different species are susceptible to CWIS effects during different life history stages. Knowledge of the organism's life cycle and determination of local water circulation patterns related to the structure are essential to estimating an individual species' potential for impacts due to the CWIS.

Once potential involvement is determined, actual effects on organisms can be estimated. One hundred percent loss of individuals impinged, entrapped, or entrained should be assumed unless valid field or laboratory data are available to support a lower loss estimate. The most commonly entrained life stages include eggs, larvae, and juveniles. Because of their small size, limited or no swimming ability, and highly vulnerable physiology, these life stages will most certainly experience high mortality rates as a result of entrainment. The presumption is that entrainment and passage through the cooling system will kill most if not all of these organisms. Therefore, any assertions that entrainment survival rates are greater than zero should be viewed with skepticism, unless evidence to the contrary is quite strong and convincing.

The final step in the IM&E study is to relate the estimated loss of individuals to effects on the whole population. The magnitude of the expected environmental impact should be estimated both in terms of short term and long term impact with reference to the following factors:

c) Documentation of the current IM&E of the species noted above and an estimate of IM&E to be used as the calculation baseline, including:
   i) Absolute damage (# of organisms impinged or entrained on a monthly or yearly basis);
   ii) Percent damage (% organisms impinged or entrained);
   iii) Absolute and percent damage to any endangered species or otherwise critical aquatic organism;
   iv) Absolute and percent damage to commercially valuable or sport fisheries;
   v) Whether the impact might endanger the protection and propagation of a balanced population of fish and shellfish in and on the body of water from which the cooling water is withdrawn (long term impacts).

5) Technology and Compliance Assessment Information

a) **Design and Construction Technology Plan**, includes the following:
   If the permittee has chosen to use design and construction technologies and/or operational measures, in whole or in part to meet BTA requirements, the permittee should submit a Design and Construction Technology Plan to the Department for review and approval. The plan should explain the technologies and/or operational measures which are in place and/or which have been selected to meet the requirements and should contain the following information:
   i) capacity utilization rate for the facility (or individual CWIS, where appropriate) and supporting data, including average annual net generation in megawatt hours as measured over a 5-yr period (if available) of representative operating conditions and the total net capacity of the facility in megawatts (MW) and calculations;
   ii) A narrative description of the design and operation of all design and construction technologies and/or operational measures (existing or proposed) to reduce impingement mortality and/or entrainment;
   iii) calculations of the reduction in impingement mortality and/or entrainment of all life stages of fish and shellfish that would be achieved by the technologies and/or operational measures selected based on the Impingement Mortality and/or Entrainment Characterization Study; and

iv) Design and engineering calculations, drawings, and estimates prepared by a qualified professional to support the description mentioned in the paragraphs above.

b) **Technology Installation and Operation Plan,** includes the following:
This plan is one of the most important pieces of documentation for implementing the requirements of the rule. It serves to (1) guide facilities in the installation, operation, maintenance, monitoring, and adaptive management of selected design and construction technologies and/or operational measures; (2) provide a schedule and methodology for assessing success in meeting applicable performance standards; and (3) provide a basis for determining compliance with the rule requirements. If the permittee has chosen to use design and construction technologies and/or operational measures in whole or in part to comply with the applicable requirements, the permittee should submit the following information for review and approval by the Department:
i) A schedule for the installation and maintenance of any new design and construction technologies;
ii) A list of operational parameters to be monitored, including the location and the frequency of monitoring;
iii) A list of activities that will be undertaken to ensure the efficacy of the installed design and construction technologies and operational measures, and the schedule for implementing them; and
iv) A schedule and methodology for assessing the efficacy of any installed design and construction technologies and operational measures in achieving applicable performance standards, including an adaptive management plan for revising design and construction technologies and/ or operational technologies if the assessment indicates that applicable performance standards are not being met.

6) **Restoration Plan**

Facilities may use restoration measures that produce and/or result in levels of fish and shellfish in the facility's waterbody or watershed that are substantially similar to those that would result through compliance with the applicable performance standards or alternative site-specific requirements. If the permittee proposes to use restoration measures, in whole or in part, to meet the applicable requirements, the permittee should submit the following information:

a) A demonstration to the Department that the permittee has evaluated the use of design and construction technologies and/or operational measures and an explanation of how the permittee determined that restoration would be more feasible, cost-effective, or environmentally desirable;
b) A narrative description of the design and operation of all restoration measures (existing and proposed) that the permittee has in place or will use to produce fish and shellfish;
c) Quantification of the ecological benefits of the proposed ecological measures;
d) Design calculations, drawings, and estimates to document that the proposed restoration measures in combination with design and construction technologies and/or operational measures, or alone, will meet BTA requirements;
e) A plan utilizing an adaptive management method for implementing, maintaining, and demonstrating the efficacy of the restoration measures the permittee has selected and for determining the extent to which the restoration (in combination with design and construction technologies and operational measures, if appropriate), have met the applicable requirements;
f) A summary of any past or ongoing consultation with appropriate Federal, State, and Tribal fish and wildlife management agencies on permittee's use of restoration measures;
g) A description of the information to be included in a biannual status report to the Department.

7) **Information to Support a Site-specific Determination of BTA**

According to EPA's Phase II rule, if the permittee requests a site-specific determination of BTA because of costs significantly greater than those considered for a similar facility in establishing the applicable performance standards, the permittee should provide to the Department the information specified in paragraphs a) and c) below. If the permittee requests a site-specific determination of BTA because of costs significantly greater than the benefits of meeting the applicable performance standards at the site, the permittee should provide the information specified in paragraphs a), b), and c) below.

a) **Comprehensive Cost Evaluation Study.** The permittee should perform and submit the results of a study that includes:

i) Engineering cost estimates in sufficient detail to document the costs of implementing design and construction technologies, operational measures, and/or restoration measures at the facility that would be needed to meet the applicable performance standards;
ii) A demonstration that the costs documented above significantly exceed either those considered by EPA in establishing the applicable performance standards or the benefits of meeting the applicable performance standards; and
iii) Engineering cost estimates in sufficient detail to document the costs of implementing the design and construction technologies, operational measures, and/or restoration measures in permittee's Site-Specific Technology Plan developed in accordance with paragraph c) below.

b) **Benefits Valuation Study.** If the permittee is seeking a site-specific determination of BTA because of costs significantly greater than the benefits of meeting the applicable performance standards at the facility, the permittee should use a comprehensive methodology to fully value the impacts of IM&E at the site and the benefits achievable by meeting the applicable performance standards. In addition to the valuation estimates, the benefits study should include the following:
i) A description of the methodologies used to value commercial, recreational, and ecological benefits;
ii) Documentation of the basis for any assumptions and quantitative estimates;
iii) An analysis of the effects of significant sources of uncertainty on the results of the study;
iv) A narrative description of any non-monetized benefits that would be realized at the site if the permittee were to meet the applicable performance standards and a qualitative assessment of their magnitude and significance.

c) **Site-Specific Technology Plan.** Based on the results of the Comprehensive Cost Evaluation Study and the Benefits Valuation Study, if applicable, the permittee should submit a Site-Specific Technology Plan to the Department for review and approval. The plan should contain the following information:
i) A narrative description of the design and operation of all existing and proposed design and construction technologies, operational measures, and/or restoration measures selected;
ii) An engineering estimate of the efficacy of the proposed and/or implemented design and construction technologies or operational measures, and/or restoration measures;
iii) A demonstration that the proposed and/or implemented design and construction technologies, operational measures, and/or restoration measures achieve an efficacy that is as close as practicable to the applicable performance standards;
iv) Design and engineering calculations, drawings, and estimates prepared by a qualified professional to support the elements of the Plan.

8) Verification Monitoring Plan

This plan is intended to measure the efficacy of the implemented design and construction technologies and/or operational measures. The plan should include at least two years of monitoring to verify the full-scale performance of the proposed or already implemented design and construction technologies and/or operational measures. Verification monitoring should begin once the technologies and/or operational measures are implemented and continue for a sufficient period of time (but at least two years) to assess success in reducing IM&E. Components of the Verification Monitoring Plan should include:

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.
b) A proposal on how naturally moribund fish and shellfish that enter the CWIS would be identified and taken into account in assessing success in meeting the performance standards; and,
c) A description of the information to be included in a bi-annual status report, used to assess the facility's success in meeting the performance standards for IM&E reduction and to guide adaptive management in accordance with the requirements in the facility's Technology Installation and Operation Plan.

How Do Staff Determine What Is "Best Technology Available"?

As discussed above, s. 316(b) of the Clean Water Act and ch. 283.31(6), Wis. Stats., require that the location, design, construction, and capacity of a CWIS reflects the best technology available (BTA) for minimizing adverse environmental impact. In order to make decisions regarding whether a facility will meet these requirements, the

Department will need to evaluate information submitted by the permittee to determine whether proposed (or existing) technologies are BTA. While some things may be true to most situations, the optimal combination of measures that will most effectively minimize adverse environmental impact will likely be site and facility specific. It will be necessary for the Department to determine BTA on a case-by-case basis making full use of all of the relevant information available at the time.

For example, it would seem obvious that a once-through system with a large volume intake, located in an area of high biological value, would not represent BTA to minimize adverse environmental impact. However, an exception might be made if data shows that impacts to the biota are low and subsequent reduction of critical populations is minimal. The opposite case could also be true. A low volume intake in an area of low biological value would frequently result in a determination of BTA in that location, but exceptions to this could include cases where rare or endangered species may be significantly affected. In each circumstance, biological studies should provide useful data when it comes time to make a judgment about appropriate BTA. Site-specific studies, good local knowledge, and informed judgments are essential in all cases. Some example questions that should be considered include:

1. Can impingement mortality and/or entrainment be minimized by modification of proposed (or existing) screening systems?
2. Can impacts be minimized by increasing the size of the intake to decrease through-screen velocities?
3. Should the existing intake be abandoned and replaced with a new intake with a more appropriate design and/or at a different location?

When making BTA decisions, staff will need to identify organisms that need protection, identify potential adverse environmental impacts (including impingement mortality and entrainment), and consider the potential for indirect impacts (e.g., disruption of thermal regimes and/or normal water circulation, aesthetics, noise, wetland disturbances, etc.). The following discussions should also be considered when evaluating whether a permittee has met the requirements of "best technology available."

Location

Intake location is an important factor influencing the potential for impingement, entrainment, and destruction of habitat. Careful site selection for a CWIS is the first line of defense in minimizing loss or damage to an aquatic population. Once the site is selected, one or a combination of technologies can be employed to further reduce losses due to IM&E. Since the distribution of aquatic organisms is seldom random, historical and recent biological data in the area of the CWIS should be reviewed carefully. The following are some criteria for consideration during the selection of an appropriate CWIS location:

1. Generally, a CWIS shouldn't be located in spawning areas, nursery grounds, migratory routes, or river mouths, since these are areas large concentrations of fish are expected. Impacts to sensitive, threatened, and endangered species should be avoided. Historical data and current field studies should be designed to clearly illustrate the biological community present at the proposed/existing site. Survey results should be helpful when determining where new intakes and/or intake pipelines should be built to minimize impacts to spawning, feeding, nursery, or migration areas, as well as evaluating impacts to sensitive, threatened, and endangered species.

2. The CWIS should be designed to minimize shelter and surface area for attachment or attraction of organisms which would counteract attempts to place the intake in an environmentally acceptable location. The CWIS should not serve as an attractant to immature or adult fish, either by physical alteration of the environment, by providing shelter, or by the influence of heated water (except where heated water is essential for maintenance reasons).

3. Withdrawal from various vertical depths in the water column should be investigated and attempts made to avoid the largest concentration of fish, eggs, and larvae (keeping in mind daily and seasonal variations).

4. Total design intake flows should not alter the natural stratification of the source water.

5. If a new CWIS is proposed, a Chapter 30, Stats., permit for placing a structure on the bed and/or removal of material from the waterway may be required. As part of that permitting process, a s. NR 347, Wis. Adm. Code, sampling plan for reviewing the presence / absence of contaminants that may be dredged, moved or disturbed as the intake structure and pipeline are constructed may also be required.

6. Navigation impacts should be evaluated. A minimum water depth should be maintained above the structure to avoid boats and other watercraft, where possible. (These issues will likely be evaluated at the time of Chapter 30 permit review, where appropriate.)

Capacity
One of the best ways to minimize the impacts of a CWIS is to reduce the rate and amount of the water that is withdrawn. This may only be an option for facilities with once through cooling and could come at the expense of an increase in heat through the discharge. Both of these consequences should be considered prior to making final decisions on the intake rate and amount.

Cooling water withdrawals that result in water loss or consumptive use (likely for all power plants) that will be >2 MGD must comply with ch. NR 142, Wis. Adm. Code, *Water Resources Management and Conservation.* Department staff that process Chapter 30 permits will likely use s. 142.06(3) as the approval/denial process.

Design/Technology
It is impossible to design any one type of uniform structure that will minimize environmental impact in every situation. However, in general, most designs should incorporate some type of outside screening device that will guard against impingement losses. If field studies reveal a location where entrainment of fish eggs or larvae are also a concern, and the intake can't be located differently, screens with even smaller slots may be necessary. Regardless of screen mesh size, CWIS should be designed to minimize through-screen velocities. A maximum through screen velocity of 0.5 fps is thought to be protective of most fish species. Additional intake designs that maximize survival of impinged fish exist and may also be implemented. These include fish-handling systems such as fish buckets, fish troughs, fish baskets, fish pumps, fish elevators and spray wash systems. These designs either divert organisms away from the intake structure or collect impinged organisms, protect them from further damage and return them back to the source water. In order to decide which technologies are best suited to obtain BTA for a given site, staff will need to understand the range of technologies available that address entrainment and impingement. As discussed previously, the location and design of each CWIS will be unique to the site-specific situation.

Since the 1970s, industry and other groups have been working on CWIS technologies that would be both biologically- and cost-effective. This has led to the development of a variety of technologies that address different biological, environmental, and engineering concerns associated with different target species, waterbodytypes, and physical locations (onshore, offshore, in-river). Research continues on new technologies, as well as modifications to existing technologies.

Example CWIS Technologies.

Descriptions and other information regarding the most commonly used CWIS technologies are contained in USEPA's "*Technical Development Document for the Final Regulations Addressing Cooling Water Intake Structures for New Facilities*" (Chapter 5) and "*Technical Development Document for the Proposed Section 316(b) Phase II Existing Facilities Rule*" (Chapter 3) which also contains additional references on intake impacts.

USEPA 2001. *Technical Development Document for the Final Regulations Addressing Cooling Water Intake Structures for New Facilities.* Office of Water. EPA-821-R-01-036. http://www.epa.gov/waterscience/316b/technical/technicaldd.html .

USEPA 2002. *Technical Development Document for the Proposed Section 316(b) Phase II Existing Facilities Rule.* Office of Water. EPA-821-R-02-003. http://www.epa.gov/waterscience/316b/devdoc/.

Monitoring Requirements in WPDES Permits

Once proposed technologies and/or restoration measures have been implemented to meet BTA standards, follow-up monitoring should be required in the WPDES permit in order to determine whether these measures are in fact meeting the performance standards. IM&E monitoring can usually be accomplished through direct measurement of the numbers, sizes and weights of organisms impinged and entrained (accounting for daily and seasonal variation). Impingement monitoring usually involves sampling screens and/or catchment areas, counting impinged organisms, and extrapolating the count to an annual basis. Entrainment monitoring typically involves sampling a portion of the intake flow at a select location, collecting organisms by sieving water through nets or other collection devices, counting the organisms, and extrapolating the counts to an annual basis.

In cases where a CWIS has been present for some time (without significant modification), and some monitoring has been done which demonstrates ongoing compliance, it may be acceptable to reduce the level of monitoring required in the WPDES permit from previous levels. However, where a new CWIS has been approved, or where significant changes in intake location, design, construction, capacity, or operation have taken place, a more vigorous monitoring program should be required to demonstrate that the CWIS is meeting BTA standards.

WPDES permit language should include monitoring requirements for permittees with approved CWIS' to demonstrate compliance with the appropriate standards. Monitoring programs should include measurements of impingement, entrainment, maximum through-screen velocity, and visual or remote inspections to insure that chosen technologies are operating as designed.

Additional Guidance On Cooling Water Intake Structures And Related Topics

- WDNR site - http://dnr.wi.gov/org/es/science/energy/oe.htm
- Public Service Commission of Wisconsin - http://psc.wi.gov/
- Electric Power Research Institute - http://www.epri.com/
- EPA website - http://www.epa.gov/ost/316b/

APPENDIX 1:
Statutory Timelines and Agency Responsibilities for Approval of New Power Plants

The Public Service Commission (PSC) and the Department are both involved in making regulatory decisions regarding several categories of energy-related projects, including new electric-generating facilities. The PSC and DNR are also responsible for complying with the Wisconsin Environmental Policy Act (WEPA) and the Power Plant Siting Law (s. 196.491(3), Wis. Stats.). The Power Plant Siting Law establishes a tight schedule for review of proposed power plant projects.

The formal process begins with the DNR's review of an "Engineering Plan" to identify the regulatory requirements for the facility, which must be submitted at least 60 days before the filing of an application with the PSC. The Department's review of the Engineering Plan must be completed within 30 days of it's receipt. The applicant then has 20 days to submit applications for the permits identified during the review of the Engineering Plan and the Department has another 30 days to determine if those applications are complete. In making the application completeness determination, the Department also considers whether it has enough information to do an adequate WEPA review (including an environmental impact statement or environmental assessment) and shares those conclusions with the PSC. Once the Department finds the applications to be complete, it has 120 days to make regulatory decisions for the permits or approvals necessary for construction of the facility to begin.

The applicant must also file an application for a Certificate of Public Convenience and Necessity (CPCN) with the PSC. The PSC then has only 180 days from finding that an application is complete to make a final determination on whether to approve the project. If the PSC does not make its determination within the statutory time frame, the CPCN is automatically granted. Within this time frame, the PSC (generally with the Department as a cooperating agency) must complete the WEPA process, hold a public hearing on the CPCN application, make a decision at an open meeting, and draft an order for final approval at a future open meeting.

FIGURE 1. SCHEDULE OF STATUTORY EVENTS FOR REVIEWING POWER PLANTS (S. 196.491, WIS. STATS.)

Day 0 – Engineering Plan received by DNR
Day 30 – DNR response to Engineering Plan regarding permits and approvals required
Day 50 – Project proponent submits applications for DNR permits
Day 60 – Project proponent submits CPCN application to PSC
Day 80 – DNR makes determination of application(s) completeness
Day 90 – PSC makes determination of CPCN application completeness
(DNR and PSC review permit applications, prepare WEPA document, hold public hearings)
Day 200 – DNR makes decisions on permits needed for construction of the facility
Day 270 – PSC makes decision on CPCN
Day 271 – Construction of power plant facilities may commence

The rapid, statutorily required schedule described above puts considerable pressure on the Department to accelerate the review of proposed power generation facilities and complete activities necessary to issue the appropriate permits, when appropriate. In order to insure that strict timelines are met and all needed information is gathered and assessed appropriately, the Department usually assigns a team of staff to review each power plant project, including someone responsible for the review of CWIS submittals and requirements.

The Department's new Office of Energy is assigned responsibility for overseeing the overall implementation of new power plant project review procedures and for coordinating the review of Engineering Plans for proposed power plants. For each project, a "Project Manager" may be appointed from either the central office or region, a case-by-case basis. The affected Region will designate a Regional Coordinator for the project (may be the same as the "Project Manager" if that person is in the Region). The Project Manager and Regional Coordinator are charged with establishing and maintaining effective communication between (and within) the Department, the PSC, and all affected outside parties. (Additional information regarding the Department's Office of Energy is available at: http://dnr.wi.gov/org/es/science/energy/oe.htm)

APPENDIX 2:
CWIS Evaluation Report Format

The following format is recommended for Comprehensive Demonstration Study (CDS) reports and other information provided to support a finding that the cooling water intake represents best technology available. Copies of all such reports should be submitted to the CWIS Program Coordinator in Madison, the Permit Coordinator, Basin Engineer, and any other appropriate regional staff (e.g., fisheries experts, endangered resources specialists, etc., as appropriate).

1. Title page (facility name, waterbody name, company, permit information, etc.).
2. Table of contents.
3. An executive summary of 2-3 paragraphs (essence of material and conclusions).
4. Detailed presentation of methods used in data collection, analysis and/or interpretation.
5. Supportive reports, documents, and raw data.
6. Bibliographic citations to page number of cited text.
7. An interpretive, comprehensive narrative summary of all studies done to support a finding that the CWIS represents best technology available. Sources of data used in the summary should be cited to page number. The summary should include a clear discussion stating why the report shows (or does not show) that the CWIS in question minimizes impact on the water resources and aquatic biota in the vicinity of the intake and throughout the waterbody segment.
8. An appendix listing the companies and consultants who conducted the work used in the report.

Reports can be mailed to the CWIS program coordinator and central office permit coordinators at:

Department of Natural Resources
Bureau of Watershed Management
101 S. Webster Street
PO Box 7921
Madison, WI 53707-7921

NSP

Northern States Power Company

414 Nicollet Mall
Minneapolis, Minnesota 55401-1927
Telephone (612) 330-5500

September 21, 2000

Metro/Major Facilities
Attn: Discharge Monitoring Reports
Minnesota Pollution Control Agency
520 Lafayette Road North
St. Paul, MN 55155

Attention: Mary Hayes

PRAIRIE ISLAND NUCLEAR GENERATING PLANT
NPDES Permit No. MN0004006
Monthly Discharge Monitoring Reports

In accordance with Chapter 6 Part 3 of the subject NPDES permit, we are submitting our Discharge Monitoring Reports for discharges SD-001, SD-002, SD-003, SD-004, SD-005, SD-006, SD-007, SD-012, WS-001 and WS-002 at the Prairie Island Nuclear Generating Plant. These reports cover the period August 1, 2000 through August 31, 2000. We are also submitting the Bromine/Chlorine Monthly Supplemental Report. With the summary information to be found on the discharge SD-001 monitoring report form, we propose to discontinue this supplemental report after the MPCA and NSP determine any further need for it.

Please note that the flows reported for discharges WS-001 and WS-002 include a total of both outfalls.

In accordance with Chapter 2 Part 4 of the subject NPDES permit, we are submitting the records of the daily maximum, minimum, and average temperatures for the monitoring locations of the temperature monitoring system. As approved by the MPCA, the discharge monitoring report forms for stations SW-001, SW-002, SW-003, and SW-004 have been discontinued since the summary data requested by each form is found in the attached records. Discharge canal monitoring was out of service or operating incorrectly August 17 to 25.

A plant status report of the continuous chlorination/bromination treatment program is included with the Bromine/Chlorine Monthly Supplemental Report, and provides a summary of August operations including the monthly demand result. With the cross connect valve open the unit 2 chemical injection system fed both cooling water systems in the continuous bromination mode from August 18 to 22. The cross connect valve was closed while the chemical injection systems were operating during the rest of the month. With the cross connect valve shut, both systems were operated in the continuous bromination mode except for several shutdown periods and except while the unit 2 system was in continuous chlorination mode from August 27 to 31. The dates of the unit 1 chemical injection system shutdown periods were August 14 until supply from unit 2 through the opened cross connect valve on August 18, and August 27 to 31. The dates of the unit 2 chemical injection system shutdown periods were August 15 and August 16 to 18.

The enclosed memorandum titled "August River Temperatures" describes two periods in August after average ambient river temperature had been at 78°F or above for two consecutive days. This ambient temperature condition triggers the permit requirement to run all cooling towers to the maximum practical extent, which was considered the operation scenario at the time. For your information, attached with the memorandum is the *Star Tribune* summary of the Twin Cities air temperatures for the month.

The report on the zebra mussel control treatment conducted on the unit 1 circulating water system on August 15 and on the unit 2 circulating water system on August 17 is enclosed. The treatment was conducted with approved levels of Nalco-Calgon's EVAC, and the report provides details of the treatment levels, durations and effectiveness as well as information on the resultant loss of fish within the plant's circulating water system. Attached with the report is the assessment of fish loss as discussed at the follow up meeting with state agencies on August 28.

If you have any questions, please call me at 612-330-6625.

Sincerely,

Jim Bodensteiner
Senior Environmental Analyst

Enclosures

c: Terry Coss
Marilyn Danks (DNR)
Gary Gramm (Dept of Ag)
Kevin Holstrom
Gerald Joachim
Gary Kolle
Katherine Logan (MPCA Rochester)
Ken Mueller
Steve Schaefer
John Sullivan (WI DNR)
ERAD Record Center

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XCEL ENERGY
Prairie Island Nuclear Generating Plant
1717 Wakonade Drive East
Welch, Minnesota 55089
(651)-388-1121

DATE SEPTEMBER 01,2000

NAME JIM BODENSTEINER
ADDRESS ENVIROMENTAL SERVICES

SUBJECT: CONTINUOUS CHLORINATION/BROMINATION

The plant operated in the continuous bromination mode in a split feed mode(cross-connect shut) until the middle of August when there were numerous system manipulations during the addition of the zebra mussel chemical(Calgon EVAC) to the intake canal.

At 1800 August 14th Unit 1 chem injection system was shutdown and the cross-connect valve remained shut. At 1000 August 15th Unit 2 chem injection sytem was shutdown for minor maintenance. At 2200 August 15th Unit 2 chem injection sytem was restarted in continuous bromination mode with cross connect valve shut. At 1600 August 16th Unit 2 chem injection system was shutdown. At 1630 August 18th Unit 2 chem injection system was restarted in the continuous bromination mode with the cross connect valve OPEN so it was feeding both cooling water systems. At 0600 August 22nd the cross connect valve was shut for repair on Unit 1 system. At 1400 August 23rd Unit 1 chem injection system was restarted in continuous bromination mode with the cross connect valve SHUT. At 0810 August 27th Unit 1 chem injection system was shutdown for repair and the cross connect valve remained shut. At 0600 August 28th Unit 2 chem injection system sodium bromide pump was off for unknown reason. Tank level changes seems to indicate that it may have tripped off late on August 27th. This put the plant in a continuous chlorination mode. Operation continued in this continuous chlorination mode until 1130 August 31 st when Unit 1 chem injection system was restarted in continuous bromination mode and Unit 2 sodium bromide pump was restarted placing Unit 2 chem injection system in a continuous bromination mode(cross connect SHUT). At 1530 Unit 1 chem injection system was shutdown for maintenance(cross connect SHUT)

On August 19th and 20th the normal sample point for Unit 1 cooling water(WS001) was plugged and the daily sample was taken at an alternate sample point slightly upstream of the normal sample point which would have resulted in slightly higher sample results(conservatively higher). The sample point was unplugged and was returned to service on August 21st.

Please contact me at Ext. 4440 if additional information is needed. Thank you.

Sincerely yours,

Gerald Joachim
Senior Radiation Protection Specialist

XCEL ENERGY
Prairie Island Nuclear Generating Plant
1717 Wakonade Drive East
Welch, Minnesota 55089
(651)-388-1121

DATE SEPTEMBER 01,2000

NAME JIM BODENSTEINER
ADDRESS ENVIROMENTAL SERVICES

SUBJECT: AUGUST RIVER TEMPERATURES

A late July weather warmup that lasted into early August caused the daily average upstream river temperature to rise above 78 degrees with the second consecutive day occurring on August 1st. In addition an early August warmup caused daily average upstream river temperature to rise above 78 degrees for seven days. Daily average upstream temperatures listed below.

UPSTREAM RIVER TEMPERATURE
DAILY AVERAGE

August 1	79.2
2	79.0
3	78.2
10	80.3
11	79.5
12	79.5
13	80.0
14	80.4
15	80.3
16	78.3

The plant NPDES permit requires "running all cooling towers to the maximum practical extent" after the second consecutive day above 78 degrees. The plant met this permit requirement by running all four towers and 46 of the possible 48 fans. 2 fans remained out of service because repair would require turning off 24 fans for around 1 day.

The daily average upstream river temperature remained below 78 for the rest of August. The highest daily average downstream temperature was 81.5 degrees on August 14th.

The discharge canal temperature system was out of service from late August 17th to late afternoon August 25th.

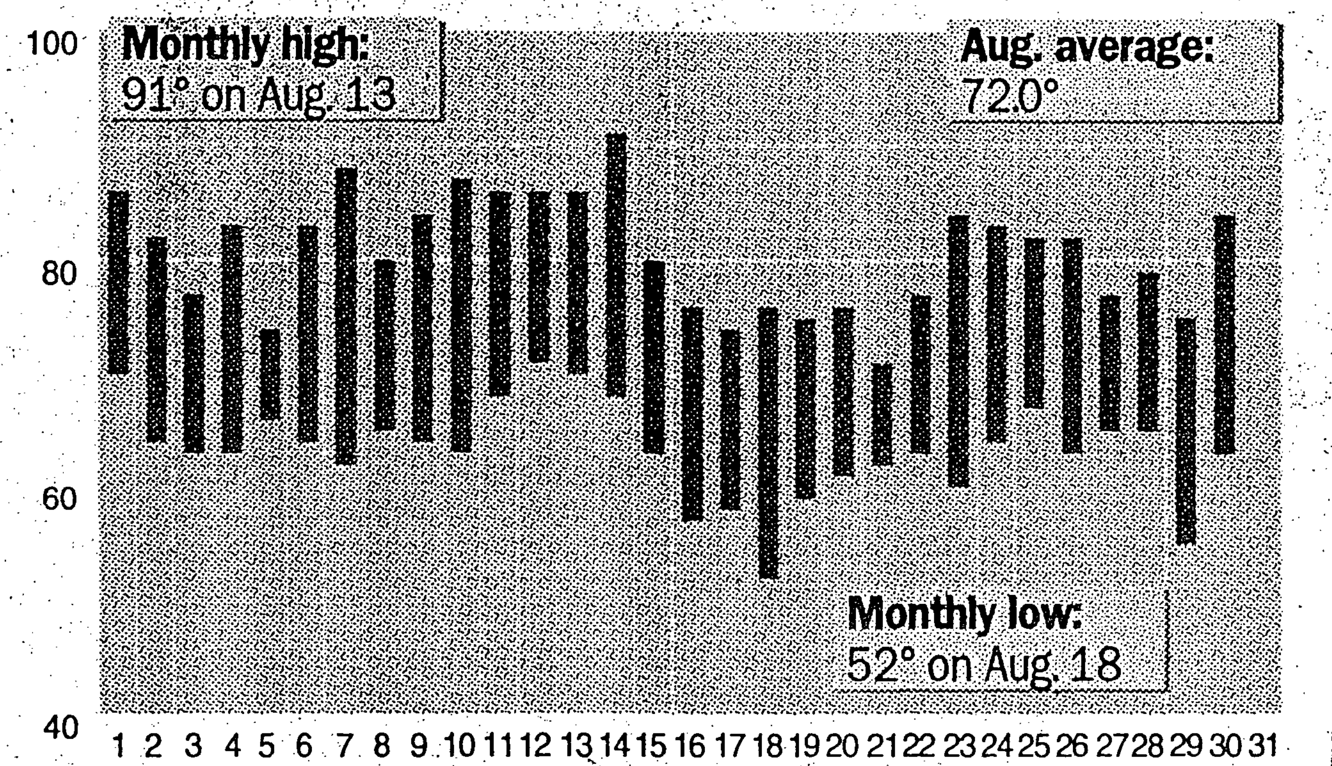
#121 intake screen remained out of service until 1100 August 31st due to bearing problems.

Please contact me at Ext. 4440 if additional information is needed. Thank you.

Sincerely yours,

Gerald Joachim
Senior Radiation Protection Specialist

High/low temperatures for August 2000



Mpls / St. Paul Area Temperature
(STARTRIBUNE)

NSP – Prairie Island Nuclear Generating Plant
Report on the Zebra Mussel control treatment of the Circ water system.

This is a report on the treatment of the Unit 1 and Unit 2 Circulating water systems at the Prairie Island Nuclear Generating Plant. This report discusses the chronology of events, the killing of fish and the effectiveness of the treatment. Finally, some changes for the 2001 treatments will be discussed.

Summary:
NSP treated the Unit 1 circ water system on 15 August 2000. The Unit 2 side of the circ water system was treated two days later on 17 August. The treatment was very successful in eradicating Zebra Mussels. An unfortunate effect was the killing of approximately 100,000 primarily small fish in the circ water system. For the treatment in 2001, a longer treatment time using a lower dosage of the biocide will be considered. Also the treatments will likely be separated by approximately a week.

Report:
NSP contracted with the NALCO chemical company to provide services and the chemical biocide to treat the circ. water systems. The biocide used was EVAC™.

The treatment of Unit 1 circ water system was performed on 15 August 2000. During the summer months the circ water system at Prairie Island is operated in a once through configuration. Intake water is pumped through the plant, and then over four cooling towers. After the towers, the water flows through the cooling tower return canal, down a ½ mile discharge canal, and finally out to the Mississippi river.

The Unit 1 treatment duration was 7 hrs. 45 minutes (1145 to 1930). The chemical addition rate was raised to the maximum permitted rate of 4 ppm active ingredient. The flow treated was 270,000 gpm. This is slightly over half of the total circ water flow of 525,000 gpm. In the targeted area, which was primarily the plant screen house, concentrations of 1.3 to 2.3 ppm active ingredient were obtained.

The next day, 16 August, dead fish were reported in the discharge canal. A rough estimate of the number of dead fish was 75,000. The appropriate state agencies were notified. The estimated number of fish killed was presented in a press release the same day. The dead fish were almost exclusively 2 to 3 inches in length. A few adult fish were killed. It is important to note that EVAC™ attacks the gills of aquatic organisms, suffocating them. As a result, EVAC™ is not a threat to scavengers feeding on the dead fish.

It had not been expected that fish would be killed in the discharge canal. A few hundred fish in the intake canal were expected to be affected. Based on experience with earlier chemical treatments, plant personnel expected three mechanisms would remove nearly all of the biocide by the time the water reached the discharge canal. First, there is a high biological demand in the water and in the cooling towers. Second, the river water has a high concentration of suspended solids. Suspended solids tie up the EVAC™, making is unavailable to organisms. Finally, because only one Unit was treated at a time, the treated circ water experiences a 1:1 dilution from the untreated Unit's discharge, before being pumped to the cooling towers.

On 17 August, Unit 2 was treated. The treatment lasted 11 hrs. 20 minutes (1120 – 2240). Again, the circ water flow treated was 270,000 gpm. The chemical addition rate was reduced slightly from the Unit 1 treatment, to 3.6 ppm active ingredient. The intent was to reduce the addition rate and increase the treatment duration to reduce the effect of the biocide on the remaining fish. In the targeted area, concentrations of 1.0 to 1.7 ppm active ingredient were obtained.

On the evening of the 17th, many distressed small fish were observed in the discharge canal, as well as some adult channel cat fish. Concentrations of EVAC™ were measured in the discharge canal of 0.2 to 0.3 ppm active ingredient. It was estimated that an additional 25,000 fish were killed as a result of the treatment of Unit 2. It should be noted that for these treatments the permit approval was based on restricting the amount of biocide that could be applied. No discharge limits or monitoring were imposed. The treatments were conducted within these restrictions. As a result, no measurements of biocide were taken in the discharge canal for the first (Unit 1) treatment on 15 August.

Presently, the population of Zebra Mussels at Prairie Island is sparse. It is estimated that there is no more than one adult mussel per square meter of surface area. No juveniles have been sighted yet. Therefore, to measure the efficacy of the treatments adult mussels are brought in from Lake Pepin and placed in bioboxes. The over all average mortality rates for the six bioboxes was just over 91%. This was very good, and a significant improvement over the treatment of Unit 1 in 1999. (Unit 2 was not treated in 1999). For the treatments a control population of Zebra Mussels was located in an untreated area of the circ water system. The control population experienced a 1% mortality rate.

Finally, on 28 August, representatives from NSP, Nalco, and the State agencies of concern met to discuss the treatments and resulting fish kill. The exchange of information and cooperation was greatly appreciated by all participants.

Root cause and contributing factors:
Clearly the EVAC™ was the cause of the fish kill. However two contributing factors are important. First, the discharge canal temperature was 88 °F during the treatments. This relatively high temperature may have already placed a stress on the fish making them more vulnerable to the EVAC™. Second, the two treatments were performed only two days apart. Fish not killed by the first treatment on the 15th, could still have been distressed on the 17th, when the second treatment was performed. Again, this could have made these fish more vulnerable to the biocide.

Considerations for next year's treatments:
For 2001 then, longer treatments will be considered, using a lower dosage of the biocide. The next treatments will likely be 24 hours in length with a target of 1.0 ppm active in the

portions of the circ water systems being treated (i.e. the plant screen house). Also, consideration will be given to spacing the treatments out, increasing the time between treatments to around 5 to 7 days. Thought will be given to performing the treatment when the discharge canal temperature is cooler, however cooler discharge temperatures mean cooler intake temperatures. The biocide is less effective in cooler water, so this could be counter productive.

Joachim, Gerald J

From: Mueller, Kenneth N
Sent: Thursday, August 31, 2000 3:02 PM
To: Gruber, Mark E; Kolle, Gary; Bodensteiner, James J
Cc: *dl PI Environmental; Schuelke, Don; Giese, Bradley; Orr, Daniel J; Coss, Terry E
Subject: PI Aug.- 2000 Fish-kill Assessment

Importance: High

Report prepared 8/31/00 by KN Mueller - Environmental Analyst

The following explanation is provided with intent to clarify rationale, assumptions, and calculations used for determining estimated numbers and composition of small fish killed in the discharge canal, as a result of zebra mussel control treatments performed Tuesday 8/15 and Thursday 8/17 at the Prairie Island Plant.

On Wed. 8/16/00 at approximately noon, KNM was paged by Mark Gruber alerting him to dead fish in the discharge canal. At approximately 3 pm KNM, DJO and BDG inspected the discharge canal between electrofishing runs. The composition was estimated as 50% yoy channel catfish (1½" - 4") and 50% shiner/minnow species (juv. & adult). No attempt was made at that time to determine total numbers or collect fish, because we had to continue electrofishing.

That afternoon M.Gruber & G.Kolle spot-checked areas around the discharge canal, and counted fish within a 10' section of shoreline that appeared representative of the entire discharge canal shoreline. They arrived at approximately 150 fish within that 10' section. They estimated ~ 15 fish/foot, which they multiplied by the number of feet of discharge canal shoreline: 15 fish/foot X 5000 feet = ~ 75,000 fish (original reported estimate). Using the composition estimate, that equates to ~ 37,500 yoy channel catfish (1½" - 4") and ~ 37,500 shiner/minnow species (juv. & adult).

On Fri. 8/18/00 KNM estimated approximately 20 fish/foot along the shoreline of the discharge canal, but there was a higher percentage of shiner/minnow species and green sunfish, and fewer additional small catfish than were observed on 8/16. The dead fish observed in the canal on Wednesday were not removed, so it was assumed that an additional 5 fish/foot had accumulated. The additional 5 fish/foot adds 25,000 fish to the original estimate of 75,000.

The following percent composition is for the additional 25,000 small fish estimated on Friday. Percent composition was based on shoreline observations and further supported by examination of 1½ 5-gal. pails of small fish collected from the discharge canal:

~ 80% shiner/minnow species (~ 20,000)
~ 10% channel catfish (~ 2,500)
~ 10% green sunfish (~ 2,500)

The following is the final estimated total number of small fish lost in the discharge canal:

8/16		8/18		
~ 37,500	+	~ 20,000	=	~ 57,500 shiner/minnow species
~ 37,500	+	~ 2,500	=	~ 40,000 channel catfish
				~ 2,500 green sunfish
				~ 100,000 small fish

Assessment summaries of fish killed in the intake canal and large fish collected from the discharge canal are attached as Table 1 and Table 2, respectively.

Table 1.xls Table 2.xls

TABLE 1.					Screen house dead fish (count and lengths)																
		Ch. cat	F-w drum	Gr. Sun	Bl. Gill	F-h cat	S-m buff	Giz. Shad	Carp	Walleye	Sauger	S-h redh	W. bass	S-m bass	R. carpsu	Mooneye	Goldeye	Shiner	Bowfin		Total
	1																				
	2	2	1	12	7													70			
	3	5	6	8	28			82	2			1									
	4	4	37	15	12			1					1								
	5	5	10	11	15	1															
	6	16		1	33								1			1					
	7	36	4		45	1		1													
	8	120	12		11	2															
	9	82	11			1															
	10	41	15			2															
	11	12	10			3															
Length	12	10	5			3															
(Inches)	13	6	1			1															
	14	17	7									3		1							
	15	9	1																		
	16	10	3				1	1		1		2									
	17	8	1									2	1				1				
	18	7	1				2		1			3							4		
	19	3	1						2												
	20	1	1				1		6						1						
	21	1					1		4						1						
	22	2					2		3		1										
	23						1			1											
	24	2					1			1											
	25	1								1											
	26	1	1																		
	27	1																			
	28																				
	29																				
	Total	402	128	47	151	14	9	85	18	4	1	11	3	1	2	1	1	70	4		952
								+571 Y-o-Y													
								(40-120mm)													

TABLE 2.		Discharge canal dead adult fish (count and lengths)								
		Ch. cat		Gr. Sun		S-m buff		Carp		Total
	1			1						
	2			3						
	3			3						
	4			10						
	5			3						
	6	3		2						
	7	2		1						
	8	6								
	9	3								
	10	13				1				
	11	5								
Length	12	19								
(Inches)	13	13								
	14	31								
	15	28								
	16	26								
	17	23								
	18	46								
	19	18								
	20	36								
	21	13								
	22	17								
	23	13								
	24	18								
	25	7						1		
	26	9								
	27	5								
	28	4								
	29	3								
	30	10						4		
	Total	371		23		1		5		400
		+56 unmeasured								

BROMINATION/CHLORINATION REPORT

From: 01-AUG-00 To: 31-AUG-00

Day	Bromine Kgms/day	Chlorine Kgms/day	Time mins/day	U-1 Residual	U-2 Residual	Outfall Residual
1	72.7	79.9	1440	0.09	0.10	<.001
2	72.7	76.6	1440	0.11	0.10	<.001
3	67.1	78.8	1440	0.08	0.07	<.001
4	67.1	78.8	1440	0.11	0.09	<.001
5	67.1	77.6	1440	0.11	0.08	<.001
6	67.1	78.9	1440	0.11	0.10	<.001
7	72.7	82.6	1440	0.08	0.09	<.001
8	44.7	82.6	1440	0.15	0.14	<.001
9	28.0	93.3	1440	0.14	0.15	<.001
10	55.9	95.7	1440	0.16	0.16	<.001
11	78.0	95.7	1440	0.15	0.15	<.001
12	55.9	91.0	1440	0.15	0.16	<.001
13	67.1	91.3	1440	0.15	0.17	<.001
14	61.5	84.1	1440	0.15	0.12	<.001
15	28.0	34.8	960	<0.01	0.09	<.001
				<0.01	0.11	
16	33.6	34.8	1080	<0.01	0.12	<.001
17	0	0	0	<NIS>	<NIS>	<NIS>
18	5.6	10.8	90	<NIS>	<NIS>	<NIS>
				<0.01	0.21	<.001
				<0.01	0.22	
19	28.0	52.5	1440	<0.01	0.22	<.001
				0.07	0.09	<.001
20	28.0	44.7	1440	0.08	0.10	<.001
21	44.7	49.9	1440	0.07	0.11	<.001
22	39.2	50.5	1440	0.05	0.08	<.001
23	67.1	65.2	1440	0.02	0.16	<.001
				0.13	0.19	
24	78.3	70.6	1440	0.19	0.24	<.001
25	111.9	70.6	1440	0.19	0.22	<.001
26	89.5	93.2	1440	0.19	0.23	<.001
27	67.1	84.0	1440	0.17	0.21	<.001
28	0	21.4	1440	<0.01	0.17	<.001
29	0	81.8	1440	<0.01	0.21	<.001
30	0	51.1	1440	<0.01	0.26	<.001
31	11.2	64.0	1440	<0.01	0.22	<.001
				0.15	0.20	<.001

Maximum Daily Chlorination Rate = 182.7 Kgms/day on the 26th.

FACILITY NAME/ADDRESS:
NSP - Prairie Island Nuclear Power Plant
1717 Wakonade Dr E
Welch, MN 55089

WASTEWATER TREATMENT DISCHARGE MONITORING REPORT

PERMITTEE NAME/ADDRESS:
NSP
414 Nicollet Mall
Minneapolis, MN 554011993

PERMIT #	LIMIT STATUS	FORMER #
MN0004006	FINAL	010M 1

STATION INFORMATION:
SD-001 (Combined Effluent)
Surface Discharge, Effluent To Surface Water

	MONITORING PERIOD	
	YEAR/MO./DAY	YEAR/MO./DAY
FROM	2000/08/01	TO 2000/08/31

☐ No Discharge

PARAMETER		QUANTITY		UNITS	CONCENTRATION			UNITS	FREQUENCY OF ANALYSIS	SAMPLE TYPE
Flow 50050	SAMPLE VALUE	******	23448	MG	******	756.4	******	mgd	Cont	EST
	PERMIT REQ	******	REPORT CalMoTot		******	REPORT DailyAve	******		1 x Day	MeaCon
pH 00400	SAMPLE VALUE	******	******	****	8.4	******	8.4	SU	1/7	GRAB
	PERMIT REQ	******	******		6.0 CalMoMin	******	9.0 CalMoMax		1 x Week	Grab
Phosphorus Total (as P) 00665 *	SAMPLE VALUE	******	******	****	******	******	NR	mg/L		
	PERMIT REQ	******	******		******	******	REPORT DailyMax		1 x Week	Grab
Chlorine Rate 50059	SAMPLE VALUE	******	182.7	kg/day	******	******	******	*****	1/31	CALC
	PERMIT REQ	******	REPORT DailyMax		******	******	******		1 x Day	Calcul
Oxidants (Bromine) Tot Residual Interm 34046	SAMPLE VALUE	******	******	****	******	******		mg/L		
	PERMIT REQ	******	******		******	******	.05 InstantMax		1 x Day	Grab
Oxidants (Bromine) Tot Residual Contin 04223	SAMPLE VALUE	******	******	****	******	******	<0.001	mg/L	27/31	CALC
	PERMIT REQ	******	******		******	******	.001 DailyMax		1 x Day	Calcul
Oxidants (Chlorine) Tot Residual Interm 03775	SAMPLE VALUE	******	******	****	******	******		mg/L		
	PERMIT REQ	******	******		******	******	.2 InstantMax		1 x Day	Grab

Send original with supplemental DMR (if applicable) by the 21st day of month following reporting period to:
MINNESOTA POLLUTION CONTROL AGENCY
520 LAFAYETTE RD
ST. PAUL, MN 55155-4194
ATTN: Discharge Monitoring Report

I certify that I am familiar with the information contained in this report and that to the best of my knowledge and belief the information is true, complete, and accurate.

[signature] 9-14-00
SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT — DATE

SIGNATURE OF CHIEF OPERATOR — PHONE — DATE — CERTIFICATION#

COMMENTS:

FACILITY NAME/ADDRESS:
NSP - Prairie Isla[illegible]uclear Power Plant
1717 Wakonade Dr E
Welch, MN 55089

WASTEWATER TREA[illegible]ENT DISCHARGE MONITORI[illegible]EPORT

PERMITTEE NAME/ADDRESS:
NSP
414 Nicollet Mall
Minneapolis, MN 554011993

PERMIT #	LIMIT STATUS	FORMER #
MN0004006	FINAL	010M 1

STATION INFORMATION:
SD-001 (Combined Effluent)
Surface Discharge, Effluent To Surface Water

	MONITORING PERIOD (YEAR/MO./DAY)
FROM	2000/08/01
TO	2000/08/31

☐ No Discharge

PARAMETER		QUANTITY		UNITS	CONCENTRATION			UNITS	FREQUENCY OF ANALYSIS	SAMPLE TYPE
Oxidants (Chlorine) Tot Residual Contin 03774	SAMPLE VALUE	******	******	****	******	******	<0.001	mg/L	5/31	CALC
	PERMIT REQ	******	******		******	******	.04 DailyMax		1 x Day	Calcul
Plant Capacity Fctr % of Capacity 00180	SAMPLE VALUE	******	******	****	******	100.6	******	%	Cont	MEAS
	PERMIT REQ	******	******		******	REPORT CalMoAvg	******		1 x Day	Measur

* Phosphate descaler injection discontinued

Send original with supplemental DMR (if applicable) by the 21st day of month following reporting period to: MINNESOTA POLLUTION CONTROL AGENCY 520 LAFAYETTE RD ST. PAUL, MN 55155-4194 ATTN: Discharge Monitoring Report	*I certify that I am familiar with the information contained in this report and that to the best of my knowledge and belief the information is true, complete, and accurate.*	SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT: [signature] DATE: 9-15-00 — SIGNATURE OF CHIEF OPERATOR / PHONE / DATE / CERTIFICATION#

COMMENTS:

FACILITY NAME/ADDRESS:
NSP - Prairie Island Nuclear Power Plant
1717 Wakonade Dr E
Welch, MN 55089

WASTEWATER TREATMENT
DISCHARGE MONITORING REPORT

PERMITTEE NAME/ADDRESS:
Northern States Power Co
414 Nicollet Mall
Minneapolis, MN 554011993

PERMIT #	LIMIT STATUS	FORMER #
MN0004006	FINAL	011M 1

STATION INFORMATION:
SD-002 (Steam Generator Blowdown Discharge)
Surface Discharge, Effluent To Surface Water

MONITORING PERIOD

	YEAR/MO./DAY		YEAR/MO./DAY
FROM	2000/08/01	TO	2000/08/31

☐ No Discharge

PARAMETER		QUANTITY			UNITS	CONCENTRATION			UNITS	FREQUENCY OF ANALYSIS	SAMPLE TYPE
Flow	SAMPLE VALUE	******	0.044		MG	******	0.001	******	mgd	1/31	EST
50050	PERMIT	******	REPORT CalMoTot			------	REPORT CalMoAvg	------		1 x Month	Estima
TSS	SAMPLE VALUE	<0.001	<0.001		kg/day	******	<0.1		mg/L	1/31	GRAB
00530	PERMIT	65.3 CalMoAvg	217.0 DailyMax			------	30 CalMoAvg	100 DailyMax		1 x Month	Grab

Send original with supplemental DMR (if applicable) by the 21st day of month following reporting period to:
MINNESOTA POLLUTION CONTROL AGENCY
520 LAFAYETTE RD
ST. PAUL, MN 5 -4194
ATTN: Discharge onitoring Report

COMMENTS:

I certify that I am familiar with the information contained in this report and that to the best of my knowledge and belief the information is true, complete, and accurate.

[signature] 9-15-00
SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT | DATE

SIGNATU OF CHIEF OPERATOR | PHONE | DATE | C IFICATION#

FACILITY NAME/ADDRESS:
NSP - Prairie Island Nuclear Power Plant
1717 Wakonade Dr E
Welch, MN 55089

WASTEWATER TREATMENT DISCHARGE MONITORING REPORT

PERMITTEE NAME/ADDRESS:
Northern States Power Co
414 Nicollet Mall
Minneapolis, MN 554011993

PERMIT #	LIMIT STATUS	FORMER #
MN0004006	FINAL	012M 1

STATION INFORMATION:
SD-003 (Radwaste Treatment Effluent)
Surface Discharge, Effluent To Surface Water

	MONITORING PERIOD (YEAR MO. DAY)
FROM	2000/08/01
TO	2000/08/31

☐ No Discharge

PARAMETER		QUANTITY		UNITS	CONCENTRATION			UNITS	FREQUENCY OF ANALYSIS	SAMPLE TYPE
Flow	SAMPLE VALUE	******	0.030	MG	******	0.001	******	mgd	1/31	EST
50050	PERMIT	-------	REPORT CalMoTot		-------	REPORT CalMoAvg	-------		1 x Month	Estima
TSS	SAMPLE VALUE	<0.001	<0.001	kg/day	******	<0.1		mg/L	1/31	GRAB
00530	PERMIT	26.0 CalMoAvg	86.9 DailyMax		-------	30 CalMoAvg	100 DailyMax		1 x Month	Grab

Send original with supplemental DMR (if applicable) by the 21st day of month following reporting period to:
MINNESOTA POLLUTION CONTROL AGENCY
520 LAFAYETTE RD
ST. PAUL, MN 55155-4194
ATTN: Discharge Monitoring Report

I certify that I am familiar with the information contained in this report and that to the best of my knowledge and belief the information is true, complete, and accurate.

[signature] 9-15-00
SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT — DATE

SIGNATURE OF CHIEF OPERATOR — PHONE — DATE — CERTIFICATION#

COMMENTS:

FACILITY NAME/ADDRESS:
NSP - Prairie Island Nuclear Power Plant
1717 Wakonade Dr E
Welch, MN 55089

WASTEWATER TREATMENT DISCHARGE MONITORING REPORT

PERMITTEE NAME/ADDRESS:
Northern States Power Co
414 Nicollet Mall
Minneapolis, MN 554011993

PERMIT #	LIMIT STATUS	FORMER #
MN0004006	FINAL	013M 1

STATION INFORMATION:
SD-004 (Neutralizer + Resin Rinse Discharge)
Surface Discharge, Effluent To Surface Water

MONITORING PERIOD

	YEAR/MO./DAY		YEAR/MO./DAY
FROM	2000/08/01	TO	2000/08/31

☐ No Discharge

PARAMETER		QUANTITY		UNITS	CONCENTRATION			UNITS	FREQUENCY OF ANALYSIS	SAMPLE TYPE
Flow	SAMPLE VALUE	******	0.312	MG	******	0.010	******	mgd	10/31	EST
50050	PERMIT	------	REPORT CalMoTot		------	REPORT CalMoAvg	------		1 x Month	Estima
TSS	SAMPLE VALUE	0.2	3.6	kg/day	******	5.3	21.0	mg/L	10/31	GRAB
00530	PERMIT	97.9 CalMoAvg	326.0 DailyMax		------	30 CalMoAvg	100 DailyMax		1 x Month	Grab

Send original with supplemental DMR (if applicable) by the 21st day of month following reporting period to:
MINNESOTA POLLUTION CONTROL AGENCY
520 LAFAYETTE RD
ST. PAUL, MN 55155-4194
ATTN: Discharge Monitoring Report

COMMENTS:

I certify that I am familiar with the information contained in this report and that to the best of my knowledge and belief the information is true, complete, and accurate.

[signature] 9-15-00

SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT | DATE

SIGNATURE OF CHIEF OPERATOR | PHONE | DATE | CERTIFICATION#

FACILITY NAME/ADDRESS:
NSP - Prairie Island Nuclear Power Plant
1717 Wakonade Dr E
Welch, MN 55089

WASTEWATER TREATMENT DISCHARGE MONITORING REPORT

PERMIT #	LIMIT STATUS	FORMER #
MN0004006	FINAL	014M 1

PERMITTEE NAME/ADDRESS:
Northern States Power Co
414 Nicollet Mall
Minneapolis, MN 554011993

STATION INFORMATION:
SD-005 (Unit 1 Turbine Bldg Sump Dschg)
Surface Discharge, Effluent To Surface Water

	MONITORING PERIOD YEAR/MO./DAY
FROM	2000/08/01
TO	2000/08/31

☐ No Discharge

PARAMETER		QUANTITY		UNITS	CONCENTRATION			UNITS	FREQUENCY OF ANALYSIS	SAMPLE TYPE
Flow	SAMPLE VALUE	******	1,611	MG	******	0.052	******	mgd	1/31	EST
50050	PERMIT	******	REPORT CalMoTot		------	REPORT CalMoAvg	------		1 x Month	Estima
TSS	SAMPLE VALUE	******	******	****	******	12.6	12.6	mg/L	1/31	GRAB
00530	PERMIT	******	------		------	30 CalMoAvg	100 DailyMax		1 x Month	Grab
Oil Total Recoverable	SAMPLE VALUE	******	******	****	******	1.0	1.0	mg/L	1/31	GRAB
00552	PERMIT	******	------		------	10 CalMoAvg	15 DailyMax		1 x Month	Grab

Send original with supplemental DMR (if applicable) by the 21st day of month following reporting period to: MINNESOTA POLLUTION CONTROL AGENCY 520 LAFAYETTE RD ST. PAUL, MN 55155-4194 ATTN: Discharge Monitoring Report	*I certify that I am familiar with the information contained in this report and that to the best of my knowledge and belief the information is true, complete, and accurate.*	SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT	DATE 9-15-00
		SIGNATURE OF CHIEF OPERATOR / PHONE / DATE	CERTIFICATION#

COMMENTS:

FACILITY NAME/ADDRESS:
NSP - Prairie Island Nuclear Power Plant
1717 Wakonade Dr E
Welch, MN 55089

WASTEWATER TREATMENT
DISCHARGE MONITORING REPORT

PERMITTEE NAME/ADDRESS:
Northern States Power Co
414 Nicollet Mall
Minneapolis, MN 554011993

PERMIT #	LIMIT STATUS	FORMER #
MN0004006	FINAL	015M 1

STATION INFORMATION:
SD-006 (Unit 2 Turbine Bldg Sump Dschg)
Surface Discharge, Effluent To Surface Water

MONITORING PERIOD

	YEAR MO. DAY		YEAR MO. DAY
FROM	2000/08/01	TO	2000/08/31

☐ No Discharge

PARAMETER		QUANTITY			UNITS	CONCENTRATION			UNITS	FREQUENCY OF ANALYSIS	SAMPLE TYPE
Flow	SAMPLE VALUE	******	1.436		MG	******	0.046	******	mgd	1/31	EST
50050	PERMIT	******	REPORT CalMoTot			------	REPORT CalMoAvg	------		1 x Month	Estima
TSS	SAMPLE VALUE	******	******		****	******	18.2	18.2	mg/L	1/31	GRAB
00530	PERMIT	******	------			------	30 CalMoAvg	100 DailyMax		1 x Month	Grab
Oil Total Recoverable	SAMPLE VALUE	******	******		****	******	1.0	1.0	mg/L	1/31	GRAB
00552	PERMIT	******	------			------	10 CalMoAvg	15 DailyMax		1 x Month	Grab

Send original with supplemental DMR (if applicable) by the 21st day of month following reporting period to:
MINNESOTA POLLUTION CONTROL AGENCY
520 LAFAYETTE RD
ST. PAUL, MN 55 4194
ATTN: Discharge itoring Report

I certify that I am familiar with the information contained in this report and that to the best of my knowledge and belief the information is true, complete, and accurate.

[signature] 9-15-00
SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT — DATE

SIGNATU F CHIEF OPERATOR — PHONE — DATE — C ICATION#

COMMENTS:

FACILITY NAME/ADDRESS:
NSP - Prairie Island Nuclear Power Plant
1717 Wakonade Dr E
Welch, MN 55089

WASTEWATER TREATMENT DISCHARGE MONITORING REPORT

PERMITTEE NAME/ADDRESS:
Northern States Power Co
414 Nicollet Mall
Minneapolis, MN 554011993

PERMIT #	LIMIT STATUS	FORMER #
MN0004006	FINAL	016M 1

STATION INFORMATION:
SD-007 (Metal Cleaning Effluent Discharge)
Surface Discharge, Effluent To Surface Water

	MONITORING PERIOD (YEAR/MO./DAY)
FROM	2000/08/01
TO	2000/08/31

[X] No Discharge

PARAMETER		QUANTITY		UNITS	CONCENTRATION			UNITS	FREQUENCY OF ANALYSIS	SAMPLE TYPE
Flow	SAMPLE VALUE	******		MG	******		******	mgd		
50050	PERMIT	******	REPORT CalMoTot		------	REPORT CalMoAvg	------		1 x Day	Estima
TSS	SAMPLE VALUE			kg/day	******			mg/L		
00530	PERMIT	.6 CalMoAvg	1.9 DailyMax		------	30 CalMoAvg	100 DailyMax		1 x Day	Grab
pH	SAMPLE VALUE	******	******	****		******		SU		
00400	PERMIT	******	------		6.0 CalMoMin	------	9.0 CalMoMax		1 x Week	Grab
Copper Total (as Cu)	SAMPLE VALUE			kg/day	******			mg/L		
01042	PERMIT	.02 CalMoAvg	.02 DailyMax		------	1.0 CalMoAvg	1.0 DailyMax		1 x Day	Grab
Iron Total (as Fe)	SAMPLE VALUE			kg/day	******			mg/L		
01045	PERMIT	.02 CalMoAvg	.02 DailyMax		------	1.0 CalMoAvg	1.0 DailyMax		1 x Day	Grab
Oil Total Recoverable	SAMPLE VALUE			kg/day	******			mg/L		
00552	PERMIT	.2 CalMoAvg	.3 DailyMax		------	10 CalMoAvg	15 DailyMax		1 x Day	Grab

Send original with supplemental DMR (if applicable) by the 21st day of month following reporting period to:
MINNESOTA POLLUTION CONTROL AGENCY
520 LAFAYETTE RD
ST. PAUL, MN 55155-4194
ATTN: Discharge Monitoring Report

I certify that I am familiar with the information contained in this report and that to the best of my knowledge and belief the information is true, complete, and accurate.

[signature] 9-15-00

SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT — DATE

SIGNATURE OF CHIEF OPERATOR — PHONE — DATE — CERTIFICATION#

COMMENTS:

FACILITY NAME/ADDRESS:
NSP - Prairie Island Nuclear Power Plant
1717 Wakonade Dr E
Welch, MN 55089

WASTEWATER TREATMENT DISCHARGE MONITORING REPORT

PERMITTEE NAME/ADDRESS:
Northern States Power Co
414 Nicollet Mall
Minneapolis, MN 554011993

PERMIT #	LIMIT STATUS	FORMER #
MN0004006	FINAL	030M 1

STATION INFORMATION:
SD-012 (Intake Screen Backwash + Fish Retn)
Surface Discharge, Effluent To Surface Water

MONITORING PERIOD

	YEAR/MO./DAY
FROM	2000/08/01
TO	2000/08/31

☐ No Discharge

PARAMETER		QUANTITY		UNITS	CONCENTRATION			UNITS	FREQUENCY OF ANALYSIS	SAMPLE TYPE
Flow	SAMPLE VALUE	******	62	MG	******	2	******	mgd	1/31	EST
50050	PERMIT	******	REPORT CalMoTot		------	REPORT CalMoAvg	------		1 x Month	Estima

Send original with supplemental DMR (if applicable) by the 21st day of month following reporting period to:
MINNESOTA POLLUTION CONTROL AGENCY
520 LAFAYETTE RD
ST. PAUL, MN 5-4194
ATTN: Discharg onitoring Report

I certify that I am familiar with the information contained in this report and that to the best of my knowledge and belief the information is true, complete, and accurate.

SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT	DATE
[signature]	9-15-00

SIGNAT OF CHIEF OPERATOR | PHONE | DATE | TIFICATION#

COMMENTS:

FACILITY NAME/ADDRESS:
NSP - Prairie Island Nuclear Power Plant
1717 Wakonade Dr E
Welch, MN 55089

WASTEWATER TREATMENT DISCHARGE MONITORING REPORT

PERMIT #	LIMIT STATUS	FORMER #
MN0004006	FINAL	

PERMITTEE NAME/ADDRESS:
Northern States Power Co
414 Nicollet Mall
Minneapolis, MN 554011993

STATION INFORMATION:
WS-001 (Unit 1 Plant Cooling Water Dschg)
Waste Stream, Internal Waste Stream

MONITORING PERIOD

	YEAR/MO./DAY
FROM	2000/08/01
TO	2000/08/31

☐ No Flow

PARAMETER		QUANTITY		UNITS	CONCENTRATION			UNITS	FREQUENCY OF ANALYSIS	SAMPLE TYPE
Flow	SAMPLE VALUE	******	963.2	MG	******	31.1	******	mgd	30/31	EST
50050	PERMIT	******	REPORT CalMoTot		------	REPORT CalMoAvg	------		1 x Day	MeaCon
Oxidants Total Residual	SAMPLE VALUE	******	******	****	******	******	0.19	mg/L	30/31	6024B
34044	PERMIT	******	------		------	------	2.0 DailyMax		1 x Day	Grab

NOTE: FLOW IS A TOTAL OF WS001 & WS002

Send original with supplemental DMR (if applicable) by the 21st day of month following reporting period to:
MINNESOTA POLLUTION CONTROL AGENCY
520 LAFAYETTE RD
ST. PAUL, MN 55155-4194
ATTN: Discharge Monitoring Report

I certify that I am familiar with the information contained in this report and that to the best of my knowledge and belief the information is true, complete, and accurate.

SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT — DATE 9-15-00

SIGNATURE OF CHIEF OPERATOR — PHONE — DATE — CERTIFICATION#

COMMENTS:

FACILITY NAME/ADDRESS:
NSP - Prairie Island Nuclear Power Plant
1717 Wakonade Dr E
Welch, MN 55089

WASTEWATER TREATMENT DISCHARGE MONITORING REPORT

PERMITTEE NAME/ADDRESS:
Northern States Power Co
414 Nicollet Mall
Minneapolis, MN 554011993

PERMIT #	LIMIT STATUS	FORMER #
MN0004006	FINAL	022M 8

STATION INFORMATION:
WS-002 (Unit 2 Plant Cooling Water Dschg)
Waste Stream, Internal Waste Stream

MONITORING PERIOD

	YEAR MO. DAY		YEAR MO. DAY
FROM	2000/08/01	TO	2000/08/31

☐ No Flow

PARAMETER		QUANTITY		UNITS	CONCENTRATION			UNITS	FREQUENCY OF ANALYSIS	SAMPLE TYPE
Flow	SAMPLE VALUE	******	963.2	MG	******	31.1	******	mgd	30/31	EST
50050	PERMIT	------	REPORT CalMoTot		------	REPORT CalMoAvg	------		1 x Day	MeaCon
Oxidants Total Residual	SAMPLE VALUE	******	******	****	******	******	0.26	mg/L	30/31	GRAB
34044	PERMIT	------	------		------	------	2.0 DailyMax		1 x Day	Grab

NOTE: FLOW IS A TOTAL OF WS001 & WS002

Send original with supplemental DMR (if applicable) by the 21st day of month following reporting period to: **MINNESOTA POLLUTION CONTROL AGENCY** **520 LAFAYETTE RD** **ST. PAUL, MN 55[illegible]4194** **ATTN: Discharg[illegible]nitoring Report**	*I certify that I am familiar with the information contained in this report and that to the best of my knowledge and belief the information is true, complete, and accurate.*	[signature] 9-15-00 SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT — DATE SIGNATU[illegible] OF CHIEF OPERATOR — PHONE — DATE — C[illegible]FICATION#

COMMENTS:

Chapter 4

NSP-1983

PRAIRIE ISLAND
MN PCA
NPDES - GEN.
03500

NSP

Northern States Power Company

414 Nicollet Mall
Minneapolis, Minnesota 55401
Telephone (612) 330-5500

October 14, 1983

16

Howard Krosch
Division of Fish & Wildlife
MN Dept of Natural Resources
Centennial Office Building
St Paul, Minnesota 55155

Don L Kriens
Division of Waste Quality
MN Pollution Control Agency
1935 West County Road B2
Roseville, Minnesota 55113

File: PI NPDES
MN0004006

PRAIRIE ISLAND NUCLEAR GENERATING PLANT
Chlorination of Circulating Water System
Fish Loss Report

Enclosed, for your information, is a report on the fish loss due to chlorination of the circulating water system at the Prairie Island Nuclear Generating Plant in August, 1983.

Feel free to contact Glen Kuhl at the Prairie Island Environmental Lab at (612) 388-1121, extension 349, if you have any questions concerning this report.

W E Jensen
Senior Consultant
Regulatory Services

ah

enclosure

cc: G M Kuhl

11 NOV 5 1983

Internal Correspondence NSP

		Date	August 30, 1983
From	G. M. Kuhl Phycologist	Location	Prairie Island
To	S. F. Schmidt Admin Reg Compliance	Location	GO (2)

Subject FISH LOSS DUE TO CHLORINATION OF THE PINGP CIRCULATING WATER SYSTEM

An estimated total of 37,124 fish were killed during the chlorination of the circulating water system at PINGP on August 20, 1983. Tables 1 and 2 list representative length frequencies and totals for all species lost. When possible, unmeasured fish were designated as young-of-the-year (yy), juvenile, and adult. During instances where this was not possible fish not measured were recorded as "unmeasured".

Gizzard shad comprised 61.7% of the total loss with channel catfish representing 26.5% of the total. Other game fish in decreasing order of abundance, included white bass, crappie spp., bluegill, sauger and walleye. These species comprised 3.9% of the total fish loss.

Adult fish were separated from yy and juvenile fish, enumerated and measured individually (Table 1). Estimated numbers of yy and juvenile fish were based on the number of fish counted per bucket with this number extrapolated over all buckets (Table 2).

As in the 1981 chlorination, copper sulfate was used in an attempt to drive fish from the circulating water system prior to chlorination. In cooperation with a Minnesota Department of Natural Resources licensed applicator, copper sulfate was added on two occasions. On Friday, August 19, copper sulfate was added at a rate of two pounds per minute for 15 minutes to the new discharge canal while the plant was operating in open helper cycle. This provided adequate mixing and flow to hopefully drive fish from the canal. On Saturday, August 20, copper sulfate was added at a rate of three pounds per minute for 60 minutes to the remainder of the circulating water system. Based on calculations of the quantity of water in the system the application rates were expected to allow copper sulfate concentrations to reach 0.5 ppm, which should repel fish.

FORM 17-3467

Fish loss during the 1983 chlorination was slightly greater than the 28,095 lost during 1981 but considerably less than the 162,448 lost during the 1980 chlorination. Species composition was similar to previous years with gizzard shad and channel catfish being major contributors of fish loss.

G M Kuhl

G. M. Kuhl

sw

Section 316 (b) Demonstration for the Prairie Island Generating Plant on the Mississippi River near Red Wing, Minnesota

December, 1976

Nus Corporation

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

LIST OF FIGURES (CONTINUED)

LIST OF TABLES

LIST OF TABLES (CONTINUED)

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LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

1. STATEMENT OF THE PROBLEM

The Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500), Section 316(b), require that cooling water intake structures reflect the best technology available for minimizing adverse environmental impact. Adverse impact can result from entrainment and impingement of aquatic organisms. Entrainment is the withdrawal of organisms into the cooling water system. It involves organisms which are small enough to pass through the intake screen mesh, including primarily planktonic forms such as phytoplankton, zooplankton, ichthyoplankton, and benthic drift organisms. Mortality can vary, depending on the system and the trophic level involved, and is usually less than 100 percent in open systems but may approach 100 percent in closed systems.

Larger organisms can become entrapped or impinged against screening equipment. These larger organisms are predominantly fish which may tire or become injured and are unable to escape. High impingement mortality often results from natural die-offs or weakening of fish prior to impingement (Edsall and Yocum 1972, Quirk, Lawler and Matusky 1974) or cold-induced lethargy (EPA 1976a, USAEC 1972). The use of traveling screens may reduce mortality but frequently induces additional injury.

According to the current EPA draft guidance manual (1976a) for Section 316(b), "Regulatory agencies should clearly recognize that some level of intake damage can be acceptable and thus represents a minimization of environmental impact." This demonstration provides "best possible estimate of what damage is or may be occurring" and relates this to population levels and natural variability of the indigenous Mississippi River populations near the Prairie Island Nuclear Generating Plant (PINGP).

2. SUMMARY

Section 316(b) of the Federal Water Pollution Control Act Amendments of 1972 requires cooling water users to determine biological effects of their intake systems and to demonstrate that the design, construction, location and operation reflect the best technology available for minimizing impact. Under the National Pollutant Discharge Elimination System (NPDES) Section 402 of P.L. 92-500, Minnesota has been given the authority to administer the law using the Section 316(b) amendments and Minnesota Regulation WPC(u)(3).

The Minnesota guide for the administration of Section 316(b) requires the demonstrator to show the environmental effects of cooling water intakes through documentation of the magnitude of impingement and entrainment impacts (MPCA 1975). Supplemental information on the aquatic ecosystem in the intake region is also requested. Federal and state requirements have been addressed in this demonstration by providing extensive baseline data and a detailed presentation and analysis of entrainment and impingement data at the Prairie Island Nuclear Generating Plant (PINGP).

Northern States Power Company (NSP) has conducted six years of studies of the Mississippi River ecosystem near PINGP and, since plant operation began in 1974, NSP has conducted extensive intake studies. The river at PINGP can be classified as somewhat eutrophic and supporting a healthy and very diverse flora and fauna. The main channel and the associated side channels of slack water provide a mixture of lentic and lotic habitats.

The entrainment of primary producers (phytoplankton) reduced standing crops of chlorophyll a but did not produce detectable effects on total numbers of algae. Chlorophyll a reduction usually amounted to 50 percent or less. Primary productivity of entrained algae was depressed up to 90 percent from passage through PINGP. Respiration was similarly depressed on most collection dates. In summary, while the numbers of intact algae are not greatly affected by plant passage, the biological activity of the algal community is frequently reduced by 50 percent or more.

Studies of the effects of plant passage on phytoplankton failed to produce any detectable differences in the community of the main channel of the Mississippi River, either in species composition or primary productivity, corroborating the conclusion of EPA (1976b) that entrainment effects on phytoplankton are usually of short duration and confined to a relatively small portion of the water body.

Zooplankton entrained by PINGP was noticeably affected on two-thirds of the dates sampled. Usually only one or two groups exhibited detectable mortality after plant passage. Excepting cladocerans, some mortality was observed for all groups on some collection dates.

Zooplankton collected at the intake and discharge was also compared to zooplankton collected in the water body near the plant. No significant differences in total zooplankton densities could be detected, even within the recirculation canal. Some preliminary data indicated reduction of copepods in areas directly within the discharge. The low degree of entrainment impact at PINGP is further supported by EPA's (1976b) comment that in most cases the effects of zooplankton entrainment are of relatively short duration and confined to a relatively small area of the water body.

The entrainment of benthos was not studied; however, the extensive program of artificial substrate studies permitted a prediction of taxa most likely to be entrained. Benthic entrainment is not predicted to seriously affect aquatic communities near PINGP.

There are two potential sources of impact to the fish communities near PINGP: entrainment of eggs and young and impingement of larger fish. A total of 8,371,000 eggs and 61,645,000 larvae and juvenile fish were estimated to have been entrained between May 12 and September 10, 1975. However, larval and juvenile entrainment represented only an estimated 6 percent of the 1,038,000,000 young fish estimated to have passed through the outlet of Sturgeon Lake during the same period. This represents a conservative estimate of loss to the total system because fish eggs and larvae are also present in the main channel.

Entrainment losses of eggs and young fish were estimated to represent 2,830,000 potential adult fish, 99 percent of which were forage species. This loss of forage fish could decrease predator production by an estimated 3,400 kg (7,500 lbs) or 5,900 fish. However, the larval and juvenile forage fish entrained represent only about 3 percent of the estimated number passing through the outlet of Sturgeon Lake.

Entrained sport and commercial species represented less than one percent of the total potential adult loss. Sauger had the greatest potential loss among the sport fish (5,600 fish). This potential loss is 0.9 to 2.4 percent of the estimated population for the Sturgeon Lake to Lake Pepin region. The impact of the potential adult loss will probably not be detectable due to the highly mobile nature of sauger in the PINGP area. Approximately 730 potential adult white bass are estimated to be lost due to entrainment. This represents 0.4 to 0.5 percent of the population estimated between Sturgeon Lake and Lake Pepin. Walleye, sunfish, crappies, northern pike and yellow perch were the other sport fish that were entrained. Estimated adult loss for these species represented less than 10 percent of their combined annual angler harvest, and probably a much smaller percentage of their actual populations in the PINGP area.

Commercially important fishes that were entrained included freshwater drum, carp, buffalo, catfish, sucker and carpsucker. The potential loss of carp and catfish appears insignificant compared to commercial catch data; the impact on the other taxa is unclear due to low commercial catches. However, a comparison of numbers entrained to estimated numbers of young passing through the mouth of Sturgeon Lake indicates low potential impact to resident populations.

Impingement analyses were conservative estimates based on the number of fish impinged per year in relation to the best population estimates that could be determined from available data.

Small fish, mostly 40-200 mm, accounted for most of the 146,063 fish impinged in 1974 and 93,466 fish impinged in 1975.

Although gizzard shad composed more than three-fourths of the fish impinged, losses represent only 1 to 2 percent of the estimated 1973 Sturgeon Lake population.

Potential impact on the channel catfish population was inconclusive due to apparently low population estimates based on trawl samples. However, the numbers of young impinged represent a small fraction of the number which could be produced in one year by the estimated adult population or number of catfish commercially harvested in one year.

The numbers of impinged freshwater drum represented 10 to 12 percent of the young estimated for the plant area or North Lake, based on trawl collections, and 5.2 percent of the commercial harvest of adults in 1974.

Annual impingement losses of young white bass, sauger and walleye were 0.1 to 1 percent of the estimated sport fish populations between Sturgeon Lake and Lake Pepin. Potential adult losses would be substantially less due to mortality between the young and sport harvest sizes.

The combined impact of the impingement and entrainment losses for fish, plankton and benthos is considered to represent an acceptable level of impact for a generating facility of the size of PINGP. Losses to lower trophic levels are, at most, barely detectable in the immediate plant vicinity. Fish entrainment losses represent such low percentages of ambient populations that no short or long term effects are expected to be detectable.

The numbers of young fish impinged per year appear to represent only a small percentage increase in the mortality resulting from natural causes and fishing. The numbers of young white bass, walleye and sauger impinged are approximately 0.2 percent of their adult populations in the region and represent an even smaller percentage loss of recruitment into the sport fishery. Due to the apparent excess of forage fish (most gizzard shad) and minimal cropping of sport fish, there is not expected to be a noticeable change in the dynamic predator/prey relationship or in recruitment into the harvested populations.

3 DESCRIPTION OF THE PLANT

The Prairie Island Nuclear Generating Plant (PINGP) is a two-unit plant utilizing pressurized water nuclear steam supply systems. Each unit produces a gross electrical output of 560 MWe for Northern States Power Company's network system. Unit 1 operation began in December 1973 and Unit 2, one year later.

3.1 LOCATION OF PLANT AND INTAKE

PINGP is located on the Minnesota shore of the Mississippi River 65 km (40 mi) southeast of Minneapolis and St. Paul, Minnesota and 10 km (6 mi) upstream of Red Wing, Minnesota (Figure 3.1-1). The plant is situated on Prairie Island, a low island terrace peninsula formed by the Mississippi River on the east and the Vermillion River on the west. Most of the land surrounding the plant is under cultivation. Relatively small areas of forest and swamp vegetation occur in some lowlands. The Mississippi River in the vicinity of PINGP is a complex system of river lakes, sloughs, channels and islands (Figure 3.1-2). Major features include North and Sturgeon lakes, just upstream of the plant, and the main river channel, which is closer to the Wisconsin shore. Lock and Dam No. 3, which controls the levels of the Mississippi River and Sturgeon Lake, is 2 km (1 mi) downstream of the

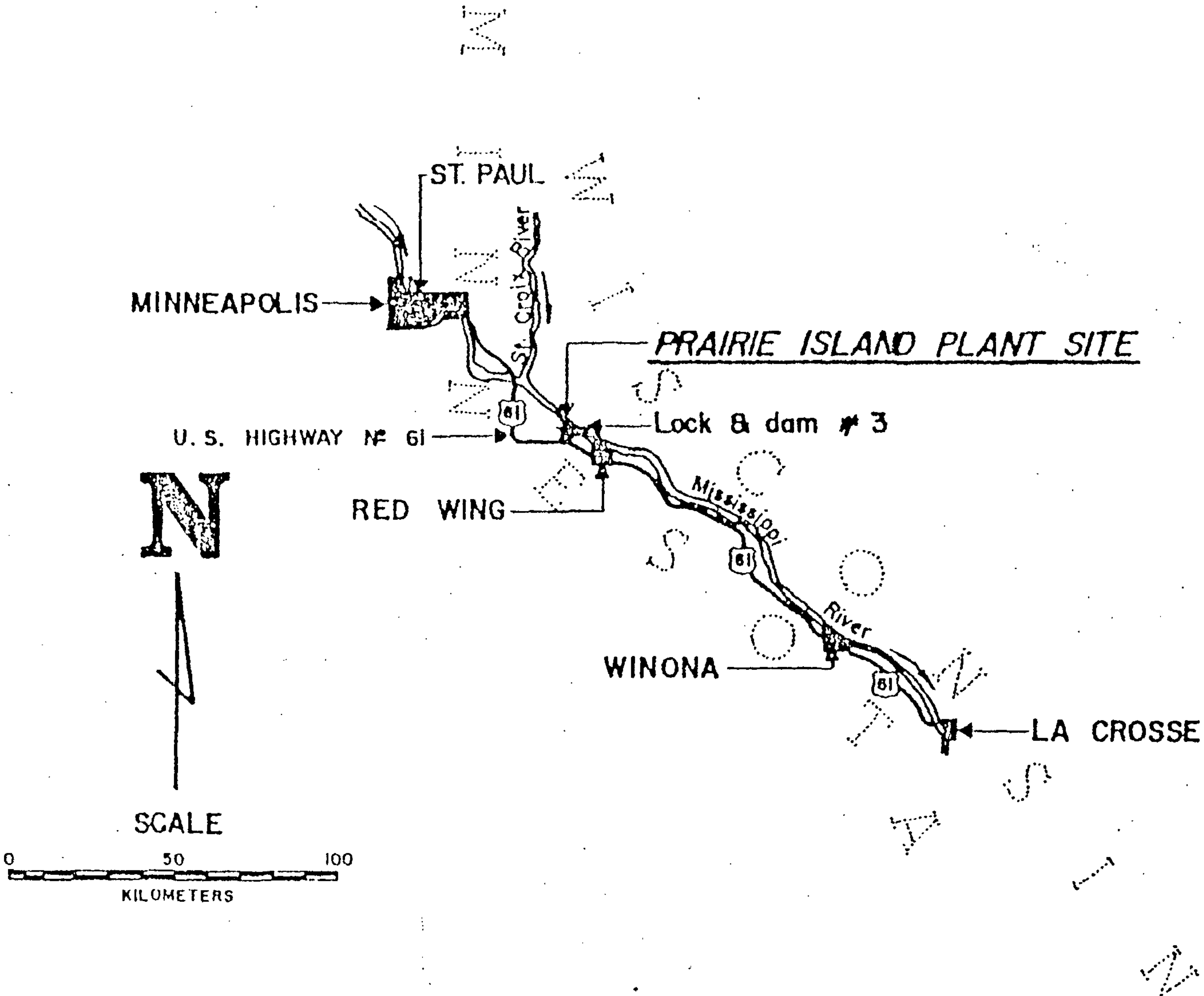


FIGURE 3.1-1

GENERAL LOCATION OF PINGP

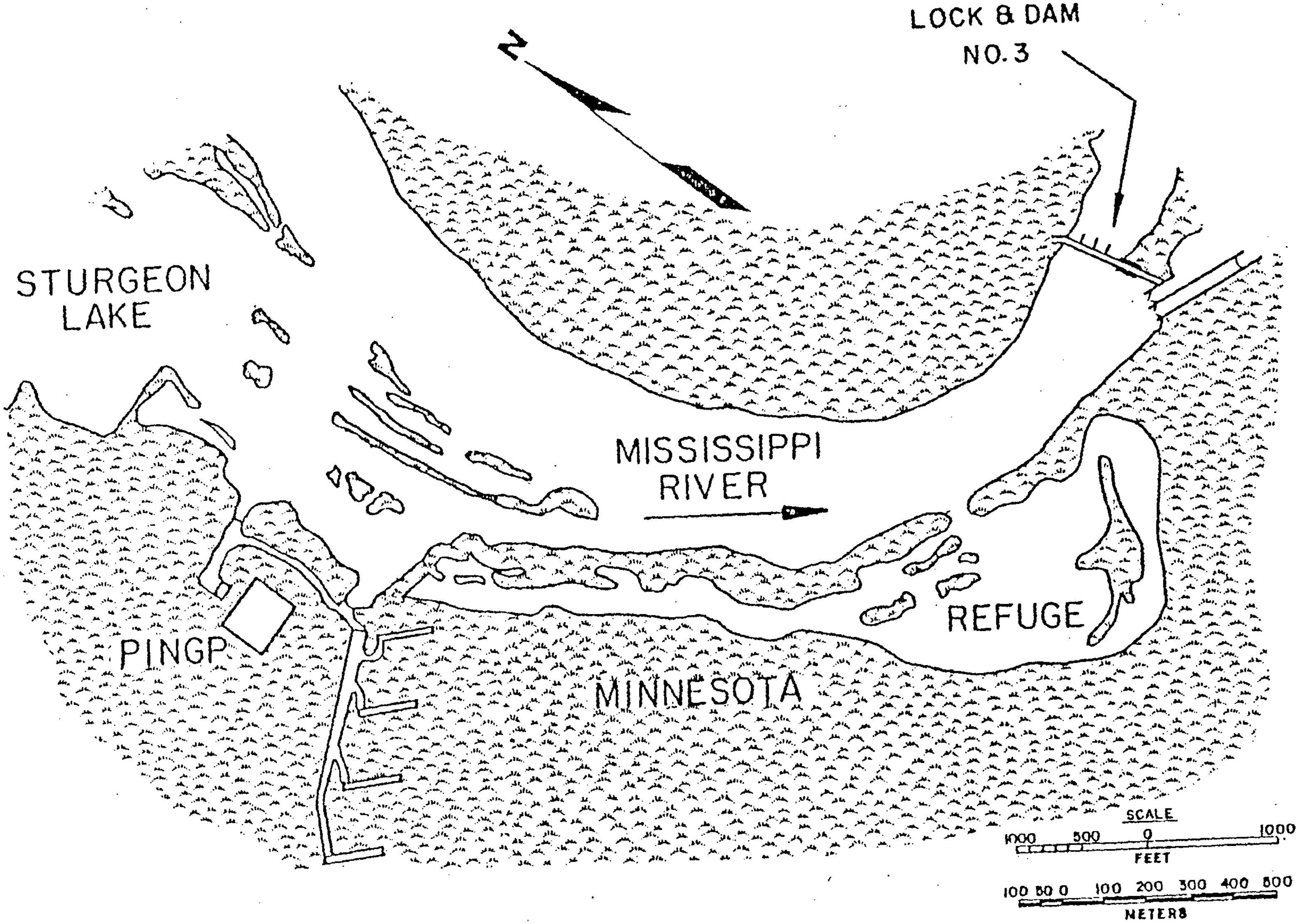


FIGURE 3.1-2

IMMEDIATE LOCATION OF PINGP

site. The average monthly river discharge at Prescott, Wisconsin, which is 24 km (15 mi) upstream from PINGP, is 457 m^3/sec (16,130 cfs) (USGS 1928-1975).

3.2 INTAKE DESIGN

Cooling water is drawn from the river into an intake canal, which is 34 m (112 ft) wide and 231 m (758 ft) long. A skimmer wall at the mouth of the intake canal excludes floating debris from the intake (Figure 3.2-1). At the screenhouse (Figure 3.2-2), the water passes through a bar rack, which consists of 1 cm wide vertical steel bars spaced 7.6 cm apart. The water then passes through eight vertical traveling screens. The screens are constructed of wire mesh with 1 cm square openings. After passing through the traveling screens, the water enters one of four circulating water pumps [capacity of one pump = 10.08 m^3/sec (356 cfs)] and is pumped through the condensers. Water velocities in the intake system vary from 2 to 6 cm/sec (0.1-0.2 fps) at the skimmer wall and from 6 to 30.5 cm/sec (0.2-2.5 fps) in front of the bar rack.

Any debris collecting on the traveling screens as the water passes through is washed from the rotating screens by high-pressure water jets. The debris is carried into a sluice canal and then to the trash baskets. These baskets are constructed of metal grating with 1.7 X 3.3 cm openings and are 1.5 X 1.5 X 1.5 m overall.

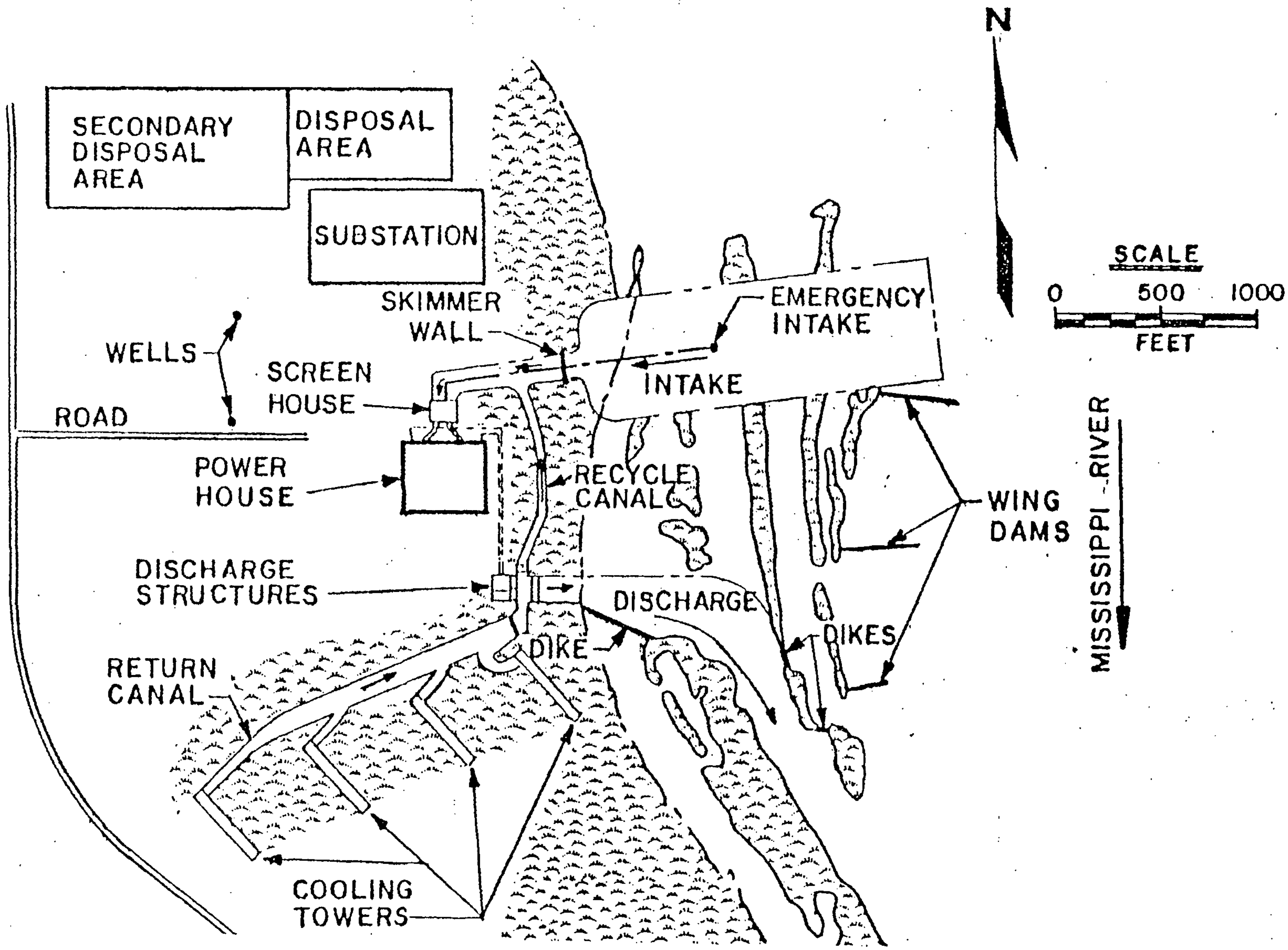


FIGURE 3.2-1

FLOW PATHS IN THE PINGP CONDENSER SYSTEM

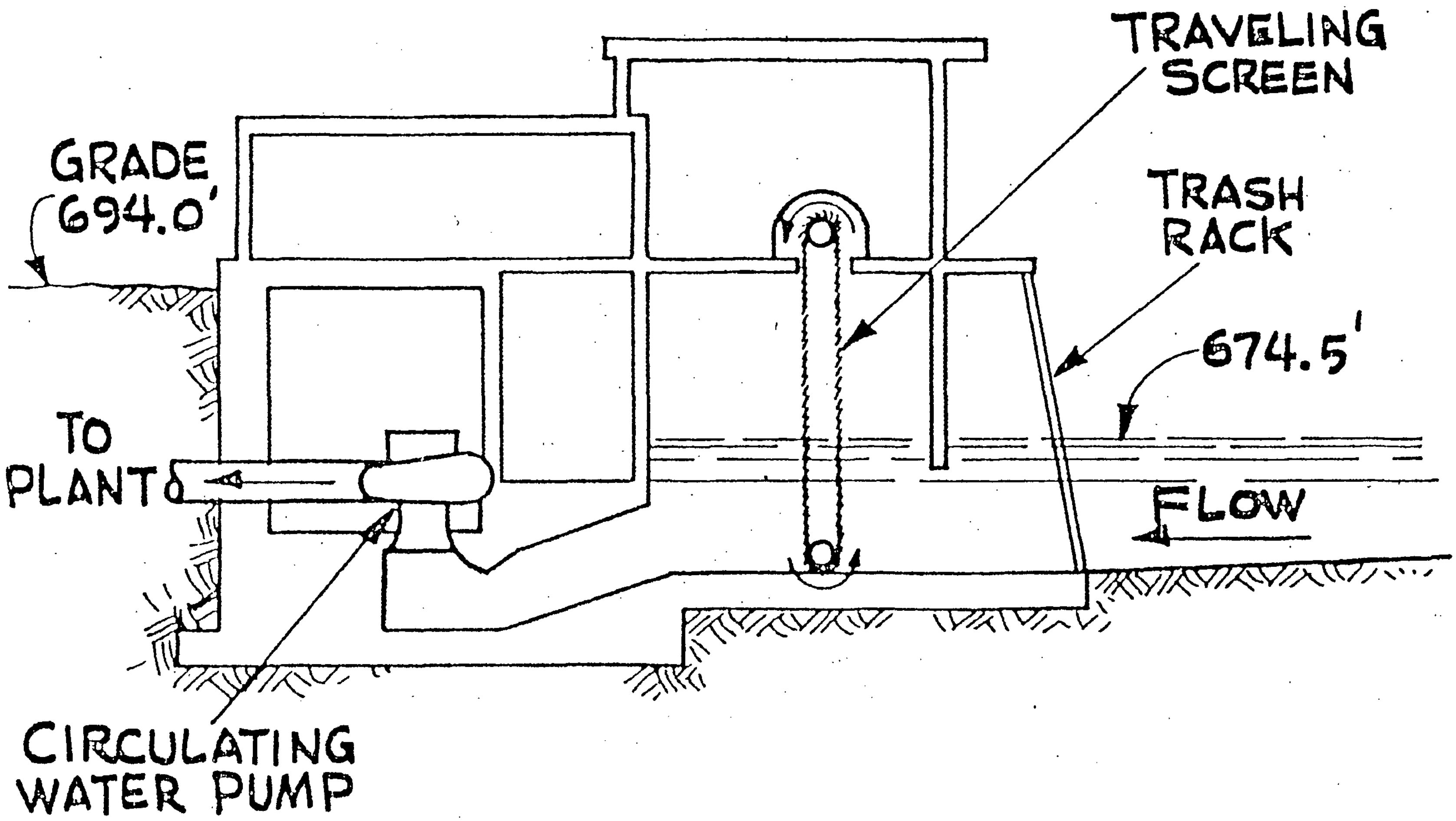


FIGURE 3.2-2

CROSS-SECTION OF PINGP SCREENHOUSE

3.3 OPERATING MODES

There are three possible modes of operation at PINGP because of the condenser cooling-water design. These are the open cycle mode, the helper cycle mode, and the closed cycle mode. Cooling towers do not operate in the open cycle mode and water taken through the condensers from the intake is discharged directly to the river. The helper cycle mode also signifies once-through flow but with the cooling towers in operation to decrease the temperature of the system water before it is discharged back to the river.

Under closed cycle operation (Figure 3.3-1), the normal operating mode of the plant, water is piped from the condensers to the cooling tower pump basin and then to the cooling towers. Water from the cooling towers drains into the discharge basin and is routed through the recycle canal and intake canal back to the screenhouse. Under these conditions, up to 90 percent of the intake water is recycled. Under normal closed-cycle operation with cooling towers in operation, the intake or makeup water appropriation is 5.2 m^3/sec (183 cfs) to make up for the loss of 1 m^3/sec (33 cfs) cooling tower evaporation and 4.2 m^3/sec (150 cfs) discharge.

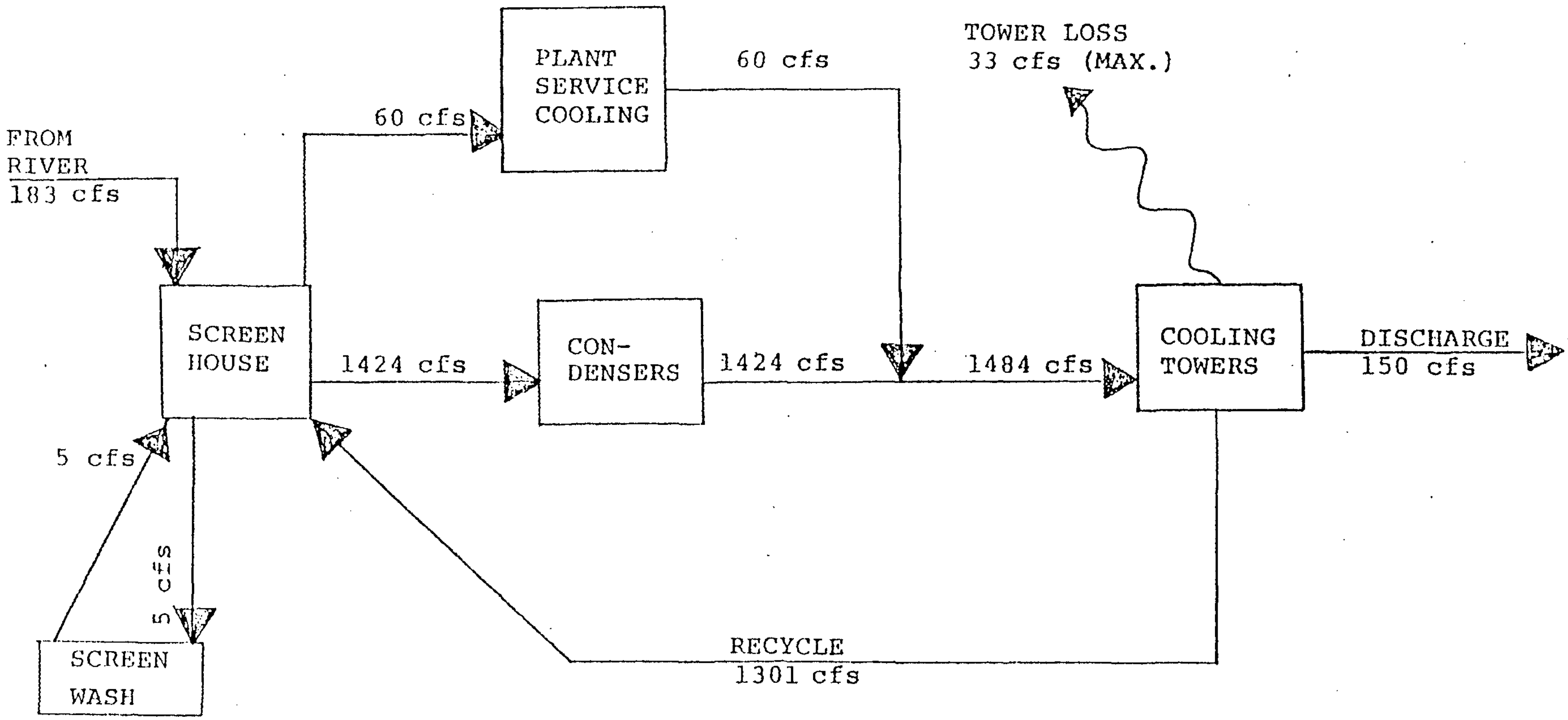


FIGURE 3.3-1

FLOW RATES IN THE CLOSED-CYCLE MODE FOR CONDENSER COOLING AND THE SERVICE WATER SYSTEM

3.4 INTAKE VELOCITIES

Intake velocities were measured on June 23 and June 28, 1976. Velocity profiles (Appendix 1) were taken in front of the bar rack and immediately in front of the skimmer wall.

During the June 23 survey, the blowdown rate was 7.8 m^3/sec (275 cfs). In front of the skimmer wall, velocities ranged from 0.0 to 0.2 m/sec (0.0-0.7 fps). Velocities in front of the bar rack were higher, with most readings varying between 0.2 and 0.4 m/sec (0.7-1.3 fps).

During the June 28 survey, velocities at the skimmer wall were measured at blowdown rates of 18.5 m^3/sec (655 cfs) and 36.8 m^3/sec (1300 cfs). At the lower blowdown rate, velocities at the skimmer wall were between 0.00 and 0.25 m/sec (0.00-0.82 fps). At the blowdown rate of 36.8 m^3/sec (1300 cfs), roughly equivalent to helper cycle operations, the velocities at the skimmer wall ranged from 0.05 to 0.30 m/sec (0.16-0.09 fps).

3.5 INTAKE FLOW VOLUMES

Recent studies indicated that intake flow volumes are an important factor in impingement and entrainment (EPA 1976a). Under closed cycle mode, the makeup water appropriation or intake volume at PINGP is approximately 5.2 m^3/sec (183 cfs). During 1975, the average makeup water appropriation was approximately 11.2 m^3/sec (400 cfs). A frequency analysis for appropriations based on 1975 plant records is:

Appropriation (m^3/sec)	Appropriation (cfs)	Percent of Year (1975)
<2.8	<100	<0.1
2.8-5.7	100-200	40.8
5.7-11.3	200-400	19.7
11.3-17.0	400-600	17.0
17.0-22.7	600-800	6.1
22.7-28.3	800-1000	8.6
>28.3	>1000	3.1
no data	no data	4.7

All appropriation flows greater than 17.0 m^3/sec occurred between May and September. Highest intake volumes were reported in July when appropriation was greater than 22.4 m^3/sec more than 70 percent of the time. Peak intake volumes corresponded with the peak flow periods for the Mississippi River near PINGP and the appropriation was less than 5 percent of the total Mississippi River flow measured at Prescott, Wisconsin (Table 3.5-1). The maximum percent withdrawal for 1975 was recorded on September 8, when approximately 14 percent of Mississippi River flow was used for the appropriation flow.

TABLE 3.5-1

PERCENTAGE OF MEAN MONTHLY MISSISSIPPI RIVER FLOW ENTERING PINGP INTAKE CANAL, JANUARY-SEPTEMBER 1975

Month	River Flow[a]	Average Intake Flow (cfs)	Percent of Mean Monthly River Flow Entering Intake Canal
January	7,995	188	2.4
February	8,691	299	3.4
March	9,944	341	3.4
April	45,860	454	0.1
May	65,220	791	1.2
June	36,200	304	0.8
July	38,010	782	2.1
August	11,790	576	4.9
September	10,950	415	3.8

[a]1975 USGS data (cfs) at Prescott, Wisconsin

3.6 COOLING WATER TEMPERATURES

When the generating station is operating in the closed cycle mode, an average of 36.9 m^3/sec (1301 cfs) of heated water is returned to the intake canal via the circulating water system.

A survey was conducted on February 12, 1974 to establish temperature and flow patterns within the intake canal. The ambient water temperature during the survey was 0°C (32°F), while that in the circulating water system was approximately 24°C (75°F). Considerable turbulence and upwelling occurred where the recycle flow entered the intake canal. The water stratified as it moved toward the screenhouse, with temperatures in the upper layer corresponding with the recycle water temperature of 22 to 24°C (72-75°F). Bottom water temperatures were more closely related to ambient water temperatures, ranging from 1.0 to 12°C (34-54°F). The ranges of intake canal temperatures at varying depths on February 12, 1974 were:

Depth	Temperature Range
Surface	22-24°C (72-75°F)
1 m	18-23.4°C (64-74°F)
2 m	3-23.4°C (37-74°F)
2.5 m	1-23 (35-73°F)

Water temperatures near the bottom increased as flow proceeded along the intake canal. Water temperatures near the screenhouse were nearly homogeneous from top to bottom (22.8-24°C) (73-75°F).

Temperatures in the intake, discharge and circulation canal are recorded automatically. Figure 3.6-1 shows the monthly minimum and maximum water temperatures in the intake canal for the first two years of full time operation (1974 and 1975).

3.7 BIOCIDES

Chlorine is used in many generating plant condensers and cooling towers to control biological growth, especially algae. PINGP employs a mechanical tube cleaning system; thus, no chemical additions are required for this aspect of plant operation. However, the inlet water for the service water system is chlorinated. Chlorine is injected for 20-minute periods three times a day. The injection rate is controlled so that total residual chlorine is less than 0.3 mg/l at the point where the service water system flow enters the circulating water system. The service water system flow at that point represents about 4 percent of the circulating water volume (see Figure 3.3-1); thus the maximum total

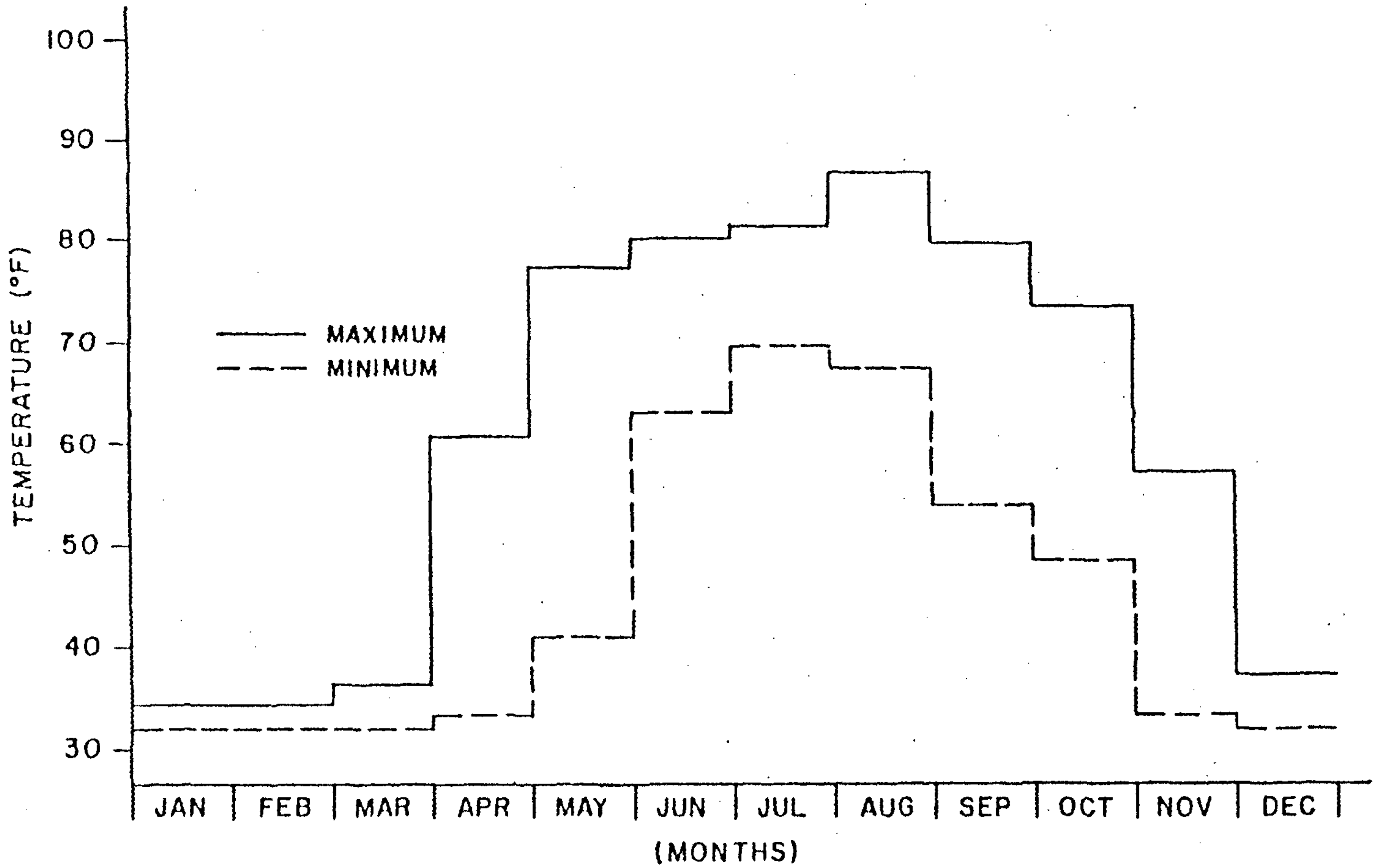


FIGURE 3.6-1

MINIMUM AND MAXIMUM WATER TEMPERATURES IN THE PINGP INTAKE CANAL, JANUARY 1, 1974 TO DECEMBER 31, 1975 (FROM NSP 1975 AND KING 1976) residual chlorine concentration which is present after mixing with the recirculation water is 0.02 mg/l.

The chlorine residual is further reduced by the chlorine-demand constituents of the recirculation water and by dilution which occurs when the recirculation water enters the intake canal. The permissible limit for total chlorine in the State of Minnesota for intermittent discharges is 0.2 mg/l, for periods not to exceed 2 hours (Olsen, personal communcation). Chlorine levels in the intake canal are, therefore, well below the permissible limits.

4. DESCRIPTION OF THE AQUATIC ENVIRONMENT NEAR PINGP

4.1 HYDROLOGY

The river basin above PINGP has a drainage area of approximately 72,500 km^2 (45,000 mi^2). The basin covers central and southern Minnesota, and includes portions of Wisconsin, South Dakota and Iowa.

The numerous lakes in the region are the result of Pleistocene glaciation. The flow characteristics of the Mississippi River and its tributaries are largely determined by the natural storage provided by these lakes and numerous swamps (USAEC 1973). The nearest permanent USGS hydrological gauging station is located at Prescott, Wisconsin, approximately 24 km (15 mi) upstream from PINGP. Flow records at Prescott are available from 1928 through 1975.

Records for the 48 years show an average monthly discharge of 457 m^3/sec (16,130 cfs). The annual mean flow duration curve for the Mississippi River at Prescott is shown in Figure 4.1-1. Maximum discharge for the period of record was 6,460 m^3/sec (228,000 cfs), reported on April 18, 1965; the minimum flow was 39.1 m^3/sec (1,380 cfs), registered on July 13, 1940. The minimum consecutive-day, low-flow rates from 1928 to 1975 show that the five lowest years of record all

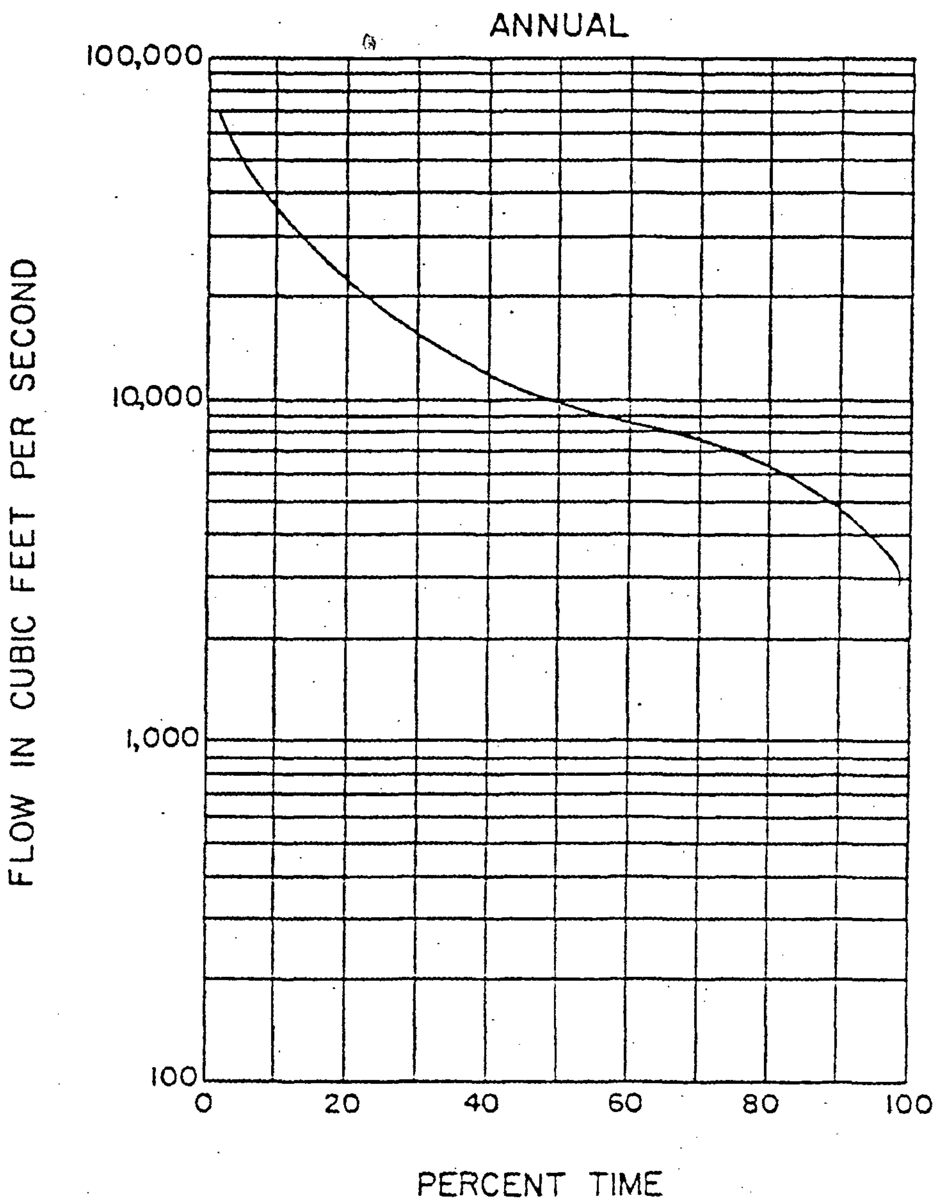


FIGURE 4.1-1

MEAN FLOW DURATION CURVE FOR MISSISSIPPI RIVER AT PRESCOTT, WISCONSIN, OCTOBER 1928-SEPTEMBER 1974 occurred before 1941; thus it appears that structures, such as Lock and Dam No. 3, on the river have served to augment low flow (USAEC 1973). Median monthly flows and projected 7-day, 10-year low flows are listed in Table 4.1-1. Consecutive day, average-low flow frequencies for the Mississippi River at Prescott are shown in Figure 4.1-2.

Flood flow conditions are most common during the spring and early summer months; highest frequencies occur in April. The most serious flooding is associated with heavy rainfall and melting of heavy snows. Major floods in the main streams occur on the average of 2-3 years out of 10 (USAEC 1973). The maximum flood of record for the upper Mississippi River occurred in April, 1965. The frequency probability of this flood was estimated as that occurring once in 150 years.

The numerous side channels of slack-water areas are of special importance to PINGP. The North Lake-Sturgeon Lake chain has several cross connections resulting in a diversion of part of the Mississippi River flow through the lakes. In analysis of the flow through the lake, it was estimated that between 19 and 32 percent of the total river flow at Lock and Dam No. 3 passed through the outlet of Sturgeon Lake at river flows between 226.4 and 1867.8 m^3/sec, respectively (Grotbeck personal communication). This was

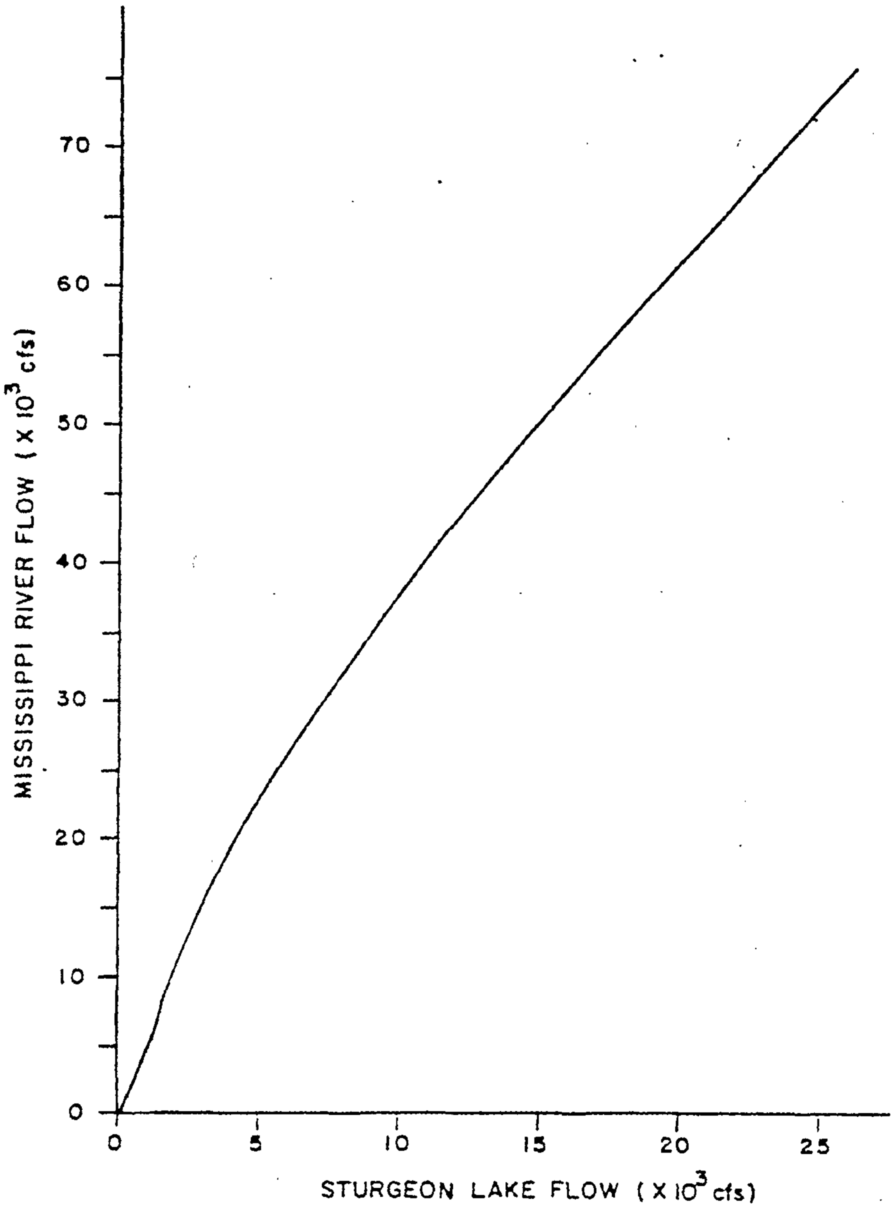


FIGURE 4.1-3

STURGEON LAKE FLOW VS. MISSISSIPPI RIVER FLOW, AS MEASURED AT LOCK AND DAM NO. 3

4.2 WATER QUALITY

4.2.1 General Characteristics

PINGP is located in a section of the Mississippi River that is affected by discharges from the Minneapolis-St. Paul metropolitan complex. Other environmental factors which influence water quality near the site include the 2.7 m (9 ft) minimum depth navigation channel, nutrient and sediment runoff from surrounding croplands and the lock and dam system.

Water quality at or near PINGP has been monitored from June 21, 1967 to the present. Table 4.2-1 lists the minimum, maximum and mean concentrations for the chemical parameters examined.

Waters near PINGP show relatively high nutrient levels, a characteristic of waters located downstream from municipal waste treatment facilities. As a result of these enriched conditions, somewhat eutrophic conditions prevail. Phosphorus and nitrogen levels are generally highest during the winter-spring transition period and decrease markedly during the summer. Largely because of assimilation of CO_2 by algae, there is also a trend toward higher pH as summer progresses.

TABLE 4.2-1 (Sheet 1 of 2)

MINIMUM, MAXIMUM AND MEAN CONCENTRATIONS OF WATER QUALITY PARAMETERS, SUBSURFACE SAMPLES UPSTREAM OF PINGP, JUNE 21, 1970 THROUGH DECEMBER 19, 1975[a]

Concentration (mg/1 unless otherwise noted)	Minimum	Maximum	Mean
Solids, Total	192	443	272
Solids, Dissolved	134	367	244
Solids, Suspended	1.4	85	29
Hardness, Total (as $CaCO_3$)	116	268	185
Hardness, Calcium (as $CaCO_3$)	76	180	120
Hardness, Magnesium (as $CaCO_3$)	40	100	66
Alkalinity, Total (as $CaCO_3$)	102	232	156
Alkalinity, Phenolphthalein (as $CaCO_3$)	0	24	2.9
Ammonia Nitrogen (N)	0	1.14	0.39
Carbonate[b] (CO_3)	0	27.6	2.2
Bicarbonate[b] (HCO_3)	103	235	178
Chloride (Cl)	2	32.9	12.8
Nitrate Nitrogen[c] (N)	0.03	4.2	1.03
Sulfate (SO_4)	10	110	39
Phosphorus[c], Soluble (P)	0.005	0.550	0.15
Silica (S_10_2)	0.4	16.2	8.6
Calcium[b] (Ca)	30.4	72	48
Magnesium[b] (Mg)	9.7	24	16
Sodium, (Na)	3.9	28.5	11.5
Iron, Total[c] (Fe)	0.04	2.36	0.68
Color[c] (APHA units)	20	100	53
Turbidity (JTU)	1	52	13
Ryznar Index (at 77°C)	5.9	8.5	7.2
Conductivity (μmhos/cm)	245	572	390
pH	7.4	9.2	8.0
BOD[b]	1.1	9.45	3.2

TABLE 4.2-1 (Sheet 2 of 2)

[a]Prior to plant operation (1970-1973) samples collected at site location
[b]Minimum, maximum and mean calculated for the period of June 1970 to December 1975.
[c]Minimum, maximum and mean calculated for the period of January 1970 to December 1975.

4.2.2 Water Temperature

Monthly minimum and maximum temperatures at Lock and Dam No. 3 from September 5, 1969 to November 30, 1973 (before plant operation) are listed in Table 4.2-2. The temperature patterns are typical of large temperate river systems. Water temperatures typically remain between 0.0 and 1.7°C (32-35°F) from late November through early March and rise rapidly during the spring. Maximum water temperatures were reported in July and August. The ambient temperature regimes in the area are not likely to produce any stress on the fauna that would contribute to entrainment or impingement susceptibility (USAEC 1973).

4.2.3 Dissolved Oxygen

Organisms undergoing stress as a result of reduced dissolved oxygen (DO) levels may be more susceptible to impingement and entrainment. Reduced DO levels have been shown to reduce maximum sustained swimming speed of fish (Davis et al. 1963), as well as to affect reproduction, vigor and development.

Dissolved oxygen levels have been monitored in the Mississippi River near the PINGP intake canal since July 1970. The pattern of DO in the Mississippi River at PINGP is characteristic of an enriched or eutrophic lotic environment.

TABLE 4.2-2

OBSERVED MAXIMUM AND MINIMUM WATER TEMPERATURES IN THE MISSISSIPPI RIVER ABOVE LOCK AND DAM NO. 3, SEPTEMBER 5, 1969 - NOVEMBER 30, 1973[a]

Month	Maximum		Minimum	
	°C	°F	°C	°F
January	2	35	0	32
February	2	36	0	32
March	4	40	1	33
April	17	62	3	37
May	22	71	8	47
June	26	79	13	55
July	29	84	18	65
August	29	84	16	60
September	27	80	13	55
October	19	66	4	40
November	12	54	0	32
December	2	35	0	32

[a]September 5, 1969 to May 3, 1971 data from USAEC (1973); May 4, 1971 to November 30, 1973 data from NSP (1972-1974)

Significant fluctuations in DO occur over the course of the year and during the diel cycle. Maximum monthly DO levels show supersaturation levels, especially during the spring and summer, whereas minimum levels are, in many cases, significantly undersaturated. Surface waters may contain 2 to 3 times more DO than bottom waters. Measurements taken from 1970 to 1975 in the Mississippi River near the intake canal show that DO levels fell below 5 mg/l only once (to 3.65 mg/l on August 3, 1972), during that period (Figure 4.2-3).

During the past 4 years, DO levels in the river near the intake canal and in the main channel have generally increased, probably as a result of improved waste treatment in the Minneapolis-St. Paul area. No critically low dissolved oxygen levels (below 5 mg/l) have been reported since August 1972. Thus, it appears that ambient levels of DO will not contribute to the susceptibility of organisms to entrainment or impingement.

Dissolved oxygen within the intake and recirculation canals was monitored in 1975 (Table 4.2-3). DO readings in the intake and recirculation canal were also taken in 1974 during one unit operation. DO was measured at two stations within

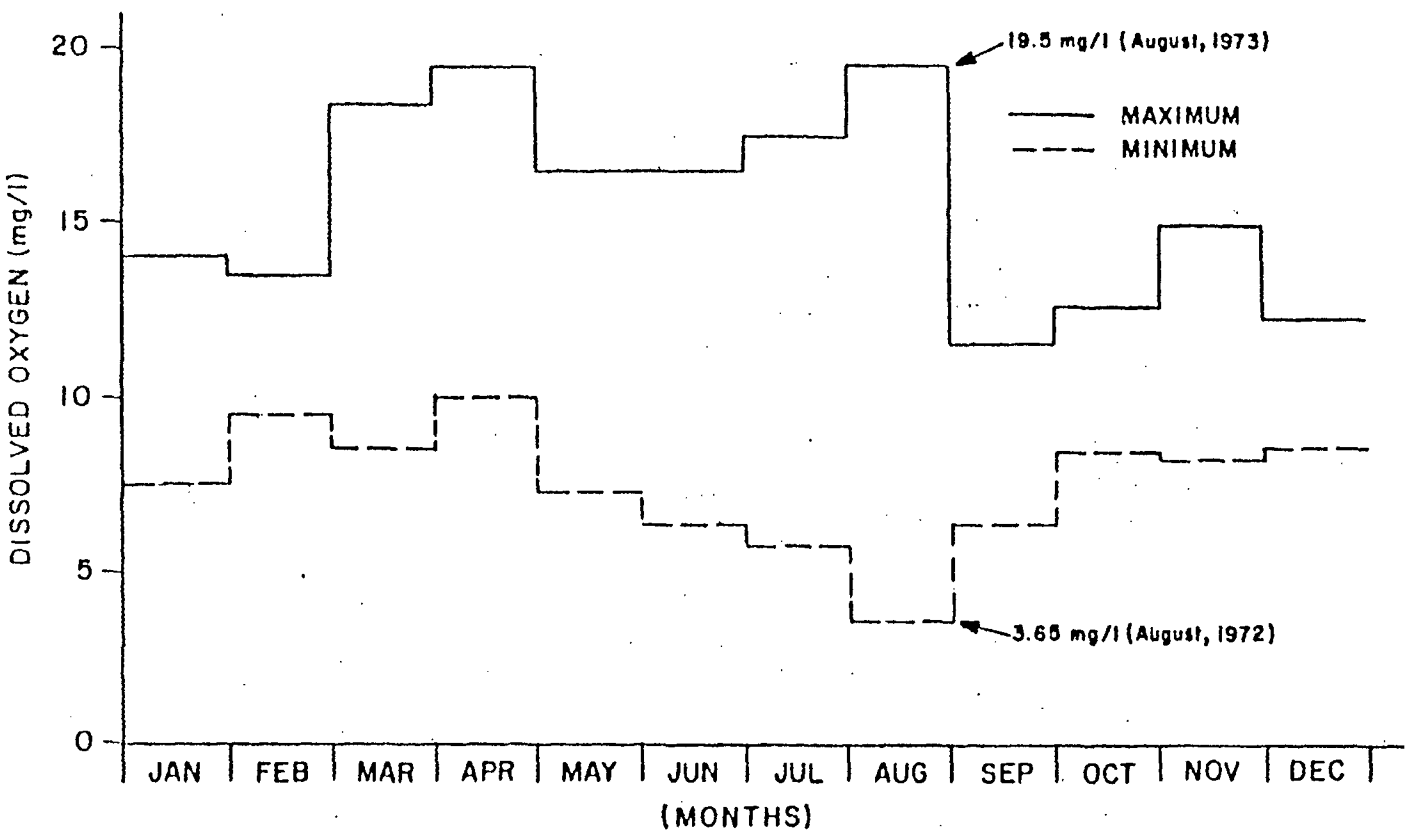


FIGURE 4.2-3

MAXIMUM AND MINIMUM MONTHLY DISSOLVED OXYGEN CONCENTRATION IN THE MISSISSIPPI RIVER NEAR THE PINGP INTAKE CANAL, JULY 1970 - DECEMBER 1975 (FROM MILLER 1971-1976)

[a] Measured at surface, middepth and bottom

[b] Measured at Prairie Island Station B- (Figure 4.3-2) (1970-1972) and X-1 (Figure 4.3-3) (1973-1975)

TABLE 4.2-3

DISSOLVED OXYGEN IN THE INTAKE CANAL AND RECIRCULATION CANAL, JANUARY 15 TO DECEMBER 19, 1975

	Station								
	X_1 Intake Canal At Skimmer Wall			X_2 Intake Canal After Recirculation Water Added			X_3 Recirculation Canal		
Date	T	M	B	T	M	B	T	M	B
1/15	13.85	13.0	12.4	9.15	10.0	9.45	8.75	8.8	8.7
2/18	9.6	9.6	9.6	8.95	9.0	9.35	8.6	8.65	8.7
3/11	--	11.1	10.9	9.7	9.7	9.7	9.55	9.55	9.55
4/22	8.15	11.0	13.05	--	--	--	8.2	--	8.15
5/20	7.1	8.1	7.8	--	--	--	7.3	--	7.1
6/24	9.5	9.9	10.5	--	--	--	9.8	--	10.0
7/24	5.8	--	5.9	--	--	--	7.15	--	7.1
9/2	8.05	--	8.0	--	--	--	9.65	--	9.1
9/16	9.05	--	9.5	--	--	--	7.75	--	7.75
10/14	11.3	--	10.25	--	--	--	8.2	--	8.3
11/25	12.9	--	13.0	--	--	--	8.0	--	8.0
12/19	--	--	--	--	--	--	8.2	--	8.6

T = Top
M = Middepth
B = Bottom

the intake canal (X1 and X2) and one station in the recirculation canal (see Figure 4.3-4).

DO levels in the intake canal at the skimmer wall ranged from 5.8 to 13.85 mg/l, with lowest levels being reported in July. DO measurements at Station X2 were taken during the first 3 months of 1975, and indicated that levels followed those at the skimmer wall and, to a greater degree, the recirculation canal. Recirculation water showed relatively high DO levels throughout the year, ranging between 7.1 mg/l and 9.8 mg/l (Table 4.2-3).

4.2.4 Other Existing or Planned Stresses

The major factor contributing to the eutrophic character of the Mississippi River near PINGP is the cumulative effect of effluents from the Twin Cities, approximately 28 miles (45 km) upstream of the site.

In the PINGP area, maintenance dredging of the navigation channel has been required once since 1930: in 1950 the Army Corps of Engineers removed 150,000 cubic yards of material. Barge traffic on the river causes resuspension of particulate matter.

There are no other known planned stresses to the Mississippi River near PINGP.

4.3 AQUATIC ECOLOGY

The biotic community of the Mississippi River near PINGP has been studied since 1969. Dr. Alan J. Brook of the University of Minnesota began phytoplankton surveys in 1969 and NSP began monitoring other biotic groups in 1970. These environmental monitoring programs are continuing as outlined in the Environmental Technical Specifications for PINGP.

4.3.1 Trophic Structure

The aquatic communities of the PINGP area of the Mississippi River may be characterized as typical of large midwest rivers and as having a trophic status of "eutrophic". Major factors affecting the river ecology are the proximity of the Twin Cities, the lock and dam system, the wing-dam system, barge traffic, and the numerous side channels and associated lakes of the Mississippi River. Particularly in the PINGP area, the river has a dual character: lotic in the main channel and lentic in the associated side channels and lakes, such as Sturgeon Lake. The planktonic communities in the PINGP area are well developed due to the impoundments and the numerous slackwater areas associated with the river channel. The flushing effect of the river is somewhat compensated by recruitment from associated lentic waters.

The food web of the Mississippi River near PINGP is very complex due to the interaction of the lotic and lentic environments. Benthic macroinvertebrates, excluding most molluscs, are an important link in adult fish food chains. Benthos of the PINGP area depends largely upon detritus and plankton within the water column, as evidenced by the large numbers of filter feeders in the benthic community. Thus, the planktonic input from the associated lentic habitats may be one of the major "fuels" for the ecosystem near PINGP.

4.3.2 Primary Producers

Primary production in the PINGP area results from phytoplankton, periphyton and macrophytes. Periphyton and macrophytes are restricted to areas of favorable habitat and are thus excluded from much of the deep river channel. Phytoplankton is likely the most important source of primary production (see 4.3.1) and, due to its potential for being entrained, is the primary producer that will be emphasized in this report. Primary production in the Mississippi River near PINGP may be somewhat depressed because of turbidity caused by barge traffic on the river.

4.3.2.1 Phytoplankton

The phytoplankton studies which began in 1969 (Brook 1971) have continued to the present (Brook 1972; Brook 1973; Baker and Baker 1974, 1975, 1976; Baker 1975, 1976). The following generalizations are derived from all the cited studies.

The phytoplankton associations of the PINGP area are typical of large rivers (Hynes 1972) and are dominated by diatoms most of the year. The dominant diatoms were species of Stephanodiscus and Cyclotella. Benthic diatoms (species of Navicula, Nitzschia and Synedra) were also common. While the centric diatoms tended to dominate much of the year, during the six years of phytoplankton studies at PINGP there were varying degrees of abundance of greens and blue-greens in summer and early autumn. Cryptophytes were usually abundant in late summer due to the influence of the St. Croix River. Brook (1972) reported large concentrations of Ankistrodesmus falcatus and Scenedesmus species in the summer and Aphanizomenon flos-aquae and Anabaena species in late summer and considered the area eutrophic, based on the Nygaard Quotient of 18.5.

Densities often reached 10,000 to 20,000 organisms/ml during spring and fall peaks. Lower densities occurred in 1972 and were attributed to high river flows. The studies concluded that flow is the most important determinant in algal density, phytoplankton densities being inversely proportional to flow. Baker (1975) states that "phytoplankton concentration near Prairie Island approaches the upper limit that is found in any aquatic system".

Production and productivity of the phytoplankton at PINGP have been studied using chlorophyll, biovolume, suspended particle mass and dissolved oxygen methods. Baker (1975) considered summer productivity relatively similar from 1970 through 1974. Productivity was generally higher in Sturgeon Lake than in the main channel of the Mississippi River. Within Sturgeon Lake there was often an increase in productivity along its downstream axis. Baker (1976) considers the phytoplankton of the PINGP area "nutrient-unlimited" and feels that the only productivity-limiting factors are light and the flushing rate of the Mississippi River.

4.3.2.2 Periphyton

Since periphyton is composed of largely sessile algae, it has little potential for entrainment at PINGP. The only organisms that will be entrained will be those that are scoured free from substrates and enter the phytoplankton community.

Periphyton studies at PINGP started in 1972 (NSP 1973) using glass slide artificial substrate samplers and chlorophyll a analyses. Baker (1974) started analyses of community composition in 1972 and continued in 1973, 1974 (Baker 1974) and 1975 (Baker 1975). Periphyton densities were generally maximum in summer months and resulted from several diatom species. Production was not considered limited by nutrients, but by light and temperature, depending on the season.

The communities of the main channel were composed of numerous centric diatoms (many of which were planktonic in origin) as well as typical pennate attached taxa. In early winter the diatoms Stephanodiscus niagarae and Cyclotella kutzingiana were abundant and were likely of planktonic origin. Early spring communities were dominated by Gomphonema species, Nitzschia dissipata and Cocconeis placentula. Later in spring Melosira varians became abundant and, along with species of Fragilaria, Nitzschia, Navicula and Gomphonema, dominated the collection until late fall. Navicula cincta and Nitzschia dissipata were the dominant species.

4.3.2.3 Aquatic Macrophytes

Aquatic macrophytes are generally not considered very significant as a source of food in lotic food webs. However, as a habitat former they are very significant; in particular, macrophytes provide important cover for fish and often serve as spawning and nursery areas. Macrophytes have been studied in the PINGP area from 1970 to the present (Miller 1971, 1972; Vose 1974; Mueller 1975, 1976).

Mueller (1975, 1976) examined submerged macrophytes and found the major plants to be Potamogeton crispus, P. nodosus, P. pectinatus and Vallisneria americana. The plant beds were similar in location (Figure 4.3-1) in both years although the densities of plants were somewhat less in 1975, probably due to high waters. The main channel of the river is essentially lacking in macrophytes; protected areas such as upper Sturgeon Lake support an abundant flora. The area immediately surrounding the intake supports little vegetation.

4.3.3 Zooplankton

Zooplankton, while of limited trophic significance to most lotic systems, is entrainable and thus is potentially subject to impact from plant operation. Zooplankton studies at PINGP began in 1970 (Miller 1971) and continued to the present (Miller 1972, 1973; Szluha 1974, 1975; Daggett 1976; Middlebrook 1975, 1976).

Trends in seasonal species succession and density peaks were similar for the five years of study. However, total zooplankton densities varied considerably from year to year. In 1974, mean annual densities ranged from 200 to 323/liter and monthly values often exceeded 500/liter, whereas in 1975 mean annual densities ranged between 68 and 129/liter and monthly values did not exceed 400/liter.

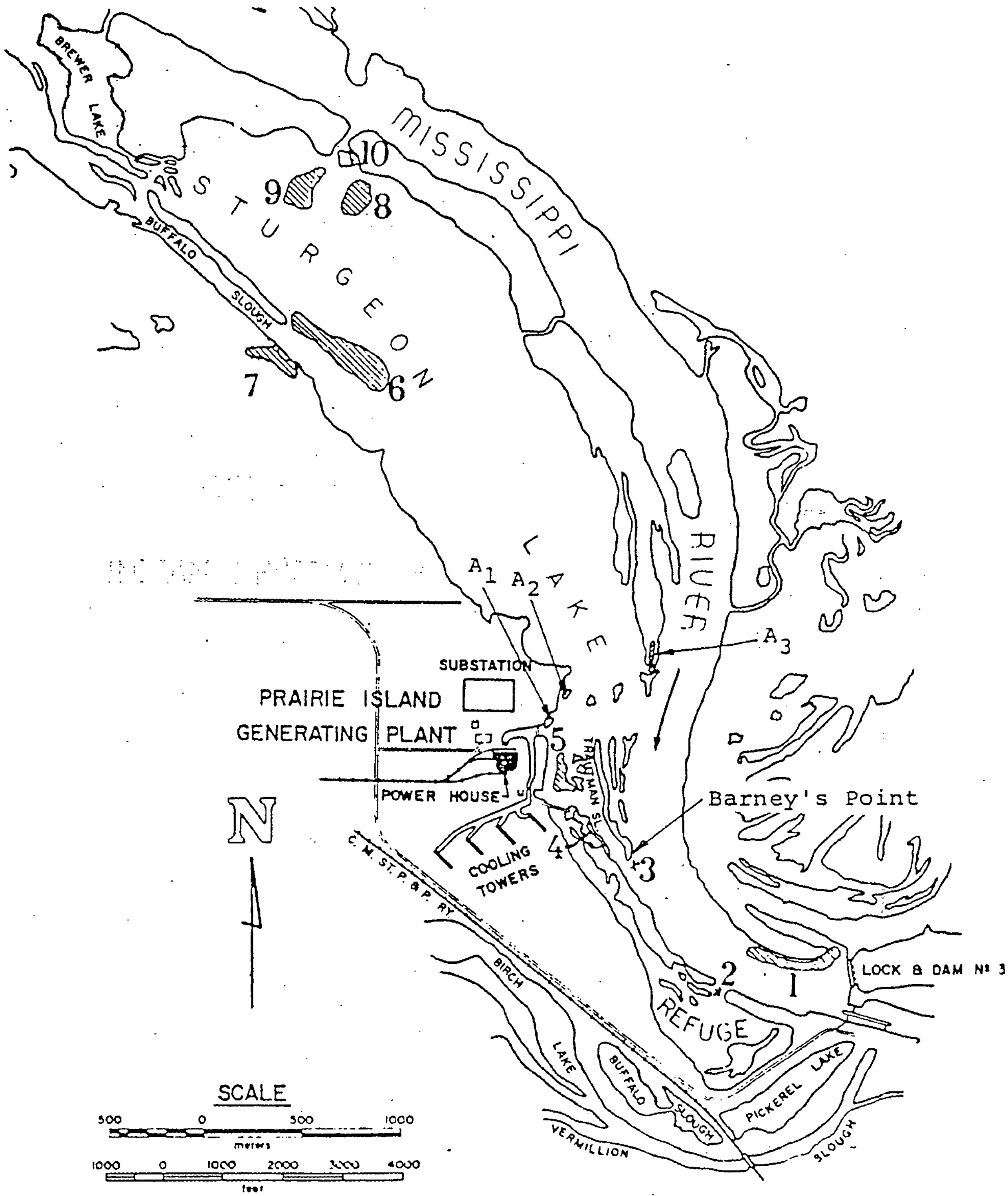


FIGURE 4.3-1

AREAS OF SUBMERGED AQUATIC VEGETATION IN THE VICINITY OF PINGP, 1975 (FROM MUELLER 1976) (Sheet 1 of 2)

Code:

a. Curled pondweed = Potamogeton crispus (L.)
b. River pondweed = Potamogeton nodosus (Poir.)
c. Sago pondweed = Potamogeton pectinatus (L.)
d. Wild celery = Vallisneria americana (Michx.)

Area 1.	a, b, c
2.	-
3.	-
4.	c
5.	a, b, c
6.	a, b, c
7.	a, b, c
8.	a, c
9.	a
10.	a, b, c, d
A_1.	a
A_2.	c
A_3.	a, c

FIGURE 4.3-1 (Sheet 2 of 2)

Seasonal trends in densities indicated maxima in summer or fall and minima in winter and spring.

Rotifers generally dominated the zooplankton of the PINGP area, as they usually do in river systems (Hynes 1972). Dominant rotifer taxa included Brachionus angularis, B. calyciflorus, B. budapestinensis, B. caudatus, Kellicottia longispina, Keratella cochlearis, K. quadrata, Polyarthra spp. and Synchaeta spp. Daggett (1976) considers the abundance of Brachionus species to indicate eutrophy.

Crustaceans were seldom dominant at the PINGP site, although in June 1974 Cyclops vernalis, Daphnia sp. and copepod nauplii dominated samples. Protozoans or copepods occasionally dominated winter or spring samples.

4.3.4 Benthic Macroinvertebrates

Macroinvertebrates of the Mississippi River near PINGP have been studied since July 1970. Preoperational information comprises about 3-1/2 years of study and operational information presently includes 2 years of study.

Several different collecting techniques were used to sample the different types of aquatic habitats near PINGP. Substrates in the main river channel and near the plant are composed of sand, silt and organic muck which are continually shifting. The Army Corps of Engineers artificial wing dams and shore stabilization areas are constructed of willow and rock. Quantitative samples of soft substrates (Miller 1973, McConville 1974, Haynes 1976) were taken with Ponar or Peterson grabs. Quantitative samples of the wing dams and shore stabilization construction were taken with artificial substrates. The artificial substrates used included a design by Miller (1971) which is composed of two concrete and two balsa wood blocks; this design was used for about 2-1/2 years in the preoperational study. Other types used included a concrete block sampler similar to that of Britt (1955), a barbeque basket sampler (Mason et al. 1967), and the Hester-Dendy multiplate sampler (Hester and Dendy 1962).

Qualitative samples, collected by dip nets and hand picking, were used to describe the benthos of shallow littoral zones that are not sampled by quantitative methods.

The organisms which colonized artificial substrates upstream of PINGP will be emphasized because they represent the species which could potentially be entrained through the phenomenon of drift.

The stations used by Miller (1972) in his preoperational studies of 1971 and 1972 are shown in Figure 4.3-2.

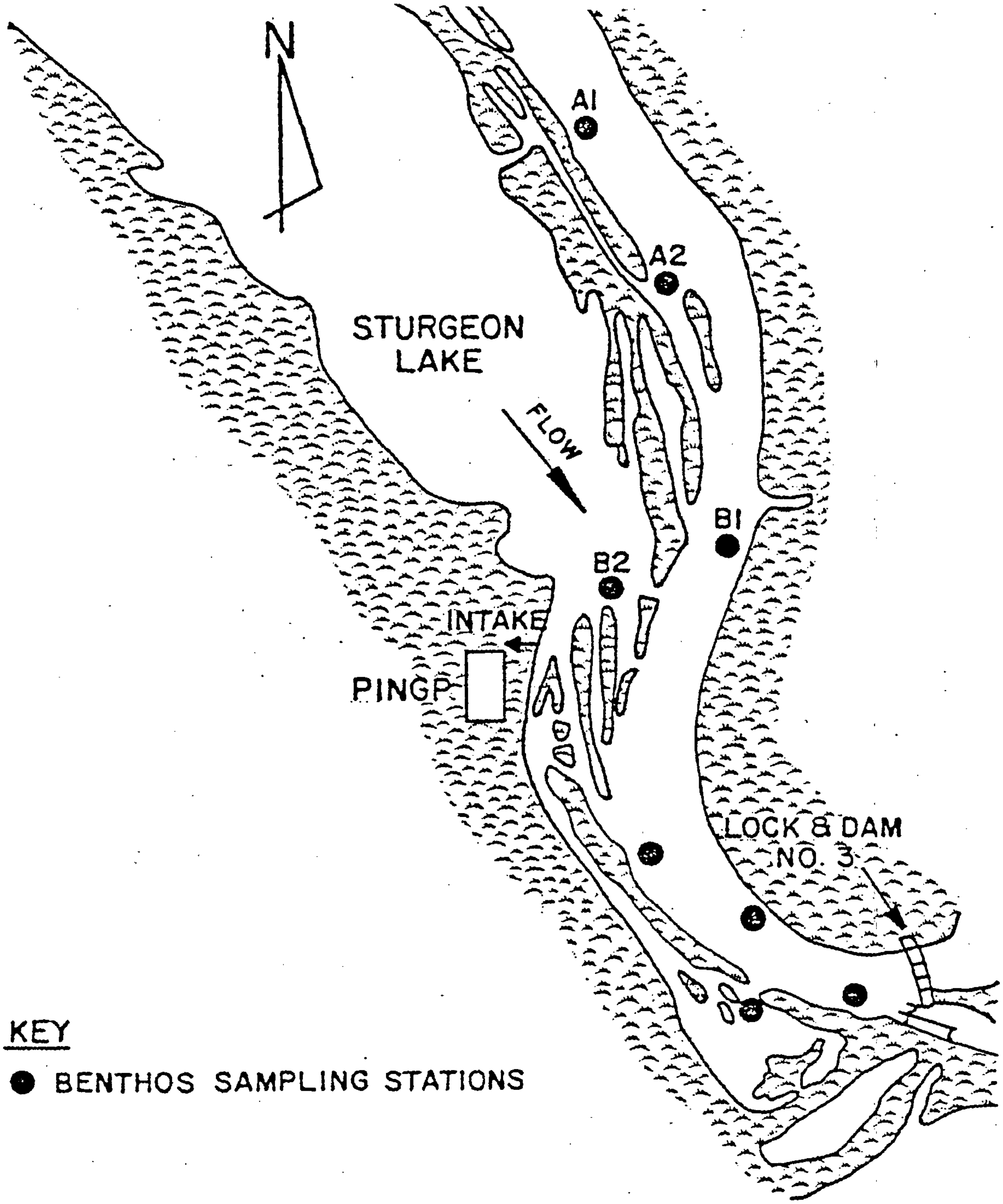


FIGURE 4.3-2

BENTHOS SAMPLING STATIONS NEAR PINGP, 1971 - 1972 (FROM MILLER 1972)

Miller (1972) experimented with various exposure times and finally decided on a 30 day exposure period for coloniziation. The 1971 studies show that Trichoptera, Ephemeroptera, and Diptera are the major macroinvertebrates to colonize the Miller substrate apparatus (Table 4.3-1). In 1972, these same three orders dominated the artificial substrates (Table 4.3-2).

In October, 1973 an additional series of sampling stations was established in the area of the intake, recycle and discharge canals (Figure 4.3-3). Station X-1, a control station, was located immediately outside the skimmer wall of the intake canal. Station X-2 was located immediately outside the screenhouse within the intake canal. Station X-3 was in the recycle canal above the juncture of recycled water and incoming make-up water from the river.

Unit 1 of PINGP began operation in 1974, although the plant was in operation for only four periods during this year (Simonet 1975). McConville (1974) states that the intermittent operation had a minimal effect on the river environment and, although subtle changes may have begun to occur, long term studies would be required to substantiate them.

TABLE 4.3-1

PERCENT COMPOSITION OF MACROINVERTEBRATES COLLECTED FROM ARTIFICIAL SUBSTRATE SAMPLERS IN THE MISSISSIPPI RIVER NEAR PINGP, 1971
(FROM MILLER 1972)

Transect[a]			Trichoptera	Ephemeroptera	Diptera	Other
A-1	Minn	W	42.3	17.9	38.7	1.2
		C	71.7	14.7	10.6	2.6
	Wisc	W	59.7	8.3	26.4	5.5
		C	32.3	14.1	30.3	23.2
A-2	Minn	W	32.1	5.6	47.1	15.1
		C	68.7	8.9	14.9	7.4
	Wisc	W	29.3	8.6	60.8	1.0
		C	46.0	20.1	22.2	11.1
B-1	Minn	W	37.5	14.6	20.8	27.1
		C	13.2	17.3	4.0	65.3
	Wisc	W	42.0	4.0	52.0	2.0
		C	25.0	65.0	8.8	1.2
B-2	Minn	W	50.8	22.1	27.1	0.0
		C	70.6	10.2	8.0	0.0
		W	56.9	8.8	32.1	2.2
	Center	C	68.1	13.0	14.0	4.6

[a]See Figure 4.3-2; Minn = Minnesota side, Wisc = Wisconsin side, Center = island that divides channel from main channel; W = balsa wood blocks, C = concrete blocks

TABLE 4.3-2

ESTIMATED DENSITY OF MACROINVERTEBRATES (NUMBERS/M^2)
COLLECTED FROM ARTIFICIAL SUBSTRATES DURING 1972
(FROM MILLER 1973)

Station[a]	Substrate[b]	June	July	September	October
A1W	TW	418	1655	1217	4413
	TC	215	280	129	395
	BW	514	1349	932	3214
	BC	215	266	108	395
A1M	TW	1084	2682	6714	3424
	TC	122	294	1586	545
	BW	1027	2149	7418	3538
	BC	151	287	1227	560
A2W	TW	533	1369	4356	3119
	TC	590	266	431	416
	BW	230	1617	3443	3899
	BC	237	244	545	251
A2M	TW	209	742	8407	5744
	TC	108	208	1062	388
	BW	114	932	8083	4717
	BC	50	280	1127	667
B1W	TW	399	-	1484	9015
	TC	79	-	309	158
	BW	647	-	2073	-
	BC	50	-	287	782
B1M	TW	609	742	-	647
	TC	187	151	-	29
	BW	704	780	-	742
	BC	158	65	-	187
B2M	TW	1065	647	913	1407
	TC	165	115	36	93
	BW	1103	894	609	913
	BC	179	108	93	43

[a] See Figure 4.3-2; W = Wisconsin side, M = Minnesota side

[b] TW = top wood; TC = top concrete; BW = bottom wood; BC = bottom concrete

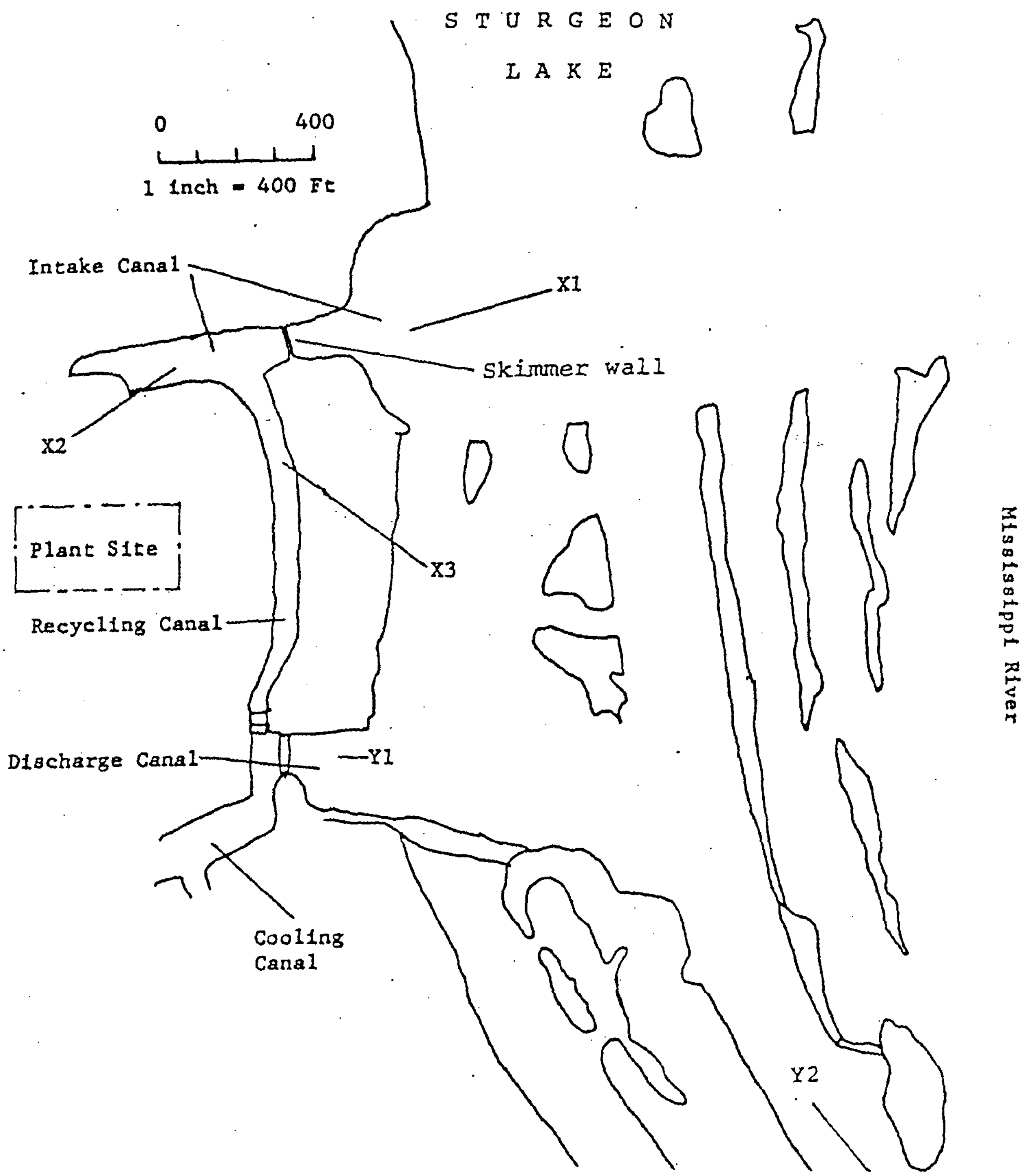


FIGURE 4.3-3

ADDITIONAL BENTHOS SAMPLING STATIONS NEAR PINGP, 1973
(FROM McCONVILLE 1974)

In addition to the regular baseline studies, an emergence study was conducted between May 13 and December 6, 1974 (McConville 1975). Emergent organisms were collected with black light insect traps at four stations (Figure 4.3-4). Some of the insects, in particular the caddisflies, emerge by migrating from the bottom of the water column and those emerging near the intake could be susceptible to entrainment at PINGP. Table 4.3-3 describes the numbers and percentage composition of the adults collected in the study.

The colonization period for the two types of artificial substrate studies was 30 days in 1974. Table 4.3-4 qualitatively lists the taxa taken from concrete block samplers and barbeque basket samplers from all the control stations as well as Station X-2 in the intake and Station X-3 in the recycling channel.

Hester-Dendy multiplate samplers were utilized for the colonization studies in 1975. A 6 week exposure period was allowed for colonizing the substrate with exception of the first two collection dates. Table 4.3-5 describes the mean number of organisms/m^2 and mean relative abundance of taxa per colonization period in stations above or in the intake structure plus Station X-3 in the recycle channel.

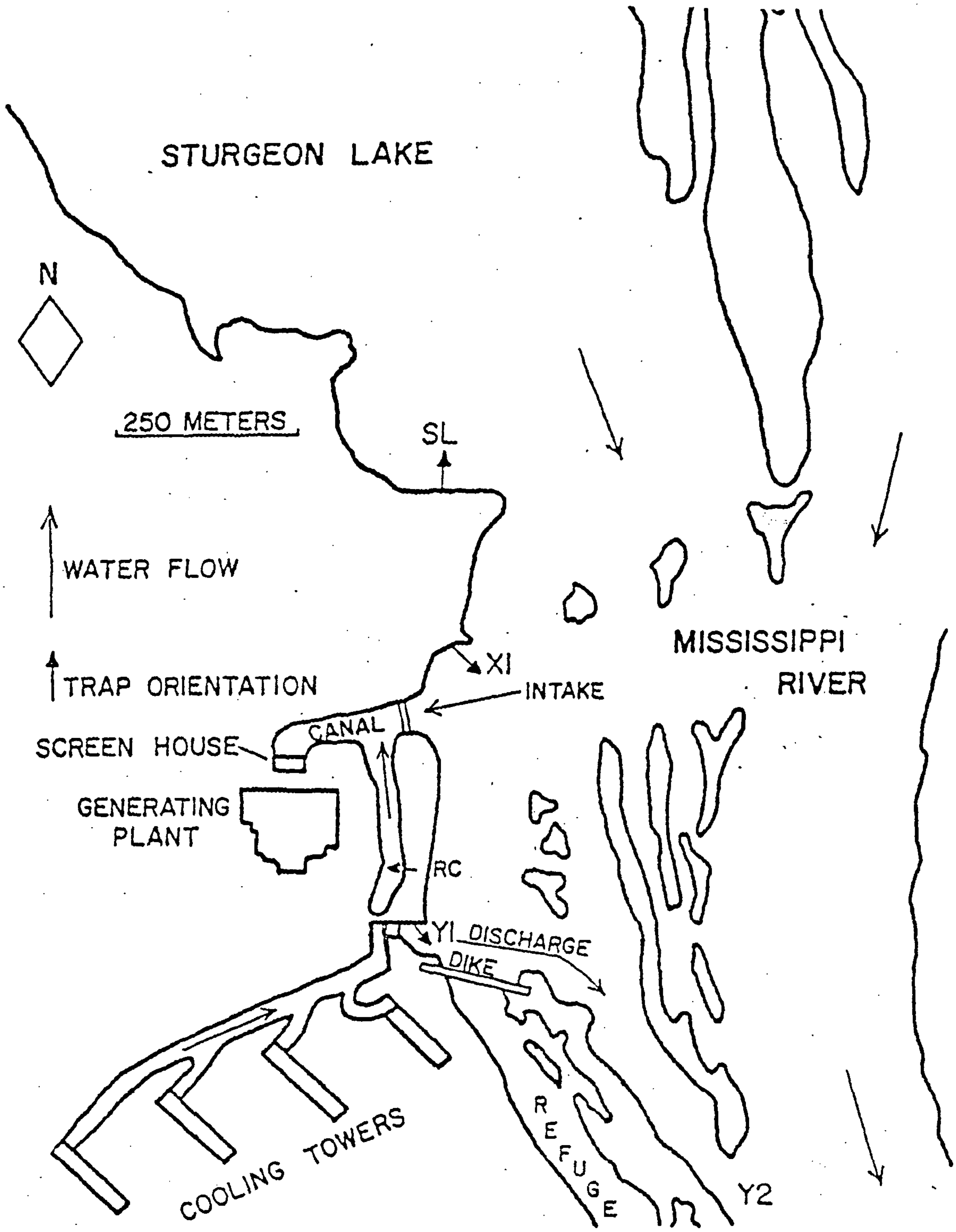


FIGURE 4.3-4

LIGHT TRAP STATIONS USED IN EMERGENCE STUDIES AT PINGP, 1974
(FROM McCONVILLE 1975)

TABLE 4.3-3

COMPOSITION OF ORDERS OF EMERGENT AQUATIC INSECTS COLLECTED FROM THE MISSISSIPPI RIVER NEAR PINGP, MAY 13 THROUGH DECEMBER 6, 1974 (FROM McCONVILLE 1975)

Order/Family	Sturgeon Lake		X-1[a]		Recycle Canal	
	Number	Percent	Number	Percent	Number	Percent
Trichoptera						
Hydropsychidae	151277	81.89	9155	52.26	8113	61.78
Psychomiidae	13406	7.26	4228	24.14	2078	15.82
Leptoceridae	7240	3.90	1171	6.68	1507	11.47
Hydroptilidae	12801	6.93	2960	16.89	1428	10.87
Other	4	*[b]	3	*	7	*
Total	184728	100.00	17517	100.00	13133	100.00
Ephemeroptera						
Caenidae	740	51.75	2980	86.85	1766	98.77
Ephemeridae	670	46.85	439	12.80	8	0.45
Other	20	1.40	12	0.35	14	0.78
Total	1430	100.00	3431	100.00	1788	100.00
Diptera						
Chironomidae	440602	99.13	71581	98.69	80679	99.20
Other	3888	0.87	947	1.31	647	0.80
Total	444490	100.00	72528	100.00	81326	100.00

[a] See Figure 4.3-4

[b] * less than 0.10 percent

TABLE 4.3-4 (Sheet 1 of 2)

MACROINVERTEBRATES COLLECTED FROM ARTIFICIAL SUBSTRATE SAMPLERS IN THE MISSISSIPPI RIVER NEAR PINGP[a] IN 1974
(FROM McCONVILLE 1975)

Macroinvertebrates	Block Samplers				Basket Samplers				
	B-1	X-1	X-2	X-3	SL	B-1	X-1	X-2	X-3
Gastropoda									
Physa sp.			*	*				*	*
Acari									
Hydrachnae			*						
Insecta									
Coleoptera									
Elmidae	*	*	*	*	*	*	*		*
Dineutus sp.									*
Berosus sp.			*						
Hydrochus sp.		*							
Hydraena sp.	*								
Diptera									
Ceratopogonidae		*	*	*					
Chironomidae	*	*	*	*	*	*	*	*	*
Chaoborus sp.	*	*							
Simuliidae			*		*	*	*	*	
Ephemeroptera									
Baetis sp.	*	*			*	*	*	*	*
Psuedocloeon sp.	*	*			*	*	*	*	*
Baetisca sp.								*	
Caenis sp.	*	*	*	*	*	*	*	*	*
Hexagenia sp.	*	*	*	*					
Cinygma sp.	*					*	*		
Rhithrogena sp.					*				
Stenonema sp.	*	*	*	*	*	*	*	*	*
Isonychia sp.					*	*			
Lepidoptera									
Elophila sp.		*							
Odonata									
Anisoptera	*								
Zygoptera		*	*	*		*	*	*	*
Plecoptera									
Alloperla sp.			*					*	
Taeniopteryx sp.		*							
Perlidae								*	
Trichoptera								*	
Cheumatopsyche sp.	*	*	*	*	*	*	*	*	*
Hydropsyche sp.	*	*	*	*	*	*	*	*	*
Athripsodes sp.				*			*	*	*
Oecetis sp.	*	*		*			*	*	

TABLE 4.3-4 (Sheet 2 of 2)

Macroinvertebrates	Block Samplers				Basket Samplers				
	B-1	X-1	X-2	X-3	SL	B-1	X-1	X-2	X-3
Pycnopsyche sp.		*	*						
Neureclipsis sp.	*	*	*		*	*	*	*	*
Polycentropus sp.	*	*	*	*	*	*	*	*	*
Malacostraca									
Amphipoda	*	*	*	*	*	*	*	*	*
Decapoda	*								
Isopoda									
Asellus sp.	*	*	*	*					
Hirudinae	*	*	*	*				*	
Oligochaeta									
Naididae	*	*	*	*		*	*	*	*
Tubificidae	*	*	*	*		*	*		
Ectoprocta									
Phylactolaemata									
Cristatellidae (only as statoblasts)	*		*	*	*	*	*	*	*
Plumatellidae		*	*	*		*	*	*	*
Nemata	*	*	*	*	*	*	*	*	
Turbellaria									
Tricladida	*	*	*	*					*
Hydrozoa									
Hydra sp.	*					*			*

a. See Figures 4.3-2 and 4.3-4 for location of stations

TABLE 4.3-5 (Sheet 1 of 9)

BENTHIC MACROINVERTEBRATES COLLECTED FROM HESTER-DENDY MULTIPLATE SAMPLERS
IN THE MISSISSIPPI RIVER NEAR PINGP IN 1975
(ADAPTED FROM HAYNES 1976)

	Station[a]									
	S.L.		B-1		X-1		X-2		X-3	
Taxa	Number[b]	Percent[c]	Number	Percent	Number	Percent	Number	Percent	Number	Percent
FEBRUARY 3, 1975										
Turbellaria	-	-			-	-	10.8	<1.0	43.2	1.4
Nemertina	-	-			-	-	-	-	54.0	1.7
Oligochaeta Naididae	-	-			-	-	3294.0	99.0	3024.0	96.2
Gastropoda *Physa* spp.	-	-			-	-	-	-	10.8	<1.0
Crustacea *Hyalella azteca*	-	-			-	-	10.8	<1.0	10.8	<1.0
Ephemeroptera *Tricorythodes* sp.	-	-			-	-	10.8	<1.0	-	-
Total Individuals	0				0		3326.4		3142.8	
Total Taxa	0				0		4		5	

TABLE 4.3-5 (Sheet 2 of 9)

Taxa	Station[a] S.L. Number[b]	Percent[c]	B-1 Number	Percent	X-1 Number	Percent	X-2 Number	Percent	X-3 Number	Percent
					MARCH 3, 1975					
Turbellaria	-	-			-	-	16.2	<1.0	10.8	11.1
Nemertina	-	-			-	-	21.6	<1.0	-	-
Nematoda	-	-			5.4	100.0	-	-	5.4	5.6
Oligochaeta										
Naididae	-	-			-	-	4617.0	99.0	37.8	38.9
Gastropoda										
Physa spp.	-	-			-	-	-	-	43.2	44.4
Diptera										
Cricotopus spp.	-	-			-	-	10.8	<1.0	-	-
Total Diptera	-	-			-	-	10.8	<1.0	-	-
Total Individuals	0				5.4		4665.6		97.2	
Total Taxa	0				1		4		4	

TABLE 4.3-5 (Sheet 3 of 9)

Taxa	S.L. Number[b]	S.L. Percent[c]	B-1 Number	B-1 Percent	X-1 Number	X-1 Percent	X-2 Number	X-2 Percent	X-3 Number	X-3 Percent
				Station[a]						
				APRIL 15, 1975						
Turbellaria							340.2	42.0	226.8	46.7
Nemertina							232.2	28.7	118.8	24.4
Oligochaeta										
Naididae							237.6	29.3	135.0	27.8
Gastropoda										
Physa spp.							5.4[d]		5.4[d]	
Diptera										
Cricotopus spp.							-	-	5.4	1.1
Total Diptera							-	-	5.4	1.1
Total Individuals							810.0		486.0	
Total Taxa							3		4	

TABLE 4.3-5 (Sheet 4 of 9)

Taxa	S.L. Number[b]	S.L. Percent[c]	B-1 Number	B-1 Percent	X-1 Number	X-1 Percent	X-2 Number	X-2 Percent	X-3 Number	X-3 Percent
	Station[a]									
MAY 27, 1975										
Turbellaria							183.6	3.1	-	-
Nemertina							64.8	1.1	-	-
Ectoprocta										
Plumatella repens							+[e]	+[e]		
Oligachaeta										
Naididae							205.2	3.5	-	-
Gastropoda										
Physa spp.							21.6[d]		-	-
Ephemeroptera										
Caenis sp.							-	-	5.4	5.9
Total Ephemeroptera							-	-	5.4	5.9
Plecoptera										
Isoperla sp.							5.4	<1.0	-	-
Total Plecoptera							5.4	<1.0	-	-
Trichoptera										
Agraylea sp.							21.6	<1.0	-	-
Athripsodes tarsi-punctatus							5.4	<1.0	-	-
Hydropsyche orris							59.4	1.0	-	-
Polycentropus sp.							91.8	1.6	-	-
Total Trichoptera							178.2	3.1	-	-
Diptera										
Conchapelopia sp.							237.6	4.1	-	-
Cricotopus spp.							610.2	10.5	-	-
Dicrotendipes sp.							394.2	6.8	5.4	5.9
Glyptotendipes sp.							43.2	<1.0	-	-
Labrundinia sp.							21.6	<1.0	-	-
Parachironomus sp.							685.3	11.8	-	-
Polypedilum (Pentapedilum) sp.							10.8	<1.0		-
Psectrocladius sp.							2393.6	41.0	75.6	82.4
Simulium jenningsii							799.2	13.7	-	-
Unidentified Chironomidae							-	-	5.4	5.9
Total Diptera							5196.3	89.1	86.4	94.1
Total Individuals							5833.4		91.8	
Total Taxa							17		4	

TABLE 4.3-5 t 5 of 9)

Taxa	S.L. Number[b]	S.L. Percent[c]	B-1 Number	B-1 Percent	X-1 Number	X-1 Percent	X-2 Number	X-2 Percent	X-3 Number	X-3 Percent
	Station[a]									
JULY 2 and 8, 1975										
Nemertina	-	-			-	-	18.9	<1.0	-	-
Ectoprocta										
Plumatella repens	-	-			-	-	+		+	
Oligochaeta										
Naididae	-	-			-	-	340.2	15.5	-	-
Tubificidae	-	-			10.8	<1.0	2.7	<1.0	-	-
Total Oligochaeta	-	-			10.8	<1.0	342.9	15.6	-	-
Gastropoda										
Physa spp.	-	-			-	-	-	-	2.7	<1.0
Crustacea										
Hyalella azteca	-	-			-	-	-	-	10.8	<1.0
Ephemeroptera										
Baetis sp. B	194.4	2.7			-	-	-	-	-	-
Caenis sp.	-	-			97.2	2.7	194.4	8.9	21.6	<1.0
Heptagenia flavescens	-	-			-	-	2.7	<1.0	2.7	<1.0
Potamanthus sp.	-	-			10.8	<1.0	-	-	-	-
Pseudocloeon parvulum	-	-			10.8	<1.0	-	-	-	-
S. integrum	64.8	<1.0			118.8	3.3	18.9	<1.0	2.7	<1.0
S. interpunctatum	-	-			54.0	1.5	-	-	-	-
Stenonema sp. A	-	-			-	-	2.7	<1.0	2.7	<1.0
Stenonema sp. B	-	-			-	-	2.7	<1.0	-	-
Tricorythodes sp.	-	-			-	-	10.8	<1.0	2.7	<1.0
Total Ephemeroptera	259.2	3.6			291.6	8.1	232.2	10.6	32.4	1.3
Plecoptera										
Perlesta placida	21.6	1.0			-	-	-	-	-	-
Trichoptera										
Cheumatopsyche sp.	540.0	7.5			10.8	<1.0	2.7	<1.0	2.7	<1.0
Hydroptila sp.	-	-			10.8	<1.0	-	-	-	-
Hydropsyche orris	5724.0	79.3			75.6	2.1	210.6	9.6	137.7	5.6
Neureclipsis sp.	172.8	2.4			151.2	4.2	78.3	3.6	5.4	<1.0
Polycentropus sp.	-	-			280.8	7.8	-	-	2.7	<1.0
Total Trichoptera	6436.8	89.2			529.2	14.7	291.6	13.3	148.5	6.0
Diptera										
Conchapelopia sp.	151.2	2.1			86.4	2.4	32.4	1.5	72.9	3.0
Corynoneura sp.	-	-			10.8	<1.0	-	-	-	-
Cricotopus spp.	-	-			-	-	-	-	108.0	4.4
Dicrotendipes sp.	-	-			10.8	<1.0	24.3	1.1	2.7	<1.0
Eukiefferiella sp.	43.2	<1.0			-	-	-	-	-	-
Glyptotendipes sp.	-	-			2473.2	68.6	1061.1	48.4	1771.2	71.8
Parachironomus sp.	-	-			-	-	54.0	2.5	108.0	4.4
Polypedilum (Pentapedilium) sp.	129.6	1.8			32.4	<1.0	70.2	3.2	110.7	4.5
Procladius spp.	-	-			-	-	10.8	<1.0	-	-
Psectrocladius sp.	-	-			10.8	<1.0	35.1	1.6	97.2	3.9
Rheotanytarsus sp.	172.8	2.4			140.4	3.9	18.9	<1.0	2.7	<1.0
Stenochironomus sp.	-	-			10.8	<1.0	-	-	-	-
Total Diptera	496.8	6.0			2775.6	76.9	1306.8	59.6	2273.4	92.1
Total Individuals	7214.4				3607.2		2192.4		2467.8	
Total Taxa	10				19		20		19	

TABLE 4.3-5 (Sheet 6 of 9)

Taxa	Station[a]									
	S.L.		B-1		X-1		X-2		X-3	
	Number[b]	Percent[c]	Number	Percent	Number	Percent	Number	Percent	Number	Percent
					AUGUST 19, 1975					
Hydrozoa	-	-	-	-	-	-	-	-	861.3	1.0
Turbellaria	-	-	-	-	-	-	-	-	10.8	<1.0
Nematoda	-	-	-	-	-	-	648.0	5.3	507.6	<1.0
Oligochaeta										
Naididae	-	-	-	-	-	-	5313.6	43.8	74884.5	96.6
Ephemeroptera										
Baetis sp. B	194.4	2.5	129.6	1.8	5.4	<1.0	-	-	-	-
Baetis sp. C	43.2	<1.0	75.6	1.0	10.8	<1.0	-	-	-	-
Caenis sp.	-	-	21.6	<1.0	13.5	<1.0	-	-	-	-
Heptagenia flavescens	43.2	<1.0	-	-	-	-	-	-	-	-
Isonychia sp.	-	-	194.4	2.7	-	-	-	-	-	-
Stenonema exiguum	-	-	21.6	<1.0	5.4	<1.0	-	-	-	-
S. integrum	129.6	1.7	97.2	1.3	62.1	1.4	-	-	2.7	<1.0
S. quinquespinatum	21.6	<1.0	-	-	-	-	-	-	-	-
Stenonema sp. B	21.6	<1.0	-	-	-	-	-	-	-	-
Stenonema sp.	-	-	43.2	<1.0	-	-	-	-	-	-
Tricorythodes sp.	-	-	-	-	2.7	1.0	-	-	-	-
Total Ephemeroptera	453.6	5.8	583.2	8.1	99.9	2.3	-	-	2.7	<1.0
Trichoptera										
Cheumatopsyche sp.	1317.6	16.9	712.8	9.9	18.9	<1.0	86.4	<1.0	-	-
Hydropsyche frisoni	-	-	10.8	<1.0	-	-	32.4	<1.0	-	-
H. orris	4320.0	55.4	4546.8	63.0	124.2	2.8	5270.4	43.5	156.6	<1.0
Neureclipsis sp.	950.4	12.2	345.6	4.8	421.2	9.5	10.8	<1.0	64.8	<1.0
Polycentropus sp.	-	-	-	-	162.0	3.6	-	-	-	-
Potamyia flava	-	-	291.6	4.0	5.4	<1.0	140.4	1.2	21.6	<1.0
Unidentified Hydropsychidae	-	-	280.8	3.9	-	-	172.8	1.4	-	-
Total Trichoptera	6588.0	84.5	6188.4	85.8	731.7	16.5	5713.2	47.1	243.0	<1.0
Coleoptera										
Stenelmis spp.	-	-	43.2	<1.0	-	-	-	-	2.7	<1.0
Diptera										
Ablabesmyia sp.	-	-	-	-	-	-	-	-	56.7	<1.0
Conchapelopia sp.	86.4	1.1	162.0	2.2	194.4	4.4	97.2	<1.0	21.6	<1.0
Dicrotendipes sp.	-	-	-	-	5.4	<1.0	10.8	<1.0	-	-
Glyptotendipes sp.	410.4	5.3	32.4	<1.0	3348.9	75.4	270.0	2.2	912.6	1.2
Hemerodromia sp.	-	-	-	-	2.7	<1.0	10.8	<1.0	-	-
Parachironomus sp.	-	-	-	-	5.4	<1.0	21.6	<1.0	2.7	<1.0
Polypedilum (Pentapedilum) sp.	237.6	3.0	194.4	2.7	16.2	<1.0	-	-	-	-
Psectrocladius sp.	-	-	-	-	29.7	<1.0	43.2	<1.0	2.7	<1.0
Rheotanytarsus sp.	21.6	<1.0	10.8	<1.0	-	-	-	-	-	-
Tribelos sp.	-	-	-	-	5.4	<1.0	-	-	-	-
Total Diptera	756.0	9.7	399.6	5.5	3608.1	81.3	453.6	3.7	996.3	1.3
Total Individuals	7797.6		7214.4		4439.7		12128.4		77508.9	
Total Taxa	13		18		19		14		14	

TABLE 4.3-5 (Sheet 7 of 9)

Taxa	Station[a] S.L. Number[b]	S.L. Percent[c]	B-1 Number	B-1 Percent	X-1 Number	X-1 Percent	X-2 Number	X-2 Percent	X-3 Number	X-3 Percent
SEPTEMBER 29, 1975										
Hydrozoa	-	-	-	-	-	-	-	-	27.0	<1.0
Turbellaria	-	-	-	-	-	-	-	-	27.0	<1.0
Ectoprocta										
Pectinatella magnifica	-	-	-	-	+	-	-	-	+	
Plumatella repens	+	-	-	-	-	-	-	-	+	
Endoprocta	-	-	-	-	-	-	+	-	+	-
Oligochaeta										
Naididae	-	-	-	-	267.3	8.3	48599.9	85.4	159494.4	99.4
Ephemeroptera										
Baetis sp. C	10.8	<1.0	21.6	<1.0	-	-	-	-	-	-
Isonychia sp.	-	-	37.8	<1.0	-	-	-	-	-	-
Stenonema integrum	-	-	67.5	1.1	8.1	<1.0	-	-	-	-
S. interpunctatum	-	-	-	-	2.7	<1.0	-	-	-	-
Stenonema sp. A	10.8	<1.0	-	-	-	-	-	-	-	-
Total Ephemeroptera	21.6	<1.0	126.9	2.1	10.8	<1.0	-	-	-	-
Odonata										
Enallagma sp.	-	-	-	-	10.6	<1.0	-	-	-	-
Trichoptera										
Cheumatopsyche sp.	326.7	5.9	756.0	12.7	-	-	124.2	<1.0	-	-
Hydropsyche frisoni	-	-	-	-	-	-	10.8	<1.0	-	-
H. orris	1304.2	23.5	2646.0	44.5	27.0	<1.0	7732.8	13.6	108.0	<1.0
Neureclipsis sp.	275.4	5.0	129.6	2.2	245.7	7.6	32.4	<1.0	27.0	<1.0
Polycentropus sp.	10.8	<1.0	86.4	1.5	194.4	6.0	218.7	<1.0	-	-
Potamyia flava	367.2	6.6	486.0	8.2	10.8	<1.0	21.6	<1.0	-	-
Unidentified Hydropsychidae	1036.8	18.7	259.2	4.4	-	-	-	-	27.0	<1.0
Total Trichoptera	3321.1	59.9	4363.2	73.4	477.9	14.8	8140.5	14.3	162.0	<1.0
Coleoptera										
Stenelmis spp.	-	-	-	-	5.4	<1.0	-	-	-	-
Diptera										
Ablabesmyia sp.	-	-	-	-	8.1	<1.0	10.8	<1.0	-	-
Conchapelopia sp.	48.6	<1.0	97.2	1.6	-	-	2.7	<1.0	-	-
Cricotopus spp.	-	-	140.3	2.4	-	-	-	-	-	-
Dicrotendipes sp.	121.5	2.2	-	-	118.8	3.7	-	-	-	-
Glyptotendipes sp.	1428.3	25.8	874.7	14.7	2251.8	69.9	145.8	<1.0	617.1	<1.0
Parachironomus sp.	-	-	-	-	-	-	-	-	27.0	<1.0
Polypedilum (Pentapedilum) sp.	75.6	1.4	-	-	18.9	<1.0	-	-	-	-
Psectrocladius sp.	523.8	9.5	302.4	5.1	54.0	1.7	5.4	<1.0	54.0	<1.0
Rheotanytarsus sp.	-	-	43.2	<1.0	-	-	-	-	-	-
Unidentified Chironomidae (pupae)	-	-	-	-	-	-	-	-	54.0	<1.0
Total Diptera	2197.8	39.7	1457.8	24.5	2451.6	76.1	164.7	<1.0	752.1	<1.0
Total Individuals	5540.5		5947.9		3223.6		56905.1		160462.5	
Total Taxa	13		14		14		11		10	

TABLE 4.3-5 (Sheet 8 of 9)

Taxa	S.L. Number[b]	S.L. Percent[c]	B-1 Number	B-1 Percent	X-1 Number	X-1 Percent	X-2 Number	X-2 Percent	X-3 Number	X-3 Percent
	Station[a]									
NOVEMBER 11, 1975										
Hydrozoa			167.4	<1.0	-	-	243.0	<1.0	-	-
Turbellaria			-	-	-	-	27.0	<1.0	-	-
Nematoda			54.0	<1.0	108.0	<1.0	324.0	<1.0	621.0	<1.0
Ectoprocta										
Plumatella repens			-	-	-	-	+	-	-	-
Oligochaeta										
Naididae			19826.1	89.5	36561.6	97.7	126009.0	99.4	233604.0	99.7
Ephemeroptera										
Stenonema integrum			-	-	72.0	<1.0	-	-	-	-
Total Ephemeroptera			-	-	72.0	<1.0	-	-	-	-
Trichoptera										
Cheumatopsyche sp.			59.4	<1.0	-	-	-	-	-	-
Hydropsyche orris			351.0	1.6	3.6	<1.0	108.0	<1.0	-	-
Neureclipsis sp.			62.1	<1.0	10.8	<1.0	-	-	-	-
Polycentropus sp.			-	-	36.0	<1.0	-	-	-	-
Potamyia flava			496.8	2.2	43.2	<1.0	-	-	-	-
Total Trichoptera			969.3	4.4	93.6	<1.0	108.0	<1.0	-	-
Diptera										
Conchapelopia sp.			16.2	<1.0	36.0	<1.0	-	-	-	-
Cricotopus spp.			-	-	36.0	<1.0	-	-	-	-
Glyptotendipes sp.			159.3	<1.0	381.6	<1.0	-	-	-	-
Orthocladius spp.			135.0	<1.0	36.0	<1.0	-	-	-	-
Psectrocladius sp.			837.0	3.8	72.0	<1.0	-	-	-	-
Rheotanytarsus sp.			-	-	36.0	<1.0	-	-	-	-
Total Diptera			1147.5	5.2	597.6	1.6	-	-	-	-
Total Individuals			22164.3		37432.8		126711.0		234225.0	
Total Taxa			11		13		5		2	

TABLE 4.3-5 (Sheet 9 of 9)

Taxa	S.L. Number[b]	S.L. Percent[c]	B-1 Number	B-1 Percent	X-1 Number	X-1 Percent	X-2 Number	X-2 Percent	X-3 Number	X-3 Percent
Turbellaria							135.0	<1.0	-	-
Nematoda							783.0	1.8	13905.0	12.1
Ectoprocta										
Plumatella repens							+	-	+	-
Oligochaeta										
Naididae							42228.0	97.4	100927.0	87.8
Gastropoda										
Physa spp.							54.0	<1.0	54.0	1.0
Trichoptera										
Hydropsyche orris							54.0	<1.0	-	-
Total Trichoptera							54.0	<1.0	-	-
Diptera										
Cricotopus spp.							54.0	<1.0	-	-
Glyptotendipes sp.							27.0	<1.0	-	-
Polypedilum (Pentapedilum) sp.							27.0	<1.0	-	-
Total Diptera							108.0	<1.0	-	-
Total Individuals							43362.0		114886.0	
Total Taxa							8		3	

[a] See Figure 4.3-2

[b] Mean number of organisms per m^2

[c] Mean percent relative abundance

[d] Dead at time of collection; not included in totals

[e] + = present as colonies; not included in totals

The faunal composition shown in the colonization studies of 1974 and 1975 is important because the community formed is a result of drift phenomenon. Thus, the taxa of this community could potentially be entrained.

During the 1975 survey a total of 147 macroinvertebrate taxa was collected by all sampling methods (Table 4.3-6). Fifty-one taxa were exclusive to qualitative sampling, 13 to Petersen grab sampling, and 23 to the multiplate samplers. Throughout all years of study, the quantitative grab samples contained mainly Oligochaeta and Chironomidae. Numerous Mollusca were also collected in the grab samples.

TABLE 4.3-6

BENTHIC MACROINVERTEBRATES COLLECTED
IN THE VICINITY OF PINGP IN 1975
(FROM HAYNES 1976) (Sheet 1 of 4)

Taxa	Petersen Dredge	Multiplate Sampler	Qualitative Samples
Porifera			+
Hydrozoa		+	
Turbellaria	+	+	+
Nemertina		+	
Nematoda	+	+	
Ectoprocta			
Pectinatella magnifica Leidy	+	+	+
Plumatella repens (Linnaeus)		+	+
Entoprocta			
Urnatella gracilis Leidy	+	+	+
Annelida			
Oligochaeta			
Branchiura sowerbyi Beddard	+		+
Other Tubificidae	+	+	+
Naididae*	+	+	+
Hirudinea			
Dina lateralis (Verrill)			+
Erpobdella punctata (Leidy)			+
Helobdella stagnalis (Linnaeus)			+
Placobdella montifera Moore			+
P. parasitica (Say)			+
Unidentified Hirudinea			+
Mollusca			
Gastropoda			
Amnicola sp.	+		+
Bulimnaea megasoma (Say)	+		
Ferrissia sp.	+		+
Goniobasis sp.	+		+
Gyraulus spp.	+		+
Helisoma spp.	+		+
Lymnaea sp.	+	+	
Physa spp.	+	+	+
Pleurocera sp.	+		+
Stagnicola sp.	+		+
Valvata tricarinata (Say)	+		
Unidentified Gastropoda	+		

TABLE 4.3-6 (Sheet 2 of 4)

Taxa	Petersen Dredge	Multiplate Sampler	Qualitative Samples
Pelecypoda			
Lampsilis sp.	+		
Leptodea fragilis Rafinesque	+		
Pisidium sp.	+		
Sphaerium sp.	+		+
Unidentified Unionaceae	+		
Arthropoda			
Hydracarina			+
Crustacea			
Asellus sp.	+	+	+
Crangonyx gracilis group Smith			+
Gammarus lacustris Sars			+
G. pseudolimnaeus Bousfield			+
Gammarus sp.			+
Hyalella azteca (Saussure)		+	+
Orconectes sp.			+
Collembola			
Isotomurus palustris (Muller)			+
Ephemeroptera			
Baetis sp. A			+
Baetis sp. B		+	
Baetis sp. C		+	
Baetisca bajkovi Neave			+
Baetisca sp.			+
Caenis sp.	+	+	+
Ephemerella temporalis McDunnough			+
Ephoron album (Say)	+		
Heptagenia flavescens (Walsh)		+	
Hexagenia limbata (Serville)	+		
Isonychia sp.		+	
Leptophlebia sp.			+
Metretopus borealis Eaton			+
Potamanthus sp.		+	+
Pseudocloeon parvulum McDunnough		+	+
Pseudocloeon sp.			+
Siphlonurus alternatus (Say)			+
Stenonema exiguum Traver		+	
S. integrum (McDunnough)		+	+
S. interpunctatum (Say)		+	+
S. quinquespinatum Lewis		+	+
S. tripunctatum (Banks)			+
Stenonema sp. A		+	
Stenonema sp. B		+	
Tricorythodes sp.		+	+

TABLE 4.3-6 (Sheet 3 of 4)

Taxa	Petersen Dredge	Multiplate Sampler	Qualitative Samples
Odonata			
Argia sp.			+
Enallagma sp.		+	+
Unknown Zygoptera		+	
Plecoptera			
Isoperla bilineata (Say)		+	+
Isoperla sp.		+	
Perlesta placida (Hagen)		+	
Taeneopteryx maura Pictet		+	
Hemiptera			
Belastoma sp.			+
Corixidae			+
Gerris sp.			+
Plea striola			+
Ranatra sp.			+
Saldidae			+
Trepobates sp.			+
Neuroptera			
Climacea areolaris (Hagen)			+
Trichoptera			
Agraylea sp.		+	
Athripsodes tarsi - punctatus (Vorhies)		+	+
Cheumatopsyche sp.	+	+	+
Hydropsyche frisoni Ross		+	
H. orris Ross	+	+	+
Hydroptila sp.		+	+
Leptocella sp.			+
Neureclepsis sp.	+	+	+
Orthotrichia sp.			+
Polycentropus sp.		+	+
Potamyia flava (Hagen)	+	+	+
Pycnopsyche sp.			+
Unidentified Hydropsychidae	+	+	
Unidentified Hydroptilidae			+
Coleoptera			
Berosus sp.			+
Coptotomus nr. interrogatus (Fabricius)			+
Dubiraphia vittata (adults) (Melsheimer)			+
Dubiraphia sp. (larvae)	+		+
Dineutus nr. discolor Aube			+
Gyrinus sp. A			+
Gyrinus sp. B			+
Haliplus sp.			

Taxa	Petersen Dredge	Multiplate Sampler	Qualitative Samples
Coleoptera			
Helophorus sp.			+
Hygrotus sp.			+
Laccobius sp.			+
Liodessus sp.			+
Peltodytes spp.			+
Stenelmis spp.	+	+	+
Tropisternus lateralis (adults) (Fabricius)			+
Tropisternus sp. (larvae)			+
Unidentified Hydrophilidae			+
Diptera			
Ablabesmyia sp.	+	+	+
Chaoborus punctipennis (Say)	+		+
Chironomis spp.	+		+
Coelotanypus sp.	+		
Conchapelopia sp.	+	+	+
Corynoneura sp.		+	+
Cricotopus spp.	+	+	+
Cryptochironomus spp.	+	+	+
Dicrotendipes sp.	+	+	+
Endochironomus sp.		+	+
Eukiefferiella sp.		+	
Glyptotendipes sp.	+	+	+
Hemerodromia sp.	+	+	+
Labrundinia sp.		+	
Micropsecta sp.		+	
Nanocladius sp.		+	
Orthocladius spp.		+	
Palpomyia spp. group	+		+
Parachironomus demijerea	+		
Parachironomus sp.		+	+
Polypedilum (Fallax) sp.			+
P. (Pentapedilum) sp.	+	+	+
Procladius spp.	+	+	
Psectrocladius sp.		+	
Rheotanytarsus sp.		+	
Simulium jenningsii Malloch		+	+
Stenochironomus sp.	+	+	
Tanypus sp.	+		
Tribelos sp.		+	+
Trissocladius sp.		+	
Xenochironomus sp.	+		
Unidentified Chironomidae	+	+	+
Totals 147	54	69	105

*Mixed populations of *Nais* spp. and *Pristina* sp., the former predominating.

4.3.5 Fish and Fisheries

Fishes in the vicinity of PINGP have been the subject of intensive studies since 1970. Additional data on commercial fishing are available from the Wisconsin and Minnesota Departments of Natural Resources.

Species collected at PINGP by type of gear in 1975 and species collected by all types of gear in 1973 and 1974 are presented in Table 4.3-7. Sampling was conducted with multiple gears to reduce the inherent bias resulting from gear selectivity. Electrofishing and seining yielded more species than the other sampling methods. However, seining data are biased against fishes which are large and occur offshore whereas electrofishing data are biased against smaller and demersal fishes. Standing crops of small fishes can be estimated from seining data for shallow waters and trawl data for deeper waters. Gill net and trap net data permit spatial comparisions of the relative numbers of the larger and most important species.

Fishes of the PINGP region have been classified according to their value and size by Gustafson et al. (1976) as follows.

TABLE 4.3-7

COMMON AND SCIENTIFIC FISH NAMES AND METHODS OF FISH CAPTURE IN THE PINGP AREA, 1975 (FROM GUSTAFSON ET AL. 1976) (Sheet 1 of 3)

Common Name	Scientific Name	Method of Capture						
		Trapnet	Gillnet	Trawl	Electro-Fishing	Seine	1973	1974
Chestnut lamprey	*Ichthyomyzon castaneus*							x
Silver lamprey	*Ichthyomyzon unicuspis*				x			x
Longnose gar	*Lepisosteus osseus*	x	x		x	x	x	x
Shortnose gar	*Lepisosteus platostomus*	x	x		x	x	x	x
Bowfin	*Amia calva*	x	x			x	x	x
American eel	*Anquilla rostrata*						x	x
Gizzard shad	*Dorosoma cepedianum*	x	x	x	x	x	x	x
Goldeye	*Hiodon alosiodes*		x				x	x
Mooneye	*Hiodon tergisus*	x	x		x		x	x
Northern pike	*Esox lucius*	x	x		x	x	x	x
Carp	*Cyprinus carpio*	x	x	x	x	x	x	x
Brassy minnow	*Hybognathus hankonsoni*					x		x
Silvery minnow	*Hybognathus nuchalis*							x
Silver chub	*Hybopsis storeriana*		x	x	x	x		x
Golden shiner	*Notemigonus crysoleucas*							x
Emerald shiner	*Notropus atherinoides*			x	x	x		x
River shiner	*Notropus biennius*			x	x	x		x
Common shiner	*Notropis cornutus*					x		x
Pugnose minnow	*Notropis emiliae*				x	x		x
Blacknose shiner	*Notropis heterolepis*							x
Spottail shiner	*Notropis hudsonius*			x	x	x		x
Red shiner	*Notropis lutrensis*				x	x		
Rosyface shiner	*Notropis rubellus*				x	x		x
Spotfin shiner	*Notropis spilopterus*				x	x		x
Redfin shiner	*Notropis umbratilis*				x	x		
Mimic shiner	*Notropis volucellus*					x		x
Bluntnose minnow	*Pimephales notatus*				x	x		x
Fathead minnow	*Pimephales promelas*							x

TABLE 4.3-7 (Sheet 2 of 3)

Common Name	Scientific Name	Method of Capture: Trapnet	Gillnet	Trawl	Electro-Fishing	Seine	1973	1974
Bullhead minnow	*Pimephales vigilax*				x	x		x
Carpsucker species	*Carpiodes* species	x	x	x	x	x	x	x
White sucker	*Catostomus commersoni*	x				x		x
Smallmouth buffalo	*Ictiobus bubalus*	x	x	x	x	x	x	x
Bigmouth buffalo	*Ictiobus cypinellus*	x	x	x	x	x	x	x
Spotted sucker	*Minytrema melanops*							x
Silver redhorse	*Moxostoma anisurum*	x	x		x		x	x
River redhorse	*Moxostoma carinatum*							x
Shorthead redhorse	*Moxostoma macrolepidotum*	x	x	x	x	x	x	x
Black bullhead	*Ictalurus melis*	x	x					x
Yellow bullhead	*Ictalurus natalis*						x	x
Brown bullhead	*Ictalurus nebulosus*	x	x				x	x
Channel catfish	*Ictalurus punctatus*	x	x	x	x	x	x	x
Tadpole madtom	*Noturus gyrinus*					x		
Flathead catfish	*Pylodictis olivaris*	x			x		x	x
Trout perch	*Percopsis omiscomaycus*			x	x	x		x
Burbot	*Lota lota*		x		x			x
White bass	*Morone chrysops*	x	x	x	x	x	x	x
Rock bass	*Ambloplites rupestris*	x	x		x	x	x	x
Green sunfish	*Lepomis cyanellus*				x	x	x	x
Pumpkinseed	*Lepomis gibbosus*				x		x	x
Bluegill	*Lepomis macrochirus*	x	x	x	x	x	x	x
Hybrid sunfish	*Lepomis macrochirus X?*							x
Smallmouth bass	*Micropterus dolomieui*	x	x		x	x	x	x
Largemouth bass	*Micropterus salmoides*						x	x
White crappie	*Pomoxis annularis*	x	x	x	x	x	x	x
Black crappie	*Pomoxis nigromaculatus*	x	x	x	x		x	x
Johnny darter	*Etheostoma nigrum*					x		x

TABLE 4.5-7 (Sheet 3 of 3)

Common Name	Scientific Name	Method of Capture: Trapnet	Gillnet	Trawl	Electro-Fishing	Seine	1973	1974
Yellow perch	*Perca flavescens*	x			x	x	x	x
Log perch	*Percina caprodes*				x	x		x
Sauger	*Stizostedion canadense*	x	x	x	x	x	x	x
Walleye	*Stizostedion vitreum vitreum*	x	x	x	x	x	x	x
Freshwater drum	*Aplodinotus grunniens*	x	x	x	x	x	x	x

Large rough fish (carp, carpsuckers, shorthead redhorse)

Game fish (channel catfish, smallmouth bass, walleye, sauger, white bass, northern pike)

Panfish (rock bass, bluegill)

Minnows and darters

Other fish (gizzard shad, mooneye, black bullhead, freshwater drum)

These categories will be used in subsequent discussions to summarize the voluminous data collected in the PINGP area.

4.3.5.1 Sport Fishery

In the PINGP area the angling season is continuous for all species except sturgeon. Although tip-up apparatuses can be used for ice fishing, there is little ice fishing because of ice-choked channels and treacherous conditions.

A creel survey was undertaken to establish a series of guidelines or indices to be used in assessing sport fishery success, pressure, and harvest in relation to PINGP operation (Hawkinson 1974). During 1973-1975, six river sections (Figure 4.3-5) were surveyed in rotation. PINGP is located at the lower end of sections 1 and 2 and at the upper end of section 3. Section 4 includes the tail-waters of Lock and Dam No. 3.

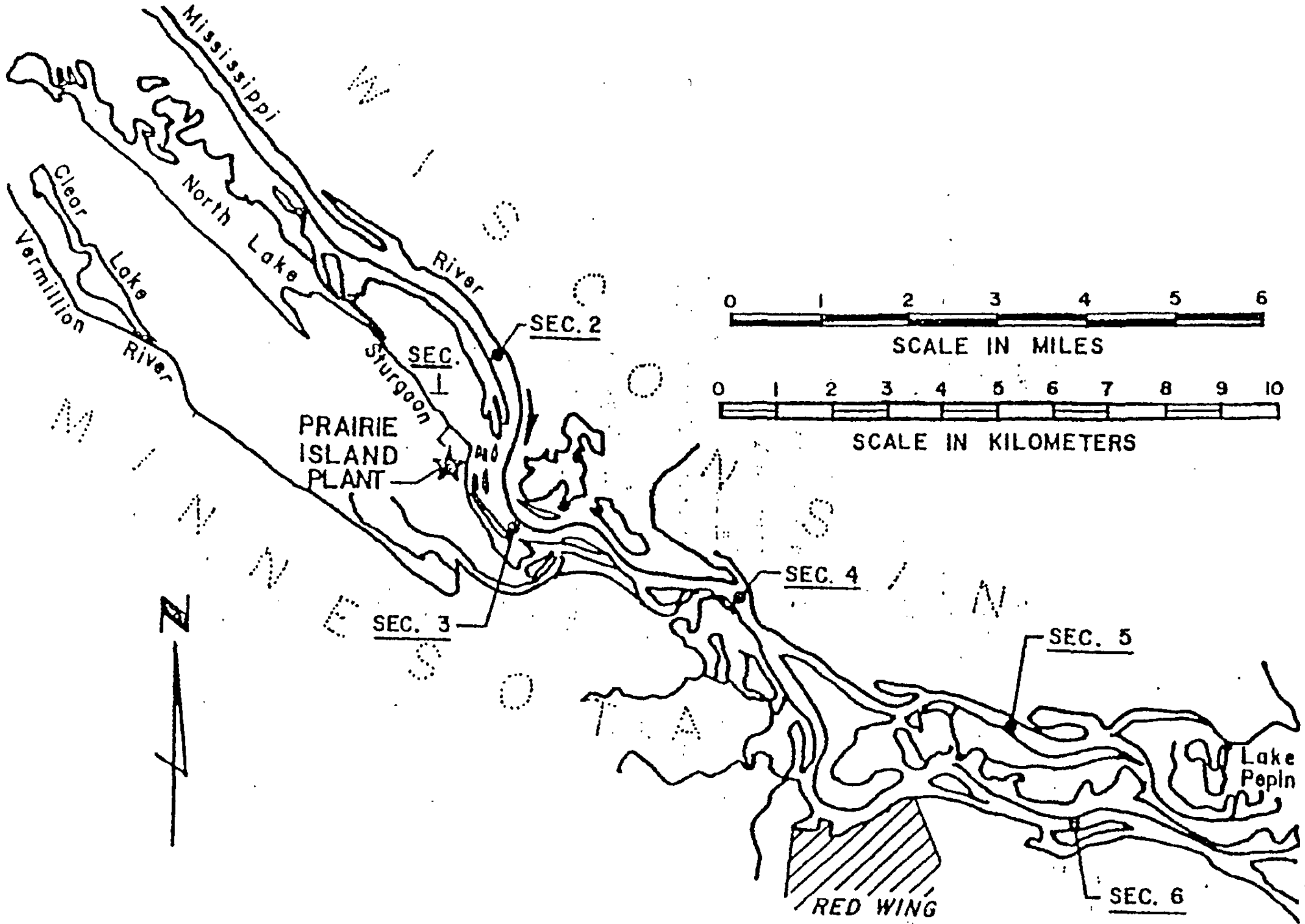


FIGURE 4.3-5

CREEL SURVEY AREAS NEAR PINGP, 1973-1975
(FROM NAPLIN AND GUSTAFSON, 1975)

Estimated sport harvest and catch rates of fish in the PINGP region are shown in Tables 4.3-8 through 4.3-12.

Fishing pressure was very similar in 1973 and 1974 but declined by about 33 percent in 1975. In March and April, in the fishery in the tailwaters of the dam, there was a steady increase in fishing pressure from 18,378 man-hours in 1971 to 93,594 man-hours in 1974 and a decline to 88,855 man-hours in 1975.

There is little fishing pressure in Sturgeon Lake, the main channel above the Lock and Dam No. 3 and the immediate plant area. The highest fishing pressure occurs in section 4, especially in March and April (Gustafson et al. 1976) because (1) fishing is good in this section and highly publicized, (2) the section is easily accessible and easy to fish, and (3) sauger, walleyes and white bass concentrate in the tailwaters.

Interviews with fishermen indicated that the most sought after species were saugers, walleyes and "anything that bites." The most commonly caught fish were walleyes, saugers, white bass and drum. The composition of the May-November sport catch was similar from 1973 through 1975,

TABLE 4.3-8

ESTIMATED HARVESTS OF THREE MAJOR GAME SPECIES CAUGHT IN THE VICINITY OF PINGP 1973 and 1974
(FROM NAPLIN AND GEIS 1975)

Date		SPECIES White bass	Sauger	Walleye	Total
1974 April 30- Dec. 3	Number of fish	10,349	19,522	6,342	36,213
	Weight of fish (kg)	6,416.4	11,518.0	4,756.5	22,691.0
	Kilograms per hectare	4.01	7.19	2.97	14.17
1974 May 10- Nov. 5	Number of fish	10,284	15,503	5,591	31,378
	Weight of fish (kg)	6,376.1	9,146.7	4,193.4	19,716.2
	Kilograms per hectare	3.98	5.71	2.62	12.31
1973 May 10- Nov. 5	Number of fish	13,942	18,042	7,381	39,365
	Weight of fish (kg)	7,528.5	7,036.5	4,133.3	18,698.3
	Kilograms per hectare	4.70	4.40	2.58	11.68

TABLE 4.3-10

OVERALL CATCH RATE OF ALL ANGLERS FISHING THE PINGP AREA MAY 10 - NOVEMBER 5, 1973[a] AND PERCENT SUCCESSFUL ANGLERS[b] (FROM HAWKINSON 1974) (Sheet 1 of 2)

	Fishing Success (fish/m-h)						
	Sections						
	1	2	3	4	5	6	Total
M-h surveyed	11.0	4.0	3.0	2,643.0	1,820.0	600.0	5,081.0
% successful anglers	40	75	100	59	56	51	57
Species Caught							
Northern pike				* (6)	* (1)	0.02(10)	* (17)
Walleye		0.50(2)		0.04 (96)	0.16(291)	0.10(62)	0.09 (451)
Sauger				0.30(787)	0.14(254)	0.13(70)	0.22(1120)
White bass		0.25(1)	0.33(1)	0.29(772)	0.03 (60)	0.05(30)	0.17 (864)
Crappies				0.01 (23)	0.01 (25)	0.01 (6)	0.01 (54)
Bluegill sunfish				* (5)	0.01 (10)	* (1)	* (16)
Pumpkinseed sfh.					0.02 (40)		0.01 (40)
Green sunfish					0.02 (35)		0.01 (35)
Hybrid sunfish						* (1)	* (1)
L. M. bass						* (2)	* (2)
S. M. bass				* (5)	* (1)		* (6)
Perch					* (5)	* (1)	* (6)
Flathead catfish	0.36			0.02 (44)	0.02 (32)	0.01 (5)	0.02 (85)
Suckers & Rdhs.					* (1)		* (1)
Carp				0.01 (17)	* (4)	0.01 (4)	0.01 (25)
Drum				0.03 (70)	0.02 (31)	0.02(14)	0.02 (115)

[a] In fish/man-hours; numbers of fish caught in parenthesis next to the rate and the man-hours fished under the section number

[b] At least one fish caught

TABLE 4.3-9

ESTIMATED NUMBERS OF FISH HARVESTED IN THE VICINITY OF PINGP, 1975, BASED ON OVERALL CATCH RATES AND ESTIMATED MAN-HOURS
(FROM GUSTAFSON ET AL. 1976)

	Mar.-Apr. only	March - November 23, 1975						
Section	4	1	2	3	4	5	6	Total
Hrs. Surveyed	7795.9	16.5	4.0	4.0	9980.3	1355.5	298.7	
Estimated man-hours	63737	394	187	212	88855	17513	4556	111717
Species:								
Mooneye/goldeye	0*	0	0	0	0	0	0	0
Northern pike	127	0	0	0	177	70	0	223
Carp	0	0	0	0	89	158	46	293
Brown bullhead	0	0	0	0	0	53	0	53
Channel catfish	0	0	0	0	267	88	0	355
Flathead catfish	0	0	0	0	0	18	0	18
Burbot	0	0	0	0	0	0	0	0
White bass	0	24	0	53	5776	823	200	6876
Rock bass	0	0	0	0	0	35	0	35
Sunfish	64	0	0	0	355	1190	0	1545
Smallmouth bass	0	0	0	0	177	18	0	195
Largemouth bass	0	0	0	0	0	53	0	53
Crappies	0	0	0	0	267	2487	0	2754
Yellow perch	0	0	0	0	0	18	0	18
Sauger	15042	310	0	0	22036	1313	1130	24789
Walleye	3187	167	94	53	4620	2855	501	8290
Freshwater drum	0	0	0	0	355	18	228	601
Overall estimated harvest	18420	501	94	106	34119	9197	2105	46122

*None were caught by interviewed anglers

TABLE 4.3-10 (Sheet 2 of 2)

Fishing Success (fish/m-h)

	Sections 1	2	3	4	5	6	Total
Sturgeon				* (1)			* (1)
Gar				* (1)			* (1)
Rock Bass				* (2)	* (1)		* (3)
Mooneye				* (1)			* (1)
Catch/m-hr.	0.36(4)	0.75(3)	0.33(1)	0.69(1831)	0.44(791)	0.36(216)	0.56(2846)

TABLE 4.3-11

OVERALL CATCH RATE FOR INTERVIEWED ANGLERS IN PINGP VICINITY, APRIL 30-DECEMBER 3, 1974 (FROM NAPLIN AND GEIS 1975)

	SECTION 1	2	3	4	5	6	1974 Total
Man-hours surveyed	16.3	14.5	No anglers interviewed	2872.8	961.1	226.3	4091.0
Percent Successful anglers*	64	84		63	55	45	61
SPECIES CAUGHT							
Carp				0.01 (20)	0.01 (6)	0.01 (2)	0.01 (28)
Channel catfish	0.31 (5)	0.14 (2)		tr** (11)	tr (3)	0.02 (4)	0.01 (25)
Brown bullhead				tr (8)			tr (8)
Flathead catfish				tr (1)	tr (1)		tr (2)
Northern pike		0.07 (1)		tr (12)	0.01 (9)	0.01 (2)	tr (24)
White bass	0.49 (8)	1.38 (20)		0.18 (510)	0.02 (21)	0.06 (14)	0.14 (573)
Sauger		0.07 (1)		0.37 (1061)	0.10 (94)	0.12 (26)	0.29 (1182)
Walleye	0.18 (3)	0.07 (1)		0.03 (81)	0.22 (214)	0.19 (44)	0.08 (343)
Smallmouth bass				tr (10)			tr (10)
Largemouth bass				tr (1)	tr (2)		tr (3)
Sunfish***				tr (2)	0.05 (46)		0.01 (48)
Rock bass				0.01 (19)			0.01 (19)
Crappies				tr (4)	0.01 (7)		tr (11)
Freshwater drum	1.23 (20)	0.41 (6)		0.02 (60)	0.01 (11)	0.06 (13)	0.03 (110)
1974 Total	2.21 (36)	2.14 (31)		0.63 (1800)	0.43 (414)	0.46 (105)	0.58 (2386)

*At least one fish caught

**0 < trace (tr) ≤ 0.005

***Bluegill, pumpkinseed, green sunfish, and hybrid sunfish

TABLE 4.3-12

OVERALL CATCH RATES FOR INTERVIEWED ANGLERS IN PINGP VICINITY, 1975[a]
(FROM GUSTAFSON AND DIEDRICH 1976)

	Mar.-Apr. Only	March-November 23, 1975						
Section	4	1	2	3	4	5	6	Total
Hrs. Surveyed	7,795.9	16.5	4.0	4.0	9,980.3	1,355.5	298.7	11,659.0
Estimated Man-hours	63,737	394	187	212	88,855	17,513	4,556	111,717
Species:								
Mooneye/goldeye	-	-	-	-	** tr (2)	-	-	tr (2)
Northern pike	0.002 (14)	-	-	-	0.002 (20)	0.004 (6)	-	0.002 (26)
Carp	-	-	-	-	0.001 (7)	0.009 (12)	0.010 (3)	0.002 (22)
Brown bullhead	-	-	-	-	tr (1)	0.003 (4)	-	tr (5)
Channel catfish	-	-	-	-	0.003 (26)	0.005 (7)	-	0.003 (33)
Flathead catfish	-	-	-	-	tr (4)	0.001 (1)	-	tr (5)
Burbot	-	-	-	-	tr (2)	-	-	tr (2)
White bass	tr (1)	0.061 (1)	-	0.250	0.065 (650)	0.047 (64)	0.044 (13)	0.063 (729)
Rock bass	-	-	-	-	tr (2)	0.002 (3)	-	tr (5)
Sunfish	0.001 (6)	-	-	-	0.004 (39)	0.068 (92)	-	0.012 (131)
Smallmouth bass	-	-	-	-	0.002 (24)	0.001 (2)	-	0.002 (26)
Largemouth bass	-	-	-	-	-	0.003 (4)	-	tr (4)
Crappies	tr (3)	-	-	-	0.003 (35)	0.142(192)	-	0.019 (227)
Yellow perch	-	-	-	-	-	0.001 (2)	-	tr (2)
Sauger	0.236(1,842)	0.788(13)	-	-	0.248(2,472)	0.075(102)	0.248 (74)	0.228(2,661)
Walleye	0.050 (393)	0.424 (7)	0.500(2)	0.250 (1)	0.052 (516)	0.163(221)	0.110 (33)	0.067 (780)
Freshwater drum	-	-	-	-	0.004 (41)	0.001 (2)	0.050 (15)	0.005 (58)
Overall estimated harvest	0.290(2,259)	1.273(21)	0.500(2)	0.500(2)	0.385(3,841)	0.527(714)	0.462(138)	0.405(4,718)

*None were caught by interviewed anglers
**0 <trace (tr) <.001

[a]Catch/man-hour with number caught by interviewed anglers in parentheses

except that crappies became more prominent in 1975. Dominant species during 1975 were sauger (33.3 percent), white bass (29.6 percent), walleyes (15.7 percent) and crappies (9.1 percent). Number of fish caught per man-hour was 0.56 in 1973, 0.58 in 1974, and 0.41 in 1975.

4.3.5.2 Commercial Fishery

Fishes are commercially harvested in the PINGP region with gill nets, seines, and set lines. Commercial fishing pressure is lighter in Pool 3 than in Pools 4 and 4A (Grotbeck, personal communication).

Catch data for the major species are presented for five recent years of record to establish the present status of the fishery (Table 4.3-13). Carp were predominant in the catch, with most of them coming from Lake Pepin. The catch of carp has generally increased after 1970 in Pool 3 and decreased in Pool 4.

Freshwater drum or sheepshead in Lake Pepin represented the second largest catch during most years but were exceeded by buffalo in 1974. The catch of drum declined after 1970.

Most of the buffalo were harvested in Pools 3 and 4A whereas most of the catfish were harvested in Pools 4 and 4A.

TABLE 4.3-13

COMMERCIAL CATCH OF FISH (POUNDS) IN POOLS 3, 4 AND 4A (LAKE PEPIN) DURING 1970-1974. WISCONSIN AND MINNESOTA LANDINGS COMBINED (FERNHOLZ, PERSONAL COMMUNICATION)

	Catfish			Buffalo		
	3	4	4A	3	4	4A
1970	759	19,223	27,181	83,234	7,405	56,364
1971	202	14,556	23,193	23,749	7,033	51,518
1972	652	17,912	12,935	39,141	5,350	65,936
1973	630	9,246	19,792	47,967	5,418	31,970
1974	64	19,854	17,902	13,285	4,387	80,279

	Carp			Freshwater Drum		
	3	4	4A	3	4	4A
1970	26,231	109,104	1,500,784	5,492	3,919	186,029
1971	13,418	197,484	2,026,879	594	2,617	187,865
1972	195,820	51,333	969,236	1,449	2,092	101,128
1973	307,908	35,512	1,355,626	1,076	3,187	60,836
1974	231,093	56,371	987,362	913	4,771	55,587

Other species of fish are unimportant in the harvest. These include suckers, quillback, mooneye, goldeye, bowfin and gars. Turtles are also harvested.

A majority of the total fish harvested were from Lake Pepin. The catch of catfish and drum was relatively low in Pool 3 and the catch of buffalo and drum was relatively low in Pool 4.

4.3.5.3 Tag and Recapture Studies

Sport fishes were tagged and released near PINGP during 1973, 1974 and 1975. Some of the species moved considerable distances upstream and downstream. The average distance moved in 1975 was 52.6 miles for white bass, 17.6 miles for sauger, and 22.2 miles for walleye. These studies indicate that discrete populations of these species do not occur in the PINGP region.

Although not designed for population estimates, the tag and recapture data can be used to obtain a rough estimate of the population numbers within the angling size range (Table 4.3-14). The simplest method of population estimation assumes that the rate of capture of tagged fish is identical to the rate of capture in the whole population. Thus, the percentage of tagged fish caught is equivalent to the percentage of the total population caught within the same size range of those

TABLE 4.3-14

POPULATION ESTIMATES OF SPORT FISHES IN THE 12-MILE PINGP STUDY AREA BASED ON PETERSON AND SCHNABEL TAG AND RECAPTURE METHODS [a]

Species	Number in 12-Mile Study Area: Peterson	Schnabel
Northern pike	2,442	- [b]
Channel catfish	22,720	-
White bass	173,910	155,335
Smallmouth bass	7,215	-
Largemouth bass	795	-
Sauger	609,809	228,784
Walleye	162,721	123,512

[a] Estimates for number of fish within the size range caught by fishermen. Calculated from data in Gustafson et al. (1976) and Naplin and Geis (1975).

[b] Dash indicates no estimate made because total catch not determined in 1974.

TABLE 4.1-1

MISSISSIPPI RIVER FLOW AT PRESCOTT, WISCONSIN, 1940-1975[a]

Month	Median Flow		7-day 10 year flow[b]	
	m/3sec	cfs	m/3sec	cfs
January	238	8,390	103	3,641
February	228	8,050	105	3,719
March	377	13,320	120	4,222
April	1,137	40,125	213	7,523
May	822	29,020	246	8,699
June	719	25,390	185	6,527
July	459	16,190	123	4,340
August	339	11,970	98	3,445
September	286	10,080	107	3,785
October	350	12,360	112	3,969
November	350	12,340	119	4,200
December	260	9,160	107	3,767

[a]1940-1965 data from USAEC (1973); 1965-1975 data from USGS.
[b]Based on 46 years of data for the months of January through May, and 47 years of data for June through December.

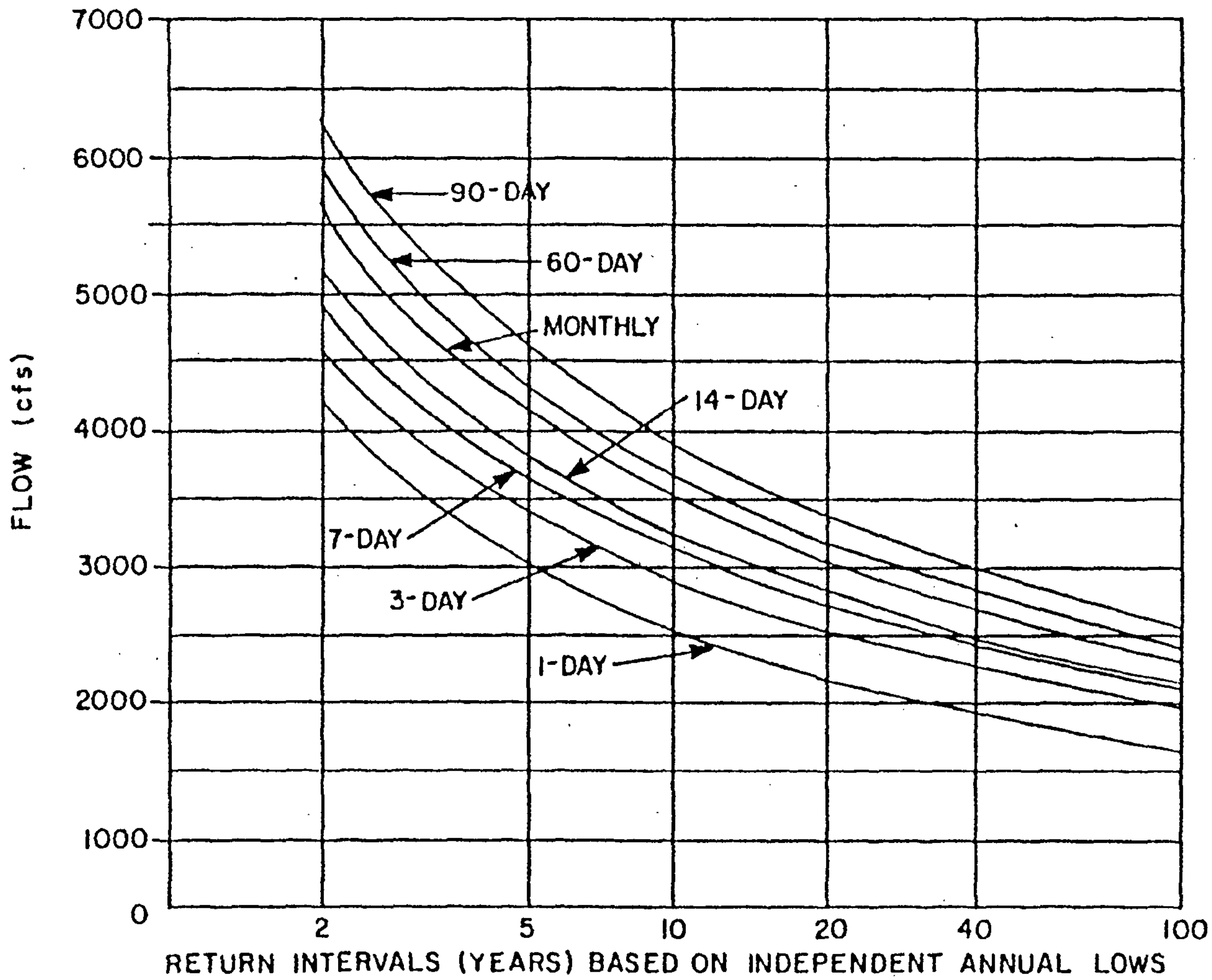


FIGURE 4.1-2

CONSECUTIVE DAY AVERAGE LOW FLOW FREQUENCIES,
MISSISSIPPI AT PRESCOTT, WISCONSIN 1928-1974

the range of flows from May 21 through September 4, 1975 when fish entrainment studies were conducted. The average flow for this period was 650 m^3/sec. The relationship between the flow through Sturgeon Lake and the flow in the main channel of the Mississippi River is shown in Figure 4.1-3.

The approximate retention times for the North Lake-Sturgeon Lake chain are 74 and 7.6 hours for total river flows of 226.4 and 1867.8 m^3/sec, respectively, based on lake volumes given in Stefan (1973). Sturgeon Lake alone had estimated retention times of 42.6 and 3.8 hours for the above flows.

tagged. Assuming that tags were observed and conscientiously reported, there is no reason to expect that the ratio of recaptured fish (R) to tagged fish (M) does not represent the rate of exploitation due to fishing in the region. Rate of exploitation (u) is given by Ricker (1975) as:

$$u = \frac{R}{M}$$

Having established u for the PINGP region, the distribution of the population to be estimated is determined by the distribution of the catch or sample taken for census (C). The sport fish catch in the 12-mile (1,601 hectares) PINGP study area (Section 4.3.5.1) is taken as C to estimate sport fish populations (N) in the same region. The formula for the Petersen method (Ricker 1975) is:

$$N = \frac{MC}{R} = \frac{C}{u}$$

These parameters are more specifically defined as follows:

N = total number of fish in the 12-mile study area from Sturgeon Lake to the headwaters of Lake Pepin

M = total number of fish tagged in 1974 and 1975 (total of 3,737 for all species) minus the number (92) of recaptures in 1974. In this case, data were treated as a single census by estimating the numbers of tagged fish at large in 1975. This approach provides a somewhat high estimate of tagged fish available in 1975 because natural mortality of fish tagged in 1974 is not accounted for.

C = sport catch of each species in the 12-mile study area. The fact that many of the tagged fish moved out of the study area does not affect the rate of recapture if it is assumed that all tagged fish were reported or that distance from the site did not affect degree of reporting.

In an electrofishing study of river carpsuckers, Behmer (1969) concluded that the Schnabel method gave a low estimate and the Peterson method (Ricker 1975) gave a maximum estimate of the population. Application of both methods gives a possible range which is expected to include the actual population size.

Ricker's (1958) formula for the Schnabel method for a multiple census is:

$$N = \frac{\Sigma(C_t M_t)}{R+1}$$

where

C_t = total catch on day t,

M_t = total tagged fish at large on day t,

R = total number of recaptures

For this analysis the formula is applied as:

$$N = \frac{CM_{1974} + CM_{1975}}{R_{1974\ \&\ 1975} + 1}$$

This formula gives a high estimate because many of the fish were not tagged until the summer of each year and therefore were less available for recapture.

Of the six assumptions needed to justify tag and recapture estimates (Ricker 1975), five were probably reasonably met: (1) marked and unmarked fish suffer the same mortality, (2) marked and unmarked fish are equally vulnerable to capture, (3) marked fish do not lose their marks, (4) marked fish become randomly mixed or at least disperse both upstream or downstream, (5) there is a negligible amount of recruitment to the population between tagging and recapturing, or at least recruitment is balanced by movement out of the area. Because the sixth assumption (that all tags are reported) may not be met, the population estimates may be somewhat high for the size ranges considered.

4.3.5.4 Trawl Studies

Fishes were trawled in the immediate PINGP plant area in 1973, and in North Lake and the intake and discharge area during the spring, summer and fall of 1974 and spring and fall of 1975 (Figure 4.3-6). In 1974 and 1975, a semi-balloon trawl having a 29 ft (8.8 m) footrope and 24 ft (7.3 m) headrope was trawled approximately 600 m (2000 ft) in 7 minutes at each station. Area sampled per tow (0.2788 ha or 0.689 acre) was calculated from an estimated effective sampling width of 15 ft times distance of tow. Efficiency of the trawl is assumed to be approximately 50 percent due

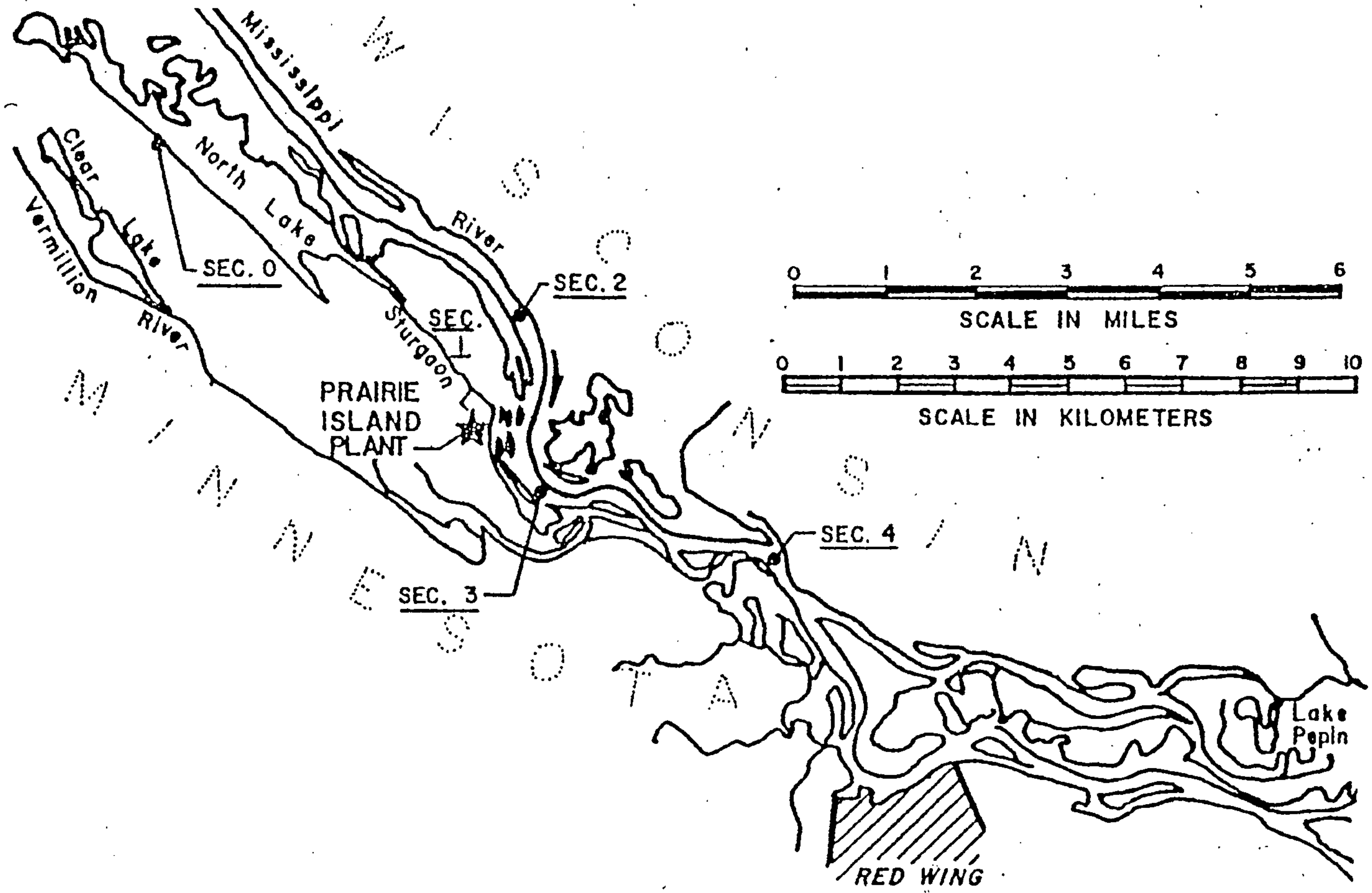


FIGURE 4.3-6

FISH STUDY AREAS NEAR PINGP, 1970-1975
(FROM GUSTAFSON ET AL. 1976)

to partial closing of the net and avoidance reaction to the net. A definitive efficiency factor is not available.

Fish trawling studies were conducted in the PINGP region during 1973-1975 (Table 4.3-15). Consistent sampling protocol during the last two years permitted calculation (described in Table 4.3-15) of standing crop in terms of number per hectare. Data for the three years can be directly compared in terms of catch per hour since number per hectare is approximately half of catch per hour in the 1974 and 1975 data.

In the pre-operational (1973) sampling of the plant area, catches were dominated by YOY (young-of-year) freshwater drum (88 percent), followed by YOY channel catfish, YOY gizzard shad, and carp. These species and several important sport fish species showed no decline in subsequent years and often showed much higher population densities than in 1973 when YOY were recruited into the populations near the plant.

Relatively large numbers of gizzard shad, white bass, white crappie, and black crappie in the North Lake samples were dominated by YOY. Thus, the habitats occurring in North Lake are more important as a nursery ground than those in the plant area.

98

TABLE 4.3-15

TRAWL CATCH OF FISHES IN NORTH LAKE AND PINGP PLANT AREA (INTAKE AND DISCHARGE) IN 1973 [a], 1974 [b], AND 1975 [b]. DENSITIES ROUNDED TO NEAREST WHOLE NUMBER.

Species	Plant area 1973	Plant area 1974			North Lake 1974			Plant area 1975		North Lake 1975	
	Catch/hour	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Fall	Spring	Fall
Shortnose gar							3				
Mooneye			8 [c]								
Goldeye			3 [c]								
Gizzard shad	19 [c]			27		248 [c]	326 [c]	1		258	618 [c]
Bigmouth buffalo				2					3	3	
Smallmouth buffalo			2	4	2	2		1		1	
Carpsucker spp.							3	2		2	
Shorthead redhorse	3									1	
Carp	6	15	24	20	2	4	3	5	7	2	11
River shiner								2			
Silver chub		7	3	13	24	4	3	1	3	1	
Pugnose minnow			16								
Emerald shiner		1				6	21			1	3
Spottail shiner					17		3			16	42
Bullhead minnow						2					
Channel catfish	84 [c]	1	32	2		11			3		
Tadpole madtom		1		1							
Northern pike	1										
Trout-perch		2	60	6	4	22	21	10	2	5	6
White bass	4		3	1	4	119 [c]	10	5		137	5
Bluegill							5				1
White crappie	4			2	2	144 [c]	334 [c]		2	10	49
Black crappie		1	5	1	2	22 [c]	18	4		3	35
Walleye	1	1		1	4		5	3			3
Sauger	1	5	5	1		4		4			
Freshwater drum	877 [c]	25	794 [c]	79	9	81 [c]	134	10	11	2	9
Total	1,000	59	955	160	70	669	889	48	31	442	782

[a] Catch/hour; data from Hawkinson (1974).
[b] Number/hectare; 1974 data from Naplin and Geis (1975),1975 data from Gustafson et al. (1976). Trawl had 29 ft. footrope and 24 ft. headrope. Single tow area calculated as 15 ft. width (to allow for partial closing of net and avoidance of trawl) times 2000 ft. per tow = 30,000 sq. ft. = 0.2788 hectares. Density times ~2 = catch/hour.
[c] Predominantly or entirely YOY.

Assuming that trawl samples were representative of the water bodies sampled, total population estimates can be calculated. Maximum densities observed during 1974 and 1975 were multiplied by surface areas given by Hawkinson (1974): 438 ha (1,082 acres) for North Lake and 83.4 ha (206 acres) for the plant area. Population estimates for certain dominant or important species are:

	Plant Area	North Lake
Gizzard Shad	2,252	270,684
Carp	2,002	4,818
Channel Catfish	2,669	4,818
White Bass	2,190	60,006
Crappies	417	154,176
Walleye	250	2,190
Sauger	417	1,752
Drum	66,220	58,692

The calculations represent low population estimates because these species are likely to concentrate in habitats that were not trawled (e.g., shallows, heavy beds of macroflora, other types of cover). Due to the pelagic nature of gizzard shad, many of them would be missed by bottom trawling. The estimate of six million gizzard shad in the 323.8 ha (800 acre) Sturgeon Lake during the late summer of 1973 (Andersen 1975) may be a more realistic standing crop.

4.3.5.5 Seining Studies

Seining studies have been conducted in the PINGP region from 1971 through 1975. A 100 ft (30.5 m) seine used in the early studies was replaced with a 50 ft (15.3 m) seine in 1974 and 1975. Area seined [300 sq m (3,228 sq ft)] was estimated from the length of the seine and the distance seined per tow in 1974 and 1975.

The 1971 and 1972 studies established the species composition and general distribution of the small species and YOY of the area.

Fish were seined near and above PINGP during the summer of 1973. Subsequently sampling was expanded to below Lock and Dam No. 3 during spring, summer and fall.

Seining data for 1974 (Table 4.3-16) and 1975 (Table 4.3-17) permit a comparison of the relative abundance of fishes along the shoreline in the three major study areas. Areas seined (Gustafson et al. 1976) were used to determine total number of fish per hectare.

Seine catches were highest in the tailwaters of Lock and Dam No. 3 in 1974, followed by the region above the plant and the immediate plant area. In these samples, species of

TABLE 4.3-16

SEINE CATCH IN THE PINGP REGION, 1974
(ADAPTED FROM NAPLIN AND GEIS 1975) (Sheet 1 of 2)

Species	Above Plant		Plant Area		Tailwaters of Lock and Dam 3		Total	
	No. of Fish	% Total	No. of Fish	% Total	No. of Fish	% Total	No. of Fish	% Total
Shortnose gar	-[a]	-	3	1.2	1	0.1	4	0.2
Gizzard shad (YY)	162	15.8	17	7.0	150	18.0	329	15.6
Gizzard shad (Other)	2	0.2	-	-	-	-	2	0.1
Bigmouth buffalo	-	--	-	-	1	0.1	1	0.1
Smallmouth buffalo	1	0.1	2	0.8	-	-	3	0.1
Carpsucker (YY)	3	0.3	6	2.5	-	-	9	0.4
Carpsucker (Other)	11	1.1	5	2.1	2	0.2	18	0.9
Shorthead redhorse	4	0.4	1	0.4	2	0.2	7	0.3
Carp (YY)	-	-	-	-	2	0.2	2	0.1
Carp (Other)	4	0.4	2	0.8	4	0.5	10	0.5
Silver chub	100	9.7	17	7.0	40	4.8	157	7.5
Notropis species	479	46.6	56	23.0	499	59.8	1034	49.2
Common shiner	8	0.8	1	0.4	-	-	9	0.4
Emerald shiner	181	17.6	15	6.2	264	31.6	460	21.9
Roseyface shiner	85	8.3	5	2.1	172	20.6	262	12.5
Spotfin shiner	26	2.5	3	1.2	-	-	29	1.4
River shiner	2	0.2	-	-	-	-	2	0.1
Spottail shiner	171	16.6	30	12.3	63	7.6	264	12.5
Mimic shiner	-	-	1	0.4	-	-	1	0.1
Blacknose shiner	6	0.6	1	0.4	-	-	7	0.3
Other minnows	32	3.1	47	19.3	7	0.8	86	4.1
Brassy minnow	-	-	-	-	1	0.1	1	0.1
Bullhead minnow	25	2.4	28	11.5	6	0.7	59	2.8
Bluntnose minnow	7	0.7	19	7.8	-	-	26	1.2
Channel catfish	8	0.8	1	0.4	-	-	9	0.4
Yellow bullhead	-	-	-	-	1	0.1	1	0.1
Northern pike	1	0.1	-	-	1	0.1	2	0.1
Trout perch	1	0.1	-	-	-	-	1	0.1
White bass (YY)	137	13.3	24	9.9	69	8.3	230	10.9
White bass (other)	9	0.9	12	4.9	5	0.6	26	1.2

[a] Hyph[illegible] (-) indicates no fish

TABLE 4.3-16 (Sheet 2 of 2)

Species	Above Plant		Plant Area		Tailwaters of Lock and Dam 3		Total	
	No. of Fish	% Total	No. of Fish	% Total	No. of Fish	% Total	No. of Fish	% Total
Yellow perch	3	0.3	-	-	1	0.1	4	0.2
Sauger (YY)	7	0.7	2	0.8	-	-	9	0.4
Sauger (Other)	2	0.2	2	0.8	4	0.5	8	0.4
Log perch	3	0.3	4	1.7	7	0.8	14	0.7
Johnny darter	2	0.2	5	2.1	1	0.1	8	0.4
Smallmouth bass	3	0.3	-	-	-	-	3	0.1
Green sunfish	-	-	4	1.7	-	-	4	0.2
Bluegill (YY)	10	1.0	9	3.7	-	-	19	0.9
Bluegill (Other)	-	-	1	0.4	6	0.7	7	0.3
Rock bass	1	0.1	2	0.8	-	-	3	0.1
White crappie (YY)	5	0.5	1	0.4	3	0.4	9	0.4
White crappie (Other)	1	0.1	2	0.8	3	0.4	6	0.3
Black crappie (YY)	14	1.4	4	1.7	12	1.4	30	1.4
Black crappie (Other)	1	0.1	3	1.2	3	0.4	7	0.3
Drum (YY)	19	1.9	11	4.5	9	1.1	39	1.9
Drum (Other)	2	0.2	-	-	2	0.3	4	0.2
Total	1027		243		835		2105	
Hectares seined	0.81		0.27		0.33		1.41	
Fish per hectare	1268		900		2530		1493	

TABLE 4.3-17

SEINE CATCH IN THE PINGP REGION, 1975
(FROM GUSTAFSON ET AL. 1976) (Sheet 1 of 2)

Species	Above plant		Plant area		Below Lock & Dam #3		Total	
	Number of fish	Percent of total	Number of fish	Percent of total	Number of fish	Percent of total	Number of fish	Percent of total
Longnose gar	1	0.08	-	-	-	-	1	0.04
Shortnose gar	2	0.16	-	-	-	-	2	0.09
Gar (unidentified)	-*	-	1	0.4	-	-	1	0.04
Bowfin	1	0.08	-	-	-	-	1	0.04
Gizzard shad	354	28.99	110	37.9	291	37.3	755	32.89
Northern pike	-	-	-	-	-	0.5	4	0.17
Carp	9	0.74	6	2.1	-	-	15	0.65
Brassy minnow	-	-	-	-	1	0.1	1	0.04
Silver chub	3	0.25	3	1.1	1	0.1	7	0.30
Emerald shiner	233	19.08	45	15.5	301	38.6	579	25.22
River shiner	11	0.90	-	-	-	-	11	0.47
Common shiner	1	0.08	-	-	-	-	1	0.04
Bigmouth shiner	1	0.08	-	-	-	-	1	0.04
Pugnose minnow	-	-	1	0.4	1	0.1	2	0.09
Spottail shiner	46	3.66	20	6.9	30	3.8	96	4.18
Red shiner	1	0.08	1	0.4	2	0.3	4	0.17
Rosyface shiner	17	1.47	1	0.4	2	0.3	20	0.87
Spotfin shiner	34	2.78	-	-	-	-	34	1.48
Redfin shiner	4	0.33	-	-	-	-	4	0.17
Mimic shiner	1	0.08	-	-	-	-	1	0.04
Bluntnose minnow	19	1.47	-	-	-	-	19	0.82
Bullhead minnow	22	1.80	11	3.8	8	1.0	41	1.78
Carpsucker spp.	77	6.14	-	-	-	-	77	3.35
Whitesucker	1	0.08	-	-	-	-	1	0.04
Smallmouth buffalo	15	1.23	2	0.7	-	-	17	0.74
Bigmouth buffalo	33	2.70	7	2.4	1	0.1	41	1.78
Shorthead redhorse	4	0.33	4	1.4	-	-	8	0.34
Bullhead spp.	-	-	2	0.7	-	-	2	0.09
Channel catfish	8	0.66	-	-	1	0.1	9	0.39

TABLE 4.3-17 (Sheet 2 of 2)

Species	Above plant		Plant area		Below Lock & Dam #3		Total	
	Number of fish	Percent of total	Number of fish	Percent of total	Number of fish	Percent of total	Number of fish	Percent of total
Tadpole madtom	3	0.25	-	-	-	-	3	0.13
Troutperch	-	-	-	-	7	0.9	7	0.30
White bass	223	18.26	29	10.0	107	13.8	359	15.65
Rock bass	-	-	2	0.7	-	-	2	0.09
Green sunfish	2	0.16	2	0.7	-	-	4	0.17
Bluegill	17	1.39	8	2.8	-	-	25	1.09
Smallmouth bass	5	0.41	-	-	-	-	5	0.21
White crappie	25	2.05	9	3.1	1	0.1	35	1.52
Black crappie	12	0.98	-	-	4	0.5	16	0.74
Crappie spp.	-	-	21	7.2	-	-	21 n.c.	0.91
Johnny darter	5	0.41	2	0.7	2	0.3	9	0.39
Yellow perch	4	0.33	2	0.7	-	-	6	0.26
Logperch	15	1.23	-	-	6	0.8	21	0.91
Sauger	11	0.90	-	-	3	0.4	14	0.61
Walleye	1	0.08	-	-	1	0.1	2	0.09
Freshwater drum	2	0.16	1	0.3	7	0.9	10	0.43
Total	1223	100.00	290	100.00	781	100.00	2294	100.00

* Hyphen (-) indicates no fish were caught.

Notropis (minnows) accounted for approximately half of the total numbers. The most abundant non-cyprinid YOY were gizzard shad (15.6 percent) and white bass (10.9 percent).

The 1975 catch was similar to that of 1974 in terms of species composition and relative numbers in the three regions. However, total standing crop estimates were higher in 1975.

Species of *Notropis* and YOY gizzard shad each comprised approximately one-third of the 1975 catch (Table 4.3-17). The dominant species of *Notropis* was the emerald shiner, as in 1974. YOY white bass were again a major component of the catch (15.6 percent).

Table 4.3-18 compares numbers of fishes seined at all stations during 1974 and 1975 and those sampled above Lock and Dam No. 3 in 1973. The tally excludes the older fish included in Tables 4.3-16 and 4.3-17 with the exception of minnows and darters.

The 1973 seine catches are not directly comparable to subsequent surveys because sampling was done at different times of the year and a larger seine was used in 1973 (Gustafson et al. 1976) The large catch of gizzard shad, carpsucker, white bass and freshwater drum YOY in 1973 may be attributable

TABLE 4.3-18

SEINE CATCH (NUMBER PER HECTARE) IN THE PINGP REGION, 1973-1975
(ADAPTED FROM GUSTAFSON ET AL. 1976)

Species	1973[a] 0.33 ha seined		1974[b] 1.41 ha seined		1975[b] 1.38 ha seined*	
	Number	No./ha	Number	No./ha	Number	No./ha
Longnose gar	-**	-	-	-	1	0.72
Shortnose gar	-	-	2	1.42	-	-
Bowfin	-	-	-	-	1	0.72
Gizzard shad	1729	5239.39	329	233.33	755	547.10
Northern pike	-	-	1	0.71	-	-
Carp	4	12.12	2	1.42	-	-
Minnows & darters	504	1527.27	1300	921.99	676	489.86
Smallmouth buffalo	-	-	3	2.13	17	12.32
Bigmouth buffalo	-	-	-	-	41	29.71
Carpsucker	98	296.97	9	6.38	77	55.80
White sucker	-	-	-	-	1	0.72
Shorthead redhorse	-	-	7	4.96	8	5.80
Bullheads	-	-	1	0.71	2	1.45
Channel catfish	-	-	9	6.38	-	-
Tadpole madtom	-	-	-	-	3	2.17
White bass	1523	4615.15	230	163.12	201	145.65
Sunfish	13	39.39	23	16.31	26	18.84
Crappies	22	66.67	39	27.66	72	52.17
Smallmouth bass	-	-	1	0.71	1	0.72
Yellow perch	-	-	8	5.67	6	4.35
Sauger	26	78.79	9	6.38	14	10.14
Walleye	-	-	-	-	2	1.45
Freshwater drum	100	303.03	39	27.66	10	7.25
Total	4019	12,178.79	2012	1426.95	1914	1386.96

* 1975 area is an estimate.

** Hyphen (-) indicates no fish were caught.

[a] 100 ft seine; summer

[b] 50 ft seine; spring, summer and fall

to the greater effectiveness of the larger seine and the fact that sampling was limited to the summer. However, a strong year class of gizzard shad in 1973 is also apparent from electrofishing studies (Section 4.3.5.6).

A comparison of the 1974 and 1975 data reveals a marked similarity in total catch and dominance by the same taxa. However, the data suggest stronger age classes of gizzard shad and suckers and a decline in the minnow/ darter component in 1975.

4.3.5.6 Electrofishing Studies

Electrofishing studies have been conducted in the PINGP region from 1970 to 1975. The earlier studies were limited in scope, but provide information on species composition which can be compared to more recent data. During the summer and fall of 1970, fish were sampled in Sturgeon Lake and tailwaters of Lock and Dam No. 3. Carp and white bass were the dominant species, followed by mooneye, walleye, black crappie, freshwater drum, and 11 other species (Table 4.3-19).

The 1971 survey from above Lock and Dam No. 3 yielded larger numbers of carp and fewer white bass than the 1970 survey. YOY gizzard shad were abundant in the late summer of 1971.

TABLE 4.3-19

ELECTROFISHING CATCH IN THE MISSISSIPPI RIVER
NEAR PINGP, 1970 AND 1971
(FROM MILLER 1971, 1972)

Species	1970[a] Summer	1970[a] Fall	1971[b] Early Summer	1971[b] Late Fall
Longnose gar			2	5
Shortnose gar	2	3	4	7
Bowfin		1		1
Gizzard shad			8	110[c]
Mooneye	20	14	1	1
Northern pike			1	1
Carp	68	41	170	166
Silver chub			1	4
American eel				1
Weed shiner				1
White sucker				4
Carpsucker spp.			8	7
Smallmouth buffalo	3	4		
Bigmouth buffalo		2	2	
Silver redhorse		3		
Shorthead redhorse			10	16
Yellow bullhead		1		
Channel catfish	2	2		3
White bass	68	41	29	18
Rock bass		3	1	6
Green sunfish			1	
Bluegill				5
Smallmouth bass	3	5		11
Largemouth bass	3	3		
White crappie			2	2
Black crappie	6	9	8	7
Sauger	1	4	12	33
Walleye	4	17	9	14
Freshwater drum	9	6	6	17

[a] Data for above and below Lock and Dam No. 3 combined, total catch given; from Miller (1971)

[b] Sturgeon Lake and Mississippi River above Lock and Dam No. 3, total catch; from Miller (1972)

[c] Predominantly or entirely YOY

Electrofishing surveys were conducted from 1973 to 1975 in the Mississippi River above PINGP, in the plant area, and below the plant at stations described by Hawkinson (1974). Stations above the plant include locations in North Lake, Sturgeon Lake, Brewer Lake, and the main river channel. Stations sampled in the plant area were located in the main channel above Lock and Dam No. 3, in the intake and discharge areas, and in several sloughs in the area. Below the plant, sampling was conducted in the tailwaters of Lock and Dam No. 3 and in the main and back channels to the Highway 63 bridges.

Table 4.3-20 presents summer electrofishing catches for 1973 in terms of total numbers and catch per hour. YOY gizzard shad dominated the catches in all three regions and were most abundant in the tailwaters. YOY of carpsucker, black crappie, and freshwater drum were also commonly caught. Larger sport fishes were most commonly caught in the tail-waters of the lock and dam.

Electrofishing catches for 1974 and 1975 are presented by season to permit an analysis of the temporal variability as related to recruitment of young fishes (Tables 4.3-21 through 4.3-26). Data are summarized for major species in Table 4.3-27. For 1974 and 1975, the number of fish per kilometer is roughly equivalent to catch per hour times 0.75.

TABLE 4.3-20

ELECTROFISHING CATCH IN THE MISSISSIPPI RIVER
NEAR PINGP, 1973
(FROM HAWKINSON 1974)

Species	Above Plant (1.25 hours) No.	Above Plant (1.25 hours) Catch/hour	Plant Area (2.75 hours) No.	Plant Area (2.75 hours) Catch/hour	Tailwaters below Lock and Dam No. 3 (1.5 hours) No.	Tailwaters below Lock and Dam No. 3 (1.5 hours) Catch/hour
American eel			1	0.36		
Gizzard shad	1191[a]	317.60	619[a]	225.09	412[a]	274.67
Mooneye	1	0.27				
Northern pike	*				8	5.33
Carp	69	18.40	45	16.36	17	11.33
Carpsucker spp.	24[a]	6.40	43[a]	15.64	1	0.67
Smallmouth buffalo			1	0.36		
Bigmouth buffalo			2	0.73		
Silver redhorse					1	0.67
Shorthead redhorse	17[a]	4.53			8	5.33
Channel catfish	5	1.33				
Flathead catfish	1	0.27	1	0.36		
White bass	16	4.27	9	3.27	66	44.00
Rock bass	15	4.00	27	9.82	36	24.00
Green sunfish	7	1.87	9	3.27	6	4.00
Pumpkinseed	1	0.27			3	2.00
Bluegill	8	2.13	158	57.45	30	20.00
Smallmouth bass			20	7.27	52	34.67
Largemouth bass					2	1.33
White crappie	6	1.60	22	8.00		
Black crappie	6	1.60	111[a]	40.36	7	4.67
Yellow perch	3	0.80	3[a]	1.09		
Sauger	16	4.27	11	4.00	41	27.33
Walleye	9	2.40	8	2.91		
Freshwater drum	59	15.73	101[a]	36.73	3	2.00

[a]Predominately YOY

*Space indicates no fish were caught

TABLE 4.3-21

ELECTROFISHING CATCH IN THE PINGP REGION, SPRING, 1974 [a]
(FROM NAPLIN AND GEIS 1975)

Species	Above Plant		Plant Area		Below Lock & Dam 3	
	No.	Catch/Hour (7.5 Hours)	No.	Catch/Hour (2.5 Hours)	No.	Catch/Hour (2.5 Hours)
Silver lamprey	-*	-	-	-	-	-
Shortnose gar	2	0.27	-	-	-	-
Longnose gar	-	-	-	-	-	-
Bowfin	1	0.13	-	-	-	-
Mooneye	3	0.40	-	-	-	-
Goldeye	-	-	-	-	-	-
Gizzard shad	-	-	1	0.40	-	-
Bigmouth buffalo	3	0.40	2	0.80	4	1.60
Smallmouth buffalo	-	-	-	-	1	0.40
Carpsucker spp.	62	8.27	3	1.20	1	0.40
White sucker	-	-	-	-	2	0.80
Silver redhorse	2	0.27	-	-	1	0.40
Shorthead redhorse	53	7.07	17	6.80	24	9.60
Carp	214	28.53	152	60.80	73	29.20
Silver chub	24	3.20	2	0.80	-	-
Pugnose minnow	-	-	-	-	-	-
Golden minnow	-	-	1	0.40	-	-
Common shiner	-	-	-	-	-	-
Emerald shiner	28	3.73	-	-	2	0.80
Rosyface shiner	10	1.33	-	-	2	0.80
Spotfin shiner	-	-	-	-	-	-
Spottail shiner	-	-	1	0.40	-	-
Silvery minnow	-	-	-	-	-	-
Fathead minnow	-	-	-	-	-	-
Bullhead minnow	1	0.13	-	-	-	-
Bluntnose minnow	3	0.40	-	-	-	-
Channel catfish	6	0.80	4	1.60	1	0.40
Flathead catfish	-	-	-	-	-	-
Northern pike	5	0.67	1	0.40	5	2.00
White bass	76	10.13	12	4.80	97	38.80
Yellow perch	3	0.40	-	-	-	-
Sauger	36	4.80	8	3.20	30	12.00
Walleye	7	0.93	1	0.40	17	6.80
Log perch	-	-	-	-	-	-
Smallmouth bass	20	2.67	3	1.20	9	3.60
Largemouth bass	-	-	1	0.40	-	-
Green sunfish	2	0.27	-	-	-	-
Pumpkinseed	-	-	3	1.20	-	-
Bluegill	15	2.00	5	2.00	17	6.80
Hybrid sunfish	-	-	-	-	-	-
Rock bass	17	2.27	8	3.20	45	18.00
White crappie	-	-	-	-	1	0.40
Black crappie	2	0.27	1	0.40	6	2.40
Freshwater drum	68	9.07	11	4.40	25	10.00
Burbot	-	-	-	-	-	-

[a] Catch/hour X 0.75 = Fish/km

*Hyphen indicates no fish were caught

TABLE 4.3-22

ELECTROFISHING CATCH IN THE PINGP REGION, SUMMER, 1974
(FROM NAPLIN AND GEIS 1975)

	Above Plant		Plant Area		Below Lock & Dam 3	
	No.	Catch/Hour (7.5 Hours)	No.	Catch/Hour (2.5 Hours)	No.	Catch/Hour (2.5 Hours)
Silver lamprey	-	-	-	-	-	-
Shortnose gar	-	-	3	1.20	-	-
Longnose gar	-	-	1	0.40	-	-
Bowfin	2	0.27	-	-	-	-
Mooneye	-	-	-	-	1	0.40
Goldeye	-	-	-	-	-	-
Gizzard shad [a]	140	18.67	152	60.80	54	21.60
Bigmouth buffalo	1	0.13	1	0.40	5	2.00
Smallmouth buffalo	2	0.27	6	2.40	1	0.40
Carpsucker spp.	27	3.60	7	2.80	4	1.60
White sucker	-	-	-	-	-	-
Silver redhorse	-	-	-	-	-	-
Shorthead redhorse	23	3.07	18	7.20	20	8.00
Carp	139	18.53	121	48.40	67	26.80
Silver chub	19	2.53	5	2.00	2	0.80
Pugnose minnow	-	-	-	-	-	-
Golden minnow	-	-	-	-	-	-
Common shiner	-	-	-	-	-	-
Emerald shiner	25	3.33	2	0.80	16	6.40
Rosyface shiner	8	1.07	8	3.20	4	1.60
Spotfin shiner	-	-	-	-	-	-
Spottail shiner	4	0.53	-	-	-	-
Silvery minnow	-	-	-	-	-	-
Fathead minnow	-	-	1	0.40	-	-
Bullhead minnow	2	0.27	2	0.80	-	-
Bluntnose minnow	-	-	-	-	-	-
Channel catfish	4	0.53	24	9.60	4	1.60
Flathead catfish	1	0.13	2	0.80	1	0.40
Northern pike	2	0.27	-	-	4	1.60
White bass [a]	69	9.20	96	38.40	112	44.80
Yellow perch	8	1.07	6	2.40	-	-
Sauger	32	4.27	18	7.20	25	10.00
Walleye	6	0.80	-	-	9	3.60
Log perch	5	0.67	5	2.00	3	1.20
Smallmouth bass	27	3.60	21	8.40	27	10.80
Largemouth bass	-	-	1	0.40	5	2.00
Green sunfish	1	0.13	41	16.40	3	1.20
Pumpkinseed	-	-	-	-	-	-
Bluegill	25	3.33	252	100.80	202	80.80
Hybrid sunfish	-	-	3	1.20	3	1.20
Rock bass	2	0.27	54	21.60	34	13.60
White crappie	-	-	1	0.40	-	-
Black crappie	4	0.53	11	4.40	6	2.40
Freshwater drum [a]	76	10.13	76	30.40	12	4.80
Burbot	-	-	1	0.40	2	0.80

a Predominantly YOY

TABLE 4.3-23

ELECTROFISHING CATCH IN PINGP REGION, FALL, 1974
(FROM NAPLIN AND GEIS 1975)

Species	Above Plant		Plant Area		Below Lock & Dam 3	
	No.	Catch/Hour (7.5 Hours)	No.	Catch/Hour (2.5 Hours)	No.	Catch/Hour (2.5 Hours)
Silver lamprey	-	-	-	-	2	0.80
Shortnose gar	3	0.40	-	-	-	-
Longnose gar	1	0.13	-	-	-	-
Bowfin	-	-	-	-	-	-
Mooneye	2	0.27	-	-	-	-
Goldeye	-	-	-	-	-	-
Gizzard shad[a]	540	72.00	388	152.20	100	40.00
Bigmouth buffalo	-	-	-	-	-	-
Smallmouth buffalo	-	-	-	-	-	-
Carpsucker spp.	9	1.20	-	-	-	-
White sucker	2	0.27	-	-	1	0.40
Silver redhorse	-	-	-	-	-	-
Shorthead redhorse	11	1.47	6	2.40	7	2.80
Carp	96	12.80	35	14.00	181	72.40
Silver chub	25	3.33	6	2.40	2	0.80
Pugnose minnow	3	0.40	-	-	-	-
Golden minnow	-	-	-	-	-	-
Common shiner	1	0.13	-	-	-	-
Emerald shiner	6	0.80	1	0.40	2	0.80
Rosyface shiner	3	0.40	3	1.20	-	-
Spotfin shiner	1	0.13	-	-	-	-
Spottail shiner	16	2.13	4	1.60	1	0.40
Silvery minnow	1	0.13	-	-	-	-
Fathead minnow	-	-	-	-	-	-
Bullhead minnow	3	0.40	10	4.00	-	-
Bluntnose minnow	2	0.27	-	-	-	-
Channel catfish	2	0.27	1	0.40	4	1.60
Flathead catfish	-	-	1	0.40	-	-
Northern pike	4	0.53	-	-	5	2.00
White bass	47	6.27	16	6.40	41	16.40
Yellow perch	7	0.93	3	1.20	1	0.40
Sauger	7	0.93	2	0.80	8	3.20
Walleye	15	2.00	2	0.80	15	6.00
Log perch	4	0.53	1	0.40	1	0.40
Smallmouth bass	36	4.80	11	4.40	14	5.60
Largemouth bass	-	-	6	2.40	25	10.00
Green sunfish	11	1.47	50	20.00	9	3.60
Pumpkinseed	-	-	-	-	-	-
Bluegill	52	6.93	342	136.80	275	110.00
Hybrid sunfish	1	0.13	8	3.20	1	0.40
Rock bass	9	1.20	52	20.80	14	5.60
White crappie	12	1.60	12	4.80	-	-
Black crappie	16	2.13	9	3.60	14	5.60
Freshwater drum	47	6.27	4	1.60	2	0.80
Burbot	-	-	-	-	-	-

a Predominantly YOY

TABLE 4.3-24

ELECTROFISHING CATCH IN PINGP REGION, SPRING, 1975
(FROM GUSTAFSON ET AL. 1976)

Species	Above Plant		Plant Area		Below Lock & Dam 3	
	No.	Catch/Hour (7.5 Hrs.)	No.	Catch/Hour (2.5 Hours)	No.	Catch/Hour (2.5 Hours)
Longnose gar	1	0.13	-	-	-	-
Shortnose gar	1	0.13	-	-	-	-
Gizzard shad	5	0.67	-	-	-	-
Mooneye	1	0.13	-	-	-	-
Northern pike	1	0.13	2	0.80	1	0.40
Carp	147	19.60	28	11.20	30	12.00
Silver chub	12	1.60	1	0.40	-	-
Emerald shiner	61	8.13	7	2.80	48	19.20
River shiner	-*	-	4	1.60	-	-
Pugnose minnow	4	0.53	-	-	-	-
Spottail shiner	3	0.40	1	0.40	-	-
Red shiner	1	0.13	2	0.80	-	-
Rosyface shiner	4	0.53	-	-	-	-
Spotfin shiner	-	-	4	1.60	-	-
Redfin shiner	1	0.13	-	-	-	-
Bluntnose minnow	2	0.27	1	0.40	-	-
Bullhead minnow	1	0.13	12	4.80	-	-
Carpsucker spp.	8	1.07	2	0.80	1	0.40
Smallmouth buffalo	2	0.27	1	0.40	1	0.40
Bigmouth buffalo	1	0.13	1	0.40	-	-
Silver redhorse	-	-	-	-	1	0.40
Shorthead redhorse	31	4.13	22	8.80	3	1.20
Channel catfish	8	1.07	4	1.60	-	-
Flathead catfish	-	-	2	0.80	1	0.40
White bass	35	4.67	16	6.40	20	8.00
Rock bass	7	0.93	10	4.00	6	2.40
Green sunfish	-	-	6	2.40	-	-
Pumpkinseed	-	-	3	1.20	-	-
Bluegill	6	0.80	5	2.00	2	0.80
Smallmouth bass	20	2.67	17	6.80	5	2.00
White crappie	2	0.27	-	-	-	-
Black crappie	3	0.40	1	0.40	3	1.20
Yellow perch	1	0.13	1	0.40	-	-
Logperch	-	-	-	-	1	0.40
Sauger	32	4.27	4	1.60	8	3.20
Walleye	19	2.53	2	0.80	14	5.60
Freshwater drum	63	8.40	7	2.80	17	6.80
Total	482	64.27	167	66.80	162	64.80

* Hyphen (-) indicates no fish were caught.

TABLE 4.3-25

ELECTROFISHING CATCH IN PINGP REGION, SUMMER, 1975
(FROM GUSTAFSON ET AL. 1976)

Species	Above Plant No.	Above Plant Catch/Hour (7.5 Hours)	Plant Area No.	Plant Area Catch/Hour (2.5 Hours)	Below Lock & Dam 3 No.	Below Lock & Dam 3 Catch/Hour (2.5 Hours)
Silver lamprey	-*	-	-	-	1	0.40
Longnose gar	1	0.13	-	-	-	-
Bowfin	1	0.13	-	-	-	-
Gizzard shad	226	30.13	57	22.80	29	11.60
Mooneye	-	-	-	-	1	0.40
Northern pike	4	0.53	-	-	1	0.40
Carp	97	12.93	44	17.60	38	15.20
Silver chub	20	2.67	4	1.60	2	0.80
Emerald shiner	52	6.93	2	0.80	75	30.00
Spottail shiner	6	0.80	1	0.40	-	-
Rosyface shiner	33	0.40	1	0.40	14	5.60
Spotfin shiner	2	0.27	-	-	-	-
Redfin shiner	3	0.40	-	-	1	0.40
Bluntnose minnow	4	0.53	4	1.60	2	0.80
Fathead minnow	-	-	1	0.40	-	-
Bullhead minnow	9	1.20	10	4.00	-	-
Carpsucker ssp.	27	3.60	3	1.20	4	1.60
Smallmouth buffalo	6	0.80	12	4.80	-	-
Bigmouth buffalo	-	-	1	0.40	-	-
Silver redhorse	1	0.13	-	-	1	0.40
Shorthead redhorse	25	3.33	-	-	18	7.20
Black bullhead	1	0.13	2	0.80	17	6.80
Channel catfish	5	0.67	3	1.20	4	1.60
Flathead catfish	3	0.40	1	0.40	3	1.20
Burbot	-	-	-	-	1	0.40
White bass	37	4.93	17	6.80	114	45.60
Rock bass	11	1.47	11	4.40	21	8.40
Green sunfish	3	0.40	16	6.40	6	2.40
Pumpkinseed	2	0.27	-	-	1	0.40
Bluegill	22	2.93	37	14.80	71	28.40
Smallmouth bass	28	3.73	14	5.60	55	22.00
Largemouth bass	-	-	-	-	4	1.60
White crappie	-	-	2	0.80	-	-
Black crappie	4	0.53	2	0.80	4	1.60
Johnny darter	1	0.13	-	-	-	-
Yellow perch	32	4.27	3	1.20	1	0.40
Log perch	17	2.27	1	0.40	4	1.60
Sauger	38	5.07	3	1.20	6	2.40
Walleye	22	2.93	4	1.60	20	8.00
Drum	66	8.80	8	3.20	5	2.00
Total	809	107.87	274	109.60	524	209.60

* Hyphen (-) indicates no fish were caught.

TABLE 4.3-26

ELECTROFISHING CATCH IN PINGP REGION, FALL, 1975
(FROM GUSTAFSON ET AL. 1976)

Species	Above Plant No.	Above Plant Catch/Hour (7.5 Hours)	Plant Area No.	Plant Area Catch/Hour (2.5 Hours)	Below Lock & Dam 3 No.	Below Lock & Dam 3 Catch/Hour (2.5 Hours)
Silver lamprey	1	0.13	-	-	1	0.40
Longnose gar	-*	-	2	0.80	-	-
Gizzard shad	325	4.33 [a]	121	48.40	165	66.00
Mooneye	1	0.13	-	-	3	1.20
Northern pike	2	0.27	-	-	2	0.80
Carp	61	8.13	47	18.80	63	25.20
Silver chub	15	2.00	-	-	2	0.80
Emerald shiner	121	16.13	31	12.40	106	42.40
Spottail shiner	5	0.67	-	-	-	-
Bullhead minnow	13	1.73	18	7.20	-	-
Carpsucker spp.	3	0.40	3	1.20	-	-
Smallmouth buffalo	2	0.27	3	1.20	-	-
Silver redhorse	-	-	-	-	2	0.80
Shorthead redhorse	9	1.20	4	1.60	31	12.40
Yellow bullhead	-	-	-	-	1	0.40
Channel catfish	-	-	6	2.40	5	2.00
Trout perch	3	0.40	-	-	-	-
Burbot	-	-	-	-	1	0.40
White bass	17	2.27	36	14.40	44	17.60
Rock bass	4	0.53	12	4.80	28	11.20
Green sunfish	2	0.27	2	0.80	6	2.40
Bluegill	71	9.47	30	12.00	70	28.00
Smallmouth bass	15	2.00	14	5.60	17	6.80
Largemouth bass	1	0.13	3	1.20	2	0.80
White crappie	-	-	3	1.20	-	-
Black crappie	17	2.27	2	0.80	8	3.20
Johnny darter	1	0.13	-	-	-	-
Yellow perch	6	0.80	2	0.80	-	-
Log perch	2	0.27	3	1.20	-	-
Sauger	24	3.20	5	2.00	18	7.20
Walleye	28	3.73	17	6.80	37	14.80
Drum	22	2.93	6	2.40	3	1.20
Total	771	102.80	360	144.00	615	245.60

* Hyphen (-) indicates no fish were caught.

[a] Probably should be 43.3

TABLE 4.3-27

ELECTROFISHING CATCH (NUMBER/HOUR) OF MAJOR FISH SPECIES IN THE MISSISSIPPI RIVER NEAR PINGP, 1974 AND 1975[a]

Species	Spring			Summer			Fall		
	Above Plant	Plant Area	Below Lock	Above Plant	Plant Area	Below Lock	Above Plant	Plant Area	Below Lock
1974									
Gizzard shad		0.4		18.7[b]	60.8[b]	21.6[b]	72.0[b]	152.2[b]	40.0[b]
Carpsucker	8.3	1.2	0.4	3.6	2.8	1.6	1.2		
Shorthead redhorse	7.1	6.8	9.6	3.1	7.2	8.0	1.5	2.4	2.8
Carp	28.5	60.8	29.2	18.5	48.4	26.8	12.8	14.0	72.4
Channel catfish	0.8	1.6	0.4	0.5	9.6	1.6	0.3	0.4	1.6
Northern pike	0.7	0.4	2.0	0.3		1.6	0.5		2.0
White bass	10.1	4.8	38.8	9.2[b]	38.4[b]	44.8[b]	6.3	6.4	16.4
Sauger	4.8	3.2	12.0	4.3	7.2	10.0	0.9	0.8	3.2
Walleye	0.9	0.4	6.8	0.8		3.6	2.0	0.8	6.0
Smallmouth bass	2.7	1.2	3.6	3.6	8.4	10.8	4.8	4.4	5.6
Bluegill	2.0	2.0	6.8	3.3	100.8	80.8	6.9	136.8	110.0
Black crappie	0.3	0.4	2.4	0.5	4.4	2.4	2.1	3.6	5.6
Freshwater drum	9.1	4.4	10.0	10.1[b]	30.4[b]	4.8[b]	6.3	1.6	0.8
1975									
Gizzard shad	0.7			30.1	22.8	11.6	43.3	48.4	66.0
Carpsucker	1.1	0.8	0.4	3.6	1.2	1.6	0.4	1.2	
Shorthead redhorse	4.1	8.8	1.2	3.3		7.2	1.2	1.6	12.4
Carp	19.6	11.2	12.0	12.9	17.6	15.2	8.1	18.8	25.2
Channel catfish	1.1	1.6		0.7	1.2	1.6		2.4	2.0
Northern pike	0.1	0.8	0.4	0.5		0.4	0.3		0.8
White bass	4.7	6.4	8.0	4.9	6.8	45.6	0.5	4.8	11.2
Sauger	4.3	1.6	3.2	5.1	1.2	2.4	3.2	2.0	7.2
Walleye	2.5	0.8	5.6	2.9	1.6	8.0	3.7	6.8	14.8
Smallmouth bass	2.7	6.8	2.0	3.7	5.6	22.0	2.0	5.6	6.8
Bluegill	0.8	2.0	0.8	2.9	14.8	28.4	9.5	12.0	28.0
Black crappie	0.4	0.4	1.2	0.5	0.8	1.6	2.3	0.8	3.2
Freshwater drum	8.4	2.8	6.8	8.8	3.2	2.0	2.9	2.4	1.2

[a] From Naplin and Geis (1975) and Gustaf[illegible] et al. (1976)

Gizzard shad was the most commonly caught fish in both years although very few were caught in the spring. These were predominantly YOY. An unusually strong year class of YOY gizzard shad was apparent in 1973 (Table 4.3-20).

Carp was the dominant rough fish in collections during both years. The largest catches were taken below the dam in the fall each year. Concentration in the plant area was apparent in 1974 but not in 1975.

White bass was the most commonly caught sport fish and many YOY were collected during the summer. The largest catches were taken below the dam in the summer.

Walleye and sauger were collected in all areas sampled, with the highest catch rate occurring below the dam. The catch of these species was lowest in the plant area during both sampling years. Preference for the tailwaters is apparent from a creel survey (Naplin and Gustafson 1975) as well as from this study.

The smallmouth bass and black crappie are two additional sport fishes that were generally most abundant below the dam. The highest catch rate of smallmouth bass (22 per hour) occurred below the lock in the summer of 1975.

Electrofishing studies were also conducted during the night in October of 1974 and summer and fall of 1975. Lower night-time catch rates of gizzard shad, bluegill, and smallmouth bass, in comparison to daytime catches, were partially attributable to reduced visibility. However, catches of walleye, sauger, and white bass were highest at night.

4.3.5.7 Trap Netting Studies

Trap nets were fished experimentally in Pool 4 in 1957 and 1963 (Anonymous 1964). Both studies were performed at approximately the same time of year and at the same locations.

In 1957 the most abundant fish were walleye, black crappie, bluegill, white bass, carp, freshwater drum, and shorthead redhorse. The 1963 catch was similar except that walleye and carp catches had declined and northern pike and white crappie catches were higher.

Fish were trap netted in the PINGP area from 1970 to 1975. Fyke nets were used during 1970 and 1972. A trap net described by Krosch (1968) was used subsequently. Nets were fished in 24-hour sets. Sampling was limited to August in 1973 (Hawkinson 1974) and expanded to spring, summer, and fall in subsequent years.

Table 4.3-28 indicates a dominance of carp, shorthead redhorse, white bass, crappies, sauger, and freshwater drum in 1970, 1972 and 1973. The higher 1973 catches may be attributable to using a more effective net.

Trap net data for 1974 and 1975 are presented in Tables 4.3-29 through 4.3-34 and summary Tables 4.3-35 and 4.3-36. For the 1973-1975 sampling period, the summer catch per lift of fishes above the plant was highest during 1974 when large numbers of carp and white bass were collected. In the plant area, the summer catch per lift was also highest in 1974, with freshwater drum and carp dominating the catch. Additional studies will be needed to assess possible population trends.

Total catch per net of major species was highest above the plant except during the spring when large numbers of carp and freshwater drum were collected below Lock and Dam No. 3. Catches of major sport fishes (white bass, walleye, sauger) were generally highest above the plant although these fish are known to concentrate in the tailwaters in the spring (Section 4.3.5.1). None of the major species demonstrated a clear preference for the plant area.

TABLE 4.3-28

TRAP NETTING CATCH IN THE MISSISSIPPI RIVER NEAR PINGP IN 1970[a], 1972[b] AND 1973[c] (Sheet 1 of 2)

	Above and Below Lock Down No.3						
	1970[a]	1972[b]		Plant Area 1973[c]		Above Plant 1973[c]	
	No.	No.	Catch/lift (52 lifts)	No.	Catch/lift (70 lifts)	No.	Catch/lift (40 lifts)
Longnose gar				3	0.04	3	0.08
Shortnose gar				64	0.96	62	1.55
Bowfin	1			7	0.10	7	0.18
Gizzard shad	2			11	0.16	7	0.18
Mooneye				1	0.01	1	0.02
Northern pike	9			61	0.87	48	1.20
Carp	68	128	2.46	282	3.74	134	3.35
Carpsucker				15	0.21	14	0.35
White sucker				4	0.06		
Smallmouth buffalo	1			13	0.19	12	0.30
Bigmouth buffalo				2	0.03	2	0.05
Silver redhorse	25			2	0.03	1	0.02
Shorthead redhorse	22			110	1.57	87	2.18
Greater redhorse	2						
Yellow bullhead				1	0.01	1	0.02
Brown bullhead				2	0.03		
Channel catfish	4			5	0.07	3	0.08
Flathead	1						
White bass	22	90	1.73	231	3.30	198	4.95
Rock bass	1			10	0.14	6	0.15
Bluegill	1	28	0.54	19	0.27	9	0.22
Pumpkinseed				1	0.01	1	0.02
Largemouth bass	4						
White crappie	1	54	1.03	6	0.09	3	0.08
Black crappie	3	25	0.48	61	0.87	43	1.08
Yellow perch				1	0.01	1	0.02
Sauger	1	20	0.38	123	1.76	80	2.00
Walleye	3			24	0.34	19	0.48
Drum	8	26	0.50	202	2.89	78	1.95

TABLE 4.3-28 (Sheet 2 of 2)

[a]From Miller 1971. Total catch in fall with fyke nets.

[b]From Miller 1973. Catch of dominant species with fyke nets in August.

[c]From Hawkinson 1974. Summer catch with trap nets. Above plant data for North, Sturgeon, and Brewer lakes.

TABLE 4.3-29

TRAP NET CATCH IN PINGP REGION, SPRING, 1974
(FROM NAPLIN AND GEIS 1975)

Species	Above Plant No.	Above Plant Catch/Lift for 20 lifts	Plant Area No.	Plant Area Catch/Lift for 10 lifts	Below Lock & Dam 3 No.	Below Lock & Dam 3 Catch/Lift for 10 lifts
Silver lamprey	-	-	-	-	-	-
Shortnose gar	20	1.00	2	0.20	-	-
Longnose gar	21	1.05	-	-	-	-
Bowfin	2	0.10	-	-	-	-
Mooneye	2	0.10	-	-	-	-
Goldeye	-	-	-	-	-	-
Gizzard shad	2	0.10	-	-	-	-
Bigmouth buffalo	4	0.20	1	0.10	-	-
Smallmouth buffalo	1	0.05	-	-	-	-
Carpsucker spp.	4	0.20	-	-	1	0.10
White sucker	2	0.10	2	0.20	-	-
Spotted sucker	-	-	-	-	-	-
Silver redhorse	5	0.25	1	0.10	-	-
Shorthead redhorse	39	1.95	17	1.70	2	0.20
River redhorse	1	0.05	-	-	-	-
Carp	132	6.60	70	7.00	69	6.90
Channel catfish	1	0.05	-	-	1	0.10
Black bullhead	1	0.05	1	0.10	-	-
Brown bullhead	-	-	-	-	-	-
Yellow bullhead	-	-	-	-	-	-
Flathead catfish	-	-	1	0.10	1	0.10
Northern pike	40	2.00	-	-	1	0.10
American eel	-	-	-	-	-	-
White bass	217	10.85	30	3.00	64	6.40
Yellow perch	-	-	1	0.10	-	-
Sauger	26	1.30	5	0.50	2	0.20
Walleye	10	0.50	3	0.30	2	0.20
Smallmouth bass	-	-	-	-	-	-
Largemouth bass	-	-	-	-	-	-
Bluegill	1	0.05	1	0.10	1	0.10
Rock bass	2	0.10	3	0.30	5	0.50
White crappie	1	0.05	5	0.50	1	0.10
Black crappie	22	1.10	-	-	5	0.50
Freshwater drum	67	3.35	70	7.00	148	14.80
Burbot	-	-	-	-	1	0.10

TABLE 4.3-30

TRAP NET CATCH IN PINGP REGION, SUMMER, 1974 (FROM NAPLIN AND GEIS 1975)

Species	Above Plant No.	Above Plant Catch/Lift for 20 Lifts	Plant Area No.	Plant Area Catch/Lift for 10 Lifts	Below Lock & Dam 3 No.	Below Lock & Dam 3 Catch/Lift for 10 Lifts
Silver lamprey	-	-	1	0.10	-	-
Shortnose gar	41	2.05	6	0.60	3	0.30
Longnose gar	4	0.20	1	0.10	-	-
Bowfin	8	0.40	-	-	3	0.30
Mooneye	4	0.20	1	0.10	-	-
Goldeye	1	0.05	-	-	-	-
Gizzard shad	1	0.05	-	-	-	-
Bigmouth buffalo	2	0.10	-	-	-	-
Smallmouth buffalo	-	-	-	-	2	0.20
Carpsucker spp.	13	0.65	2	0.20	-	-
White sucker	3	0.15	-	-	2	0.20
Spotted sucker	-	-	-	-	-	-
Silver redhorse	11	0.55	-	-	-	-
Shorthead redhorse	100	5.00	29	2.90	8	0.80
River redhorse	-	-	-	-	-	-
Carp	152	7.60	81	8.10	65	6.50
Channel catfish	1	0.05	2	0.20	-	-
Black bullhead	-	-	2	0.20	-	-
Brown bullhead	-	-	1	0.10	-	-
Yellow bullhead	-	-	-	-	-	-
Flathead catfish	1	0.05	-	-	-	-
Northern pike	36	1.80	5	0.50	23	2.30
American eel	1	0.05	-	-	1	0.10
White bass	146	7.30	12	1.20	24	2.40
Yellow perch	-	-	-	-	-	-
Sauger	23	1.15	-	-	3	0.30
Walleye	11	0.55	1	0.10	2	0.20
Smallmouth bass	-	-	1	0.10	-	-
Largemouth bass	-	-	-	-	1	0.10
Bluegill	10	0.50	2	0.20	1	0.10
Rock bass	6	0.30	3	0.30	-	-
White crappie	4	0.20	6	0.60	2	0.20
Black crappie	55	2.75	2	0.20	13	1.30
Freshwater drum	107	5.35	110	11.00	27	2.70
Burbot	-	-	-	-	-	-

TABLE 4.3-31

TRAP NET CATCH IN PINGP REGION, FALL, 1974
(FROM NAPLIN AND GEIS 1975)

Species	Above Plant		Plant Area		Below Lock & Dam 3	
	No.	Catch/Lift for 20 Lifts	No.	Catch/Lift for 10 Lifts	No.	Catch/Lift for 10 Lifts
Silver lamprey	-	-	-	-	-	-
Shortnose gar	58	2.90	1	0.10	1	0.10
Longnose gar	-	-	-	-	1	0.10
Bowfin	1	0.05	-	-	-	-
Mooneye	1	0.05	-	-	-	-
Goldeye	-	-	-	-	-	-
Gizzard shad	1	0.05	-	-	-	-
Bigmouth buffalo	8	0.40	-	-	-	-
Smallmouth buffalo	2	0.10	1	0.10	-	-
Carpsucker spp.	4	0.20	1	0.10	-	-
White sucker	1	0.05	-	-	2	0.20
Spotted sucker	-	-	-	-	1	0.10
Silver redhorse	4	0.20	-	-	1	0.10
Shorthead redhorse	66	3.30	13	1.30	1	0.10
River redhorse	-	-	-	-	-	-
Carp	64	3.20	64	6.40	50	5.00
Channel catfish	-	-	-	-	-	-
Black bullhead	1	0.05	7	0.70	-	-
Brown bullhead	-	-	1	0.10	-	-
Yellow bullhead	-	-	1	0.10	-	-
Flathead catfish	2	0.10	-	-	1	0.10
Northern pike	15	0.75	1	0.10	1	0.10
American eel	-	-	-	-	-	-
White bass	315	15.75	47	4.70	23	2.30
Yellow perch	-	-	-	-	-	-
Sauger	22	1.10	7	0.70	9	0.90
Walleye	8	0.40	-	-	4	0.40
Smallmouth bass	1	0.05	-	-	-	-
Largemouth bass	-	-	-	-	-	-
Bluegill	29	1.45	19	1.90	12	1.20
Rock bass	3	0.15	4	0.40	-	-
White crappie	5	0.25	2	0.20	2	0.20
Black crappie	25	1.25	19	1.90	62	6.20
Freshwater drum	28	1.40	21	2.10	31	3.10
Burbot	-	-	-	-	1	0.10

TABLE 4.3-32

TRAP NET CATCH IN PINGP REGION, SPRING, 1975
(FROM GUSTAFSON ET AL. 1976)

Species	Above Plant		Plant Area		Below Lock & Dam 3	
	No.	Catch/lift 36 lifts	No.	Catch/lift 20 lifts	No.	Catch/lift 16 lifts
Longnose gar	2	0.06	-	-	-	-
Shortnose gar	22	0.61	7	0.35	-	-
Bowfin	8	0.22	-	-	3	0.19
Gizzard shad	1	0.03	-	-	-	-
Mooneye	-*	-	-	-	-	-
Northern pike	36	1.00	3	0.15	4	0.25
Carp	123	3.42	68	3.40	117	7.31
Carpsucker	6	0.17	3	0.15	-	-
White sucker	3	0.08	1	0.05	2	0.13
Smallmouth buffalo	1	0.03	-	-	-	-
Bigmouth buffalo	-	-	2	0.10	-	-
Silver redhorse	-	-	-	-	-	-
Shorthead redhorse	33	0.95	10	0.50	6	0.38
Black bullhead	2	0.06	1	0.05	6	0.38
Brown bullhead	-	-	-	-	-	-
Channel catfish	2	0.06	3	0.15	-	-
Flathead catfish	-	-	-	-	-	-
White bass	106	2.94	15	0.75	37	2.31
Rock bass	4	0.11	2	0.10	3	0.19
Bluegill	9	0.25	7	0.35	1	0.06
Smallmouth bass	-	-	-	-	-	-
White crappie	5	0.14	7	0.35	2	0.13
Black crappie	31	0.86	5	0.25	9	0.56
Yellow perch	-	-	-	-	1	0.06
Sauger	11	0.31	6	0.30	4	0.25
Walleye	8	0.22	2	0.10	7	0.44
Drum	35	0.97	57	2.85	146	9.13

* Hyphen (-) indicates no fish were caught.

TABLE 4.3-33

TRAP NET CATCH IN PINGP REGION, SUMMER, 1975
(FROM GUSTAFSON ET AL. 1976)

Species	Above Plant		Plant Area		Below Lock & Dam 3	
	No.	Catch/lift 36 lifts	No.	Catch/lift 20 lifts	No.	Catch/lift 16 lifts
Longnose gar	13	0.36	4	0.20	-	-
Shortnose gar	64	1.78	9	0.45	3	0.19
Bowfin	22	0.61	-	-	3	0.19
Gizzard shad	-*	-	-	-	-	-
Mooneye	7	0.19	-	-	2	0.13
Northern pike	78	2.17	1	0.05	22	1.38
Carp	168	4.67	52	2.60	75	4.69
Carpsucker	15	0.42	3	0.15	-	-
White sucker	1	0.03	-	-	4	0.25
Smallmouth buffalo	18	0.50	3	0.15	-	-
Bigmouth buffalo	32	0.89	1	0.05	-	-
Silver redhorse	5	0.14	-	-	2	0.13
Shorthead redhorse	44	1.22	4	0.20	2	0.13
Black bullhead	-	-	4	0.20	1	0.06
Brown bullhead	-	-	-	-	1	0.06
Channel catfish	1	0.03	-	-	-	-
Flathead catfish	2	0.06	6	0.30	1	0.06
White bass	138	3.83	28	1.40	13	0.81
Rock bass	-	-	1	0.05	1	0.06
Bluegill	13	0.36	1	0.05	4	0.25
Smallmouth bass	1	0.03	-	-	-	-
White crappie	9	0.25	10	0.50	10	0.63
Black Crappie	174	4.83	19	0.95	19	1.19
Yellow perch	1	0.03	1	0.05	-	-
Sauger	15	0.42	3	0.15	2	0.13
Walleye	5	0.14	-	-	6	0.38
Drum	47	1.31	53	2.65	36	2.25

* Hyphen (-) indicates no fish were caught.

TABLE 4.3-34

TRAP NET CATCH IN PINGP REGION, FALL, 1975
(FROM GUSTAFSON ET AL. 1976)

Species	Above Plant		Plant Area		Below Lock & Dam 3	
	No.	Catch/lift 36 lifts	No.	Catch/lift 20 lifts	No.	Catch/lift 16 lifts
Longnose gar	-*	-	1	0.05	-	-
Shortnose gar	34	0.94	-	-	-	-
Bowfin	7	0.19	-	-	3	0.19
Gizzard shad	27	0.75	4	0.20	2	0.13
Mooneye	-	-	-	-	1	0.06
Northern pike	17	0.47	3	0.15	7	0.44
Carp	83	2.31	13	0.65	22	1.38
Carpsucker	8	0.22	-	-	-	-
White sucker	1	0.03	-	-	1	0.06
Smallmouth buffalo	2	0.06	2	0.10	-	-
Bigmouth buffalo	1	0.03	-	-	-	-
Silver redhorse	11	0.31	1	0.05	-	-
Shorthead redhorse	31	0.81	10	0.50	-	-
Black bullhead	-	-	-	-	-	-
Brown bullhead	-	-	-	-	-	-
Channel catfish	-	-	-	-	-	-
Flathead catfish	-	-	1	0.05	-	-
White bass	341	9.47	21	1.05	15	0.94
Rock bass	1	0.03	-	-	2	0.13
Bluegill	15	0.42	15	0.75	10	0.63
Smallmouth bass	-	-	-	-	-	-
White crappie	7	0.19	22	1.10	8	0.50
Black crappie	52	1.44	14	0.70	78	4.88
Yellow perch	6	0.17	2	0.10	-	-
Sauger	27	0.75	6	0.30	7	0.44
Walleye	15	0.42	2	0.10	-	-
Drum	73	2.03	21	1.05	-	-

* Hyphen (-) indicates no fish were caught.

TABLE 4.3-35

TRAP NETTING CATCH OF MAJOR SPECIES IN PINGP REGION, 1974.
NUMBERS ARE CATCH PER 24-HOUR SET ROUNDED TO NEAREST WHOLE NUMBER.

	1974								
	Spring			Summer			Fall		
	Above Plant	Plant Area	Below Lock	Above Plant	Plant Area	Below Lock	Above Plant	Plant Area	Below Lock
Shortnose gar	1	0	0	2	1	0	3	0	0
Shorthead redhorse	2	2	0	5	3	1	3	1	0
Carp	7	7	7	8	8	7	3	6	5
Northern pike	2	0	0	2	1	2	1	0	0
White bass	11	3	6	7	1	2	16	5	2
Sauger	1	1	0	1	0	0	1	1	1
Walleye	1	0	0	1	0	0	0	0	0
Black crappie	1	0	1	3	0	1	1	2	6
Freshwater drum	3	7	15	5	11	3	1	2	3
Total	28	20	29	34	25	16	29	17	17

TABLE 4.3-36

TRAP NETTING CATCH OF MAJOR SPECIES IN PINGP REGION, 1975
NUMBERS ARE CATCH PER 24-HOUR SET ROUNDED TO NEAREST WHOLE NUMBER.

	1975								
	Spring			Summer			Fall		
	Above Plant	Plant Area	Below Lock	Above Plant	Plant Area	Below Lock	Above Plant	Plant Area	Below Lock
Shortnose gar	1	0	0	2	0	0	1	0	0
Shorthead redhorse	1	1	0	1	0	0	1	1	0
Carp	3	3	7	5	3	5	2	1	1
Northern pike	1	0	0	2	0	1	0	0	0
White bass	3	1	2	4	1	1	9	1	1
Sauger	0	0	0	0	0	0	1	0	0
Walleye	0	0	0	0	0	0	0	0	0
Black crappie	1	0	1	5	1	1	1	1	5
Freshwater drum	1	3	9	1	3	2	2	1	0
Total	11	8	19	20	8	10	17	5	7

4.3.5.8 Gill Net Studies

Fish populations were studied in the PINGP region by sampling with gill nets from 1972 to 1975 (Tables 4.5-37 through 4.3-39). An experimental gill net having dimensions of 250 ft x 6 ft (76 x 1.8 m) and mesh (stretch) of 1-1/2, 2, 2-1/2, 3 and 4 inches (3.8, 5, 6.4, 7.6, 10.2 cm) was used (Hawkinson 1974). Lifts were made at 24-hour intervals.

Gill netting data permit some assessment of temporal and spatial distribution of fishes. Sauger dominated the 1972 catch. The 1973 program yielded more species in the lakes above the plant (18) than in the plant area (11) and showed highest population densities in the lakes above the plant area for several species (e.g., gizzard shad, white bass, and possibly walleye).

The spring catches of 1974 and 1975 were dominated by carp, sauger, white bass, shorthead redhorse, and shortnose gar. Major species were fairly evenly distributed with the exception of longnose gar, walleye, and crappies which were most abundant above the plant. No preference for the plant area was apparent for any species in 1974 and 1975.

TABLE 4.3-37

FISH CATCH IN GILL NETS IN PINGP REGION, 1972[a] AND 1973[b]

	1972		1973			
			Above plant		Plant area	
	No.	Catch/lift	No.	Catch/lift	No.	Catch/lift
Shortnose gar			2	0.13		
Longnose gar			1	0.06		
Goldeye			8	0.50		
Mooneye			2	0.13		
Gizzard shad	14	0.50	757[c]	47.31	35[c]	11.67
Northern pike	14	0.50	14	0.88	1	0.33
Carp	14	0.50	14	0.88	4	1.33
Carpsucker			4	0.25	3[c]	1.00
Smallmouth buffalo			3[c]	0.19		
Shorthead redhorse			10	0.63	1	0.33
Channel catfish			23	1.44	2	0.67
White bass	15	0.54	103	6.44	1	0.33
Rock bass			2	0.13	1	0.33
Black crappie			4	0.25		
Yellow perch			1	0.06		
Sauger	163	5.82	120	7.50	19	6.33
Walleye	11	0.39	42	2.63	3	1.00
Freshwater drum	10	0.36	24[c]	1.75	15[c]	5.00

[a]Miller 1973; 28 gill nets; fall; region not given; only dominant species listed

[b]Hawkinson 1974; summer; North, Sturgeon and Brewer Lakes

[c]Predominantly or entirely YOY

TABLE 4.3-38

GILL NET CATCH IN PINGP REGION, SPRING AND FALL, 1974
(FROM NAPLIN AND GEIS 1975)

	SPRING				FALL			
	Above Plant		Plant Area		Above Plant		Plant Area	
Species	No.	Catch/Lift (for 20 Lifts)	No.	Catch/Lift (for 5 Lifts)	No.	Catch/Lift (for 20 Lifts)	No.	Catch/Lift (for 5 Lifts)
Shortnose gar	21	1.05	6	1.20	58	2.90	-	-
Longnose gar	19	0.95	-	-	2	0.10	-	-
Bowfin	1	0.05	-	-	2	0.10	-	-
Mooneye	2	0.10	-	-	7	0.35	-	-
Goldeye	-	-	-	-	4	0.20	2	0.40
Gizzard shad	1	0.05	1	0.20	602	30.10	117	23.40
Bigmouth buffalo	2	0.10	-	-	1	0.05	-	-
Smallmouth buffalo	-	-	-	-	14	0.70	2	0.40
Carpsucker spp.	1	0.05	-	-	-	-	1	0.20
White sucker	1	0.05	-	-	1	0.05	-	-
Shorthead redhorse	34	1.70	6	1.20	27	1.35	9	1.80
Carp	112	5.60	37	7.40	110	5.50	12	2.40
Channel catfish	7	0.35	1	0.20	18	0.90	6	1.20
Black bullhead	1	0.05	-	-	-	-	-	-
Brown bullhead	-	-	-	-	1	0.05	-	-
Yellow bullhead	-	-	-	-	-	-	1	0.20
Northern pike	17	0.85	6	1.20	19	0.95	4	0.80
White bass	38	1.90	16	3.20	249	12.45	45	9.00
Yellow perch	-	-	-	-	6	0.30	9	1.80
Sauger	96	4.80	9	1.80	140	7.00	31	6.20
Walleye	18	0.90	1	0.20	37	1.85	2	0.40
Smallmouth bass	1	0.05	1	0.20	-	-	-	-
Bluegill	-	-	-	-	1	0.05	-	-
Rock bass	2	0.10	4	0.80	2	0.10	-	-
White crappie	1	0.05	1	0.20	18	0.90	8	1.60
Black crappie	5	0.25	4	0.80	26	1.30	8	1.60
Freshwater drum	13	0.65	2	0.40	21	1.05	1	0.20

TABLE 4.3-39

GILL NET CATCH IN PINGP REGION, SPRING AND FALL, 1975
(FROM GUSTAFSON ET AL. 1976)

	SPRING				FALL			
	Above Plant		Plant Area		Above Plant		Plant Area	
	No.	Catch/lift 16 lifts	No.	8 lifts	No.	Catch/lift 16 lifts	No.	Catch/lift 8 lifts
Shortnose gar	48	3.00	29	3.63	-	-	1	0.13
Longnose gar	26	1.63	-	-	-	-	-	-
Bowfin	6	0.38	-	-	14	0.88	-	-
Gizzard shad	45	2.81	24	3.00	874	54.63	562	70.25
Goldeye	1	0.06	2	0.25	12	0.75	-	-
Mooneye	5	0.31	-	-	5	0.31	2	0.25
Northern pike	26	1.63	5	0.63	30	0.31	2	0.25
Carp	108	6.75	66	8.25	36	2.25	18	2.25
Silver chub	1	0.06	-	-	-	-	-	-
Carpsucker	5	0.31	1	0.13	2	0.13	8	1.00
Smallmouth buffalo	2	0.13	2	0.25	4	0.25	5	0.63
Bigmouth buffalo	-*	-	-	-	1	0.06	1	0.13
Silver redhorse	1	0.06	-	-	-	-	-	-
Shorthead redhorse	23	1.43	29	3.63	14	0.88	10	1.25
Black bullhead	2	0.13	22	2.75	1	0.06	4	0.50
Brown bullhead	-	-	-	-	-	-	1	0.13
Channel catfish	14	0.88	13	1.63	20	1.25	6	0.75
Burbot	-	-	-	-	1	0.06	-	-
White bass	48	3.00	16	2.00	48	3.00	27	3.38
Rock bass	3	0.19	1	0.13	1	0.06	-	-
Bluegill	1	0.06	-	-	2	0.13	1	0.13
Smallmouth bass	1	0.06	-	-	-	-	-	-
White crappie	2	0.13	9	1.13	9	0.56	5	0.63
Black crappie	3	0.19	4	0.50	19	1.19	2	0.25
Yellow perch	3	0.19	1	0.13	1	0.06	4	0.50
Sauger	49	3.06	43	5.38	136	8.50	105	13.13
Walleye	22	1.38	2	0.25	25	1.56	15	1.88
Drum	17	1.06	8	0.50	5	0.31	6	0.75

* Hyphen (-) indicates no fish were caught.

During the fall of 1974 and 1975 the same species were dominant except that the shortnose gar had declined and gizzard shad was highly dominant. There was no apparent preference of dominant species for either of the regions when both years of data are considered.

An analysis of population level trends is hampered by variability of sampling stations and the inherent sampling error which results from variability of weather and sampling conditions. However, catch-per-lift data for sport fishes (northern pike, white bass, crappies, sauger, walleye) have remained stable or have generally increased during the study period.

4.3.5.9 Summary of Fish Studies

Tagging studies show that sport fishes move on the average of 18 to 53 miles (29-85 km) or more upstream and downstream in a single year. Therefore, the populations affected by PINGP are highly mixed and very large in comparison to the "populations" estimated for the PINGP region.

Assessment of population trends during 1973-1975 is complicated by variation in sampling procedures and conflicting results with different types of sampling gear. Relatively large seine catches of YOY of gizzard shad, white bass, and freshwater drum in 1973 may be attributable to sampling exclusively in the summer or to size of seine used. A strong 1973 year class of gizzard shad was also apparent from electrofishing catches, but not from trawl catches.

Trawl, electrofishing, and gill net catches indicate that the major sport fish (walleye, sauger, white bass) maintained their levels in the plant region during 1973-1975 and generally throughout the study area. A relatively high abundance of sauger below the lock and dam in 1973 was apparent from electrofishing and seine data, but not from trawl or gill net data.

Seasonal changes in populations result primarily from recruitment and mortality of YOY. Year-to-year variability is determined primarily by differences in year-class strengths. Both types of population fluctuation were parallel in all three study areas.

4.3.5.10 Spawning and Nursery Potential

Adult fish which have been reported to occur in the vicinity of PINGP can be assumed to spawn in the area also. A variety of habitats are utilized for spawning and early development.

A large number of species (e.g., shortnose gar, gizzard shad, northern pike, carp, catfish) that occur near the generating plant prefer backwater areas, sloughs, or flooded vegetated lowlands with minimal current for spawning. Areas of this nature provide protection from predation, prevent downstream displacement of eggs and/or larvae by river currents, and may contain a rich zooplankton food supply which may be critical in the early development period. Pool 3 appears to contain an abundance of such habitats.

Species such as white sucker, spotted sucker, silver redhorse, shorthead redhorse, sauger, and walleye prefer to spawn in swift-flowing water where the substrate varies from rock to gravel. The water currents in such areas provide a means of downstream dispersal for larvae and juveniles. This movement balances the upstream migration of these species. Areas of this habitat type are limited in the main or secondary channels in the vicinity of PINGP. However, walleye and sauger will spawn in rivers and lakes on substrates ranging from small stones to rock riprap along shore where wave action can prevent the eggs from being silted over.

Other fish, including mooneye, goldeye, and freshwater drum, produce eggs which are non-adhesive and buoyant. Eggs of this type aid in downstream dispersal. This group of fish may utilize the main channel or backwater areas of Pool 3 for spawning purposes.

In general, it appears that most species of fish that inhabit Pool 3 in the vicinity of PINGP prefer shallow backwater areas, where currents are minimal, for spawning activities. These species generally produce eggs which are demersal and adhesive in nature and are not commonly found in the water column and are therefore less susceptible to entrainment. The young of these species are also probably most abundant in backwater and shallow shore zone areas of the river. The young of other species, including carp, sauger, walleye, white sucker, black crappie, and white crappie, can be expected to occur throughout the water column and in deeper waters.

4.3.5.11 Spawning and Life History Information

Spawning and life history information for major species occurring in the PINGP region are given in Appendix 2. This information is useful in assessing the impact of PINGP on the production of fish stocks.

5 INTAKE-RELATED STUDIES

5.1 INTRODUCTION

Entrainment and impingement are the two major sources of intake impact for large water users such as PINGP. In order to assess the impact of plant intakes, EPA (1976b) has outlined a suggested program of monitoring for entrainment and impingement. Northern States Power Company has conducted several years of intake related studies at PINGP; the most recent studies include extensive impingement and entrainment programs that are similar to those recommended in the current draft guidelines (EPA 1976b). The following sections summarize the methods and results of these studies.

The following section, as well as Section 6, often uses Sturgeon Lake as a basis for comparison to plant intake effects. This will be especially true for entrainment effects. Baker (1975) demonstrated that, in spite of the dredged channel leading to the main channel of the Mississippi River, the source of plant water was largely, if not entirely, from Sturgeon Lake. While Sturgeon Lake is not totally isolated from the Mississippi River, it is sufficiently protected from main channel flow (see Section 4.1) that it tends to have a somewhat lentic character (see Section 4.3).

5.2 METHODS USED FOR INTAKE RELATED STUDIES

5.2.1 Entrainment-related Studies

5.2.1.1 Phytoplankton

The effects of entrainment on phytoplankton productivity were studied by Baker (1974, 1975). Productivity was measured using "light" and "dark" bottles suspended for 2 to 4 hours during midday at a depth of 25 cm (10 in.). Different studies were conducted to determine (among other things) the source of plant water, the effects of entrainment on phytoplankton and the overall effects of the plant on river productivity. To accomplish these goals, nine sampling stations were used: three in Sturgeon Lake, four in the main channel, one in the intake canal between the bubble curtain and the skimmer wall, and one in the discharge canal at the discharge gates (Figure 5.2-1). The entrainment studies were conducted from July to December 1974 and from May to October 1975.

The effects of entrainment on phytoplankton standing crop were investigated using chlorophyll a and mass of suspended particulates. Chlorophyll a was measured by spectrophotometric analyses of samples filtered through 0.45 micron pore membrane filters and extracted with 90 percent acetone saturated with magnesium carbonate. Pigment concentration

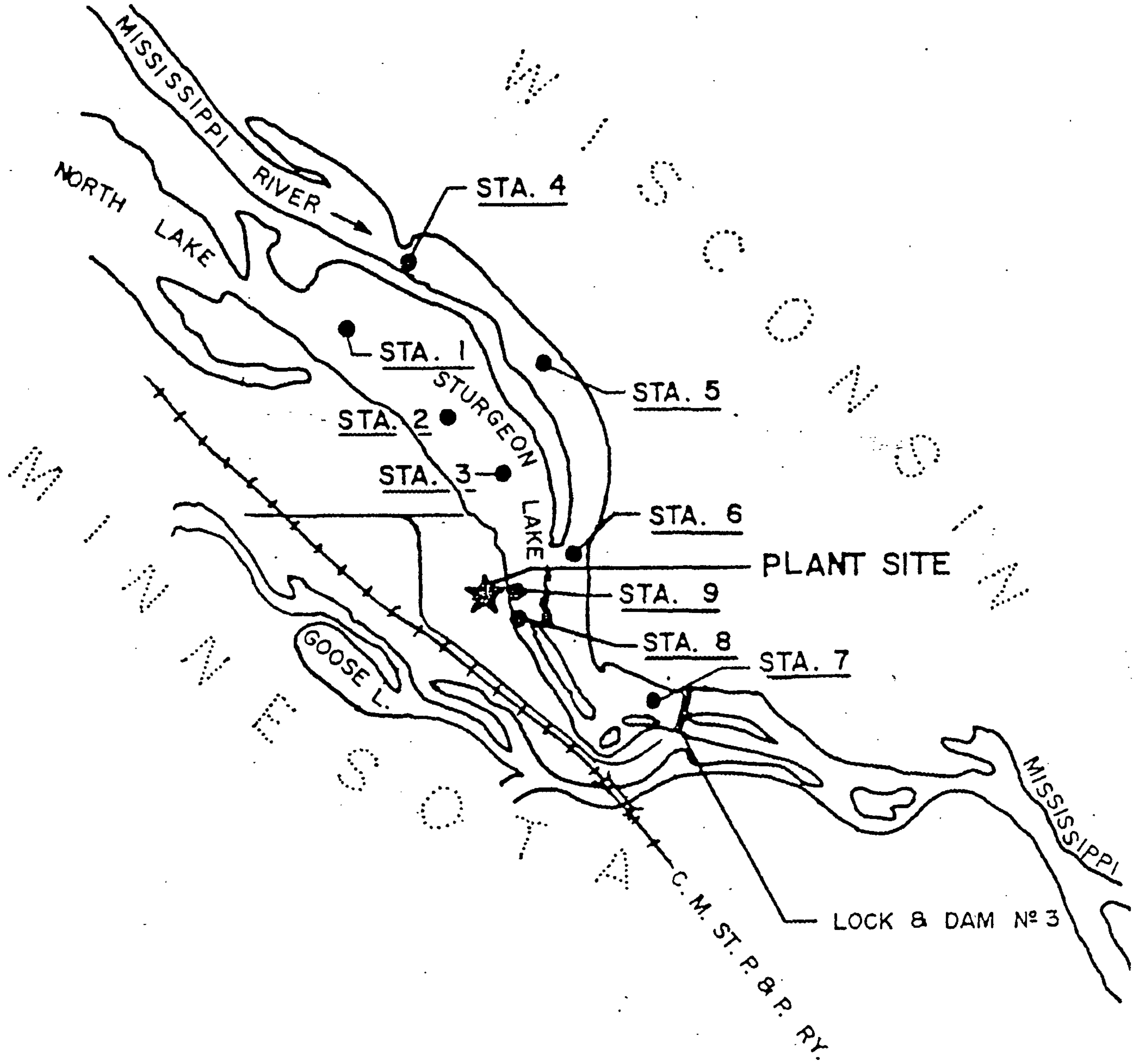


FIGURE 5.2-1

SAMPLING STATIONS FOR PHYTOPLANKTON PRODUCTIVITY, 1975
(FROM BAKER 1976)

was calculated using Lorenzen's (1967) formulae. Suspended particle mass was determined by filtration into pre-weighed membrane filters (0.45 micron pore size), desiccation and weighing.

To measure the degradation of entrained phytoplankton in 1975 studies, Baker (1976) used:

$$((I-D)/I) \times 100$$

where I = value in intake sample and D = value in discharge sample, resulting in a percentage of degradation.

Baker and Baker (1975, 1976) studied phytoplankton from 18 stations, including stations in the intake and discharge canals of PINGP (Figure 5.2-2). Samples were preserved in Lugol's, sedimented, and counted and identified using an inverted microscope with a 50X oil immersion objective. Organisms (filaments, colonies) were counted as units. Cell volumes were calculated and used to compute the biovolume contribution of each species. Results of these studies were used to evaluate the cumulative effect of plant passage and heated effluent on phytoplankton and can be considered a good measure of the significance of entrainment effects on the main channel phytoplankton.

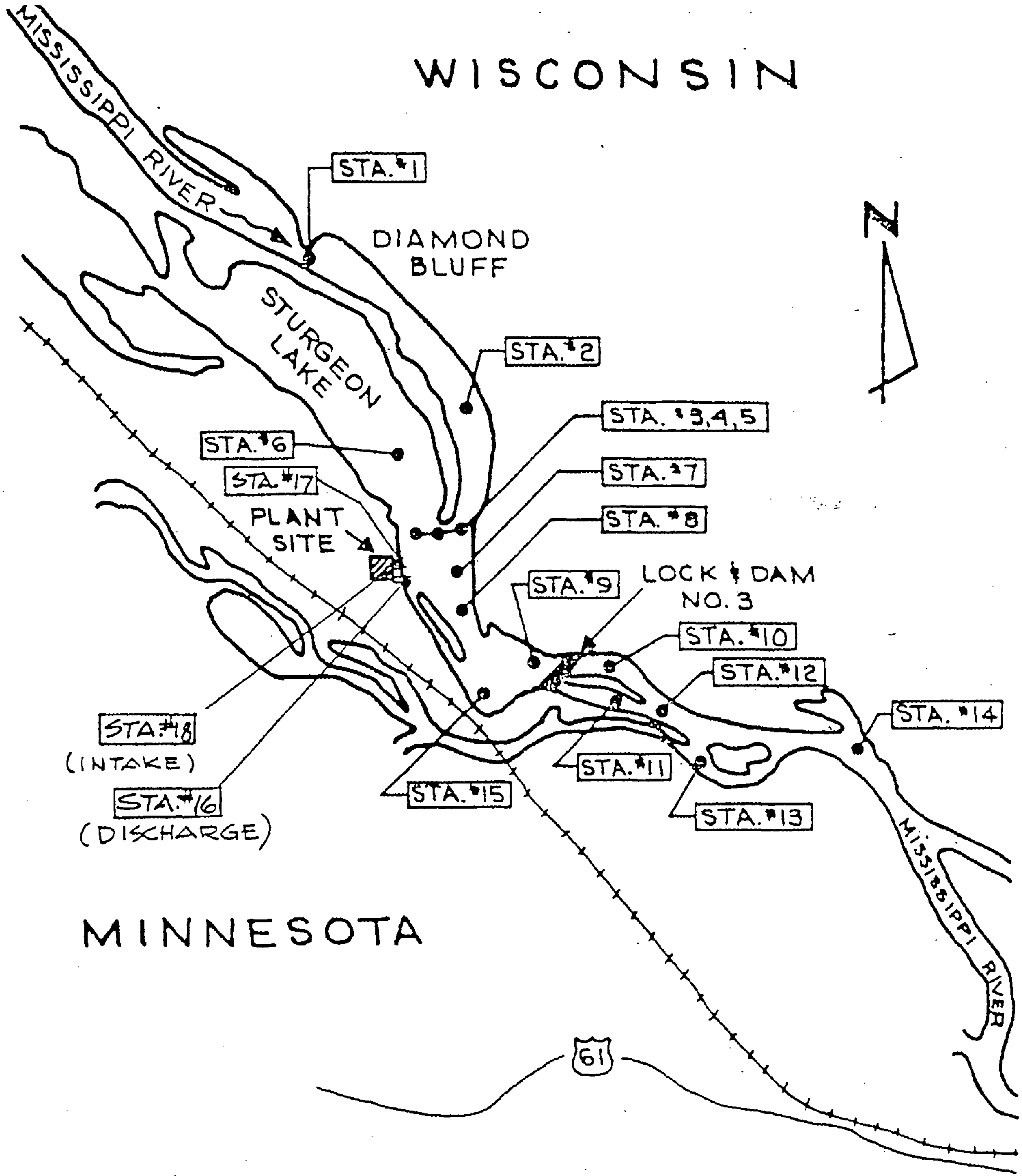


FIGURE 5.2-2

SAMPLING STATIONS FOR PHYTOPLANKTON STUDIES, 1974-1975
(FROM BAKER AND BAKER 1975-1976)

5.2.1.2 Zooplankton

Middlebrook's (1975, 1976) studies on zooplankton entrainment used a pump to obtain samples, which were then concentrated through a 64 micron net submersed in a tank. Samples were collected monthly from July 1974 through December 1974 (except August) and from June 1975 through May 1976 (except July). Collections were taken in the intake canal immediately outside the skimmer wall and in the discharge canal immediately outside the discharge gates.

Samples were taken to the laboratory where they were portioned into two subsamples, one to be counted in live condition and one preserved in formalin. The "live" samples were immediately studied and all organisms exhibiting no external or internal movement were considered dead and were enumerated. The number of "dead" organisms was subtracted from total organism counts made from preserved samples to determine the proportion that had been living at the time of collection. Counts were made in Sedgwick-Rafter cells and adjusted for volume sampled and prepared to provide organisms per liter. Organisms were grouped into Copepoda and copepodites, nauplii, Cladocera and Rotifera.

Counts of organisms from the intake and discharge canals were compared using the Students two-tailed t-test. When mortality was significant, confidence limits were determined.

To determine the effects of total plant operation (including intake effects) Szluha (1975) evaluated zooplankton of the recycle canal, discharge area and other areas in proximity to the plant (Figure 5.2-3). Samples were collected in Van Dorn bottles, filtered through a Wisconsin net and counted in a Sedgwick-Rafter cell. ANOVA analyses were used to determine differences in zooplankton among the collection stations and what effect PINGP had on zooplankton near the plant. Daggett (1976) conducted similar studies using nine sampling stations (Figure 5.2-4).

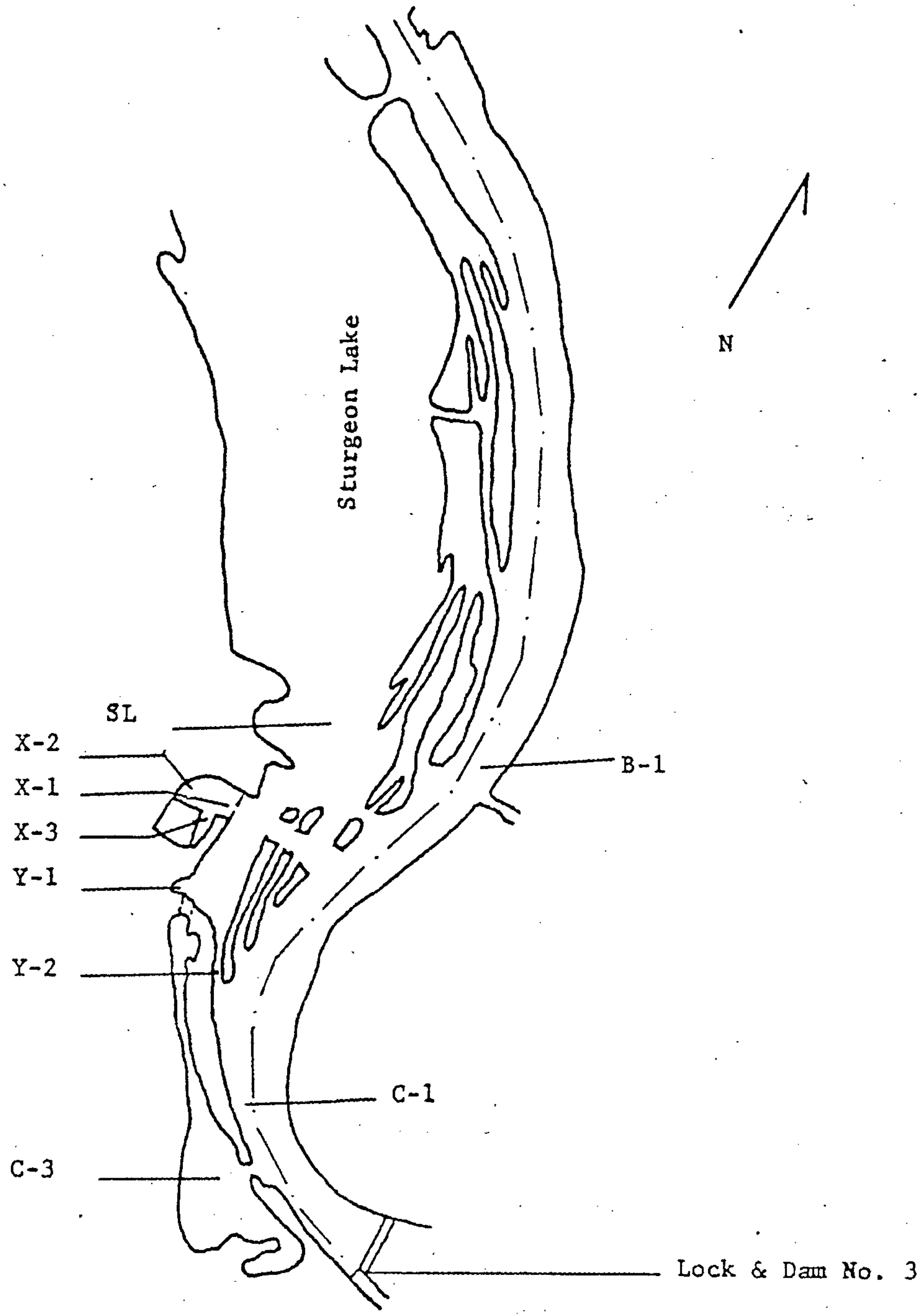


FIGURE 5.2-3

SAMPLING STATIONS FOR ZOOPLANKTON STUDIES, 1974
(FROM SZLUHA 1975)

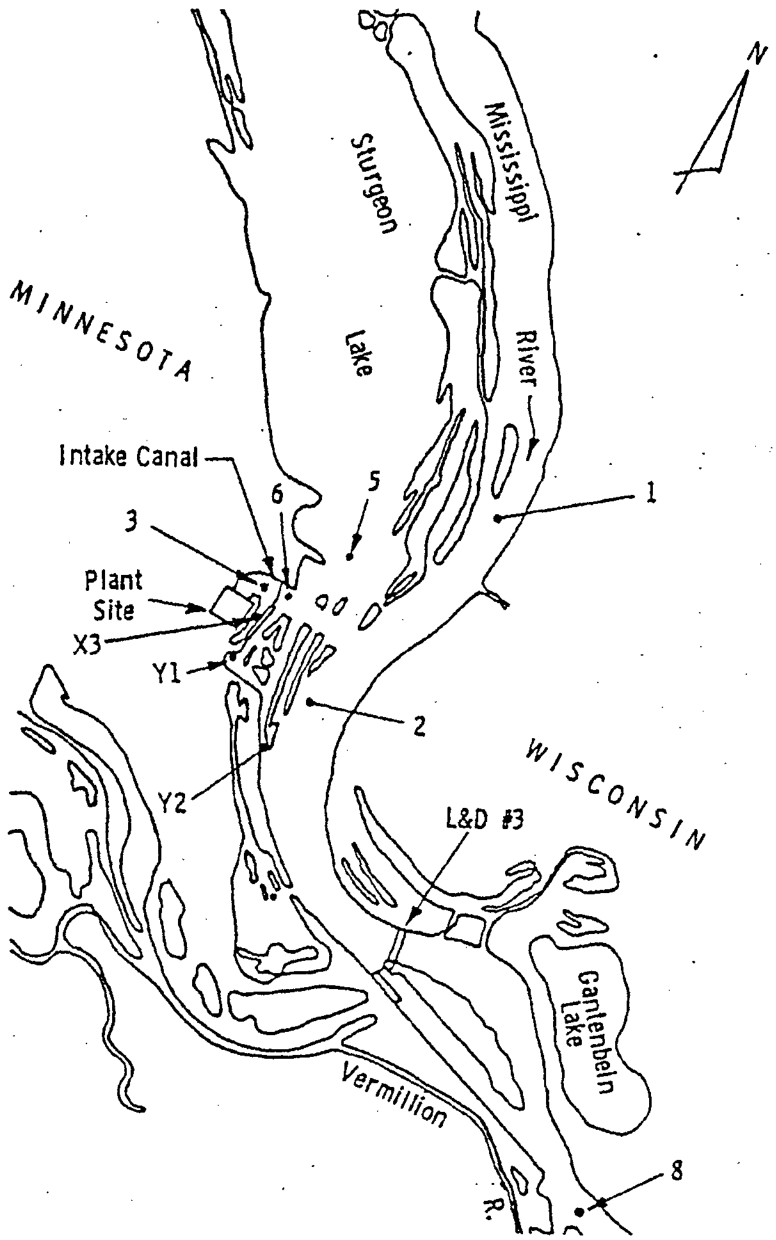


FIGURE 5.2-4

SAMPLING STATIONS FOR ZOOPLANKTON STUDIES, 1975
(FROM DAGGETT 1976)

5.2.1.3 Fish

Entrainment monitoring studies were conducted at PINGP between April 25 and September 5, 1975. Field collection and taxonomic enumeration were performed and supervised by Kenneth Mueller, NSP Field Biologist. Samples were collected during one 24-hour period each week, except for the week of August 24-30 when no samples were collected. Three stations were sampled. Samples were collected in front of the bar rack, on the plant side of the skimmer wall, and in the middle of the recirculation canal.

The Bar Rack Station was sampled throughout the study. The Bar Rack Station is the point of greatest flow of make-up water (water that had not previously passed through PINGP) through the intake canal. This point was located by a temperature survey completed in April, 1975.

The Recirculating Canal Station was sampled from April 25 through July 3, 1975. This station was used to sample the eggs and larvae reintroduced into the intake canal when cooling water was routed through the recirculating canal during closed cycle operation.

The Skimmer Wall Station was sampled from July 10 through the termination of the study. Because it was felt that the closed cycle mode of operation (5.3 m^3/sec water appropriation) would not provide sufficient flow to effectively fish the nets, this station was not sampled during the first half of the study. However, during the course of the study, make-up water appropriations were as low as 5 m^3/sec only a few times so the Skimmer Wall Station was added to the program.

All samples were collected with plankton nets constructed of 560 micron mesh nylon gauze. Each net was 2.5 m long and was attached to a frame 42.5 cm square (0.181 m^2 mouth area). A General Oceanics Model 2030 flowmeter with an R-2 low speed rotor was fitted in the mouth of each net.

All nets were fished as stationary drift nets. Between 3 and 7 nets were stacked vertically, depending on location and water depth. Early in the program all 7 nets were fished at the Bar Rack Station because of excessively high water. After May 9, only 3 or 4 nets were needed at each station to cover the entire water column.

During the first 3 weeks of the program a considerable amount of experimentation with sampling time and frequency was conducted. After May 9, collections were standardized to once every 4 hours for 24 hours with the nets in the water 2 hours of each 4 hour period. Sampling generally began at 0800 hr throughout the study.

Within 10 minutes of collection, all samples were returned to the Prairie Island laboratory where they were condensed into 0.5 gallon jars for storage. Samples were concentrated by pouring them into a #60 brass sieve (0.250 mm mesh) and washing the strained material into an 0.5 gallon jar. The samples were stained with rose bengal dye and preserved in 3 percent buffered formalin.

Prior to sorting, samples were again poured into a #60 brass sieve and washed in running water to remove the formalin. The contents of the sieve were rinsed into glass or enamel sorting pans. Both reflected light and transmitted light were used to sort samples. Fish eggs and larvae were removed from the sorting pans with fine forceps and/or pipettes and were stored in 3 percent buffered formalin until identified at a later date.

Larvae were identified to the species level when possible, but in many cases identification was possible only to the generic or family level. Eggs or larvae which could not be identified because of physical damage were termed unidentifiable. Those which could not be identified due to a lack of taxonomic information were labeled unidentified. References used in the identification of larvae included Fish (1932), Gerlach (1973), Lippson and Moran (1974), May and Gasaway

(1967), Meyer (1970), Nelson (1968), Norden (1961), Snyder (1971), Snyder and Snyder (1976), and Taber (1969).

The criteria used to differentiate the early developmental periods into phases are those proposed by Snyder and Snyder (1976):

Egg - the period that starts with oogenesis and terminates upon hatching

Protolarva - the larval phase which begins at hatching continues until the appearance of at least 3 distinct fin rays in the finfold

Mesolarva - the larval phase which begins at the end of the protolarval phase and continues until just before the appearance of pelvic fins or fin buds, and the appearance of the full complement of soft fin rays in the median fins

Metalarva - the larval phase which extends from the termination of the mesolarval phase to just before the disappearance of the undifferentiated finfold and attainment of the full complement of spines and fin rays with segmentation apparent in the soft rays.

Juvenile - the period extending from the end of the metalarval phase to sexual maturation.

The total number of eggs, larval fish and juvenile fish for each taxon entrained was calculated as follows:

$$N_i = \sum_{j=1}^{16} X_{ij} \cdot V_j$$

where N_i = the total number of eggs, larvae or juvenile of taxon i

X_{ij} = the mean density of taxon i during week j

V_j = the total circulating water volume for period j

j = the sampling period corresponding to the designated sampling date, i.e., May 15, May 22...September 4. A sampling period was defined as the 7 day period centered on the actual sampling dates (Table 5.2-1).

Studies related to intake monitoring were conducted by the Minnesota Department of Natural Resources (MDNR) who collected fish eggs and larvae in the vicinity of the PINGP weekly between May 19 and August 15, 1975. Sampling procedures and stations (Figure 5.2-5) are detailed in Gustafson et al. (1976).

TABLE 5.2-1

SAMPLING DATES AND CORRESPONDING SAMPLING PERIOD

Sampling Date[a]	Number of Days in Period	Extent of Sampling Period
May 15	7	May 12 - May 18
May 21	6	May 19 - May 24
May 29	7	May 25 - June 1
June 5	7	June 2 - June 8
June 12	7	June 9 - June 15
June 19	7	June 16 - June 22
June 26	7	June 23 - June 29
July 2	7	June 30 - July 6
July 10	7	July 7 - July 13
July 17	7	July 14 - July 20
July 24	7	July 21 - July 27
July 31	7	July 28 - Aug. 3
Aug. 7	7	Aug. 4 - Aug. 10
Aug. 14	7	Aug. 11 - Aug. 17
Aug. 21	11	Aug. 18 - Aug. 28
Sept. 4	13	Aug. 29 - Sept. 10

[a]Sampling also took place on April 25, May 2 and May 8; however, these dates have been omitted because of the considerable experimentation and lack of consistency on these dates.

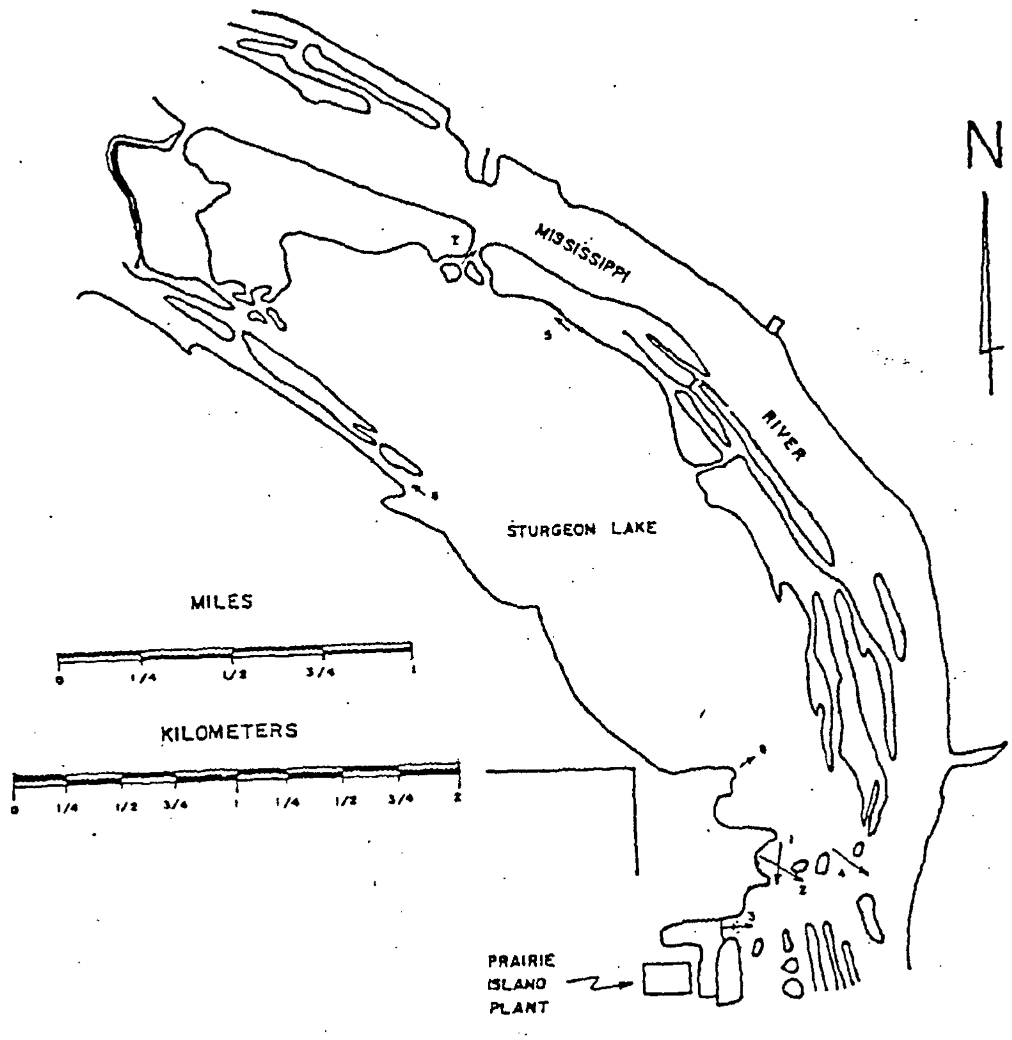


FIGURE 5.2-5

LOCATION OF SOURCE WATER FISH EGG AND LARVA SAMPLING STATIONS AT PINGP IN 1975

5.2.2 Impingement-Related Studies

5.2.2.1 Data Collection

Impingement sampling procedures were similar in 1974 and 1975 as described by Mayhew and Hess (1976). The 1974 sampling period ran from January 2, 1974 to January 2, 1975; the 1975 sampling period ran from January 1 to December 31. Trash baskets remained in place from January 2, 1974 to December 31, 1975. Trash baskets were lifted and emptied, with few exceptions, one to three times per week. All impinged organisms were separated from debris and counted. Organisms overlooked because of heavy debris loads were estimated at less than 2 percent of the total. All fish except gizzard shad were individually counted. When more than 1,000 gizzard shad were present in a sample, the total number of gizzard shad was estimated by counting the number of fish in a full pail and multiplying this number by the number of pails of gizzard shad in the sample.

Generally, total lengths of all fish were recorded. However, when the number of fish of a species exceeded 150 to 200 fish, a subsample of 50 to 100 fish was randomly chosen and measured.

Whenever feasible, live fish were released in Sturgeon Lake or the discharge canal. This occurred particularly in spring when a great number of bullheads survived the rigors of impingement. In addition, special efforts were made to rescue and release live fish during late October and early November.

Some species were grouped in reporting impingement losses. With the exception of carp and silver chub, all members of the family Cyprinidae were grouped as "minnow spp." This group included at least 10 species of minnows, shiners, and dace. River carpsucker and quillback were grouped as "carpsucker spp." "Crappie spp." included both white and black crappie. Many black, yellow, and brown bullheads were listed as "bullhead spp.", primarily in spring. Sauger and walleye were frequently reported as "sauger-walleye spp." These groupings were necessary because of the deteriorated condition of many fish and, often, the sheer numbers of fish in a sample.

Ambient water temperature and recycle canal water temperature data were taken from hourly plant computer logs; average circulating water flow, and blowdown flow and make-up water appropriation data were taken from plant thermal effluent logs. Weekly mean values were calculated from these data.

Ambient water temperature sensors were located approximately 150 m (492 ft) out from the skimmer wall on the river side of the plant.

Recycle canal water temperatures generally corresponded with upper layer intake canal water temperatures. Ambient water temperatures were similar to bottom intake canal water temperatures.

5.2.2.2 Statistical Analysis

Pearson product-moment correlation coefficients (Sokal and Rohlf 1969) were calculated for the 1975 data to determine the association between average circulating water (cfs), makeup-water appropriation (cfs), recycle canal water temperature (°F) and river water inlet (ambient) temperature (°F) with the number of impinged channel catfish, white bass, freshwater drum, black bullhead, and crappie spp. These species were selected because of impingement importance. The sample statistic calculated was:

$$r = \frac{\Sigma(Xi-\bar{X})(Yi-\bar{Y})}{[\Sigma(Xi-\bar{X}^2)\Sigma(Yi-\bar{Y})^2]^{1/2}}$$

where: Xi = Sample observation of variable X

$\bar{X}$ = Mean of all observations of variable X

Yi = Sample observation of variable Y

$\bar{Y}$ = Mean of all observations of variable Y

This sample statistic was used to test the null hypothesis that the population correlation coefficient was equal to zero (i.e., Ho: $|p|=o$). The 0.05 level of significance was used.

Partial correlation coefficients (Snedecor and Cochran 1967) were computed on several combinations to remove effects of other associated parameters. The sample statistics are of the forms:

$$r_{12.3} = \frac{r_{12} - r_{13}r_{23}}{[(1-r_{13}^2)(1-r_{23}^2)]^{1/2}}$$

and

$$r_{12.34} = \frac{r_{12.4} - r_{13.4}r_{23.4}}{[(1-r_{13.4}^2)(1-r_{23.4}^2)]^{1/2}}$$

The original data consisted of three data sets:

1. Hourly measurements of recycle-canal water temperature and river water inlet temperature.
2. Daily measurements of makeup-water appropriation and average circulating water.
3. Weekly measurements of the number of impinged fish.

Daily arithmetic averages were calculated for data set (1) and merged with daily measurements for data set (2). These daily measurements were then averaged to obtain weekly measurements to merge with data set (3). The final data set was used to calculate correlation coefficients. Computer programs used in performing the statistical analyses included selected programs from the Statistical Analysis System developed by North Carolina State University (Barr and Goodnight 1972).

5.3 RESULTS OF INTAKE-RELATED STUDIES

5.3.1 Entrainment Studies

5.3.1.1 Phytoplankton

Studies conducted by Baker (1975) demonstrated that the major source of water and phytoplankton withdrawn by PINGP is lower Sturgeon Lake, which generally supports greater densities of algae than the main channel of the river.

Standing crops of phytoplankton were lower in the discharge canal than in the intake canal in 1974 and 1975 (Table 5.3-1 and Figure 5.3-1), based on chlorophyll a data. There were no evident trends in suspended particulate mass after passage through the plant, indicating that the algae may remain physically intact although they have lost some photosynthetic capacity. Loss of chlorophyll a was at times as high as 58 percent but usually was 50 percent or less.

Primary productivity of phytoplankton in the discharge canal was reduced up to 90 percent over that of the intake canal (Table 5.3-1, Figure 5.3-1). Seasonal trends in productivity degradation were not evident in 1975, but in 1974 the highest degradation occurred during high ambient temperatures. In 1975 two units were in operation,

TABLE 5.3-1

THE EFFECT OF PASSAGE OF PHYTOPLANKTON THROUGH PINGP ON CHLOROPHYLL a, PHOTOSYNTHESIS AND RESPIRATION, 1974 (FROM BAKER 1975)

Date	Destruction of Chlorophyll a[a,b]	Reduction of Photosynthesis$_{g}$[a]	Reduction of Respiration[a]
July 16	58%	75%	80%
22	54	90	18
23	49	84	45
31	24	73	54
Aug. 6	51	76	30
10	24	74	59
14	29	72	60
22	34	61	--
29	34	63	82
Nov. 2	0	35	Stimulated
9	17	44	Stimulated
25	0	31	Stimulated
Dec. 3	40	60	Stimulated

[a]Percent Destruction or Reduction = 100 x (1 - discharge level/intake level).

[b]Chlorophyll a destruction estimates are conservative.

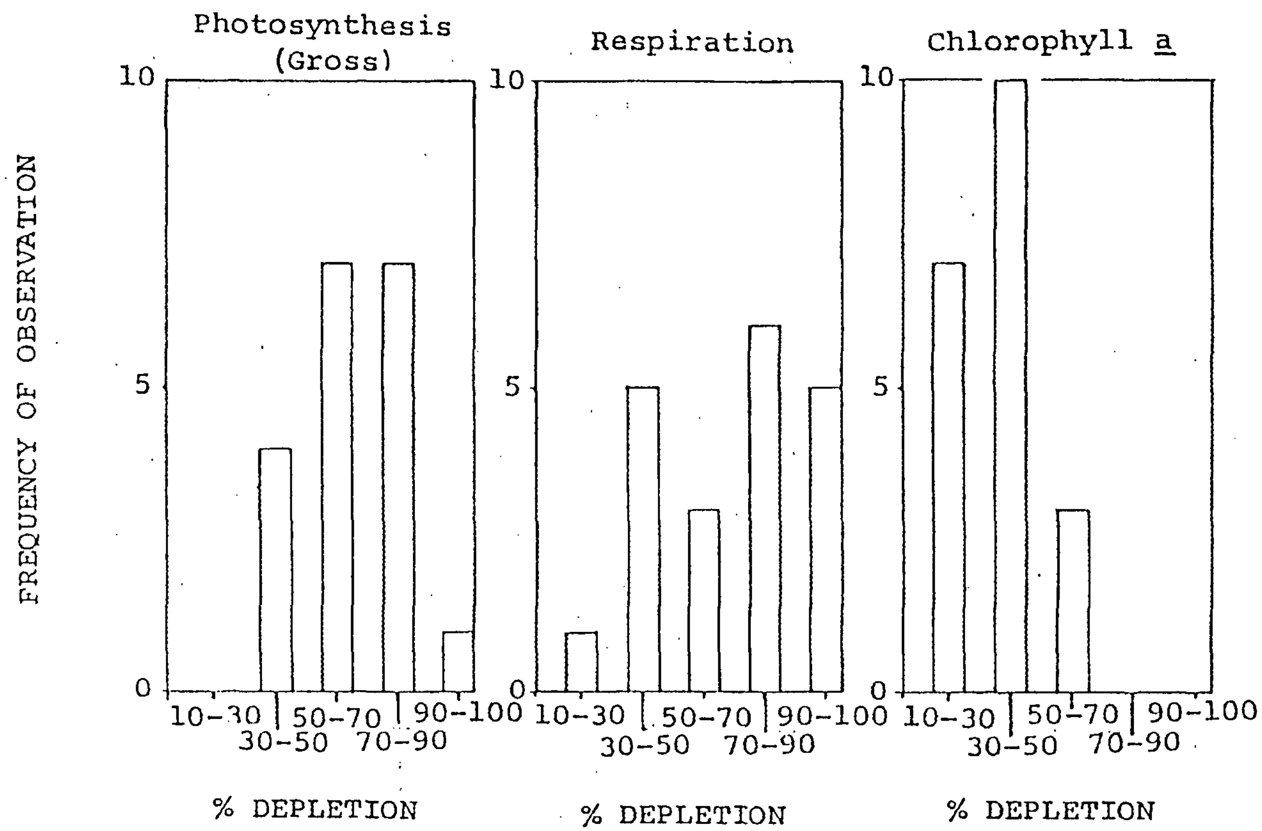


FIGURE 5.3-1

PHYTOPLANKTON DEGRADATION (PERCENT DEPLETION OF PHOTOSYNTHESIS, RESPIRATION AND CHLOROPHYLL a) DUE TO PASSAGE THROUGH PINGP, MAY - OCTOBER 1975
(FROM BAKER 1976)

probably explaining the higher percentage of time that productivity was severely depressed due to passage through PINGP.

Respiration was usually depressed by passage through PINGP (Table 5.3-1, Figure 5.3-1), although in 1974 respiration was stimulated by plant passage in late fall. There were no late fall studies in 1975.

The apparent lack of pattern to phytoplankton degradation is likely due to the variable plant operation modes (Baker 1976). Baker (1976) also calculated photosynthetic capacity (the productivity efficiency of phytoplankton based on oxygen production per unit of chlorophyll a) for phyto-plankton before and after entrainment. These calculations were performed on 1974 data which the author considered more reliable, although they only reflected one unit operation. Photosynthetic capacity of the non-entrained algae was twice that of the entrained algae.

In 1974, Baker (1975) studied productivity differences in the main channel of the Mississippi River and concluded that "any effects of Sturgeon Lake or the power plant on the productivity of the main stream were immeasurable, and were probably insignificant because of the predominant flow of the main channel."

The studies by Baker and Baker (1974, 1975) indicated little detectable damage to phytoplankton that had passed through the plant. Subtle differences were evident in the discharge canal. In 1974 concentrations of blue-green algae were usually lower than in the intake and *Aphanizomenon flos-aquae* was visibly damaged by plant passage. In 1975 there were increases of algae in the plant effluent on some dates and decreases on other dates. There were no detectable differences in phytoplankton composition or densities in the main river channel that could be attributed to the plant operation in either 1974 or 1975. These conclusions corroborate those of EPA (1976b) who stated that if there are effects from phytoplankton entrainment they are of short duration and confined to a relatively small portion of the water body.

5.3.1.2 Zooplankton

Middlebrook (1975, 1976) found that zooplankton at PINGP was significantly affected by entrainment on a number of dates. Of the fifteen dates sampled from 1974 to 1976, 66 percent of the samples were significantly affected by entrainment, based on t-tests of copepod, nauplius, cladoceran and rotifer densities (Tables 5.3-2 and 5.3-3).

TABLE 5.3-2

ESTIMATED PERCENT MORTALITY OF ZOOPLANKTON DUE TO PLANT PASSAGE AT PINGP IN 1974 (FROM MIDDLEBROOK 1975)

Organism	July 30	August 14	September 4	November 21	December 18
Copepoda	51.0±15.9*	36.2±30.0	N.S.	N.S.	N.S.
Nauplii	41.0±14.7*	33.2±28.3	N.S.	N.S.	65.9±29.0
Cladocera	N.S.	N.S.	N.S.	N.S.	N.S.
Rotifera	N.S.	33.6±26.1	15.3±14.4	N.S.	48.4±6.4
ΔT (°F)	23.9	19.3	20.9	30.0	30.7

[a]Evaluated using two-tailed Student t-test, paired observations ($P \leq 0.05$)
*Significant at $P < 0.01$
NS = No significant difference

TABLE 5.3-3

ESTIMATED PERCENT MORTALITY OF ZOOPLANKTON DUE TO PLANT PASSAGE AT PINGP IN 1975 AND 1976 (FROM MIDDLEBROOK 1976)

Date	ΔT (°F)	Copepoda	Nauplii	Cladocera	Rotifera
June 13, 1975	22.5	NS	NS	NS	NS
Aug 7, 1975	15.7	30.6±25.5	NS	NS	19.8±13.5*
Sep 8, 1975	23.0	NS	NS	NS	15.0±6.5*
Oct 9, 1975	25.6	26.6±22.7	NS	NS	NS
Nov 5, 1975	30.0	NS	NS	NS	NS
Dec 9, 1975	38.5	NP	18.7±60.3	NP	NS
Jan 12, 1976	28.1	NP	NS	NP	NS
Feb 9, 1976	36.2	NS	13.3±12.8	NP	NS
Mar 4, 1976	33.9	NS	NS	NP	NS
Apr 5, 1976	13.5	NS	NS	NS	NS
May 4, 1976	22.1	19.9±10.7*	26.6±16.7*	NS	25.4±13.5*

[a]Evaluated using two-tailed Student t-test, paired observations ($P<0.05$)
NS = No significant difference in mortality between intake and discharge
NP = Calculation not possible
* = Significant at $P\leq 0.01$

In many cases only one or two groups were affected by plant passage. In 1975-1976 copepod mortality was significant in August, October and May; copepod nauplii mortality was significant in December, February and May; and rotifer mortality was highly significant ($p \leq 0.01$) in August, September and May. Lack of significant mortality in other months and for cladocerans in all months may be partly attributable to insufficient zooplankton densities for statistical treatment. The ΔT during plant passage could not be correlated to mortality.

Szluha (1975) and Daggett (1976) compared zooplankton collections at the intake, discharge and nearby locations to determine if any differences could be related to plant operation. Szluha (1975) was unable to demonstrate statistically any change in zooplankton densities or composition due to plant operation, even within the recirculation canal. Daggett (1976) found slightly lower zooplankton densities in the discharge canal as compared to intake canal densities in May and September 1975. The recycle canal had slightly (not statistically significant) lower numbers in fall and winter. Copepods were significantly reduced in areas directly affected by the discharge (Stations X-3, Y-1, B-1 and C-1) compared to densities at the intake and Sturgeon Lake (intake source), but Daggett (1976) stresses that these data are preliminary.

5.3.1.3 Fish

Entrainment of fish eggs and young (larval and juvenile fish) was monitored on 19 dates between April 25 and September 4, 1975 (Table 5.2-1). The three earliest sampling dates (April 25, May 2 and May 8) were considered experimental because of marked differences in sampling procedures and times and were not used in the development of entrainment losses.

Collections on the three early dates yielded only 22 carp larvae, 1 unidentified percid larva and 2 burbot larvae. Collections from the remaining 16 dates between May 15 and September 4 resulted in mean densities of 2.39 eggs/100 m^3, 19.5 larvae/100 m^3 and 0.05 juveniles/100 m^3.

5.3.1.3.1 Taxonomic Composition

A total of 39 taxa, including at least 26 species from 12 families, were represented in the collections (Table 5.3-4). 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,

TABLE 5.3-4
FISH EGGS AND YOUNG COLLECTED IN ENTRAINMENT SAMPLING AT PINGP, 1975
(Sheet 1 of 2)

Scientific Name	Common Name	Developmental Phase[a]				
		E	PL	ML	MeL	J
Clupeidae	Herrings					
Dorosoma cepedianum	Gizzard shad		+	+	+	+
Salmonidae	Trouts					
Coregonus clupeaformis?	Lake whitefish				+	
Hiodontidae	Mooneyes					
Hiodon tergisus	Mooneye	+	+	+		
Hiodon spp.	Mooneye or Goldeye		+	+		
Esocidae	Pikes					
Esox lucius	Northern pike		+			
Cyprinidae	Minnows and Carps		+	+	+	
Cyprinus carpio	Carp		+	+	+	+
Hybopsis aestivalis	Speckled chub					+
Notropis atherinoides?	Emerald shiner		+	+	+	+
Pimephales vigilax	Bullhead minnow					+
Catostomidae	Suckers		+	+		
Catostomus commersoni	White sucker		+			
Carpiodes spp.	Carpsuckers		+	+		
Ictiobus spp.	Buffaloes		+	+		
Moxostoma spp.	Redhorses		+			
Ictaluridae	Freshwater catfishes					
Ictalurus punctatus	Channel catfish				+	+
Pylodictus olivarus	Flathead catfish				+	+
Noturus gyrinus	Tadpole madtom				+	

TABLE 5.3-4 (Sheet 2 of 2)

Scientific Name	Common Name	Developmental Phase[a]				
		E	PL	ML	MeL	J
Percopsidae	Trout-perches					
Percopsis omiscomaycus	Trout-perch		+			
Gadidae	Codfishes					
Lota lota	Burbot		+			
Percicthyidae	Temperate basses					
Morone chrysops	White bass		+	+	+	+
Centrarchidae	Sunfishes		+			
Ambloplites rupestris	Rock bass			+		+
Lepomis gibbosus	Pumpkinseed		+			
L. macrochirus	Bluegill		+	+	+	+
Lepomis spp.	unidentified sunfish		+	+		+
Pomoxis annularis	White crappie			+		
Pomoxis nigromaculatus	Black crappie			+	+	+
Pomoxis spp.	unidentified crappie		+	+		
Percidae	Perches		+	+		
Etheostoma nigrum	Johnny darter		+			
Etheostoma spp.	unidentified darters		+			+
Perca flavescens	Yellow perch		+	+	+	
Percina caprodes ?	Log perch		+	+	+	
Percina shumardi ?	River darter			+		
Percina spp.	unidentified darters		+	+		
Stizostedion canadense	Sauger		+	+	+	
S. vitreum	Walleye		+	+	+	
Stizostedion spp.	Sauger or Walleye					
Sciaenidae	Drums					
Aplodinotus grunniens	Freshwater drum	+	+	+	+	+

a. E = Egg; PL = Protolarva; ML = Mesolarvae; MeL = Metalarva; J = Juvenile unidentified suckers, white bass, carp, freshwater drum, buffalo, sauger, unidentified minnows and carpsuckers (Table 5.3-5). These 10 taxa comprised 90 percent of the catch of young fish.

Eggs were taken between May 15 and July 31 and again on September 4, whereas young fish were collected throughout the study.

Peak egg density (27.5/100 m^3) occurred on May 29; a secondary peak (3.34/100 m^3) occurred on June 19 (Appendix 3). On both occasions the collections were dominated by freshwater drum eggs.

Peak density of young (101/100 m^3) occurred on May 29. Secondary peaks occurred on May 21, June 26, July 10 and July 24 (Figure 5.3-2, bar rack data). On May 29, the collections were dominated by emerald shiner, white bass and gizzard shad (Table 5.3-6). Young gizzard shad and carp were most abundant on June 26, with emerald shiner, carp and sunfish predominant on July 10, and emerald shiner and freshwater drum on July 24.

5.3.1.3.2 Comparison of Sampling Locations

In the present study samples were collected at 3 locations within the cooling systems of PINGP: the skimmer wall,

TABLE 5.3-5
MEAN DENSITY AND PERCENT OF CATCH OF YOUNG FISH
COLLECTED IN ENTRAINMENT SAMPLING
AT PINGP, 1975

	No/100m^3	Percent
Notropis atherinoides?	4.36	22.3
Dorosoma cepedianum	4.00	20.5
Catostomidae	2.45	12.5
Morone chrysops	2.26	11.6
Cyprinus carpio	1.36	7.0
Aplodinotus grunniens	1.03	5.3
Ictiobus spp	0.62	3.2
Stizostedion canadense	0.55	2.8
Cyprinidae	0.51	2.6
Carpiodes spp	0.44	2.2
Percina spp	0.33	1.7
Hiodon tergisus	0.32	1.6
Lepomis spp	0.26	1.3
Percidae	0.26	1.3
Percina shumardi?	0.17	0.9
Pomoxis spp	0.12	0.6
Ictalurus punctatus	0.09	0.5
Stizostedion vitreum	0.09	0.5
Hiodon sp	0.06	0.3
Perca flavescens	0.03	0.1
Stizostedion spp	0.03	0.1
Lepomis macrochirus	0.02	0.1
Percopsis omiscomaycus	0.01	*
Etheostoma nigrum	0.01	*
Etheostoma spp	0.01	*
Percina caprodes?	0.01	*
Pomoxis nigromaculatus	0.01	*
Coregonus clupeaformis?	*	*
Esox lucius	*	*
Hybopsis aestivalis	*	*
Pimephales vigilax	*	*
Catostomus commersoni	*	*
Moxostoma spp	*	*
Noturus gyrinus	*	*
Pylodictus olivaris	*	*
Ambloplites rupestris	*	*
Lepomis macrochirus	*	*
Pomoxis annularis	*	*
Centrarchidae	*	*
Unidentifiable	0.11	0.6
Unidentified	0.01	*

*<0.01

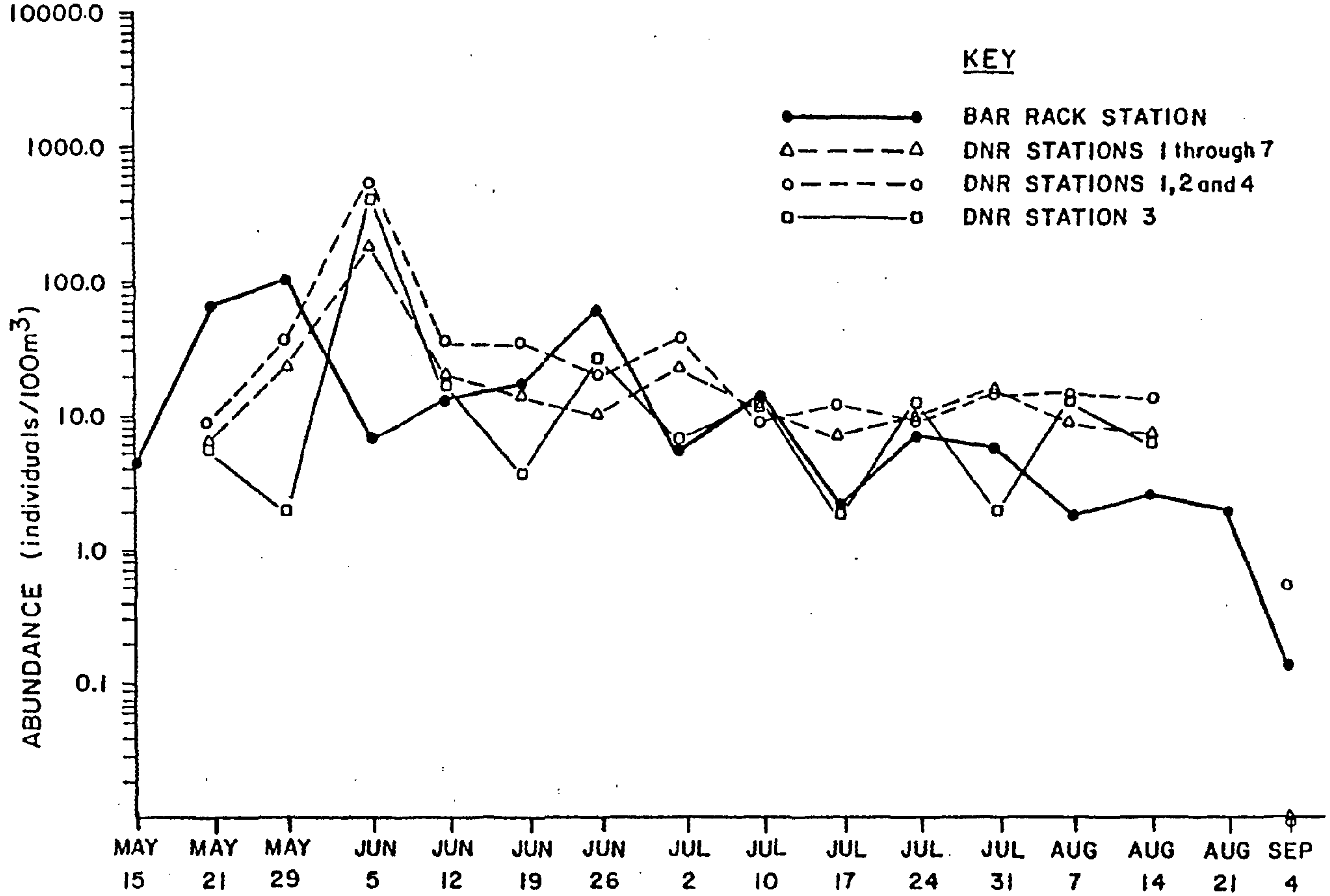


FIGURE 5.3-2

MEAN DENSITY (NO/100m^3) OF YOUNG FISH COLLECTED IN THE STURGEON LAKE AREA BY MDNR AND AT THE BAR RACK STATION IN THE PINGP INTAKE CANAL BETWEEN MAY 15 AND SEPTEMBER 4, 1975. (REFER TO FIGURE 5.2-5 FOR STATION LOCATIONS)

TABLE 5.3-6

MEAN DENSITY OF FISH LARVAE AT THE BAR RACK STATION AT PINGP, 1975

MEAN DENSITY (NO./100 CUBIC METERS) OF FISH LARVAE COLLECTED AT THE BAR RACK STATION IN THE INTAKE CANAL OF THE PRAIRIE ISLAND GENERATING PLANT ON EACH COLLECTION DATE IN 1975

	MAY 15	MAY 21	MAY 29	JUNE 5	JUNE 12	JUNE 19	JUNE 26	JULY 2	JULY 10	JULY 17	JULY 24	JULY 31	AUG 7	AUG 14	AUG 21	SEPT 4	AVG.
UNIDENTIFIABLE [a]																	
PROTOLARVA	0.03	0.38	0.72	0.03	0.0	0.12	0.24	0.0	0.04	0.17	0.0	0.0	0.0	0.0	0.0	0.0	0.11
MESOLARVA	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.09	0.0	0.01
TOTAL	0.03	0.38	0.73	0.03	0.0	0.12	0.24	0.0	0.04	0.17	0.0	0.0	0.0	0.0	0.09	0.0	0.11
UNIDENTIFIED [b]																	
EGG	0.01	1.09	2.00	0.17	0.0	0.0	0.56	0.0	0.0	0.18	0.0	0.0	0.0	0.0	0.0	0.13	0.26
PROTOLARVA	0.0	0.13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06	0.0	0.0	0.0	0.0	0.01
TOTAL	0.0	0.13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06	0.0	0.0	0.0	0.0	0.01
APLODINOTUS GRUNNIENS																	
EGG	0.0	0.32	25.52	2.90	0.61	3.34	0.76	0.10	0.05	0.41	0.01	0.0	0.0	0.0	0.0	0.0	2.13
PROTOLARVA	0.0	0.01	0.93	2.02	0.44	3.30	0.99	0.20	0.04	0.13	1.02	0.81	0.09	0.33	0.58	0.0	0.68
MESOLARVA	0.0	0.0	0.0	0.06	0.22	4.36	0.18	0.0	0.0	0.01	0.01	0.0	0.05	0.0	0.09	0.0	0.31
METALARVA	0.0	0.0	0.0	0.0	0.0	0.08	0.05	0.0	0.02	0.01	0.01	0.02	0.0	0.10	0.02	0.0	0.02
JUVENILE	0.0	0.0	0.0	0.0	0.0	0.0	0.21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01
TOTAL	0.0	0.01	0.93	2.08	0.66	7.75	1.43	0.20	0.06	0.15	1.05	0.83	0.14	0.44	0.69	0.0	1.03
COREGONUS CLUPEAFORMIS ?																	
METALARVA	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TOTAL	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
MORONE CHRYSOPS																	
PROTOLARVA	1.05	2.38	3.45	0.22	0.07	0.16	0.25	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.47
MESOLARVA	0.0	0.0	18.23	0.65	0.18	0.19	0.09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.21
METALARVA	0.0	0.0	0.0	0.97	7.24	0.69	0.14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.56
JUVENILE	0.0	0.0	0.0	0.0	0.0	0.0	0.15	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.01
TOTAL	1.05	2.38	21.68	1.84	7.49	1.03	0.63	0.0	0.0	0.02	0.01	0.0	0.0	0.0	0.0	0.0	2.26
PERCIDAE																	
PROTOLARVA	0.16	0.56	3.12	0.0	0.0	0.08	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.25
MESOLARVA	0.0	0.0	0.21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01
TOTAL	0.16	0.56	3.34	0.0	0.0	0.08	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.26
STIZOSTEDION SPP.																	
PROTOLARVA	0.37	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	0.0	0.0	0.03
TOTAL	0.37	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	0.0	0.0	0.03
STIZOSTEDION VITREUM																	
PROTOLARVA	0.72	0.60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.08
MESOLARVA	0.0	0.07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TOTAL	0.72	0.67	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.09

MEAN DENSITY (NO./100 CUBIC METERS) OF FISH LARVAE COLLECTED AT THE BAR RACK STATION IN THE INTAKE CANAL OF THE PRAIRIE ISLAND GENERATING PLANT ON EACH COLLECTION DATE IN 1975

	MAY 15	MAY 21	MAY 29	JUNE 5	JUNE 12	JUNE 19	JUNE 26	JULY 2	JULY 10	JULY 17	JULY 24	JULY 31	AUG 7	AUG 14	AUG 21	SEPT 4	AVG.
STIZOSTEDION CANADENSE																	
PROTOLARVA	0.57	7.02	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.48
MESOLARVA	0.0	1.08	0.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.07
METALARVA	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TOTAL	0.57	8.10	0.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.55
PERCINA SPP.																	
PROTOLARVA	0.09	1.09	3.49	0.41	0.0	0.07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.32
MESOLARVA	0.0	0.0	0.04	0.06	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01
TOTAL	0.09	1.09	3.53	0.47	0.0	0.08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.33
PERCINA SHUMARDI?																	
MESOLARVA	0.0	0.0	0.34	0.14	0.0	2.27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.17
TOTAL	0.0	0.0	0.34	0.14	0.0	2.27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.17
PERCINA CAPRODES?																	
PROTOLARVA	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	0.0	0.0	0.00
MESOLARVA	0.0	0.0	0.05	0.06	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
METALARVA	0.0	0.0	0.0	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TOTAL	0.0	0.05	0.05	0.09	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
PERCA FLAVESCENS																	
PROTOLARVA	0.04	0.20	0.02	0.0	0.0	0.08	0.07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03
MESOLARVA	0.0	0.03	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
METALARVA	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	0.0	0.00
TOTAL	0.04	0.23	0.08	0.0	0.0	0.08	0.07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03
ETHEOSTOMA SPP.																	
PROTOLARVA	0.0	0.01	0.0	0.0	0.09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01
TOTAL	0.0	0.01	0.0	0.0	0.09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01
ETHEOSTOMA NIGRUM																	
PROTOLARVA	0.0	0.08	0.07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01
JUVENILE	0.0	0.0	0.0	0.0	0.0	0.08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01
TOTAL	0.0	0.08	0.07	0.0	0.0	0.08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01
PERCOPSIS OMISCOMAYCUS																	
PROTOLARVA	0.0	0.08	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01
TOTAL	0.0	0.08	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01
PYLODICTIS OLIVARIS																	
METALARVA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.00
JUVENILE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06	0.0	0.0	0.0	0.00
TOTAL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.06	0.0	0.0	0.0	0.00

MEAN DENSITY (NO./100 CUBIC METERS) OF FISH LARVAE COLLECTED AT THE BAR RACK STATION IN THE INTAKE CANAL OF THE PRAIRIE ISLAND GENERATING PLANT ON EACH COLLECTION DATE IN 1975

	MAY 15	MAY 21	MAY 29	JUNE 5	JUNE 12	JUNE 19	JUNE 26	JULY 2	JULY 10	JULY 17	JULY 24	JULY 31	AUG 7	AUG 14	AUG 21	SEPT 4	AVG.
NOTURUS GYRINUS																	
METALARVA	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	0.00
TOTAL	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	0.00
ICTALURUS PUNCTATUS																	
METALARVA	0.0	0.0	0.0	0.0	0.10	0.04	0.0	0.0	0.70	0.11	0.0	0.24	0.15	0.0	0.0	0.0	0.08
JUVENILE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.02	0.01	0.0	0.0	0.0	0.00
TOTAL	0.0	0.0	0.0	0.0	0.10	0.04	0.0	0.0	0.70	0.13	0.0	0.25	0.16	0.0	0.0	0.0	0.09
HIODON SPP.																	
PROTOLARVA	0.0	0.74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.05
MESOLARVA	0.0	0.16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01
TOTAL	0.0	0.91	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06
HIODON TERGISUS																	
EGG	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	0.0	0.0	0.00
PROTOLARVA	0.09	4.23	0.02	0.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.28
MESOLARVA	0.0	0.73	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.05
TOTAL	0.09	4.97	0.02	0.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.32
ESOX LUCIUS																	
PROTOLARVA	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TOTAL	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
CYPRINIDAE																	
PROTOLARVA	0.0	0.07	0.84	0.40	0.32	0.07	1.89	0.41	1.01	0.41	0.50	0.53	0.27	0.68	0.15	0.0	0.47
MESOLARVA	0.0	0.0	0.04	0.03	0.0	0.0	0.0	0.0	0.09	0.02	0.0	0.0	0.0	0.20	0.15	0.0	0.03
METALARVA	0.0	0.0	0.0	0.0	0.0	0.04	0.0	0.0	0.03	0.01	0.01	0.0	0.0	0.0	0.0	0.0	0.01
TOTAL	0.0	0.07	0.88	0.42	0.32	0.11	1.89	0.41	1.13	0.43	0.51	0.53	0.27	0.87	0.30	0.0	0.51
PIMEPHALES VIGILAX																	
JUVENILE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.00
TOTAL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.00
NOTROPIS ATHERINOIDES?																	
PROTOLARVA	0.0	0.18	48.00	0.0	0.0	0.0	3.02	1.88	3.85	0.02	4.07	3.63	0.39	0.25	0.02	0.0	4.08
MESOLARVA	0.0	0.0	0.0	0.07	0.0	0.0	0.0	0.20	0.71	0.09	0.52	0.50	0.07	0.43	0.48	0.0	0.19
METALARVA	0.0	0.0	0.0	0.0	0.20	0.03	0.0	0.0	0.21	0.03	0.04	0.08	0.03	0.15	0.42	0.0	0.07
JUVENILE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.05	0.01	0.0	0.02	0.0	0.0	0.15	0.01
TOTAL	0.0	0.18	48.00	0.07	0.20	0.03	3.02	2.08	4.77	0.20	4.65	4.21	0.52	0.83	0.92	0.15	4.36
HYBOPSIS AESTIVALIS																	
JUVENILE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.02	0.0	0.0	0.0	0.00
TOTAL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.02	0.0	0.0	0.0	0.00

MEAN DENSITY (NO./100 CUBIC METERS) OF FISH LARVAE COLLECTED AT THE
BAR RACK STATION IN THE INTAKE CANAL OF THE PRAIRIE ISLAND GENERATING PLANT
ON EACH COLLECTION DATE IN 1975

	MAY 15	MAY 21	MAY 29	JUNE 5	JUNE 12	JUNE 19	JUNE 26	JULY 2	JULY 10	JULY 17	JULY 24	JULY 31	AUG 7	AUG 14	AUG 21	SEPT 4	AVG.
CYPRINUS CARPIO																	
PROTOLARVA	0.82	2.11	0.53	0.0	0.20	0.0	14.86	0.62	0.44	0.0	0.07	0.0	0.0	0.0	0.0	0.0	1.23
MESOLARVA	0.0	0.0	0.07	0.0	0.0	0.0	0.0	0.20	1.65	0.01	0.03	0.0	0.04	0.0	0.0	0.0	0.12
METALARVA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.00
JUVENILE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TOTAL	0.82	2.11	0.60	0.0	0.20	0.0	14.86	0.82	2.15	0.03	0.10	0.0	0.04	0.0	0.0	0.0	1.36
DOROSOMA CEPEDIANUM																	
PROTOLARVA	0.0	0.87	14.79	1.04	0.44	1.28	29.98	1.37	0.32	0.03	0.02	0.64	0.49	0.0	0.16	0.0	3.21
MESOLARVA	0.0	0.0	1.00	0.55	2.64	1.13	4.14	0.60	0.53	0.25	0.0	0.05	0.10	0.43	0.12	0.0	0.72
METALARVA	0.0	0.0	0.0	0.0	0.0	0.0	0.08	0.0	0.34	0.23	0.01	0.0	0.0	0.22	0.0	0.0	0.06
JUVENILE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.15	0.04	0.0	0.0	0.0	0.0	0.0	0.01
TOTAL	0.0	0.87	15.79	1.59	3.09	2.41	34.20	1.96	1.21	0.67	0.07	0.69	0.59	0.66	0.28	0.0	4.00
CENTRARCHIDAE																	
PROTOLARVA	0.0	0.0	0.01	0.0	0.0	0.0	0.03	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.0	0.0	0.00
TOTAL	0.0	0.0	0.01	0.0	0.0	0.0	0.03	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.0	0.0	0.00
POMOXIS SPP.																	
PROTOLARVA	0.0	0.16	1.68	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.12
MESOLARVA	0.0	0.0	0.07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TOTAL	0.0	0.16	1.75	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.12
POMOXIS NIGROMACULATUS																	
MESOLARVA	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	0.00
METALARVA	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
JUVENILE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TOTAL	0.0	0.0	0.0	0.0	0.0	0.08	0.0	0.0	0.0	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.01
POMOXIS ANNULARIS																	
MESOLARVA	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TOTAL	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
LEPOMIS SPP.																	
PROTOLARVA	0.0	0.0	0.0	0.0	0.14	0.0	1.75	0.20	1.81	0.04	0.13	0.0	0.0	0.0	0.0	0.0	0.25
MESOLARVA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.00
JUVENILE	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	0.00
TOTAL	0.0	0.0	0.0	0.0	0.14	0.0	1.75	0.20	1.84	0.08	0.13	0.0	0.0	0.0	0.0	0.0	0.26
LEPOMIS MACROCHIRUS																	
PROTOLARVA	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.0	0.18	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.02
MESOLARVA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.00
METALARVA	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	0.00
JUVENILE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.0	0.0	0.0	0.00
TOTAL	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.0	0.19	0.05	0.03	0.0	0.0	0.0	0.0	0.0	0.02

MEAN DENSITY (NO./100 CUBIC METERS) OF FISH LARVAE COLLECTED AT THE BAR RACK STATION IN THE INTAKE CANAL OF THE PRAIRIE ISLAND GENERATING PLANT ON EACH COLLECTION DATE IN 1975

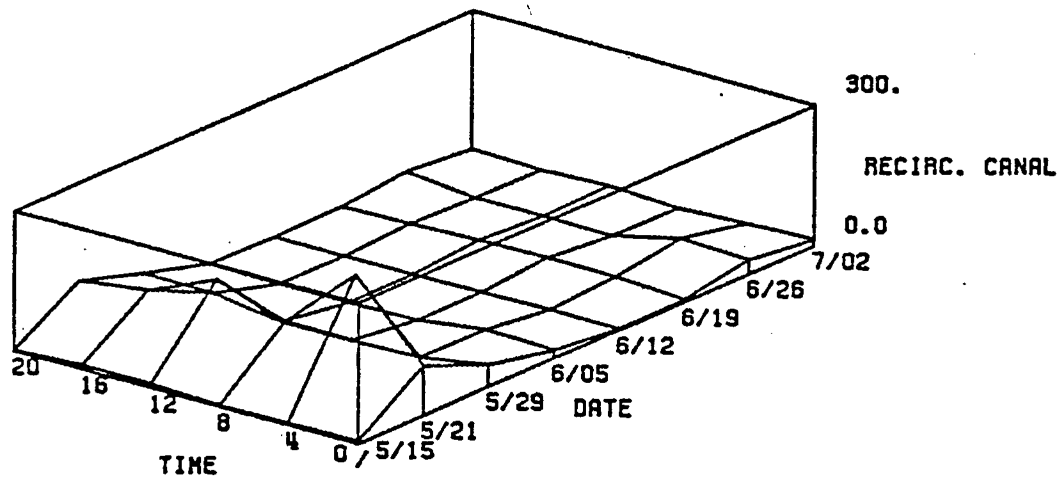
	MAY 15	MAY 21	MAY 29	JUNE 5	JUNE 12	JUNE 19	JUNE 26	JULY 2	JULY 10	JULY 17	JULY 24	JULY 31	AUG 7	AUG 14	AUG 21	SEPT 4	AVG.
LEPOMIS GIBBOSUS																	
PROTOLARVA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TOTAL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
AMBLOPLITES RUPESTRIS																	
MESOLARVA	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	0.00
JUVENILE	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	0.00
TOTAL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.00
CATOSTOMIDAE																	
PROTOLARVA	0.20	34.61	0.81	0.38	0.23	0.09	1.37	0.0	0.38	0.38	0.50	0.11	0.0	0.0	0.0	0.0	2.44
MESOLARVA	0.0	0.0	0.06	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	0.01
TOTAL	0.20	34.61	0.87	0.38	0.23	0.09	1.37	0.0	0.38	0.38	0.50	0.16	0.0	0.0	0.0	0.0	2.45
MOXOSTOMA SPP.																	
PROTOLARVA	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	0.0	0.0	0.00
TOTAL	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	0.0	0.0	0.00
ICTIOBUS SPP.																	
PROTOLARVA	0.0	8.74	0.0	0.0	0.0	0.0	0.22	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.56
MESOLARVA	0.0	0.0	0.88	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06
TOTAL	0.0	8.74	0.88	0.06	0.0	0.0	0.22	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.62
CARPIODES SPP.																	
PROTOLARVA	0.0	5.20	0.36	0.09	0.0	0.0	0.68	0.0	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.40
MESOLARVA	0.0	0.0	0.68	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.04
TOTAL	0.0	5.20	1.04	0.09	0.0	0.0	0.68	0.0	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.44
CATOSTOMUS COMMERSONI																	
PROTOLARVA	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TOTAL	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00

[a] too damaged or deteriorated for identification

[b] taxonomic data or characteristics insufficient for identification

the bar rack and the recirculation canal (see Section 5.2.1.3). No consistent differences between the densities of eggs and young at the Bar Rack Station and those at the Recirculating Canal Station or at the Skimmer Wall Station were apparent (Figures 5.3-3 and 5.3-4). Densities occasionally appeared to be higher at both the Recirculating Canal Station and the Skimmer Wall Station than at the Bar Rack Station, probably as a result of the inherent variability in ichthyoplankton densities. The Bar Rack Station apparently yields as good a representation of the number of larvae entrained as the Skimmer Wall Station, and is not markedly influenced by eggs or young fish recirculated through the recirculation canal.

The Minnesota Department of Natural Resources (MDNR) collected fish egg and larva samples in the vicinity of the PINGP intake and in Sturgeon Lake on a weekly basis between May 19 and September 5, 1975 (Gustafson et al. 1976). These data were used to estimate total numbers of young fish passing through the Sturgeon Lake Outlet, which, in turn, were compared to the total numbers entrained by PINGP on a weekly basis (Table 5.3-7). The MDNR data are considered low estimates of young fish densities due to their sampling methods: 1) sampling was only conducted in daytime, when densities are usually lower, and 2) sampling



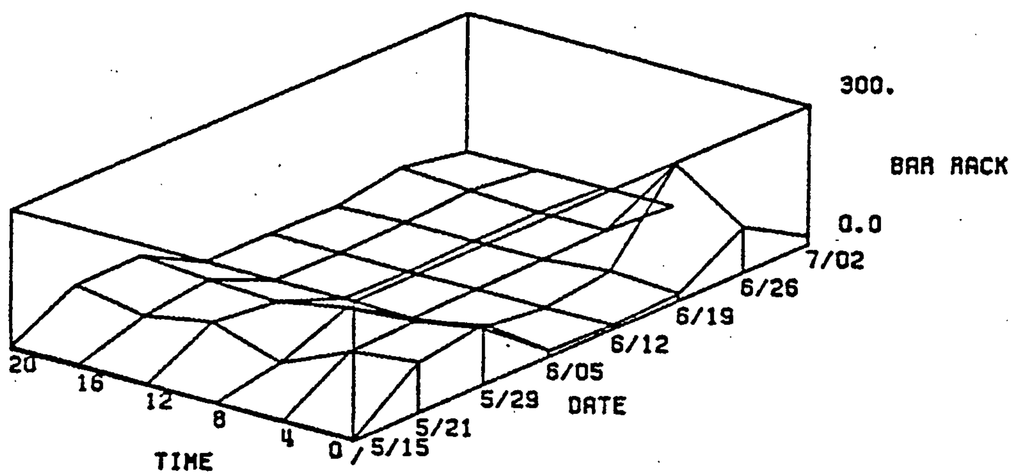


FIGURE 5.3-3

DIEL VARIATION IN MEAN DENSITY (No./100 m^3) OF EGGS AND LARVAE AT THE RECIRCULATION CANAL AND BAR RACK STATIONS AT PINGP, MAY 15-JULY 2, 1975

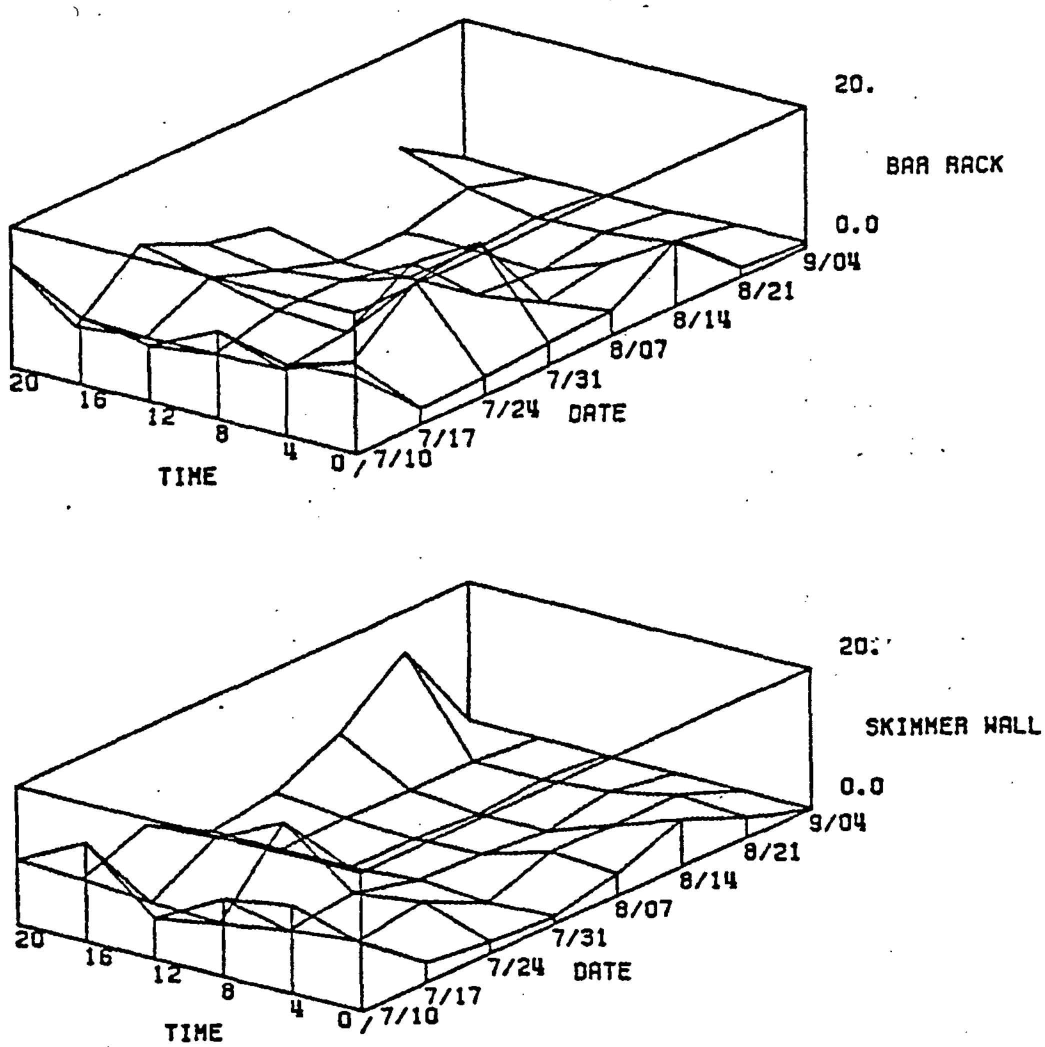


FIGURE 5.3-4

DIEL VARIATION IN MEAN DENSITY (No./100 m^3) OF EGGS AND LARVAE AT THE SKIMMER WALL AND BAR RACK STATIONS AT PINGP, JULY 10 - SEPTEMBER 4, 1975

TABLE 5.3-7

ESTIMATED NUMBER OF LARVAE AND JUVENILES PASSING THROUGH THREE LOCATIONS AT PINGP, 1975[a]

	May			June				July						August			September
	15	21	29	5	12	19	26	2	10	17	24	31	7	14	21	4
Bar Rack (BR)	0.975	17.0	23.7	0.908	1.55	3.28	7.45	0.438	3.17	0.591	1.72	1.66	0.366	0.435	0.887	0.068
MDNR Station 3[b] (Skimmer-Wall)	--	0.655	0.308	19.2	0.580	0.365	1.50	0.193	1.86	0.302	2.37	0.326	2.01	0.231	--	0
Sturgeon Lake[b] Outlet (SL)	--	20.0	61.0	610	36	54	38	140	26	24	6.2	8.6	5.4	3.1	3.0[d]	0.43
Percent entrained BR/SL x 100	--	85.0	38.8	0.1	4.3	6.1	19.6	0.3	12.2	2.5	27.7	19.3	6.8	14.0	32.2	15.8

--No sample taken or value could not be computed

[a] Total Number of larvae and juveniles x 10^6 per week

[b] Computed from data of Gustafson et al. (1976)

[c] Estimated from previous and succeeding dates.

was done with 787 micron mesh nets (compared to 560 micron nets in present study) for the first half of the study, when small larvae were most abundant, possibly resulting in loss of specimens. Thus the estimates of entrainment as percentages of Sturgeon Lake discharge (Table 5.3-7) are probably high.

The mean density of young for all MDNR stations (Stations 1-7) and for the MDNR stations in the vicinity of the PINGP intake (Stations 1, 2, and 4) were generally higher than or equal to those at the Bar Rack Station in the PINGP canal. However, there were no evident trends in the fluctuations in abundance (Figure 5.3-2). Densities peaked at the Bar Rack Station a week earlier than in Sturgeon Lake. Over the remainder of the sampling program, the density at the Bar Rack Station fluctuated widely from week to week while at the same time the mean densities for all MDNR stations and Stations 1, 2 and 4 exhibited a fairly constant rate of decline. However, densities at MDNR Station 3 fluctuated with those at the Bar Rack Station during late June, July and early August. These fluctuations are probably attributable to a number of factors including: 1) differing sampling procedures used for the present study and in MDNR studies, 2) changes in plant operation mode, and 3) changes in intake area of influence due to river flow changes. At present no single factor can explain the variations.

5.3.1.3.3 Diel Variations in Fish Entrainment

During the first half of the sampling program (May 15 to July 2), there was no consistent pattern in the abundance of eggs and larvae over the 24-hour sampling period at either the Recirculating Canal Station or the Bar Rack Station. During the second half of the program, however, densities of young fish at both the Bar Rack Station and the Skimmer Wall Station were generally higher between sunset and sunrise (i.e., 2000-0000 hrs, 0000-0400 hrs and 0400-0800 hrs sampling periods).

An examination of the vertical distribution of eggs and young of the ten most abundant taxa collected at the Bar Rack Station appears to indicate that, for most taxa, densities were consistently higher near the bottom. This did not appear to be influenced by the time of day or the date the collections were made. White bass, the only exception, showed no consistent pattern in depth distribution.

5.3.2 Impingement

A total of 44 species representing 14 families were impinged in 1974; 48 species and one hybrid fish representing 16 families were impinged during 1975. In the 1974 study, 146,063 fish, representing an average of 400 fish per day, were impinged (Table 5.3-8). In 1975, the total number of impinged fishes was 93,466, representing a daily average of 256 fish (Tables 5.3-9 and 5.3-10). Gizzard shad comprised 94 percent of the total in 1974 and 75 percent of the total in 1975. Other than gizzard shad, freshwater drum, white bass, crappies, channel catfish, black bullhead, and minnows were the most abundant fishes in the impingement catch.

Impingement rates showed wide seasonal variability. Gizzard shad were most frequently impinged in fall and winter (Figures 5.3-5 and 5.3-6). Impingement of other species occurred primarily during April-May and July-November (Figures 5.3-7 and 5.3-8). Peaks shown reflect impingement of channel catfish, white bass, freshwater drum, crappies, and black bullhead (Figures 5.3-9 through 5.3-13, respectively). Gizzard shad were impinged primarily during the winter. Bullheads were caught primarily during the spring of 1975. Carp, white bass, and crappie spp. occurred in greatest numbers in the summer. Gizzard shad, channel catfish, freshwater drum, and minnow spp. were impinged in greatest numbers in the fall.

TABLE 5.3-8 (SHEET 1 OF 4)
NUMBERS OF FISH PER WEEK COLLECTED FROM THE TRASHBASKETS AT PINGP, 1974

	Weekly Periods													
SPECIES	1-2 to 1-9	1-9 to 1-16	1-16 to 1-23	1-23 to 1-30	1-3 to 2-6	2-6 to 2-13	2-13 to 2-20	2-20 to 2-27	2-27 to 3-6	3-6 to 3-13	3-13 to 3-20	3-20 to 3-27	3-27 to 4-3	4-3 to 4-10
Chestnut lamprey														
Silver lamprey	1			1										
Undetermined lamprey														
Longnose gar														
Shortnose gar														
Gizzard shad	8750	3500	859	242	4263	650	134	18	81	21				114
Goldeye														
Mooneye														
Northern pike														
Carp	1		1		1	1								1
Silver chub			2	1	3				1					3
Minnows	2									1				23
Carpsucker spp.							1	4	3	5				3
Smallmouth buffalo						2								50
Bigmouth buffalo					1									
Shorthead redhorse								1	1					
Black bullhead	2		1	3			1							2
Brown bullhead														5
Channel catfish					1	1								
Tadpole madtom	4				3		1			1				
Flathead catfish						2								3
Undetermined ictalurid														1
Trout-perch	1													
Burbot	4													16
White bass	17	7	12	6	48	14	9	10	10	3				
Rock bass	1					3								8
Green sunfish	1					5	2							
Bluegill			3		1	8			1					
Largemouth bass														
Smallmouth bass														
Crappie spp.	4		3	1	12	11	3	7	15	12			1	124
Undetermined centrarchid														
Yellow perch	1													
Logperch						2								1
Sauger								1						1
Walleye														
Sauger-walleye										4				31
Freshwater drum	30	8	7	8	98	42	91	61	107	47			1	39
Undetermined fish						4								2
TOTAL FISH	8819	3515	889	262	4431	745	242	102	219	94			2	427
TOTAL FISH LESS GIZZARD SHAD	69	15	30	20	168	95	108	84	138	73			2	313

TABLE 5.3-8 (SHEET 2 OF 4)

SPECIES	Weekly Periods 4-10 to 4-17	4-17 to 4-24	4-24 to 5-1	5-1 to 5-8	5-8 to 5-15	5-15 to 5-22	5-22 to 5-29	5-29 to 6-5	6-5 to 6-12	6-12 to 6-19	6-19 to 6-26	6-26 to 7-3	7-3 to 7-10
Chestnut lamprey												1	
Silver lamprey													
Undetermined lamprey													1
Longnose gar													
Shortnose gar													
Gizzard shad	16	8	9	1								2	
Goldeye													
Mooneye												1	
Northern pike												16	10
Carp	3	1	13	2						2	53	26	26
Silver chub	1		12							1	3		2
Minnows	2	4	3								5	76	29
Carpsucker spp.	3												
Smallmouth buffalo													
Bigmouth buffalo													
Shorthead redhorse			1								1	2	1
Black bullhead	11	43	17	3	1					2	13	21	3
Brown bullhead										10			2
Channel catfish	2	1	4				1	1		1	4		
Tadpole madtom	2												
Flathead catfish		1	5								1	5	1
Undetermined ictalurid	1											2	
Trout-perch	1		2									3	
Burbot											1		1
White bass	43	36	36	3				1			1	8	6
Rock bass	2	2	2								2	9	6
Green sunfish	1	2	3								1	3	1
Bluegill	4	5	14	2						2	44	26	2
Largemouth bass													
Smallmouth bass													2
Crappie spp.	7	7	10	4	3					2	13	59	111
Undetermined centrarchid													
Yellow perch	2	5	1									2	
Logperch	3	2											1
Sauger	1	1								1	1		2
Walleye		1											
Sauger-walleye	22		3	1								7	
Freshwater drum	6	5	9	4				5		2	5	12	25
Undetermined fish		1					1						1
TOTAL	133	125	144	20	4		2	7		23	148	281	233
TOTAL FISH LESS GIZZARD SHAD	117	117	135	19	4		2	7		23	148	279	233

TABLE 5.3-8 (SHEET 3 OF 4)

SPECIES	Weekly Periods 7-10 to 7-17	7-17 to 7-24	7-24 to 7-31	7-31 to 8-7	8-7 to 8-14	8-14 to 8-21	8-21 to 8-28	8-28 to 9-4	9-4 to 9-11	9-11 to 9-18	9-18 to 9-25	9-25 to 10-2	10-2 to 10-9	10-9 to 10-16
Chestnut lamprey														
Silver lamprey														
Undetermined lamprey														
Longnose gar	1		1											
Shortnose gar						1								
Gizzard shad	7	19	145	12	96	77	54	289	104	590	2	9		
Goldeye														
Mooneye														
Northern pike	2	1			4									
Carp	96	13	9	2	10	3	3	1		1				
Silver chub	10	3	5	1	3		1		1	1				
Minnows	47	22	26		26	2	8	12		1				
Carpsucker spp.		2	2	3	1				1					
Smallmouth buffalo	2		1				1							
Bigmouth buffalo		1					1							
Shorthead redhorse			1		2									
Black bullhead	4		1				1							
Brown bullhead														
Channel catfish			12	1		46	19	20	61	23		1		
Tadpole madtom	8	1	4											
Flathead catfish	3	1	1			7	1	1		2				
Undetermined ictalurid														
Trout-perch		1												
Burbot														
White bass	67	53	164	55	175	43	20	23	8	7		2		
Rock bass	3		5	3	7		1	1						
Green sunfish	1	1	6											
Bluegill	3	2	43	1	15	4	2	2	2	9				
Largemouth bass														
Smallmouth bass			1			1						1		
Crappie spp.	62	25	41	23	77	75	189	284	178	70		39		
Undetermined centrarchid														
Yellow perch														
Logperch														
Sauger														
Walleye						1								
Sauger-walleye			1											
Freshwater drum	13	3	23	20	99		87	111	174	39				
Undetermined fish		2		1	2									
TOTAL	329	150	492	122	517	355	388	744	529	743	2	52		
TOTAL FISH LESS GIZZARD SHAD	322	131	347	110	421	278	334	455	425	153	0	43		

TABLE 5.3-8 (SHEET 4 OF 4)

SPECIES	Weekly Periods 10-16 to 10-23	10-23 to 10-30	10-30 to 11-6	11-6 to 11-13	11-13 to 11-20	11-20 to 11-27	11-27 to 12-4	12-4 to 12-11	12-11 to 12-18	12-18 to 12-26	12-26 to 1-2	Annual Total
Chestnut lamprey			1									2
Silver lamprey		1									1	4
Undetermined lamprey											1	2
Longnose gar		2		1					1			6
Shortnose gar		1										2
Gizzard shad		13797	23445	57189	521	273	7183	2559	2700	2458	6470	136,667
Goldeye		1					1					2
Mooneye												1
Northern pike							1					35
Carp		6	1	1	4	1	1	4	2	2	3	296
Silver chub		7	10					3		1	3	98
Minnows		336	2	9	1	18	98	14		5	24	776
Carpsucker spp.		1	1		1			1				79
Smallmouth buffalo							1	1			1	9
Bigmouth buffalo												3
Shorthead redhorse		2		1		1		1			1	18
Black bullhead		4				2	2	2		1	3	146
Brown bullhead												12
Channel catfish		324	23	21	2	1	24	2	3	14	15	637
Tadpole madtom		7	1	1								31
Flathead catfish		4	2									35
Undetermined ictalurid												3
Trout-perch							1	1				26
Burbot			1					3	1	5	3	19
White bass		143	14	30	9	8	125	36	20	59	28	1,367
Rock bass		2	1	2			2	1	1	1		57
Green sunfish		25	1	1						1	1	56
Bluegill		157	91	177	4	16	19	10	2	2	1	674
Largemouth bass		1	2	2								5
Smallmouth bass		4		1		2	1			1		13
Crappie spp.		112	20	27	16	7	23	9	9		8	1,704
Undetermined centrarchid					1							1
Yellow perch		1										13
Logperch		3	1									13
Sauger		1	1	2	1		1					13
Walleye								1		1	1	5
Sauger-walleye												69
Freshwater drum		611	389	490	115	22	168	21	13	21	17	3,143
Undetermined fish			4							3		21
TOTAL		15553	24011	57955	675	351	7651	2669	2752	2575	6581	146,063
TOTAL FISH LESS GIZZARD SHAD		1756	566	766	154	78	468	110	52	117	111	9,396

TABLE 5.3-9 (SHEET 1 OF 8)

NUMBER OF FISH PER WEEK COLLECTED FROM THE TRASHBASKETS AT PINGP, 1975

	WEEKLY PERIODS													
Species	1-2 to 1-9	1-9 to 1-16	1-16 to 1-23	1-23 to 1-30	1-30 to 2-6	2-6 to 2-13	2-13 to 2-20	2-20 to 2-27	2-27 to 3-6	3-6 to 3-13	3-13 to 3-20	3-20 to 3-27	3-27 to 4-3	4-3 to 4-10
Chestnut lamprey					1									
Silver lamprey												6	2	1
Lamprey spp.														2
Longnose gar														
Shortnose gar														
Gar spp.														
Bowfin														
Gizzard shad	4,364	2,263	750	1,837	3,257	2,136	2,519	489	1,250	703	1,344	455	364	264
Goldeye														
Mooneye									1			5		1
Goldeye/Mooneye spp.														
Central mudminnow														
Northern pike											1	2	1	1
Carp	4	9		2	2		2	1	2	1	3		1	1
Silver chub									1	1	4			1
Minnow spp.	2	5	2	2	4	3	5	1	4	4	7	4	4	3
Carpsucker spp.											1	1		3
Carpsucker-buffalo spp.														
Smallmouth buffalo											3			
Bigmouth buffalo										1			2	
Shorthead redhorse						1	1						2	
White sucker													1	
Black bullhead		1		2		2		1				2	2	
Brown bullhead				1										
Yellow bullhead														
Bullhead spp.														
Total Bullheads		1		3		2		1				2	2	

TABLE 5.3-9 (SHEET 2 OF 8)

	WEEKLY PERIODS													
Species	1-2 to 1-9	1-9 to 1-16	1-16 to 1-23	1-23 to 1-30	1-30 to 2-6	2-6 to 2-13	2-13 to 2-20	2-20 to 2-27	2-27 to 3-6	3-6 to 3-13	3-13 to 3-20	3-20 to 3-27	3-27 to 4-3	4-3 to 4-10
Channel catfish	7	17	8	11	6	5	1	7	9	4	24	25	10	8
Tadpole madtom		1		1			1				1	1	2	1
Flathead catfish											1	1		1
Undetermined Ictalurids														
Trout-perch	1		1										1	3
Burbot		1												
White bass	31	39	17	15	11	8	24	27	17	15	21	25	11	9
Rock bass			1											1
Green sunfish				1	2						3	2	3	
Bluegill	1	6	2		1	3		3		1	2	4	2	1
Bluegill X Green sunfish														
Smallmouth bass											1			
Crappie spp.		4	5	3	2	2		4	4	2	5	57	16	39
Yellow perch											1	1		
Logperch								1			2	1		
Johnny darter														
Sauger											1	1	2	
Walleye												4	2	3
Sauger-Walleye				1							1		1	
Freshwater drum	15	12	13	20	25	27	63	58	51	27	62	51	41	31
Undetermined fish	4	4	4			4	6	2	2		2	1	1	1
Total	4,429	2,362	803	1,896	3,311	2,191	2,622	594	1,341	759	1,490	649	471	365
Total less Gizzard Shad	65	99	53	59	54	55	103	105	91	56	146	194	107	101

TABLE 5.3-9 (SHEET 3 OF 8)

Species	WEEKLY PERIODS 4-10 to 4-17	4-17 to 4-24	4-24 to 5-1	5-1 to 5-8	5-8 to 5-15	5-15 to 5-22	5-22 to 5-29	5-29 to 6-5	6-5 to 6-12	6-12 to 6-19	6-19 to 6-26	6-26 to 7-3	7-3 to 7-10	7-10 to 7-17
Chestnut lamprey	1		1	1										
Silver lamprey	8	9	1	1										
Lamprey spp.														
Longnose gar														
Shortnose gar					4	1	1							1
Gar spp.														
Bowfin		1	2	1	2	1								5
Gizzard shad	120	274	275	495	113	1	7	3	3	2				
Goldeye	1		1				1							
Mooneye		3	4				8	1		1				
Goldeye/Mooneye spp.														
Central mudminnow				5	1									
Northern pike		2			1	1	7	2						4
Carp		6	6	5	25	3	19	25	15	13		2		
Silver chub	1	5	26	26	7	5	21	10	6	15				
Minnow spp.	6	50	48	101	13	7	53	50	43	91				
Carpsucker spp.	1	2	2	7	9		1					5		17
Carpsucker-buffalo spp.														
Smallmouth buffalo		1			2									
Bigmouth buffalo		2	3		3									
Shorthead redhorse	2	2	1	2	1		2	2		2		1		
White sucker		1		8	2	1		1						
Black bullhead	4	31	1,753	831	42	22	34	19	14					
Brown bullhead			12	21		2								
Yellow bullhead		1	2	1										
Bullhead spp.				524	230		50					1		1
Total Bullheads	4	32	1,767	1,377	273	24	84	19	14			1		1

TABLE 5.3-9 (SHEET 4 OF 8)

Species	4-10 to 4-17	4-17 to 4-24	4-24 to 5-1	5-1 to 5-8	5-8 to 5-15	5-15 to 5-22	5-22 to 5-29	5-29 to 6-5	6-5 to 6-12	6-12 to 6-19	6-19 to 6-26	6-26 to 7-3	7-3 to 7-10	7-10 to 7-17
	WEEKLY PERIODS													
Channel catfish	9	11	13	11	21	2	8	8	15	13		1		
Tadpole madtom		3	2			1	1							
Flathead catfish	1	1												
Undetermined Ictalurids	3									1				
Trout-perch		4	23	1		1	3	3						
Burbot														
White bass	5	13	42	57	74	14	51	20	1	1				
Rock bass	2	5	4	4	5	7	5	6	3	3				1
Green sunfish	1	2	7	7	12	2	8	2	2	4				
Bluegill	5	2	4		8	5	19	5	1	2				
Bluegill X Green sunfish				1										
Smallmouth bass														
Crappie spp.	21	22	34	86	53	20	85	28	15	21		1		4
Yellow perch	4	4	38	18	6	2	2	1	1					
Logperch	1	1		1										
Johnny darter							1							
Sauger	1	3	2	3		3	12	21	11					
Walleye		1	1											
Sauger-Walleye	1						19			1				
Freshwater drum	17	26	9	45	49	20	83	25	10	1		1		1
Undetermined fish					7	1	4		1					
Total	215	488	2,316	2,263	690	124	507	232	141	171		12		34
Total less Gizzard Shad	95	214	2,041	1,768	577	121	500	229	138	169		12		29

TABLE 5.3-9 (SHEET 5 OF 8)

Species	7-17[1] to 7-24	7-24 to 7-31	7-31 to 8-7	8-7 to 8-14	8-14 to 8-21	8-21 to 8-28	8-28 to 9-4	9-4 to 9-11	9-11 to 9-18	9-18 to 9-25	9-25 to 10-2	10-2 to 10-9	10-9 to 10-16	10-16 to 10-23
	WEEKLY PERIODS													
Chestnut lamprey														
Silver lamprey														
Lamprey spp.												1		
Longnose gar	1	2	3			1				1		1	1	3
Shortnose gar	2			1										1
Gar spp.				1									1	
Bowfin	1		1			1						1		
Gizzard shad	90	313	168	1,218	1,566	358	516	285	451	333	529	878	3,660	592
Goldeye														
Mooneye									1			1		
Goldeye-Mooneye spp.	1													
Central mudminnow			2											
Northern pike	33	18	14	13	4	3	1	1	1					
Carp	152	76	21	7		2		4	1		3	2		1
Silver chub	6	11	28	22	3	5	4	7	8	5	2	9	8	6
Minnow spp.	36	53	38	43	50	218	75	44	91	45	83	116	179	149
Carpsucker spp.	32	14	20	1						1	1			
Carpsucker-buffalo spp.		4	15	32	23	8	1							
Smallmouth buffalo			3											
Bigmouth buffalo	4	3	1						2					1
Buffalo spp.								1						
Shorthead redhorse	1	1			1		6	1	1				1	1
White sucker			1											
Black bullhead	1		1	2	1	11	4						1	4
Brown bullhead				1										
Yellow bullhead														
Bullhead spp.				1		4								
	1		1	4	1	[illegible]	4						1	4

TABLE 5.3-9 (SHEET 6 OF 8)

	WEEKLY PERIODS													
Species	7-17[1] to 7-24	7-24 to 7-31	7-31 to 8-7	8-7 to 8-14	8-14 to 8-21	8-21 to 8-28	8-28 to 9-4	9-4 to 8-11	9-11 to 9-18	9-18 to 9-25	9-25 to 10-2	10-2 to 10-9	10-9 to 10-16	10-16 to 10-23
Channel catfish	7	8	24	171	68	381	173	53	89	109	860	1,650	290	228
Tadpole madtom	1	6	2			3			1			3		
Flathead catfish	1		9	37	11	6	3	1	3		1	1	4	
Undetermined Ictalurids												8		
Trout-perch			1	1					1					
Burbot		1			1									
White bass	390	218	100	128	61	207	88	73	78	38	29	51	66	22
Rock bass	8		3	2		1							1	
Green sunfish	3			1				1	2	2	1	5	1	3
Bluegill	5	2	1		1	27	14	4	2	2	3	15	23	7
Bluegill X Green sunfish														
Smallmouth bass										1				
Crappie spp.	301	158	56	42	81	105	102	168	153	60	35	77	43	8
Unidentified Centrarchid													1	3
Yellow perch						1						1	1	
Logperch				1				1			1	2		
Johnny darter	1													
Sauger			1	2						1				2
Walleye				2									1	
Sauger-Walleye	16	7	6	1		2		1						
Freshwater drum	33	64	69	80	60	96	48	49	56	86	147	366	729	100
Undetermined fish		1	14	7	11		24	19			10	14	2	2
Total	1,115	960	602	1,817	1,944	1,439	1,059	713	939	684	1,705	3,202	5,013	1,133
Total less Gizzard shad	1,025	647	434	599	378	1,081	543	428	488	351	1,176	2,324	1,353	541

[1] Many fish not identified or counted due to decomposition

TABLE 5.3-9 (SHEET 7 OF 8)

Species	10-23 to 10-30	10-30 to 11-6	11-6 to 11-13	11-13 to 11-20	11-20 to 11-27	11-27 to 12-4	12-4 to 12-11	12-11 to 12-18	12-18 to 12-26	12-26 to 1-2	Annual Total
	WEEKLY PERIODS										
Chestnut lamprey			1			2	1				8
Silver lamprey		5			1	1		1			36
Lamprey spp.											3
Longnose gar	1						1				16
Shortnose gar						1	1				12
Gar spp.											2
Bowfin		1									17
Gizzard shad	12,519	2,932	5,581	1,884	2,306	1,578	916	5,098	1,623	1,822	70,506
Goldeye					2						5
Mooneye											26
Goldeye/Mooneye spp.											1
Central mudminnow											8
Northern pike				1							110
Carp		1	2	1	1	3		3			427
Silver chub	2	1	1	1	1						259
Minnow spp.	185	79	71	34	83	6		38	1	2	2,231
Carpsucker spp.		1	2	2	1	1	33	2			150
Carpsucker-buffalo spp.											83
Smallmouth buffalo	1							1			11
Bigmouth buffalo											22
Buffalo spp.											1
Shorthead redhorse		1							1		34
White sucker											15
Black bullhead	3	3		2	1		2				2,797
Brown bullhead								1			38
Yellow bullhead											4
Bullhead spp.											811
Total Bullheads	3	3			1		2	1			3,651

TABLE 5.3-9 (SHEET 8 OF 8)

Species	WEEKLY PERIODS 10-23 to 10-30	10-30 to 11-6	11-6 to 11-13	11-13 to 11-20	11-20 to 11-27	11-27 to 12-4	12-4 to 12-11	12-11 to 12-18	12-18 to 12-26	12-26 to 1-2	Annual Total
Channel catfish	71	45	321	658	181	51	87	79	153	212	6,223
Tadpole madtom	1	1									33
Flathead catfish	1	3			4						90
Undetermined Ictalurids											12
Trout-perch			1								45
Burbot		1	1				1				6
White bass	53	52	24	164	140	28	39	27	51	37	2,712
Rock bass	1	2		1		7		2	1		76
Green sunfish		10	3	2	6	4	5	2	2		111
Bluegill	11	13	12	8	7	3	3	1	1		242
Bluegill X Green sunfish											1
Smallmouth bass											2
Crappie spp.	25	18	29	17	20	8	1		1		2,030
Undetermined Centrarchid		2									6
Yellow perch											81
Logperch			3								15
Johnny darter											2
Sauger	1	5	2	6	13		2		2		97
Walleye					9		2	1		1	27
Sauger-Walleye spp.				4	4	5		2	1		73
Freshwater drum	395	133	90	93	243	16	29	15	5	4	3,789
Undetermined fish	3	1	1				4	1			160
Total	13,274	3,310	6,145	2,878	3,023	1,714	1,127	5,274	1,842	2,078	93,466
Total less Gizzard Shad	754	378	564	994	717	136	211	176	219	256	23,960

TABLE 5.3-10 (Sheet 1 of 2)

NUMBER OF FISH AND PERCENT OF YEARLY TOTAL FOR EACH SPECIES, BY SEASON, FOR FISHES COLLECTED FROM THE TRASH BASKETS AT PINGP FROM JANUARY 3, 1975 TO DECEMBER 31, 1975

	Winter		Spring		Summer		Fall	
	Jan. 3 to Mar. 20		Mar. 20 to June 19		June 19 to Sept. 18		Sept. 18 to Dec. 31	
Species	Number	% of Total	Number	% of Total	Number	% of Total	Number	% of Total
Chestnut lamprey	1	12.5	3	37.5			4	50.0
Silver lamprey			28	77.7			8	22.3
Lamprey spp.			2	66.7			1	33.3
Longnose gar					8	50.0	8	50.0
Shortnose gar			6	50.0	3	25.0	3	25.0
Gar spp.			--		1	50.0	1	50.0
Bowfin			7	41.2	8	47.0	2	11.8
Gizzard shad	20,912	29.7	2,378	3.4	4,965	7.0	42,251	59.9
Goldeye			3	60.0			2	40.0
Mooneye	1	4.0	23	88.1	1	4.0	1	3.9
Goldeye/Mooneye spp.					1	100.0		
Central mudminnow			6	75.0	2	25.0		
Northern pike	1	0.9	17	15.5	91	82.7	1	0.9
Carp	26	6.1	119	27.9	265	26.2	17	3.9
Silver chub	6	2.3	125	48.3	92	35.5	36	13.9
Minnow spp.	39	1.7	473	21.2	647	29.0	1,072	48.1
Carpsucker spp.	1	0.7	26	17.3	79	52.7	44	29.3
Carpsucker/buffalo spp.					83	100.0		
Smallmouth buffalo	3	27.3	3	27.3	3	27.3	2	18.1
Bigmouth buffalo	1	4.5	10	45.5	10	45.5	1	4.5
Buffalo spp.					1	100.0		
Shorthead redhorse	2	6.3	16	47.1	12	35.3	4	11.3
White sucker			14	93.3	1	6.7		
Black bullhead	6	<0.1	2,755	98.5	20	0.7	16	<0.1

TABLE 5.3-10 (Sheet 2 of 2)

Species	Winter Jan. 3 to Mar. 20		Spring Mar. 20 to June 19		Summer June 19 to Sept. 18		Fall Sept. 18 to Dec. 31	
	Number	% of Total	Number	% of Total	Number	% of Total	Number	% of Total
Brown bullhead	1	2.6	35	92.2	1	2.6	1	2.6
Yellow bullhead			4	100.0				
Bullhead spp.			804	99.1	7	0.9		
Channel catfish	99	1.6	154	2.5	975	15.7	4,995	80.2
Tadpole madtom	4	12.1	11	33.3	13	39.4	5	15.6
Flathead catfish	1	1.1	4	4.4	71	78.9	14	15.6
Undetermined Ictalurids			4	33.3			8	66.7
Trout-perch	2	4.4	39	86.7	3	6.7	1	2.2
Burbot	1	16.7			2	33.3	3	50.0
White bass	225	8.3	323	11.9	1,343	49.5	821	30.3
Rock bass	1	1.3	45	59.2	15	19.7	15	19.7
Green sunfish	6	5.4	52	46.8	7	6.3	46	41.5
Bluegill	19	7.9	58	24.0	56	23.1	109	45.0
Bluegill X green sunfish			1	100.0				
Smallmouth bass	1	50.0					1	50.0
Crappie spp.	31	1.5	486	23.9	1,171	57.7	342	16.9
Undetermined Centrarchid							6	100.0
Yellow perch	1	1.2	77	95.1	1	1.2	2	2.5
Logperch	3	20.0	4	26.7	2	13.3	6	40.0
Johnny darter			1	50.0	1	50.0		
Sauger	1	1.0	59	60.8	3	3.1	34	35.1
Walleye			11	40.7	2	7.4	14	51.9
Sauger/Walleye spp.	2	2.7	22	30.1	33	45.2	16	22.0
Freshwater drum	373	9.8	408	10.8	557	14.7	2,451	64.7
Undetermined fish	28	17.5	16	10.0	78	48.8	38	23.7

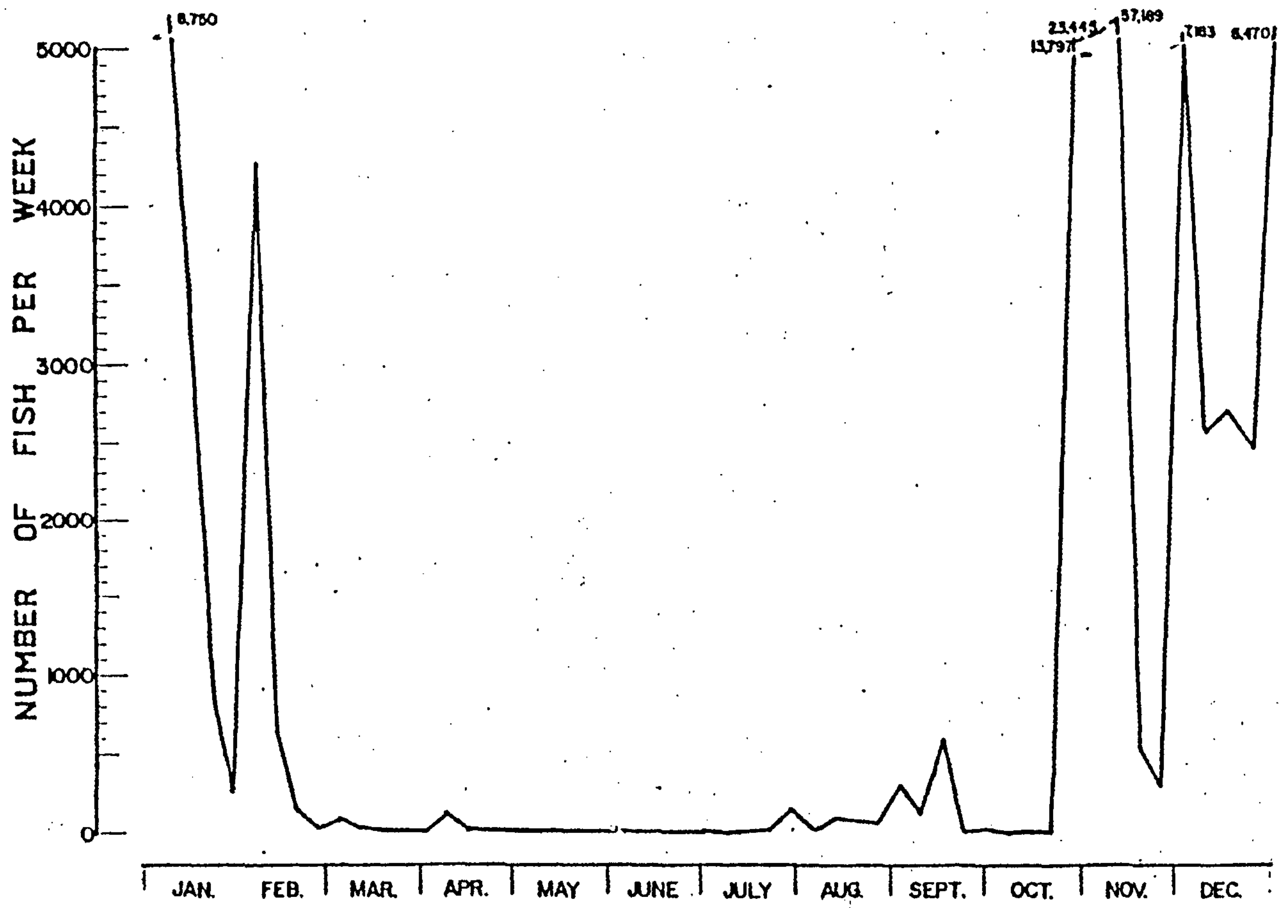


FIGURE 5.3-5
NUMBERS OF GIZZARD SHAD COLLECTED FROM THE TRASHBASKETS AT PINGP, 1974

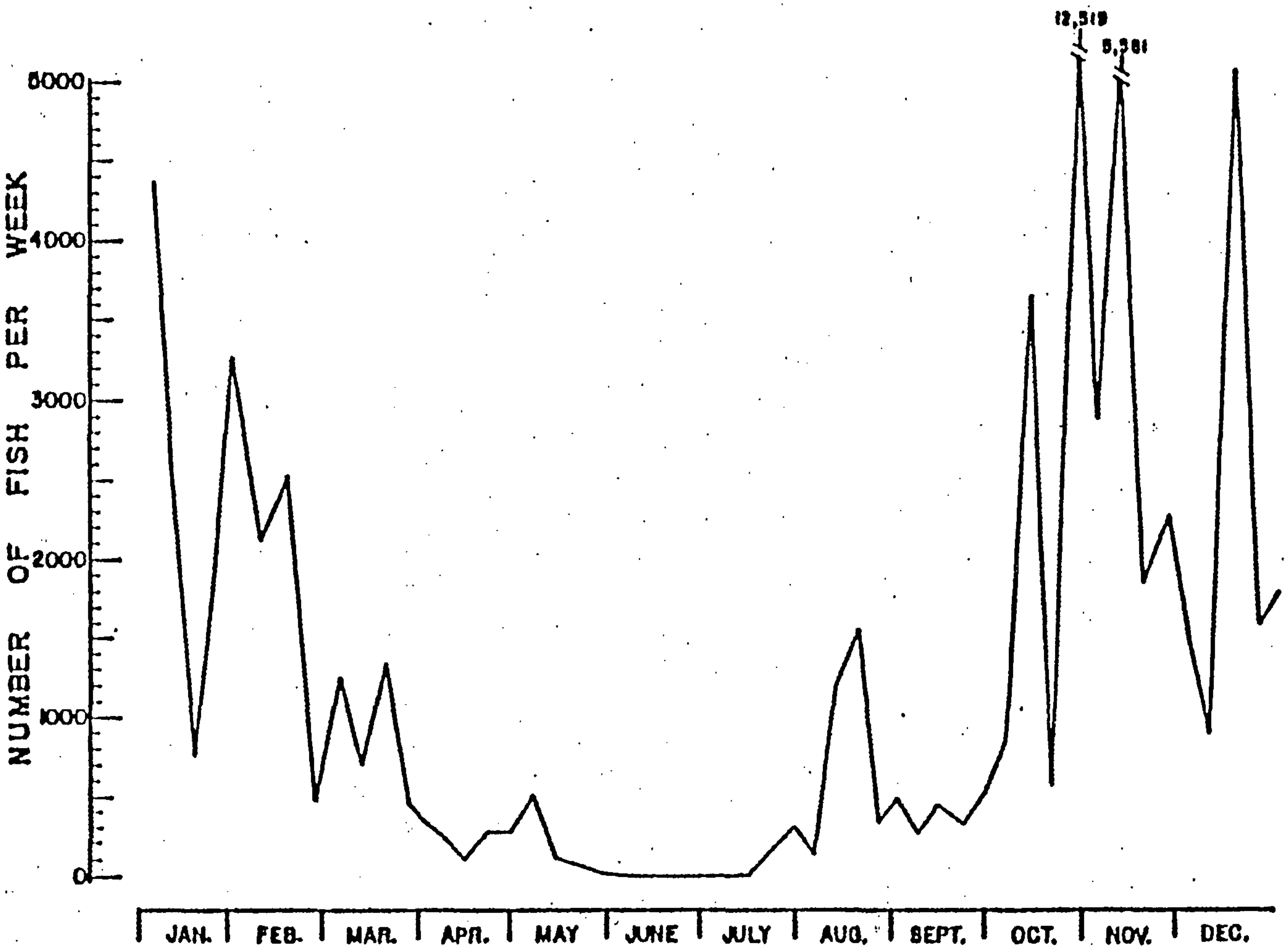


FIGURE 5.3-6

NUMBERS OF GIZZARD SHAD COLLECTED FROM THE TRASHBASKETS AT PINGP, 1975

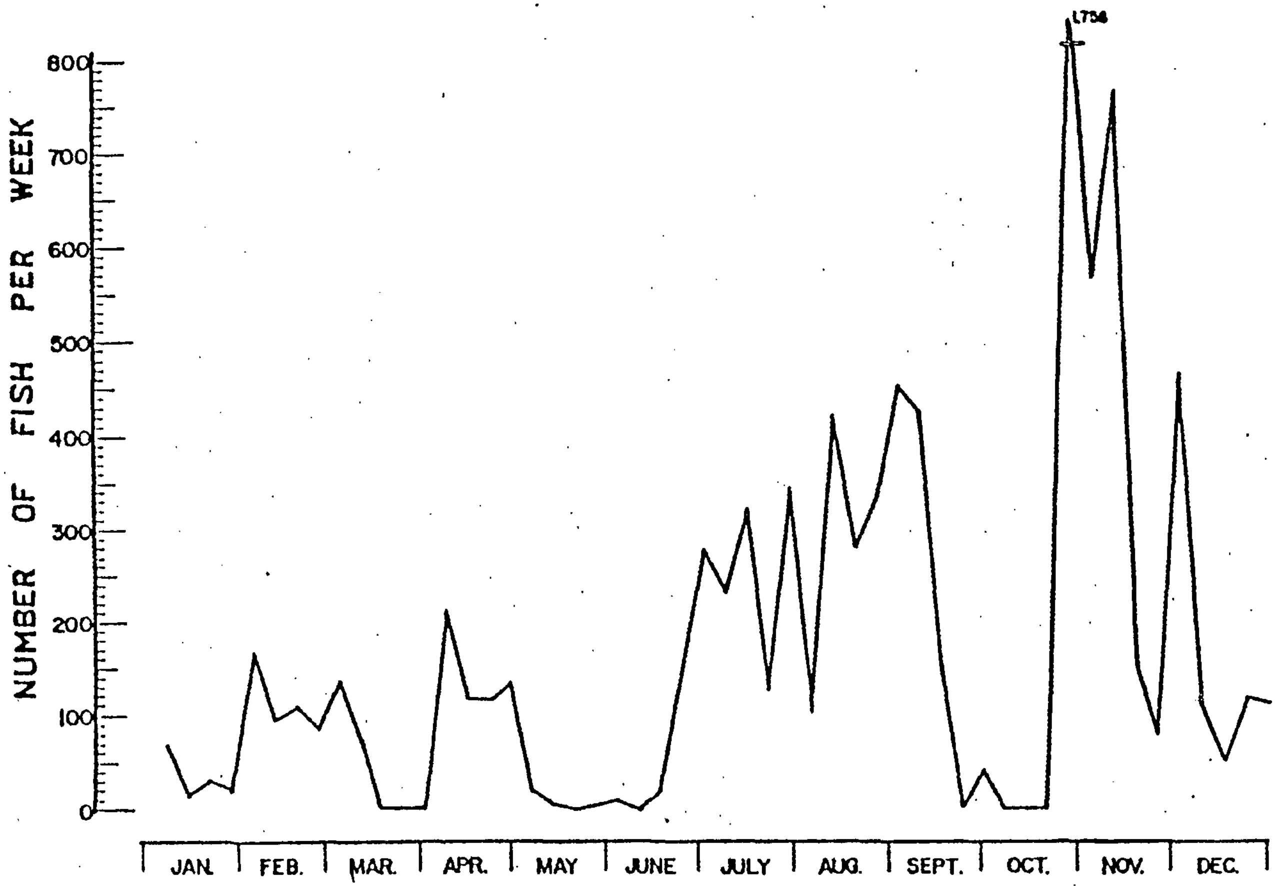


FIGURE 5.3-7
TOTAL NUMBERS OF FISH LESS GIZZARD SHAD
COLLECTED FROM THE TRASHBASKETS AT PINGP, 1974

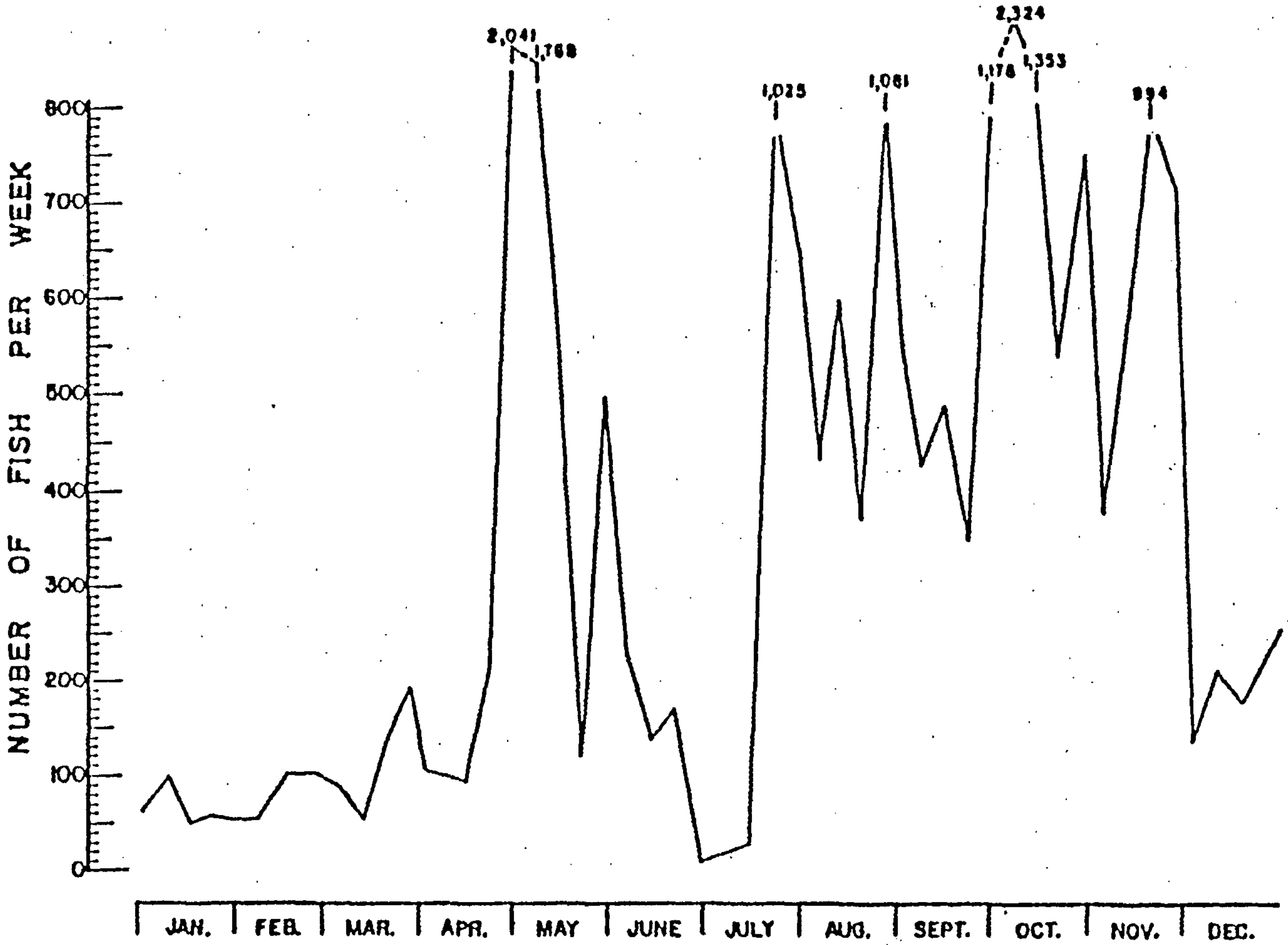


FIGURE 5.3-8
NUMBERS OF FISH LESS GIZZARD SHAD
COLLECTED FROM THE TRASHBASKETS AT PINGP, 1975

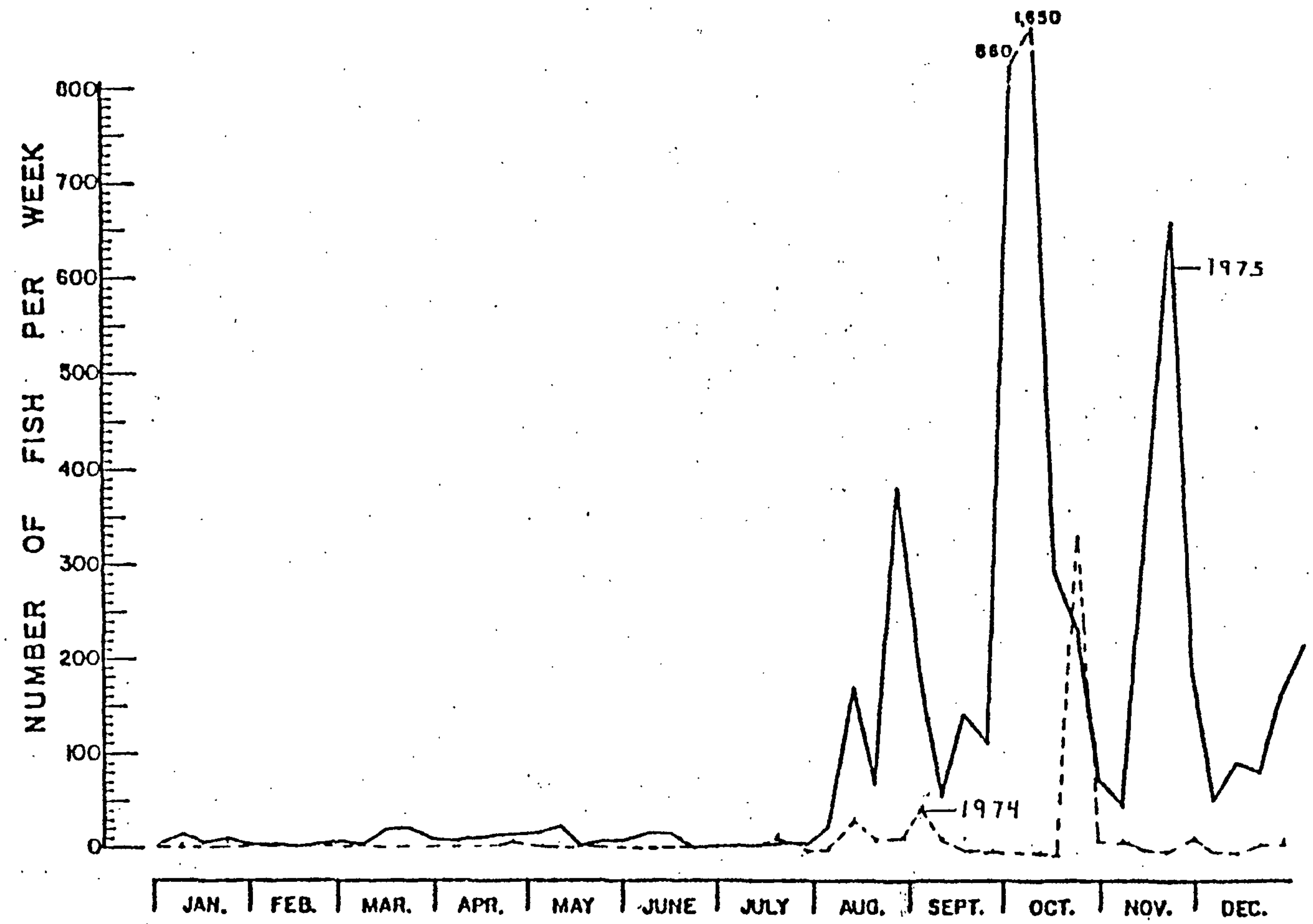


FIGURE 5.3-9
NUMBERS OF CHANNEL CATFISH COLLECTED FROM THE TRASHBASKETS AT PINGP, 1974-1975

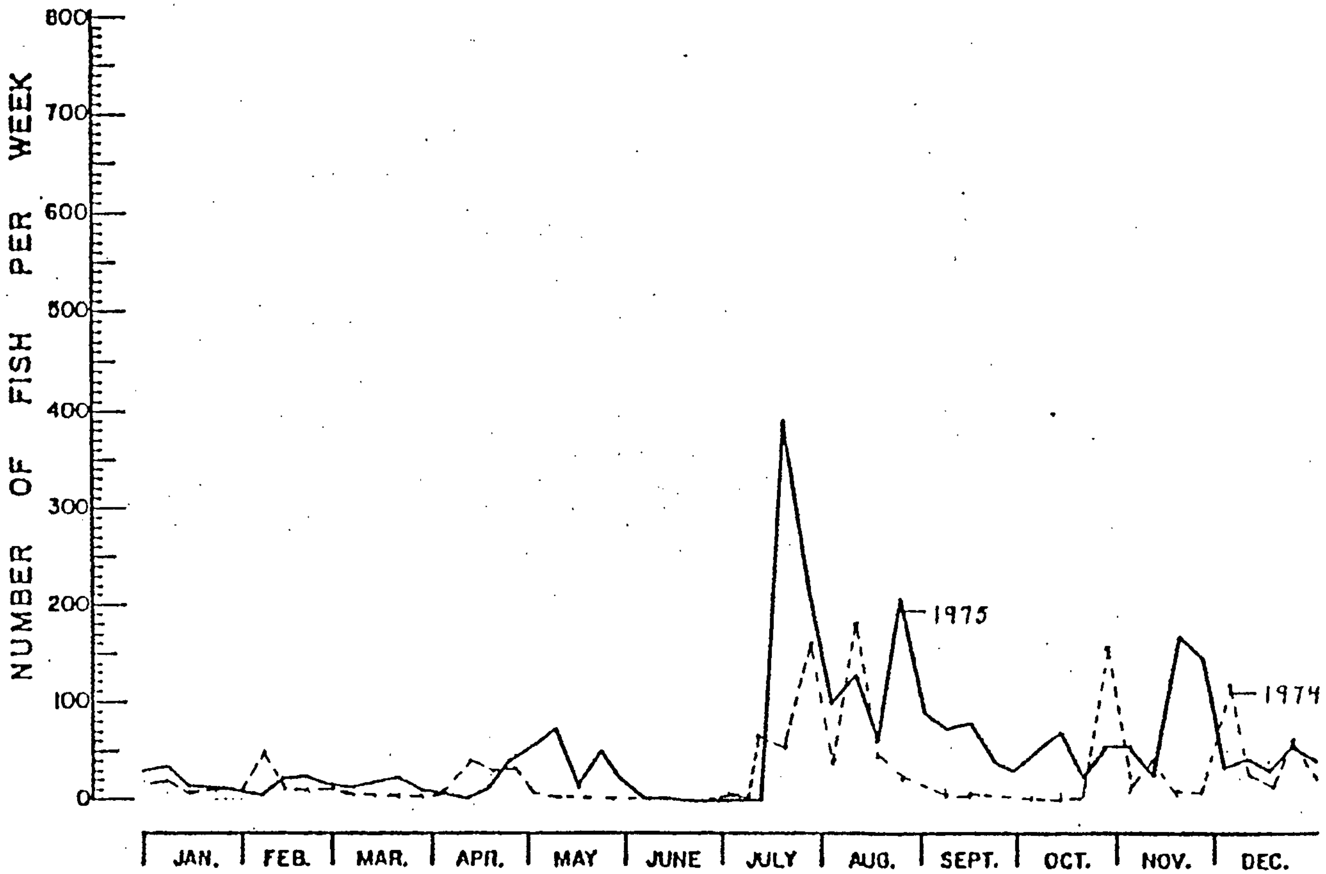


FIGURE 5.3-10

NUMBERS OF WHITE BASS COLLECTED FROM THE TRASHBASKETS AT PINGP, 1974-1975

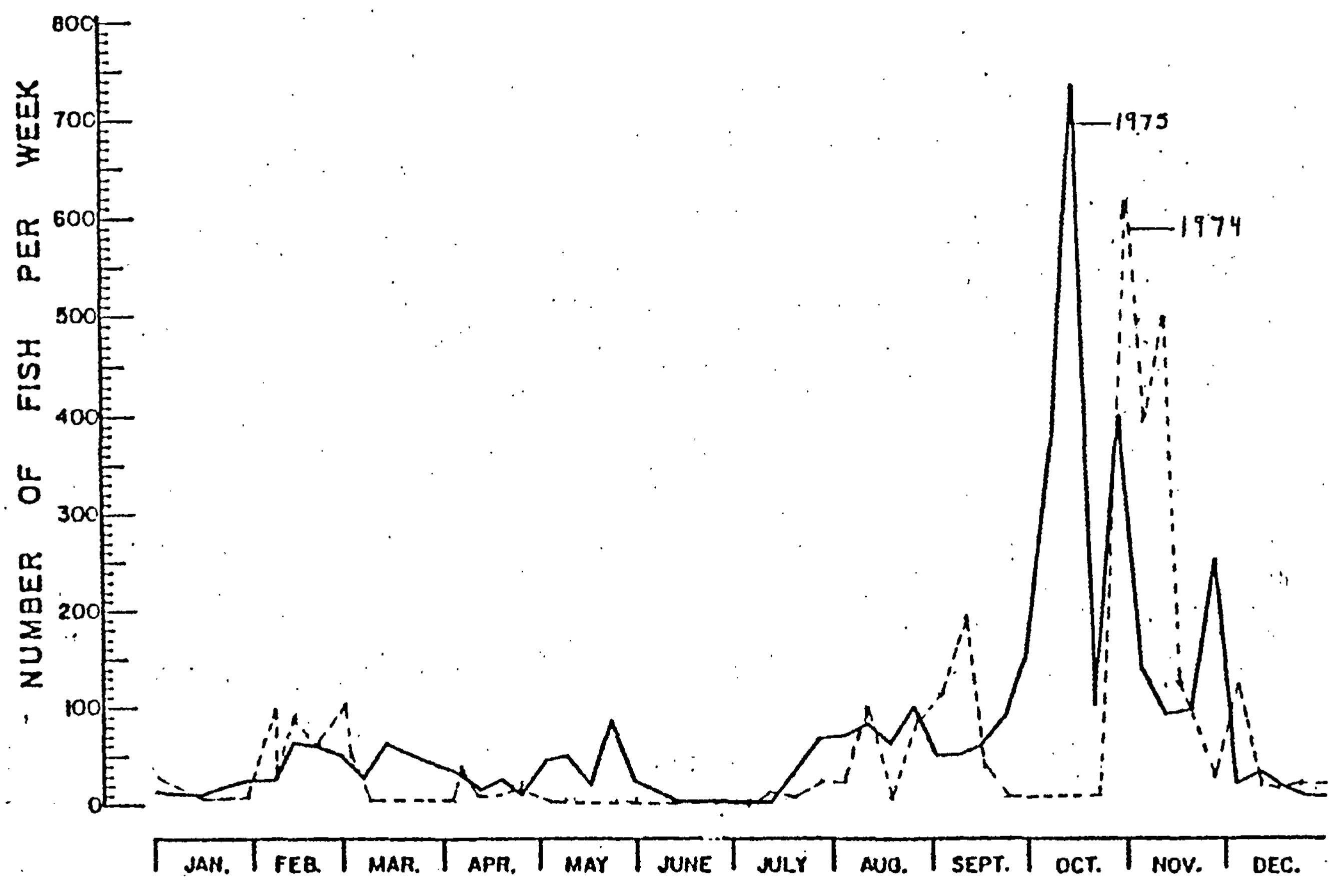


FIGURE 5.3-11
NUMBERS OF FRESHWATER DRUM COLLECTED FROM THE TRASHBASKETS AT PINGP, 1974-1975

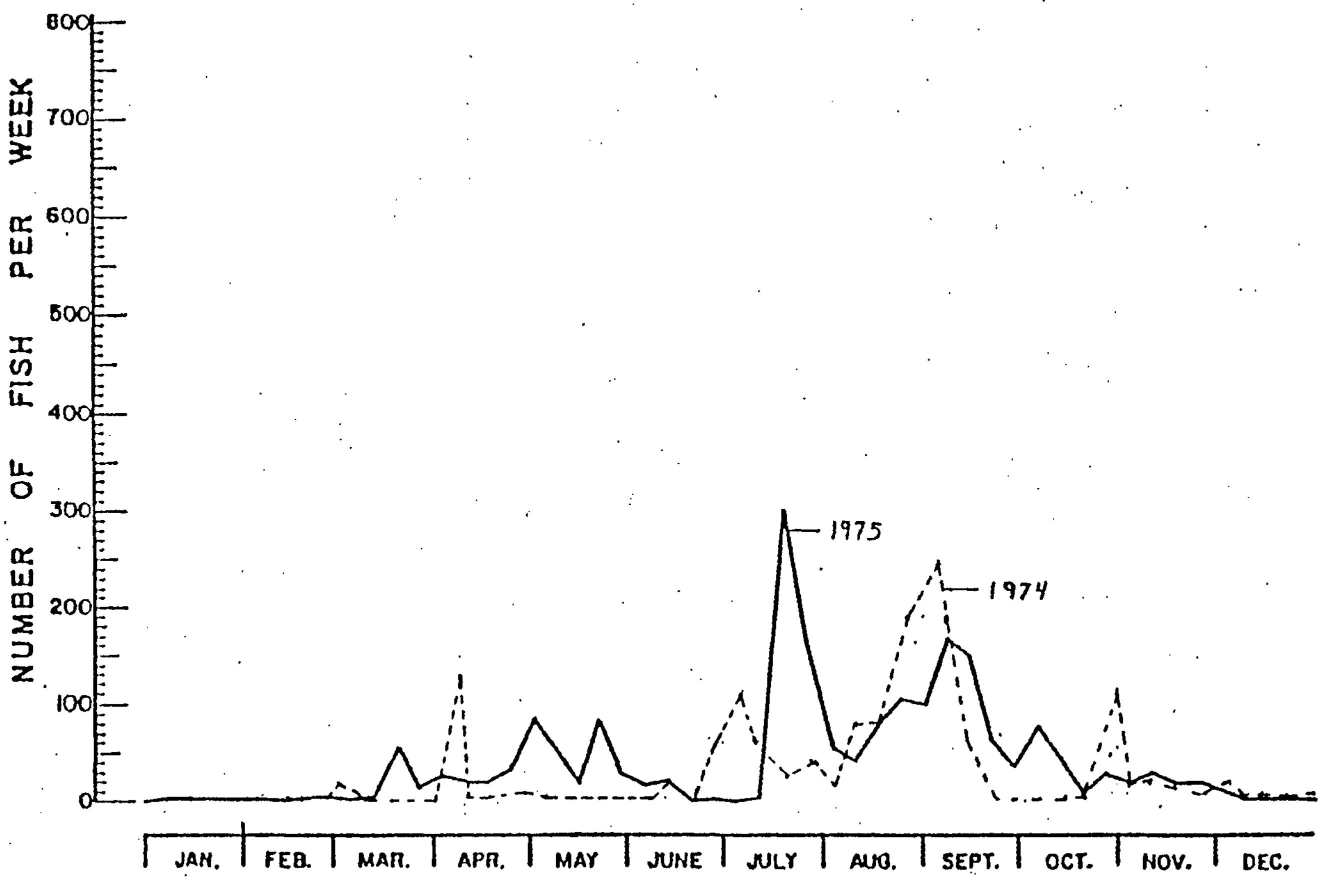


FIGURE 5.3-12
NUMBERS OF CRAPPIES COLLECTED FROM THE TRASHBASKETS AT PINGP, 1974-1975

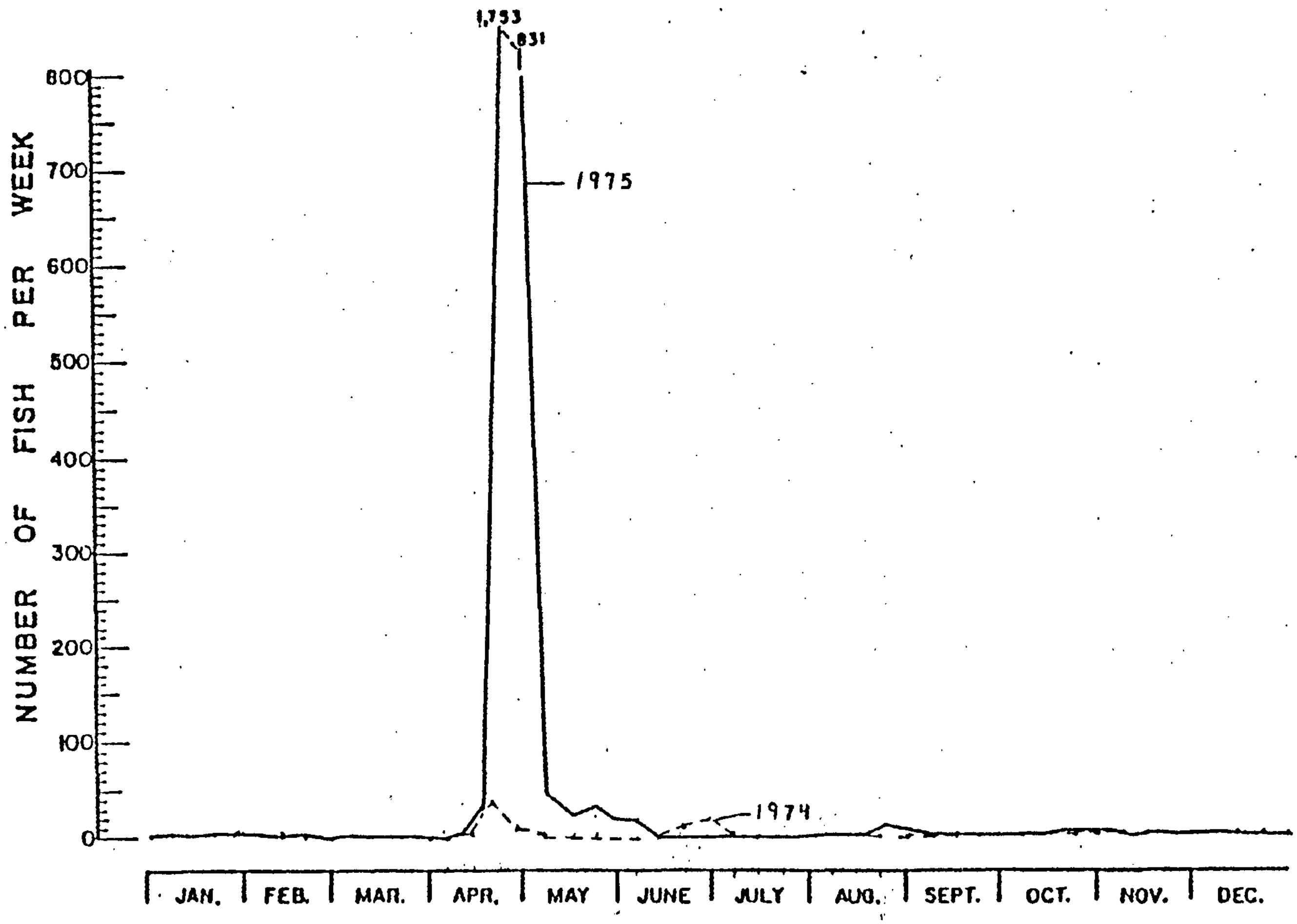


FIGURE 5.3-13
NUMBERS OF BLACK BULLHEAD COLLECTED FROM THE TRASHBASKETS AT PINGP, 1974-1975

Size ranges of all impinged fishes (Table 5.3-11) and the ranges for six selected species (Figures 5.3-14 through 5.3-5.3-19) indicate that impingement primarily affected juveniles in 1975. Generally, impingement did not affect many fishes under 60 mm or over 150-200 mm during 1974 or 1975.

Data on impingement of organisms other than fish in 1975 are presented in Tables 5.3-12 and 5.3-13. A wide variety of organisms were encountered; dominant animals were crayfish, turtles, and clams. Many of the organisms recorded, particularly birds and mammals, probably died elsewhere and floated passively into the intake. Crayfish were impinged more frequently during winter and spring. Turtles occurred primarily during late summer and early fall.

Correlation tests were made on the 1975 data to compare impingement of five fish species with water temperature and intake flow data (Tables 5.3-14 and 5.3-15; Appendix 4).

The data are based on weekly impingement totals for each species and weekly mean values of temperature and flow data. Correlations between various physical data, e.g. river water inlet temperature with makeup-water appropriation, were included to assist in finding the strongest correlations of impingement with physical data when several were apparent.

TABLE 5.3-11 (Sheet 1 of 2)

LENGTH-FREQUENCY OF IMPINGED FISHES COLLECTED FROM THE TRASH BASKETS AT PINGP FROM JANUARY 3, 1975 TO DECEMBER 31, 1975.

Total Length in Millimeters

	1-19	20-39	40-59	60-79	80-99	100-119	120-139	140-159	160-179	180-199	200-219	220-239	240-259	260-279	280-299	300-319	320-339	340-359
Chestnut lamprey										1					3	4	1	
Silver lamprey												1	3	9	7	7	5	2
Longnose gar							3				1				2	2		2
Shortnose gar									1				1					
Bowfin									1	1	1	1				1		
Gizzard shad			51	294	744	2,177	1,735	1,080	237	47	13	3	4	11	20	17	8	3
Goldeye					1	1	1						1					
Mooneye						5	8	1						1	4	5	2	
Central mudminnow				2			3	2	2	1								
Northern pike					1	3	8	12	11	12	12	6	3	3	3	1	1	1
Carp			12	44	73	21	5	3	3	1	2	3		5	2	5	5	12
Silver chub			7	61	17	46	93	21	5									
Minnow spp.		27	214	832	395	40	11	2										
Carpsucker spp.			16	20	9	3	2	3	2	1	3	2	1	3	4	1		1
Carpsucker/ Buffalo spp.			2	10	25	3												
Smallmouth Buffalo				3	1							1	1	1		1		
Bigmouth Buffalo			2	10	1		1							2	1		2	3
Buffalo spp.							1											
Shorthead redhorse			1	7	4						1	1	3	1			2	4
White Sucker				4	5		1		1				1		1			
Black bullhead			11	64	39	41	102	59	113	44	25	12	5	1	1			
Brown bullhead					1		1		1	1	2	1						

	360-379	380-399	400-419	420-439	440-459	460-479	480-499	500-519	520-539	540-559	560-579	580-599	600-619	620-639	640-659	660-679	680-699	Total
Chestnut lamprey																		9
Silver lamprey																		34
Longnose gar	1																	11
Shortnose gar			2			2		1				1				4	4	16
Bowfin				2				1					1					9
Gizzard shad	2	3		1	1													6,451
Goldeye																		4
Mooneye																		26
Central mudminnow																		10
Northern pike		2	1			1	2		1				4					88
Carp	9	13	16	19	15	8	7	2	6	1	3	1			1			297
Silver chub																		250
Minnow spp.																		1,521
Carpsucker spp.						1	1											73
Carpsucker/ Buffalo spp.																		40
Smallmouth Buffalo				1														9
Bigmouth Buffalo	2		1	1					1									27
Buffalo spp.																		1
Shorthead redhorse	2	1				1	1											29
White Sucker			1															14
Black bullhead																		517
Brown bullhead																		7

TABLE 5.3-11 (Sheet 2 of 2)

	Total Length in Millimeters																																		Total
	1-19	20-39	40-59	60-79	80-99	100-119	120-139	140-159	160-179	180-199	200-219	220-239	240-259	260-279	280-299	300-319	320-339	340-359	360-379	380-399	400-419	420-439	440-459	460-479	480-499	500-519	520-539	540-559	560-579	580-599	600-619	620-639	640-659	660-679	680-699	
Yellow bullhead					1		1	2																												4
Bullhead spp.			2	4	3	6	4	14	16	19	12	1	4	1																						86
Channel catfish		1	79	188	253	371	457	449	179	71	29	21	12	11	6	7	3	9	4	3	1	6		2	3			1								2,166
Tadpole Madtom			2	8	14	3						1			1																					29
Flathead catfish			8	32	18	8	5	1	2	1				1											1											77
Trout-Perch			2	19	18				1			3	4	1				1																		49
Burbot						1					1		1	1										1												5
White bass			42	227	173	612	236	33	11	15	34	32	14	15	7	18	29	20	11	5	1															1,535
Rock bass		2	2	3	11	12	8	7	9	2	1																									57
Green sunfish			5	7	14	40	21	6	4									2																		99
Bluegill		10	78	34	27	18	22	8	14	6	1						1							1												220
Bluegill x green sunfish							1																													1 1
Smallmouth bass															2																					2
Crappie spp.		1	152	567	248	128	42	17	12	18	19	6	4	5	4	1	1																			1,225
Yellow perch				5	15	12	12	14	9	6	3	1																								77
Logperch			1	4	8	2																														15
Johnny darter				1																																1
Sauger				1	2	1	7	17	10		5	8	12	8	6	3	1	2				1														84
Walleye					3	2		5	6	1	1					1	1			2		1	1		3											27
Sauger/Walleye spp.				4	15	2	2	5	3		4	8	6	1	2	1	1	1		1			1													57
Freshwater drum			22	174	299	461	737	242	25	37	50	41	39	42	34	25	13	11	8	2	2	2														2,266
Undetermined fish			1		1	1																														3

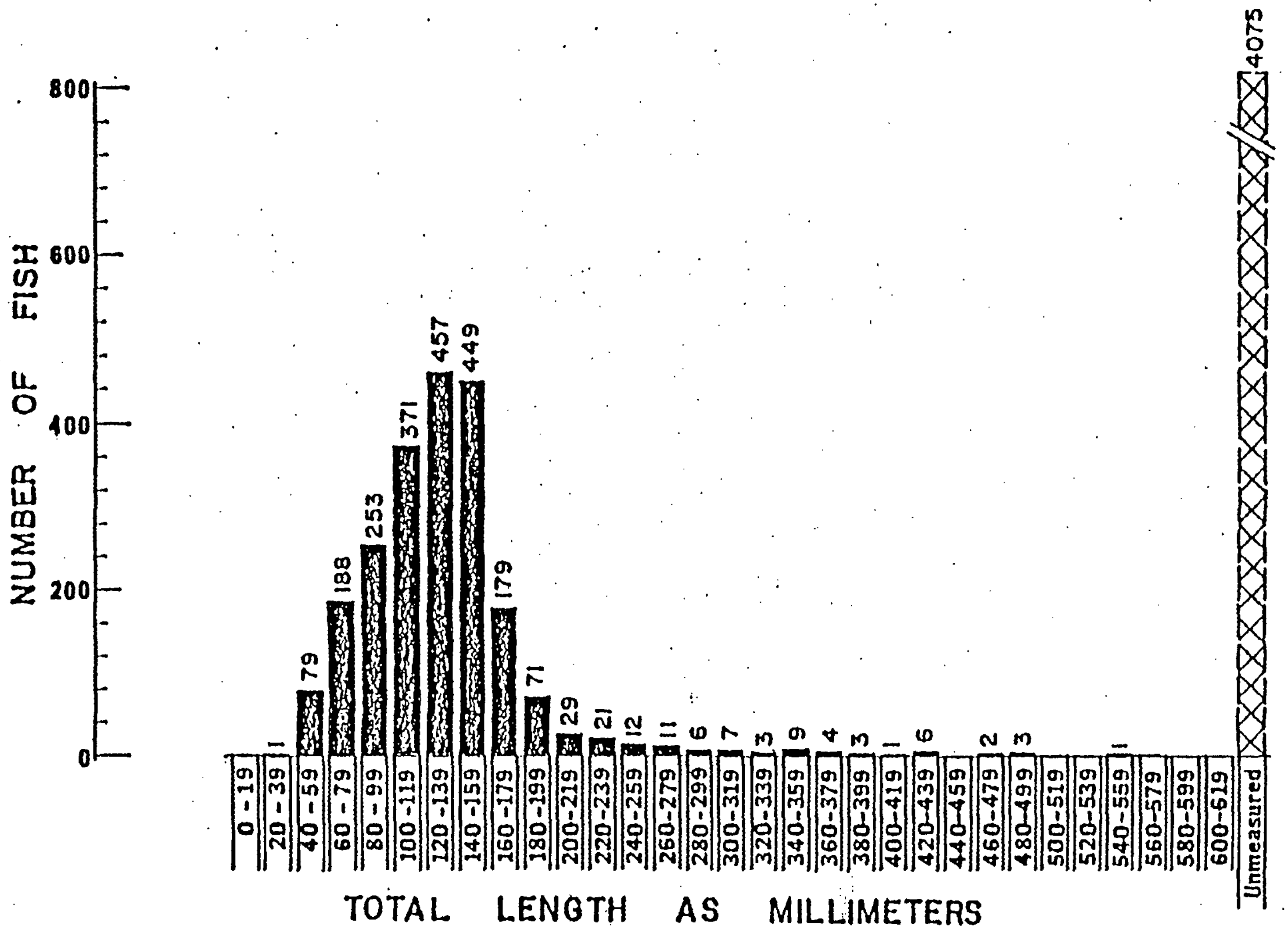


FIGURE 5.3-14

LENGTH FREQUENCY OF CHANNEL CATFISH IMPINGED AT PINGP, 1975

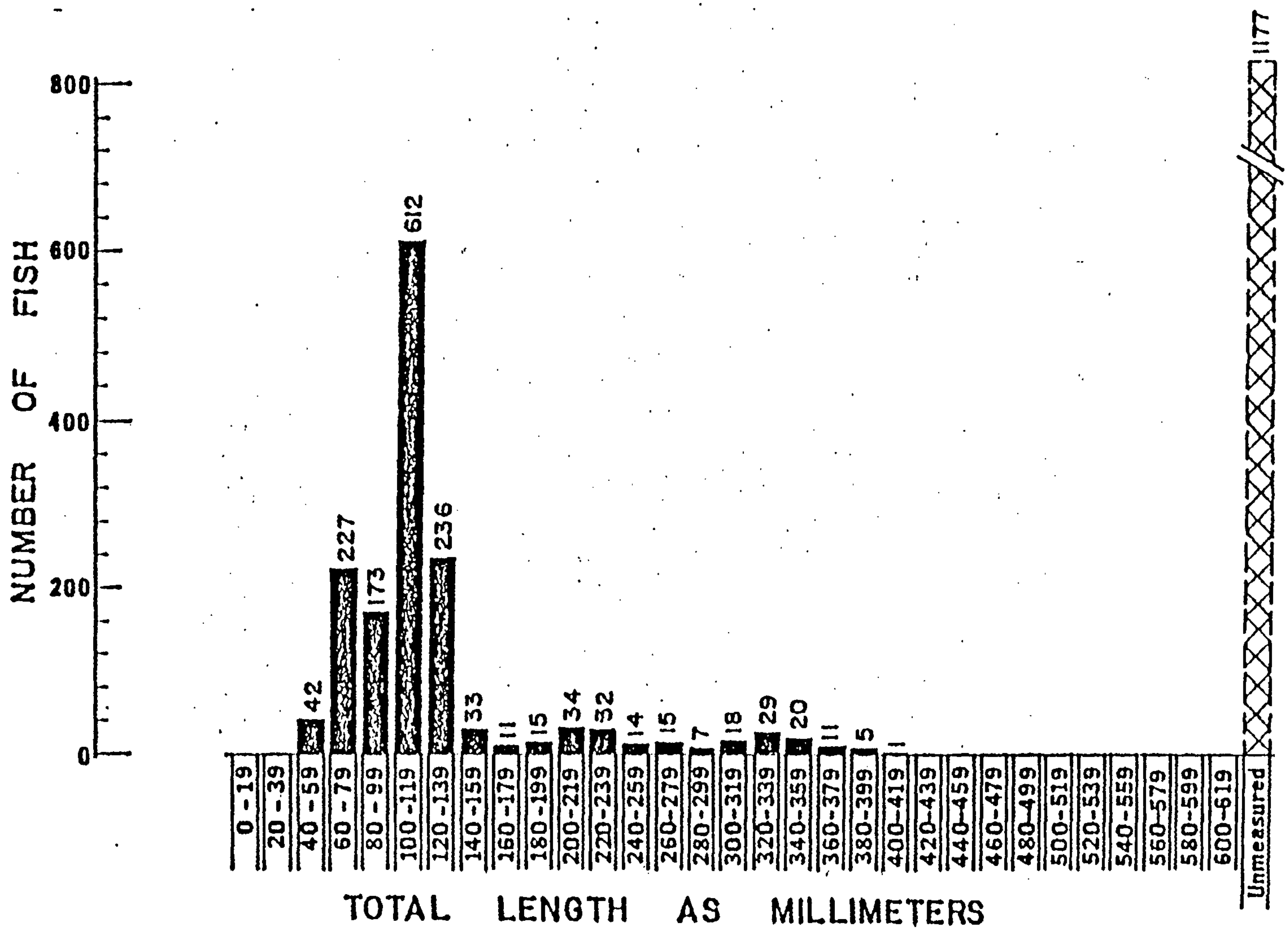


FIGURE 5.3-15

LENGTH FREQUENCY OF WHITE BASS IMPINGED AT PINGP, 1975

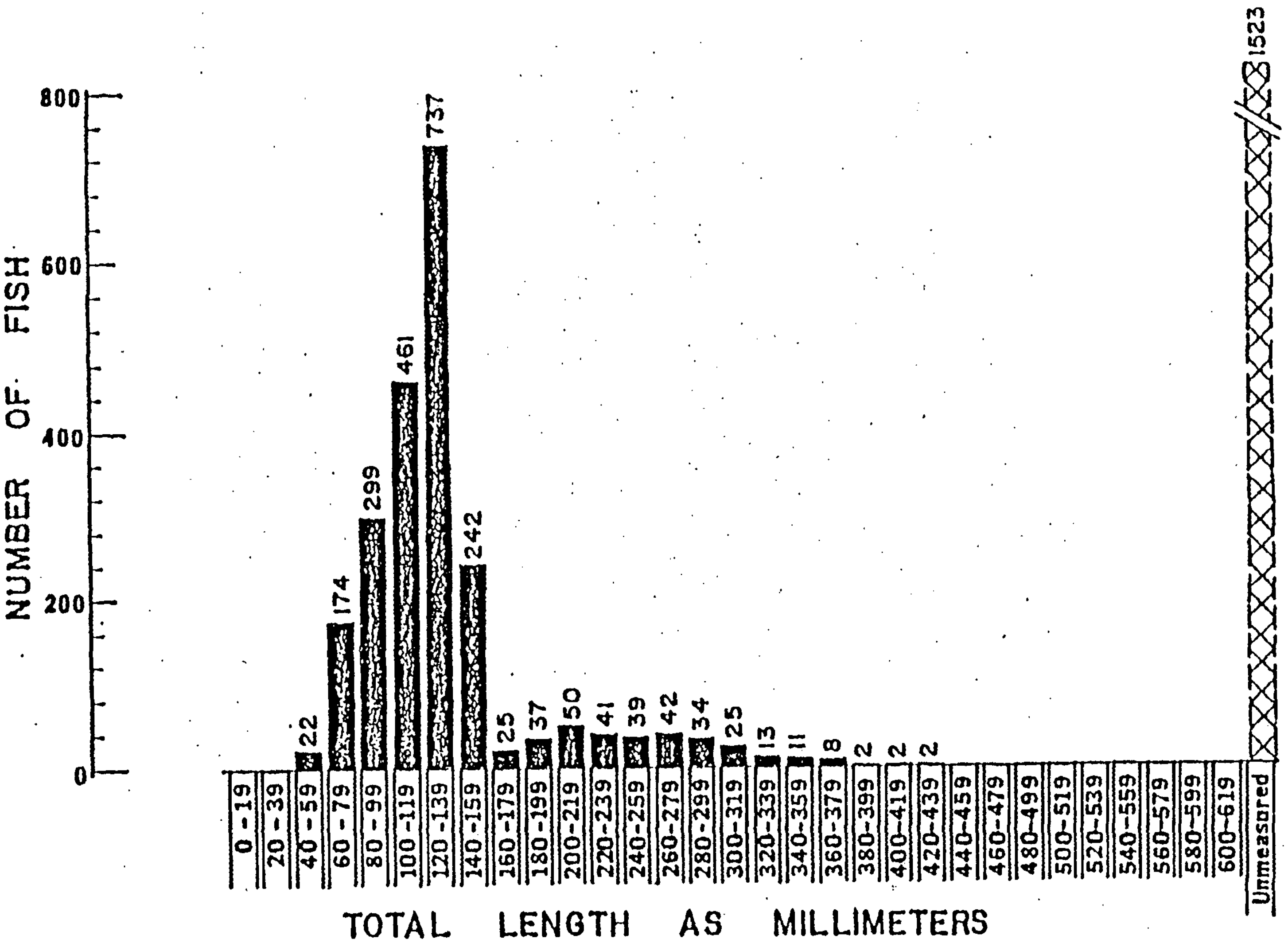


FIGURE 5.3-16

LENGTH FREQUENCY OF FRESHWATER DRUM IMPINGED AT PINGP, 1975

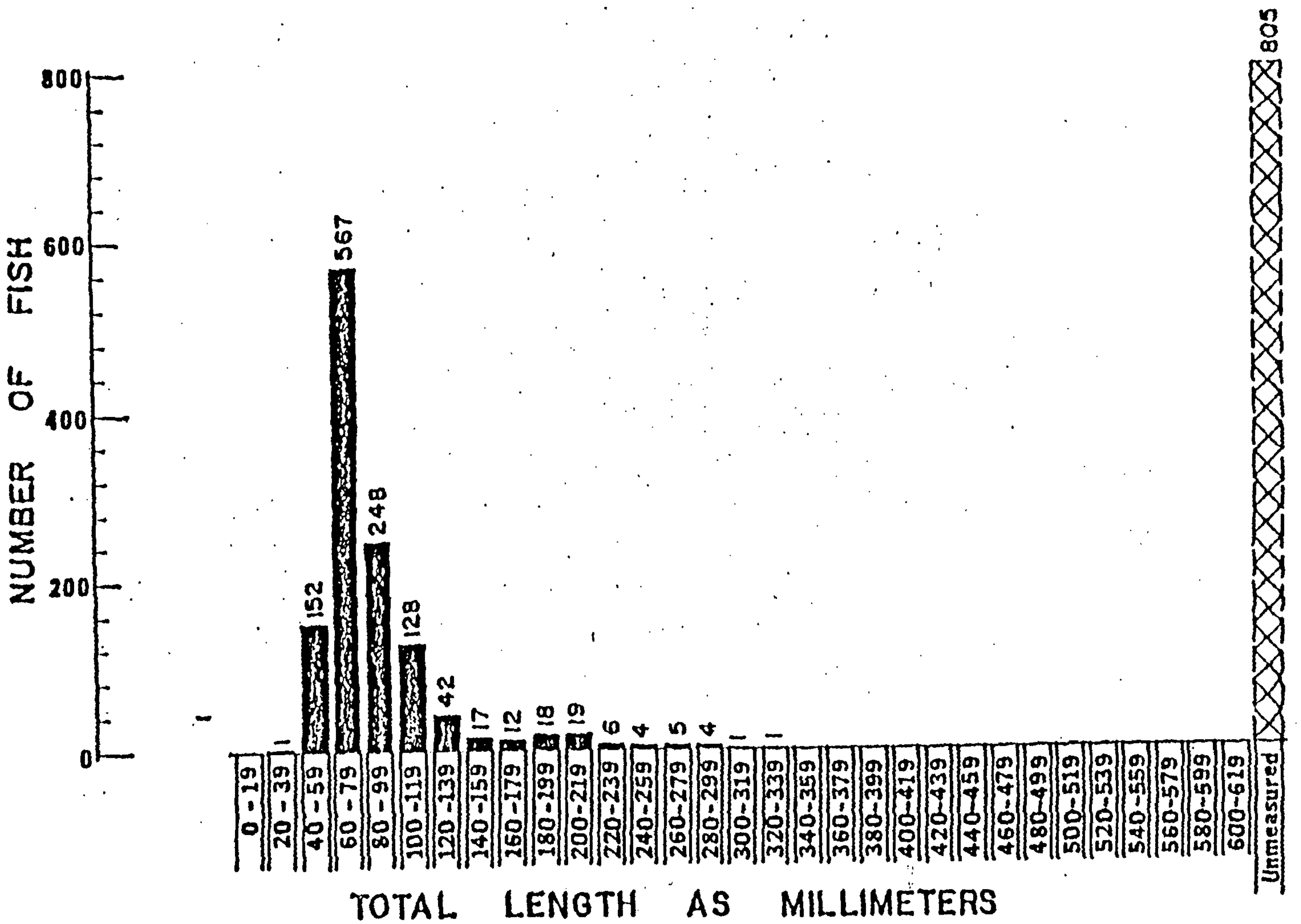


FIGURE 5.3-17

LENGTH FREQUENCY OF CRAPPIE SPP. IMPINGED AT PINGP, 1975

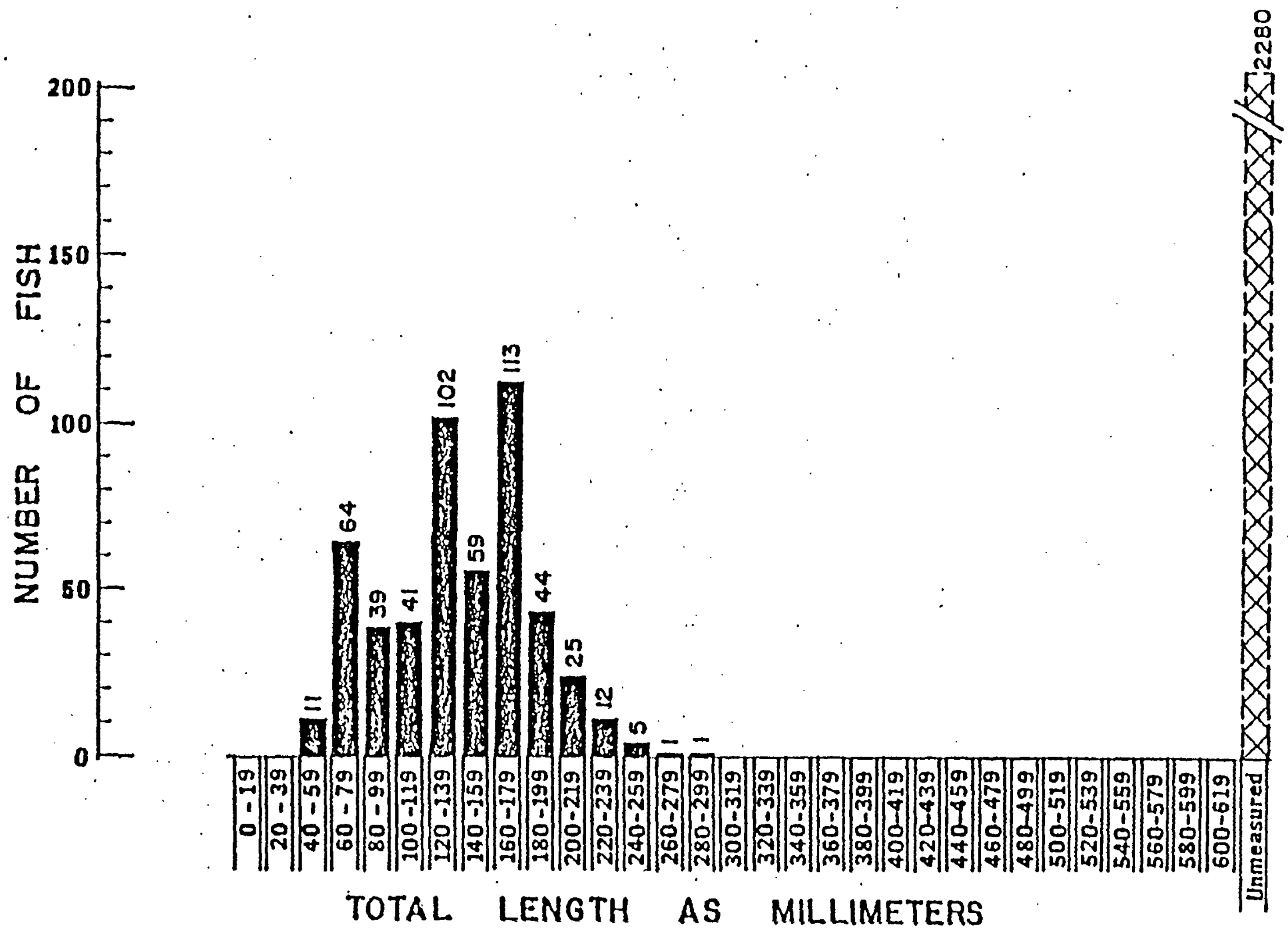


FIGURE 5.3-18

LENGTH FREQUENCY OF BLACK BULLHEAD IMPINGED AT PINGP, 1975

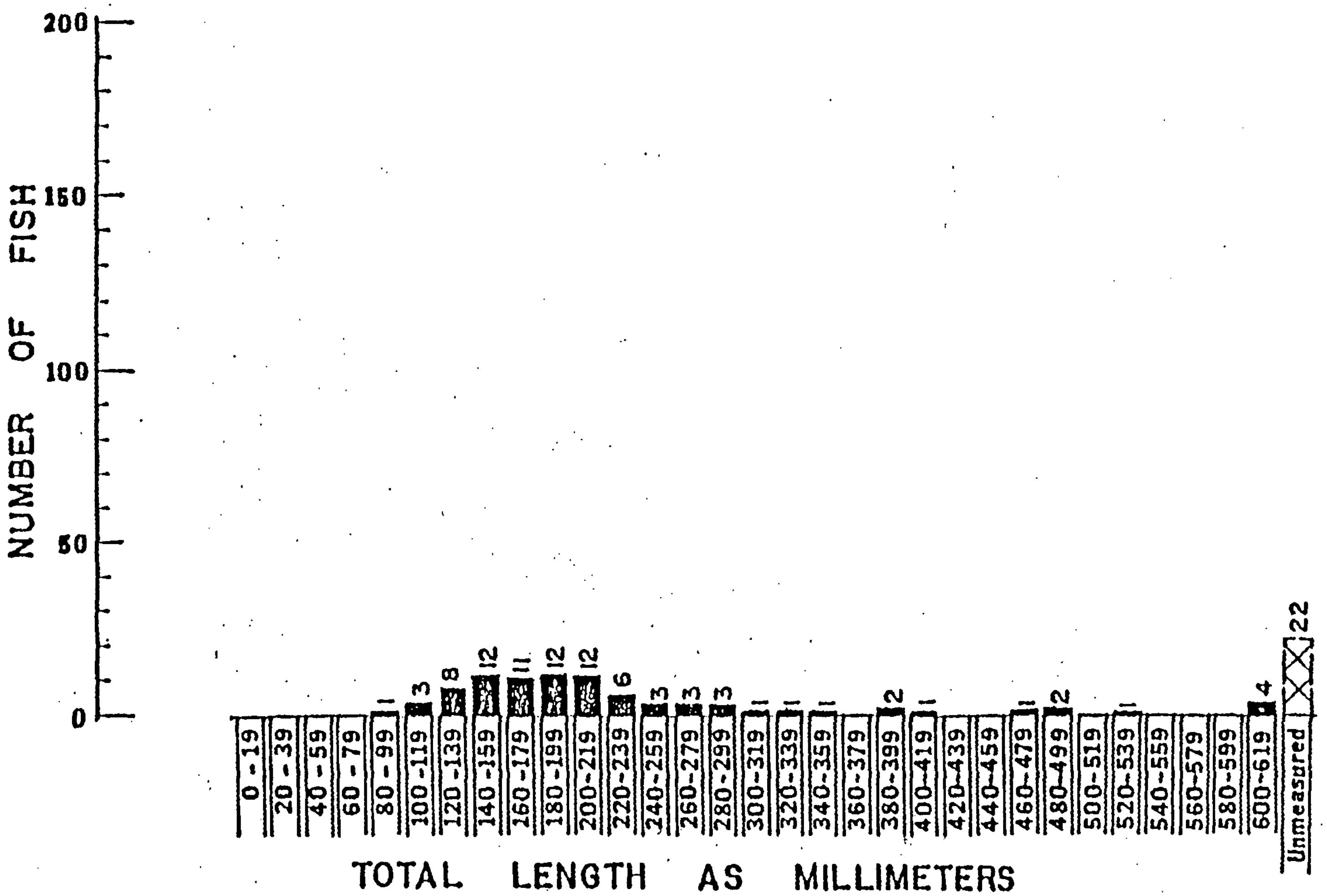


FIGURE 5.3-19

LENGTH FREQUENCY OF NORTHERN PIKE IMPINGED AT PINGP, 1975

TABLE 5.3-12 (Sheet 1 of 3)

NUMBERS OF NON-FISH ORGANISMS COLLECTED FROM THE TRASH BASKETS AT PINGP FROM JANUARY 3, 1975 TO DECEMBER 31, 1975

Organism	No. Collected
Crustaceans	
Orconectes virilis	31
Orconectes immunis	45
Cambarus diogenes	2
Female crayfish	62
Unidentified crayfish	8
Reptiles	
Snapping turtle	1
Spiny softshell turtle	59
Western painted turtle	9
Map turtle	4
False map turtle	2
Turtle carapace	1
Amphibians	
Leopard frog	11
Unidentified frog	2
American toad	7
Mudpuppy	30
Molluscs	
Leptodea fragilis	5
Proptera laevissima	1

TABLE 5.3-12 (Sheet 2 of 3)

Organism	No. Collected
Molluscs (Continued)	
Unidentified clam	134
Land snail	2
Insects	
Hexagenia	1
Hydrophilidae	2
Belostomidae	2
Dytiscidae	4
Birds	
Sparrow	3
Pigeon	6
Starling	2
Unidentified bird skeleton	4
Unidentified bird skull	9
Unidentified bird	1
Duck bones	1
Bird skull (pigeon)	2
Miscellaneous	
Unidentified leech	2
Filamentous algae	-
Pectinatella magnifica	3

TABLE 5.3-12 (Sheet 3 of 3)

Organism	No. Collected
Miscellaneous (Continued)	
Pocket gopher	1
Meadow vole	2
Muskrat skull	1
Mouse	1
Unidentified small mammal	2
Unidentified mammal skull	1

TABLE 5.3-13 (Sheet 1 of 4)

NUMBERS OF CRAYFISH, TURTLES, MUD PUPPIES AND FROGS COLLECTED PER WEEK FROM THE TRASH BASKETS AT PINGP, 1975

	WEEKLY PERIODS															
Species	1-2 to 1-9	1-9 to 1-16	1-16 to 1-23	1-23 to 1-30	1-30 to 2-6	2-6 to 2-13	2-13 to 2-20	2-20 to 2-27	2-27 to 3-6	3-6 to 3-13	3-13 to 3-20	3-20 to 3-27	3-27 to 4-3	4-3 to 4-10	4-10 to 4-17	4-17 to 4-24
Cambarus diogenes											1			1		
Orconectes virilis	1	2			1	1	2		1	2	2		2			
Oronectes immunis	1		1		4	4	1		1	1		2	4	2	2	
Crayfish (female)	1	1	1	1	4	5	3	6	4	1	5	4	4	1	1	1
Undetermined crayfish																
Total crayfish	3	3	2	1	9	10	6	6	6	4	8	6	10	4	3	1
Snapping turtle																
Spiny softshell turtle		1														1
Western painted turtle																
Map turtle																
False map turtle																
Total turtle		1														1
Mudpuppy		1											3	2	4	1
Leopard frog			1	2		3	1		1							3

TABLE 5.3-13 (Sheet 2 of 4)

Species	4-24 to 5-1	5-1 to 5-8	5-8 to 5-15	5-15 to 5-22	5-22 to 5-29	5-29 to 6-5	6-5 to 6-12	6-12 to 6-19	6-19 to 6-26	6-26 to 7-3	7-3 to 7-10	7-10 to 7-17	7-17 to 7-24	7-24 to 7-31	7-31 to 8-7	8-7 to 8-14
	WEEKLY PERIODS															
Cambarus diogenes		2														
Orconectes virilis		1											1			
Orconectes immunis	1				2	1	2			1		1		1	1	1
Crayfish (females)					2	1	1	1	1							1
Undetermined crayfish					2									1		
Total crayfish		3			6	2	3	1		1		1	1	2	1	2
Snapping turtle																
Spiny softshell turtle															2	
Western painted turtle				3	3											
Map turtle					3											
False map turtle																
Total turtle				3	6										2	
Mudpuppy					1											
Leopard frog																

TABLE 5.3-13 (Sheet 3 of 4)

Species	8-14 to 8-21	8-21 to 8-28	8-28 to 9-4	9-4 to 9-11	9-11 to 9-18	9-18 to 9-25	9-25 to 10-2	10-2 to 10-9	10-9 to 10-16	10-16 to 10-23	10-23 to 10-30	10-30 to 11-6	11-6 to 11-13	11-13 to 11-20	11-20 to 11-27	11-27 to 12-4
	WEEKLY PERIODS															
Cambarus diogenes																
Orconectes virilis						1		2		1		4	2	1		
Orconectes immunis		3		1	1								2	1		
Crayfish (females)	1	1				1	1	1	1				1	4		
Undetermined crayfish		1														
Total crayfish	1	5		1	1	2	1	3	1	1		5	8	2		
Snapping turtle																1
Spiny softshell turtle	2	6	15	4	7	1		2	2	2	5		2	1		1
Western painted turtle				1												
Map turtle								1								
False map turtle		1							1							
Total turtle	2	7	15	5	7	1		3	3	2	5		2	1		2
Mudpuppy												3	2		2	
Leopard frog																

TABLE 5.3-13 (Sheet 4 of 4)

Species	WEEKLY PERIODS 12-4 to 12-11	12-11 to 12-18	12-18 to 12-26	12-26 to 12-31	Annual Totals
Cambarus diogenes					2
Orconectes virilis		2	2		32
Orconectes immunis		2	1		43
Crayfish (females)		1	1		63
Undetermined crayfish		4			8
Total crayfish		9	4		148
Snapping turtle					1
Spiny softshell turtle	1	1	4	1	59
Western painted turtle					9
Map turtle					4
False map turtle					2
Total turtle	1	1	4	1	75
Mudpuppy	4	2	4	1	30
Leopard frog					11

TABLE 5.3-14 (Sheet 1 of 3)

SUMMARY OF SIGNIFICANT CORRELATIONS OF FISH IMPINGEMENT AND PHYSICAL DATA AT PINGP, 1975

Winter - 1/1-3/9 (N = 12)		
chancat vs. rwit	r = 0.79	p = <0.01
frhwdrm vs. mwa	r = 0.93	p = <0.01
rcwtrt vs. acw	r = 0.70	p = 0.01
rwit vs. date	r = 0.65	p = 0.02
mwa vs. date	r = 0.73	p = 0.01
Spring - 3/20-6/19 (N = 13)		
blkbull vs. acw	r = 0.61	p = 0.02
crappie vs. mwa	r = 0.67	p = 0.02
frhwdrm vs. mwa	r = 0.63	p = 0.04
rwit vs. date	r = 0.91	p = <0.01
Summer - 6/20-9/18 (N = 13)		
acw vs. rcwtrt	r = 0.63	p = 0.02
mwa vs. rcwtrt	r = 0.80	p = <0.01
rwit vs. date	r = -0.78	p = <0.01
Fall - 9/19-12/31 (N = 14)		
chancat vs. rwit	r = 0.57	p = 0.03
chancat vs. mwa	r = 0.79	p = <0.01
crappie vs. rwit	r = 0.79	p = <0.01
crappie vs. rcwtrt	r = -0.60	p = 0.02
crappie vs. mwa	r = 0.89	p = <0.01
frhwdrm vs. rwit	r = 0.64	p = 0.02

TABLE 5.3-14 (Sheet 2 of 3)

<u>Fall - 9/19-12/31</u> (Continued)

frhwdrm vs. rcwtrt - r = -0.67; p = <0.01

frhwdrm vs. mwa - r = 0.68; p = <0.01

rcwtrt vs. rwit - r = -0.88; p = <0.01

acw vs. rwit - r = 0.55; p = 0.04

mwa vs. rwit - r = 0.67; p = <0.01

mwa vs. rcwtrt - r = -0.59; p = 0.03

date vs. rwit - r = -0.94; p = <0.01

date vs. rcwtrt - r = 0.86; p = <0.01

date vs. acw - r = -0.64; p = 0.02

date vs. mwa - r = -0.56; p = 0.04

<u>All Seasons Combined</u> (N = 52)

blkbull vs. acw - r = -0.41; p = <0.01

blkbull vs. mwa - r = 0.32; p = 0.02

whtbass vs. rwit - r = 0.37; p = <0.01

whtbass vs. mwa - r = 0.41; p = <0.01

crappie vs. rwit - r = 0.53; p = <0.01

crappie vs. rcwtrt - r = -0.44; p = <0.01

crappie vs. mwa - r = 0.57; p = <0.01

frhwdrm vs. rcwtrt - r = -0.30; p = 0.03

frhwdrm vs. acw - r = 0.29; p = 0.04

rcwtrt vs. rwit - r = -0.70; p = <0.01

mwa vs. rwit - r = 0.63; p = <0.01

TABLE 5.3-14 (Sheet 3 of 3)

All Seasons Combined (N = 52)

mwa vs. rcwtrt - r = -0.35; p = 0.02

date vs. rwit - r = 0.28; p = 0.04

---

blkbull	= black bullhead	rwit	= river water inlet temperature
chancat	= channel catfish	rcwtrt	= recycle-canal water temperature
whtbass	= white bass	acw	= average circulating water
crappie	= crappie sp.	mwa	= makeup-water appropriation
frhwdrm	= freshwater drum	r	= correlation coefficient
		p	= level of significance

TABLE 5.3-15 (Sheet 1 of 2)

SELECTED CORRELATIONS AND PARTIAL CORRELATIONS OF FISH IMPINGEMENT DATA WITH PHYSICAL DATA, ALL SEASONS COMBINED (N = 52)

blkbull vs. acw	-	r	= -0.41; p = <0.01	
blkbull vs. mwa	-	r	= 0.32; p = 0.02	
blkbull vs. acw	-	$r_{12.3}$	= -0.51; p = <0.01	
blkbull vs. mwa	-	$r_{13.2}$	= 0.45; p = <0.01	
whtbass vs. rwit	-	r	= 0.37; p = <0.01	
whtbass vs. mwa	-	r	= 0.41; p = <0.01	
whtbass vs. rwit	-	$r_{12.34}$	= 0.01; p = >0.05	(N.S.)
whtbass vs. mwa	-	$r_{14.23}$	= 0.34; p = 0.03	
crappie vs. rwit	-	r	= 0.53; p = <0.01	
crappie vs. rcwtrt	-	r	= -0.44; p = <0.01	
crappie vs. mwa	-	r	= 0.57; p = <0.01	
crappie vs. rwit	-	$r_{12.34}$	= 0.06; p = >0.05	(N.S.)
crappie vs. rcwtrt	-	$r_{13.24}$	= 0.20; p = >0.05	(N.S.)
crappie vs. mwa	-	$r_{14.23}$	= 0.40; p = <0.01	
frhwdrm vs. rcwtrt	-	r	= -0.30; p = 0.03	
frhwdrm vs. acw	-	r	= 0.29; p = 0.04	
frhwdrm vs. rcwtrt	-	$r_{12.34}$	= -0.30; p = 0.03	
frhwdrm vs. acw	-	$r_{13.24}$	= 0.30; p = 0.03	

re: blkbull: $r_{12.3}$ = partial correlation coefficient of blkbull vs. acw minus mwa effect

TABLE 5.3-15 (Sheet 2 of 2)

		$r_{13.2}$	= partial correlation coefficient of blkbull vs. mwa minus acw effect
re:	whtbass:	$r_{12.34}$	= partial correlation coefficient of whtbass vs. rwit minus date and mwa effect
		$r_{14.23}$	= partial correlation coefficient of whtbass vs. mwa minus date and rwit effect
re:	crappie:	$r_{12.34}$	= partial correlation coefficient of crappie vs. rwit minus rcwtrt and mwa effect
		$r_{13.24}$	= partial correlation coefficient of crappie vs. rcwtrt minus rwit and mwa effect
		$r_{14.23}$	= partial correlation coefficient of crappie vs. mwa minus rwit and rcwtrt effect
re:	frhwdrm:	$r_{12.34}$	= partial correlation coefficient of frhwdrm vs. rcwtrt minus date and acw effect
		$r_{13.24}$	= partial correlation coefficient of frhwdrm vs. acw minus rcwtrt and date effect

On a seasonal basis, few significant correlations were determined between impingement rates and physical parameters for winter and spring and none for summer. However, a number of correlations were realized for the fall period, when river water inlet temperature fell and recycle canal water temperature remained relatively higher. Little consistency was found in the correlations from season to season. There was a significant positive correlation between freshwater drum impingement and make-up water appropriation in winter, spring and fall; however, no correlation was found on an annual basis (all seasons combined; Table 5.3-14). Also, channel catfish impingement was correlated with river water inlet temperature in winter and fall, but not for all seasons combined. White bass impingement was correlated with river water inlet temperature and makeup-water appropriation on a yearly basis, but not in any one season. Because of these inconsistencies, the low number of observations within a season (11-13) compared to the yearly basis (52), and the need to reduce the effect of time (seasons) on the correlations, further analyses were concentrated on the annual correlations.

Black bullhead, white bass, crappie spp., and freshwater drum all showed significant correlations with at least two physical parameters on an annual basis (Table 5.3-14).

It is difficult to estimate cause and effect relationships on the basis of the multiple correlations. For example, although white bass impingement was highly correlated with river water inlet temperature and makeup-water appropriation, these physical parameters did not necessarily affect white bass impingement because both were also highly correlated with each other (Table 5.3-14).

To examine the relationship of a given impingement rate with a single physical parameter, free of the influence of other physical or time (date) parameters, partial correlation coefficients were computed for the pertinent combinations (Table 5.3-15). In the case of the black bullhead, high correlations with average circulating water volume and makeup-water appropriation were retained after partial correlations were computed. The high correlation of white bass with river water inlet temperature was rendered insignificant after the partial correlation was computed, removing the date and makeup-water appropriation effects. The partial correlation of white bass and makeup-water appropriation retained its statistical significance. Of the parameters (two temperatures and one flow) originally correlated with crappie impingement, only crappies vs. makeup-water appropriation remained significantly correlated after partial correlations were computed. Freshwater drum impingement remained significantly correlated with recycle-canal water temperature and average circulating water volume.

After subjecting the annual correlations to partial correlation analysis, flow parameters, either makeup-water appropriation or average circulating water volume, remained significantly correlated with impingement rates in almost all cases while temperature parameters were no longer correlated. One exception was the partial correlation of freshwater drum with recyle canal water temperature. Average circulating water volume was also highly correlated with freshwater drum impingement.

These correlations do not imply a direct cause and effect relationship. They strongly suggest that some aspect of flow volume may be influencing impingement rates. Fish impingement may be influenced by changes in velocity in the intake or recycle canal due to changes in flow volume.

The occurrence and abundance of impinged fishes at PINGP during 1974 and 1975 was generally similar to that in 1973 (See Anonymous 1974) with a few exceptions. Two minnows (stone-roller and redbelly dace) were collected from the screens during 1975 but were not collected during the 1973 or

1974 impingement studies, nor during the 1974 waterbody sampling reported by Naplin and Geis (1975). Bluntnose minnow and johnny darter were reported from screen washes for the first time in 1975; previously they had been reported only from waterbody sampling.

Of the abundant fishes in the 1975 impingement catch, white bass, gizzard shad, freshwater drum, and crappie were also reported as abundant from the surrounding waterbody areas (including Sturgeon and North Lakes) in 1974 by Naplin and Geis (1975). Channel catfish and black bullhead were abundant in the 1975 impingement catch but insignificant in the waterbody catch in 1975; they were insignificant in the waterbody and impingement catches in 1974.

The total number of impinged fishes in 1975 was 36 percent less than the total impinged in 1974. The lower 1975 total was due to reduced gizzard shad impingement; this species comprised 75 percent of the total in 1975 compared to 94 percent in 1974. Freshwater drum, white bass, and crappie were abundant in 1975, as in 1974. Channel catfish, black bullhead, and minnows were relatively insignificant in 1974 compared to 1975.

Some annual variation in impingement was apparent. Nearly 137,000 gizzard shad were impinged in 1974; 70,506 were impinged in 1975. Gizzard shad impingement rates for 1973 (see Anonymous 1974) were apparently high, as 65,000 fish were impinged in less than three months, a number nearly as high as the total recorded for a full year of sampling in 1975. Extreme yearly variation occurred in black bullhead impingement. The numbers of black bullheads impinged during the mid-March through April period of 1973, 1974, and 1975 were 833, 76, and 1,792, respectively. Annual variations may involve one or more factors, such as fish year-class strength, environmental conditions (e.g., temperature and pool level), or plant operating modes.

The correlation analyses of the 1975 data present a somewhat different picture than that suggested by the 1974 data. The correlations in the 1974 data were inferred from simple plots of two parameters (e.g., white bass impingement rate and makeup-water appropriation) against time (see Figures 17-21 in Andersen 1975). These plots suggest correlations between white bass and recycle canal water temperature, crappies and river water inlet temperature, and crappies and recycle canal water temperature. No correlation was indicated for freshwater drum with average circulating water and recycle canal water temperature, crappies with makeup water appropriation, or white bass with makeup water appropriation. In each case, the corresponding correlation analysis for 1975 data gave opposite results. Inferences made from the 1974 data are considered to depict gross correlations. The more sophisticated correlation analyses performed on the 1975 data allow for greater accuracy in pinpointing relationships between impingement and physical parameters. The result of the correlations on the 1975 data, i.e., that flow parameters appear to be the key plant operational characteristic affecting impingement, was also acknowledged in the 1973 and 1974 reports (Anonymous 1974 and Andersen 1975).

Increased flow volumes and greater velocities in the intake and recirculating canals at PINGP could be a significant factor affecting impingement (Anonymous 1974). Intake flow velocities have been demonstrated to be an important factor in fish impingement (Kerr 1953, Sazaki et al. 1973, USAEC 1972, Bibko et al. 1974). However, flow volume or velocity is not always a primary factor in impingement rates (EPA 1976a). Grotbeck and Bechthold (1975) found little or no association of pumping rate with impingement, except for black crappie, at NSP's Monticello plant on the Mississippi River. Edwards et al. (undated) found no apparent correlation between impingement and intake flow at four Duke

Power Company plants. Grimes (1975) found cold water temperature during darkness to be a major factor in impingement. From the above, it is clear that each case is unique and must be examined independently in order to pinpoint factors affecting impingement.

6 IMPACT ASSESSMENT

6.1 PRIMARY PRODUCERS

Phytoplankton is likely the most important primary producer in the PINGP area of the Mississippi River. Assuming a relatively random distribution of phytoplankters, it may be assumed that entrainment will be directly proportional to water appropriation. Thus, the entrainment of phytoplankton is estimated at 0.1 to 4.9 percent over the year based on 1975 operation data (Table 3.5.1). However, in a normal year the seasonal distribution of entrainment would follow a different pattern (see Section 5.2.1).

The damage to phytoplankton resulting from entrainment has been studied for two years, mainly in the summer and fall (see 5.2.1). Standing crops of chlorophyll a and the rates of photosynthesis have been shown to be reduced after passage through PINGP. Under two unit operation the reduction of productivity of entrained phytoplankton may exceed 50 percent. In spite of the obvious degradation of photosynthetic ability of the entrained algae, Baker (1975) was unable to detect any effect on the productivity of main channel phytoplankton below the plant, based on 1974 one unit data. No conclusion was drawn from 1975 data; however, the lack of detectable difference due to Sturgeon Lake input to main channel productivity (Baker 1975) would indicate that a reduction of the normally higher Sturgeon Lake productivity through entrainment would only further serve to mask effects of the lake or plant. The conclusions of Baker and Baker (1975, 1976) indicate that there are no detectable differences in composition or density of phytoplankton in the main river that may be attributable to PINGP operation.

Considering the somewhat enriched status of the Mississippi River and the potential enhancement of already high algal populations due to Sturgeon Lake inputs, reductions in algal production due to entrainment at PINGP cannot be considered an adverse effect. The conclusions of the phytoplankton studies at PINGP agree with EPA (1976b) which states that entrainment effects on phytoplankton are of short duration and usually confined to a relatively small portion of the water body.

6.2 ZOOPLANKTON

Zooplankton is susceptible to entrainment in proportion to the water appropriation at PINGP, assuming a relatively uniform distribution of organisms in the source water body (which is chiefly Sturgeon Lake). Entrainment studies (see Section 5.3.1.2) have shown some detectable mortality among three of the four major groups of zooplankters. However, in 1974, during one-unit operation, Szluha (1975) was unable to detect significant differences among stations associated with the plant and those outside of plant influence. Daggett (1976) concluded preliminarily, that while total zooplankton, total rotifers and total cladocerans were not significantly different among plant-affected and control stations, there were reductions in copepod densities that could be associated with plant passage.

Entrainment effects appear to produce minimally detectable effects on the cladocerans in the discharge area of PINGP, but even the total effects of plant operation do not detectably affect total numbers of zooplankton. As noted by EPA (1976b), zooplankton entrainment does not present a potential for significant adverse impact due to the rapid reproduction rates and short life spans.

6.3 BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates comprise a major link in the food webs of the PINGP area (see Section 4.3.1). A number of benthic organisms are sessile, some burrow, some attach to substrates and others move around freely on the river bottom. Many benthic organisms drift freely or are scoured loose from substrates and many aquatic insects also enter the water column when emerging as adult flying insects. Either of the latter cases make the organisms vulnerable to entrainment.

Species composition of these benthic organisms which may be entrained can partially de determined from artificial substrate data. The organisms that colonize these substrates are generally non-burrowing surface-residing invertebrates that are likely to be the major components of the normal drift fauna of the river. Caddisflies (Trichoptera), mayflies (Ephemeroptera) and flies (Diptera) were the major groups colonizing artificial substrates (see Section 4.3.4). Caddisflies were Hydropsyche, Cheumatopsyche, Potamyia, Polycentropus, Neureclipsis, Ceraclea, Agralea, Hydroptila and unidentified species. Mayflies included Caenis, Baetis, Isonychia, Heptagenia, Stenonema, Tricorythodes and Potamanthus. Flies were mainly represented by Chironomidae and lesser numbers of Chaoborus, Polpomyia and Simulium. In some periods of 1975 the worms Naididae dominated collections.

Another estimate of the benthic invertebrates that may be entrained may be made from the emergence studies (NSP 1975) in which Hydropsychidae, Psychomyiidae and Hydroptilidae were the dominant families collected. Representatives of these families would be entrainable during emergence.

6.4 FISH EGGS AND LARVAE ENTRAINMENT

Analysis of the impact of entrainment of fish eggs and young at PINGP 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.

If the entrained stage is an egg, the estimate of the number of adults lost is calculated as follows:

$$N_a = SN_e = \frac{2}{F} N_e$$

where

N_a = number of adults in mature age classes

S = survival from egg to adult stage

N_e = number of eggs entrained

F = total life time fecundity of a female

2 = number of adults needed to be produced by a breeding pair to maintain a stable population

If the entrained stage is a larva:

$$N_a = S_1 N_1 = \frac{2}{S_e F} \times N_1$$

where

N_a, 2 and F are defined as above

S_1 = survival from larva to adult stage

N_l = number of larvae entrained

S_e = survival from egg to larva

The following assumptions are made in this analysis:

- There is 100 percent mortality of entrained eggs and larvae on passage through the plant
- The populations are at equilibrium and the total lifetime fecundity produces 2 adults
- That 0.5 percent of the eggs produced by a species with high fecundity and/or randomly broadcast eggs and little parental protection survive to the larval stage
- that 75 percent of the eggs produced by a species which exhibits nesting behavior and a high degree of parental care survive to the larval stage.

Before estimating the number of adults lost it was necessary to consolidate some taxonomic groups because of a lack of reproductive information for certain taxa. In some cases, such as the suckers, the individuals which could only be identified to family level were divided among the genera of that family based on the proportion of the larval catch comprising each genus. If only a few larvae were captured in each of several taxonomic categories, they were combined at the family level with the exception of emerald shiner and carp. Larvae were never grouped above the family level.

A total of 8,371,000 (± 4,694,000 at 95 percent confidence interval) fish eggs and 61,645,000 (± 34,529,000) 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 a conservative estimate from data collected by the MNDR of about one billion larvae and juveniles, Section 5.3.1.3.2). Weekly estimates of entrained larvae and juveniles ranged from less than 1 to 85 percent of the estimated Sturgeon Lake production. These estimates are conservative because they do not take into account the larvae and juveniles in the main channel. No estimates of larvae and juveniles in the main channel are available.

The entrained eggs and young 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 6.4-1.

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,

TABLE 6.4-1

CALCULATION OF LOSS OF ADULT FISH DUE TO ENTRAINMENT OF EGGS, LARVAE AND JUVENILES AT PINGP IN 1975. (Sheet 1 of 2)

	Number Entrained	Fecundity[a]	Survival Egg to Larva	Larvae Produced by One Female	Survival Larvae to Adult	Number of Adults Lost	Economic Classification[c]
Dorosoma cepedianum	10,370,000	1,560,000	0.005	7,800	0.0003	3,111	F
Coregonus clupeaformis	4,000	178,000	0.005	900	0.002	8	C
Hiodon tergisus	1,221,000	60,000	0.005	300	0.007	8,547	C,S
Esox lucius	4,000	981,000	0.005	4,900	0.0004	2	S
Cyprinus carpio	3,257,000	7,360,000	0.005	36,800	0.00006	195	C
Notropis atherinoides	15,961,000	2,900[b]	0.005	15	0.13	2,075,000	F
Cyprinidae	1,575,000	2,900[b]	0.005	15	0.13	204,700	F
Carpiodes spp	4,598,000	619,200	0.005	3,100	0.0006	2,759	C
Catostomus commersoni	13,000	954,000	0.005	4,800	0.0004	5	C
Ictiobus spp	6,617,000	1,610,000	0.005	8,000	0.0002	1,323	C
Moxostoma spp	36,000	135,000	0.005	680	0.003	108	C
Ictalurus punctatus	325,000	214,800	0.75	160,000	0.00001	3	C
Noturus gyrinus	3,000	200	0.75	150	0.01	30	F
Pylodictis olivaris	16,000	108,300	0.75	500	0.004	64	C
Percopsis omiscomaycus	25,000	1,400	0.005	7	0.3	7,500	F
Morone chrysops	7,297,000	3,390,000	0.005	17,000	0.0001	730	S
Ambloplites rupestris	5,000	63,000	0.75	300	0.007	35	S
Lepomis gibbosus	122,000	16,425	0.75	12,000	0.0002	24	S
L. macrochirus	742,000	97,000	0.75	73,000	0.00003	22	S
Pomoxis spp	480,000	462,200	0.75	35,000	0.00006	29	S
Etheostoma nigrum	67,000	1,600	0.75	1,200	0.002	134	F
Perca flavescens	102,000	436,800	0.03	13,100	0.0001	10	S
Percina caprodes	88,000	6,000	0.005	30	0.07	6,160	F
P. shumardi	1,711,000	1,200[2]	0.005	6	0.3	513,300	F
Stizostedion canadense	1,881,000	159,500	0.005	800	0.003	5,643	S
S. vitreum	319,000	2,257,000	0.005	11,300	0.0002	64	S
Percidae	956,000	477,000	0.005	2,400	0.0008	765	
Aplodinotus grunniens							
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	-	-	-	-	-	

TABLE 6.4-1 (Sheet 2 of 2)

	Number Entrained	Fecundity[a]	Survival Egg to Larva	Larvae Produced by One Female	Survival Larvae to Adult	Number of Adult Lost	Economic Classification[c]
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	

[a] Fecundity information obtained from Scott and Crossman (1973); Wrenn (1968); Swee and McCrimmon (1966); Bodola (1955); Daiber (1953); Winn (1958); Wolfert (1969); Ulrey, Risk and Scott (1968)

[b] Average of fecundities of several similar species.

[c] F = Forage; C = Commercial; S = Sport.

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.

Since there are no catch statistics for forage species, another means of relating the extent of impact was used. If it is assumed that each fish weighed about 8 grams (0.3 oz, the average weight of young emerald shiner in the fall as reported by Scott and Crossman 1973) when consumed by predators, approximately 22,500 kg (49,600 lbs) or 144 kg/ha (131 lbs/acre) of forage would be lost to the PINGP area (1600 ha MNDR study area). If all 22,500 kg were consumed and were converted to predator biomass at an efficiency of 15 percent, about 3,400 kg (7,500 lbs) of predator production could be eliminated from the PINGP area. The average individual weight of the three major predators (sauger, walleye and white bass) found in the area as determined from creel censuses between 1968 and 1975 was 0.57 kg (1.26 lbs)

(Gustafson and Diedrich 1976). Based on this weight, the estimated loss in predator production would be 5,900 fish. However, the surplus production of forage fish may be sufficient to accomodate both predation and exploitation due to entrainment with no loss of sport fish production.

If these estimated losses are looked at by themselves, it appears that there has been a significant loss to the forage base in the PINGP area. Another approach is to compare the number of young forage fish entrained to the total number available. This can be accomplished by using the larval fish data collected in 1975 by the MNDR (Gustafson et al. 1976) at stations near the mouth of Sturgeon Lake to develop an estimate of the total number of young forage fish passing through the Sturgeon Lake outlet (see Section 5.3.1.3.2 for discussion of MNDR data). It is assumed that the taxonomic composition of the young in the outlet is similar to that at the bar rack in the intake canal. The number of young forage fish entrained represents only 3 percent of the available production (51 million young, based on Sturgeon Lake outlet densities) of the North Lake-Sturgeon Lake complex.

Although sport and commercial species represented less than 1 percent of the total adult loss, the actual numbers of adults lost of several of the individual taxa appear to be high. Approximately 5,600 saugers (based on all mature age classes), one of the most sought after sport fish in the PINGP vicinity, were estimated to be lost due to the entrainment of larvae (Table 6.4-1). This represents about 0.9 to 2.4 percent of the estimated population between Sturgeon Lake and Lake Pepin or one-third the average spring angler harvest from section 4 of the PINGP survey area, which annually contributes about 70 percent of the entire sauger harvest for the survey area (Naplin and Gustafson 1975, Gustafson and Diedrich 1976). It is nearly 18 times the annual harvest for the area above Lock and Dam No. 3.

The impact of the loss of 5,600 sauger to the PINGP area fishery depends on the size of the population, the geographical distribution of the population and spawning activity and the proportion of available young entrained. The greatest impact would occur if Pool 3 had a small, discrete population of sauger and a majority of the spawning activity for the population occurred in the lakes upstream of the PINGP intake with a large proportion of the young produced being entrained. If, on the other hand, the population was rather mobile, capable of free movement into and out of Pool 3 and/or spawning activity were spread over a large portion of the Upper Mississippi River, the impact on the population would not be as great.

Hawkinson (1974) stated that data from tagging studies conducted by Krosch (1969) and Finke (1964) indicated that the larger fish which inhabit the PINGP area are extremely mobile and move throughout the area between Taylors Falls on the St. Croix River and Lansing, Iowa on the Mississippi River. Preliminary analysis of tag returns from the PINGP tagging study seem to indicate that the sauger found in the plant area are highly mobile (Gustafson et al. 1976). On the basis of preliminary tagging data, it would seem that Pool 3 does not have a discrete population of sauger. It also seems unlikely that North and Sturgeon Lakes are unique and, as a consequence, are not primary spawning areas for the population. There appears to be a considerable amount of similar spawning habitat in Pool 3 which would be available to the sauger population utilizing the PINGP area. Furthermore, the number of larvae entrained represents less than 3 percent of the sauger larvae carried out of Sturgeon Lake during May, (assuming that larval drift from Sturgeon Lake has a taxonomic composition similar to that at the Bar Rack Station in the intake canal).

Because of the high mobility of adult sauger, the wide availability of suitable spawning habitat, and the low proportion of sauger larvae available that are actually entrained, it is not anticipated that entrainment of larvae by the PINGP will have a significant impact on the local sauger population.

Approximately 730 adult white bass were estimated to be lost due to the entrainment of larvae at PINGP (Table 6.4-1). This represents only 0.4 to 0.5 percent of the population estimated between Sturgeon Lake and Lake Pepin and only 7 percent of the average annual sport harvest of 10,400 fish, and appears to be only a small portion of the total production for the North Lake-Sturgeon Lake complex. If it is again assumed that the taxonomic composition of the larvae in the Sturgeon Lake Outlet is similar to that at the Bar Rack Station, about 250 million white bass larvae would be present in the North Lake-Sturgeon Lake complex. Using the same method of calculation as was used for deriving entrainment losses, this would result in the production of about 25,000 adults, nearly 35 times the entrainment loss.

Nearly 11 million freshwater drum eggs and larvae were entrained at PINGP during the 1975 sampling period, resulting in a potential loss of about 1,000 adults (Table 6.4-1). This was approximately 1.5 percent of the population of young drum in the plant area, one-third of the total annual sport harvest (Section 4.3.5.1) and about equal to the average commercial harvest (Pool 3) reported by the MDNR (Section 4.3.5.2). At present, however, this species does not appear to be heavily exploited by either the recreational or sport fishery above Lock and Dam No. 3. Sport fishing pressures in Pool 4 during the 1960's were 300 to 700 times higher than current levels in the area above Lock and Dam No. 3 and harvests were 38 to 50 times greater (Skrypek 1964, Sternberg 1969, Hawkinson 1974, Naplin and Gustafson 1975, Gustafson and Diedrich 1976). During the same period, the abundance of drum in Pool 4, indicated by experimental gill net and trap net catches, was equal to or less than current levels in the area upstream of Lock and Dam No. 3 (Skrypeck 1966, Anonymous 1964, Hawkinson 1974, Naplin and Geis 1975, Gustafson et al. 1976). This indicates that the drum population in the PINGP area can stand considerably more exploitation pressure without serious damage.

Other sport fishes sustaining entrainment losses include walleye, and species of sunfish, crappies, northern pike and yellow perch (Table 6.4-1). The total adult loss was estimated to be 184 fish, which is less than 10 percent in a potential loss of about 1,000 adults (Table 6.4-1). This was approximately 1.5 percent of the population of young drum in the plant area (Table 6.5-1), one-third of the total annual sport harvest (Section 4.3.5.1) and about equal to the average commercial harvest (Pool 3) reported by the MNDR (Section 4.3.5.2). At present, however, this species does not appear to be heavily exploited by either the recreational or sport fishery above Lock and Dam No. 3. Sport fishing pressures in Pool 4 during the 1960's were 300 to 700 times higher than current levels in the area above Lock and Dam No. 3 and harvests were 38 to 50 times greater (Skrypek 1964, Sternberg 1969, Hawkinson 1974, Naplin and Gustafson 1975, Gustafson and Diedrich 1976). During the same period, the abundance of drum in Pool 4, indicated by experimental gill net and trap net catches, was equal to or less than current levels in the area upstream of Lock and Dam No. 3 (Skrypeck 1966, Anonymous 1964, Hawkinson 1974, Naplin and Geis 1975, Gustafson et al. 1976). This indicates that the drum population in the PINGP area can stand considerably more exploitation pressure without serious damage.

Other sport fishes sustaining entrainment losses include walleye, and species of sunfish, crappies, northern pike and yellow perch (Table 6.4-1). The total adult loss was estimated to be 184 fish, which is less than 10 percent of the combined annual angler harvest for these species. The operation of PINGP should not cause a significant decrease in the number of these sport fish available in the area of the plant.

Commercial fish whose larvae were entrained at PINGP included carp, buffalo, catfish, suckers and carpsuckers (quillbacks). Since the MDNR publishes only total weights of harvested species it was necessary to convert the number of adults lost to weights for comparison to commercial landings. This was accomplished by multiplying the number lost by an average weight per individual, which was usually obtained from information given in Scott and Crossman (1973). All commercial fishery data were obtained from MDNR unpublished reports.

Nearly 3.3 million carp larvae were entrained in 1975, resulting in a potential loss of 195 adults. At an average weight of 9 kg, this loss represents 1,755 kg (3,869 lbs) or about 8 percent of the average annual commercial catch from Pools 3 and 4.

Over 6.6 million buffalo larvae were entrained, resulting in a potential adult fish loss of 1,323 fish. At an average individual weight of 2.3 kg (5.1 lbs), the loss represents

3,043 kg (6,708 lbs.), an amount about equal to the average commercial harvest for Pools 3 and 4 during the period 1970 to 1974 (Section 4.3.5.2).

Approximately 4.6 million carpsucker larvae were entrained in 1975. This represents a potential adult loss of 2,759 fish or about 25,000 kg (55,000 lbs). The average annual catch for Pools 3 and 4 between 1970 and 1975 was 103 kg (227 lbs).

Over 300,000 channel and flathead catfish young were entrained, resulting in an estimated loss of 122 kg (269 lbs or 67 fish) or 5 percent of the average annual commercial catch.

The mooneye is listed as an incidental catch in both the commercial and sport fisheries statistics. It has not been abundant in the catch of any type of experimental gear fished in the PINGP area between 1973 and 1975, but in 1975 it accounted for 2 percent of the larvae entrained at the PINGP. The estimated number of adults lost due to entrainment of larvae was 8,547. This is considerably higher than the combined annual sport and commercial harvest.

Losses of carp and catfish do not appear to be significant when compared to commercial catches. The impact on the fishery of losses of the magnitude exhibited by buffaloes, carpsuckers and mooneye is unclear. It is unknown whether the low numbers of these taxa in commercial landings are due to low abundance in Pools 3 and 4 or a lack of interest by commercial fishermen.

Experimental gear catch data suggests that these fish have been low in abundance in the PINGP area between 1973 and 1975. However, if the number of larvae of each taxon at the outlet of Sturgeon Lake is considered, (assuming a taxonomic composition similar to that at the Bar Rack Station), it appears that the experimental catch may not be an adequate indicator of abundance of these species. (This is especially true since the MNDR data on larvae of Sturgeon Lake Outlet are probably relatively low estimates as discussed in Section 5.3.1.3.2). Approximately 111 million buffalo larvae, 21 million mooneye larvae and 78 million carpsucker larvae were estimated to have passed the PINGP intake in 1975. These larvae would have been the progeny of 96,00C, 280,000 and 202,000 spawning pairs of buffalo, mooneye and carpsuckers, respectively. Potential losses of adults due to entrainment represent only a small proportion of those adults which produced young that were estimated to have passed the PINGP intake; therefore, it is not likely that significant impact has or will result from larval entrainment.

6.5 FISH IMPINGEMENT

Fish losses due to impingement at PINGP were 146,063 in 1974 and 93,466 in 1975. The significance of losses of fish because of impingement at PINGP can be subjected to a general evaluation based on comparisons with population estimates (Table 6.5-1).

The most obvious result of studies at PINGP (Section 5.3.2) is the large numbers of gizzard shad impinged. Most of the gizzard shad were impinged during the late fall and winter. As pointed out by Andersen (1975), the high impingement rates appear to be temperature-related. A number of investigators have reported apparent temperature-related fall die-offs of gizzard shad (Wickliff 1953, Agersborg 1930, Miller 1960, Bodola 1966). The large number of gizzard shad in Sturgeon Lake and nearby areas and their sensitivity to temperature changes in the fall are apparently major factors causing high impingement rates at PINGP. Andersen (1975) pointed out that gizzard shad die-offs in the PINGP area appear to begin when the water temperature falls to near 12°C (53.6°F).

Total numbers of gizzard shad impinged at PINGP were 136,667 in 1974 and 70,506 in 1975 (Table 6.5-1). Bottom trawling data probably provide a low estimate of gizzard shad

TABLE 6.5-1

NUMBERS OF MAJOR FISH SPECIES IMPINGED AT PINGP, ESTIMATES OF STANDING CROP BASED ON TRAWL SURVEY, SPORT CATCHES, AND ESTIMATES OF SPORT FISH POPULATIONS

	Total impinged[b]		Trawl survey[c]		Tag and recapture[d]	
	1974	1975	Plant area 33.4 ha	North Lake 438 ha	Peterson	Schnabel
Gizzard shad[a]	136,667	70,506	2,252	270,684		
Channel catfish	637	6,223	2,669	4,818	22,720	
White bass	1,367	2,712	2,190	60,006	173,910	155,335
Crappies	1,704	2,030	417	154,176		
Drum	3,143	3,789	66,220	58,692		
Walleye	5	--	250	2,190	162,721	123,512
Sauger	13	--	417	1,752	609,809	228,784
Sauger/walleye	87	197	667	3,942	772,530	352,296

[a] Six million estimated for Sturgeon Lake (Andersen 1975)

[b] Section 5.2

[c] Section 4.5, 1974 - 1975.

[d] Section 4.5, Sturgeon Lake to Lake Pepin, 1974 and 1975.

populations because this species is a filter-feeder and occurs throughout the water column (Scott and Crossman 1973). Population estimates for the plant area are not directly comparable to impingement data because trawling was not conducted during the late fall and winter when most gizzard shad were impinged. The MNDR estimated that roughly six million gizzard shad were present in the 324 ha (800 ac) Sturgeon Lake in late summer of 1973 (Andersen 1975). Assuming this to be a representative figure, the 1974 and 1975 losses represent approximately 1 to 2 percent of the Sturgeon Lake population. Losses of this magnitude would not reduce the forage value of this species.

Trawl survey data are relatively appropriate for interpretation of losses of sport and commercial species because similar size fish occur in both trawl and impingement catches. However, trawling yields low population estimates due to concentration by certain species in untrawlable habitats such as nearshore shallows, macroflora beds, or other cover.

The average number of catfish impinged (3,430) is roughly equivalent to the apparently low population estimates for the 83.4 ha plant area and 438 ha North Lake (Table 6.5-1). However, the Peterson population estimate (22,720) and 1974 commercial landings (37,820 lbs) of adult fish suggest that the number of impinged catfish represent a small fraction of the young occurring in the region.

Young white bass losses were comparable to the trawl population estimates occurring in the plant area and represent 6.8 percent of the numbers estimated for North Lake. The young white bass represent about 1 percent of the sport fish populations estimated in tag and recapture studies. Due to natural mortality, the number of white bass impinged would have yielded an even smaller number of adults.

The number of impinged crappies is greater than the population estimated for the plant area from trawl survey data, but represents only 2.4 percent of the North Lake population. Low population estimates in the plant area are probably due to concentration of crappies in relatively unsampled habitats.

Freshwater drum in the PINGP area would be highly vulnerable to impingement, judging by the large population occurring in the plant area. However, impingement losses represent only 10 percent and 12 percent of the estimated young occurring in the plant area and North Lake, respectively.

Walleyes and saugers were impinged at a low rate relative to other species and represent 43 percent of the estimated plant area populations, 3.6 percent of the estimated North Lake populations and less than 0.1 percent of the estimated sport fish populations.

Assessment of life-of-the-plant effects on fishes near PINGP is complicated by a number of interacting factors. A balanced indigenous species of fish is multi-aged and fluctuates in relation to variability of year-class strengths, exploitation, natural mortality, and density-dependent mechanisms. Year-class strength is determined primarily by abiotic factors, especially water temperature regimes, during spawning and early development stages. Exploitation is often the major source of mortality in adult fish.

Surplus production is the substainable yield or production of new weight by a fishable stock, plus recruits added to it, less what is lost to natural mortality (Ricker 1975). In a discrete population, surplus production will increase as exploitation increases until the total rate of exploitation from fishing and power plants reduces surplus production below the level needed to sustain the population (McFadden 1975). McFadden's hypothetical model shows that a population will not decline when exploitation from power plants and fishing is less than 40 percent per year.

When the Oneida Lake walleye population was subjected to exploitation of approximately 40-50 percent in one year, it exhibited high growth rates and population levels in subsequent years (Forney 1967). Adult walleyes in Lake Erie showed no decline when subjected to 70-78 percent exploitation per year during 1962-1966 (Regier et al. 1969). High rates of exploitation resulted from heavy fishing pressure in Lake Erie and low abundance of forage fish in other lakes (Forney 1976, Moyle 1949). These studies suggest that fairly high rates of exploitation will not cause a sustained decline if year class formation and recruitment are normal. Additional exploitation associated with operation of a power plant would represent a relatively minor source of mortality in the long-term fluctuations of upper Mississippi River fish populations. Even in the immediate plant area, entrainment and impingement losses may be masked due to the great mobility of fish in the PINGP area.

7 REFERENCES CITED

Agersborg, H. P. K. 1930. The influence of temperature on fish. Ecology 2(1):136-144.

Andersen, R. A. 1975. Impingement of fishes and other organisms on the Prairie Island Plant intake traveling screens. In: Environmental monitoring and ecological studies program, Northern States Power 1974 annual report, Vol. II, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Anonymous. 1964. Exploratory fishing in Pools 3, 4, 5 and 5A of the Mississippi River, 1957 and 1963. Minnesota Department of Conservation.

Anonymous. 1974. Impingement of fishes and other organisms on the Prairie Island Plant traveling screen. In: Environmental monitoring and ecological studies program, Northern States Power 1973 annual report, Vol. II, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Baker, A. L. 1974. Studies of the periphyton of the Mississippi River, near the Prairie Island Nuclear Generating Plant -- 1973. In: Environmental monitoring and ecological studies program, Northern States Power 1973 annual report, Vol. II, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Baker, A. L. 1975. Primary productivity of the phytoplankton in the Mississippi River at Prairie Island; the effects of heated water discharge on the levels of production; and a turbidometric analysis of mass flow. In: Environmental monitoring and ecological studies program, Northern States Power 1974 annual report, Vol. I, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Baker, A. L. 1976. Studies of the productivity of the phytoplankton of the Mississippi River at Prairie Island - 1975. In: Environmental monitoring and ecological studies program, Northern States Power 1975 annual report, Vol. I, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Baker, K. K. and A. L. Baker. 1974. Studies of the phytoplankton of the Mississippi River, near the Prairie Island Nuclear Generating Plant -- 1973. In: Environmental monitoring and ecological studies program, Northern States Power 1973 annual report, Vol. II, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Baker, K. K. and A. L. Baker. 1975. Studies of the phytoplankton of the Mississippi River, near the Prairie Island Nuclear Generating Plant -- 1974. In: Environmental monitoring and ecological studies program, Northern States Power 1974 annual report, Vol. I, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Baker, K. K. and A. L. Baker. 1976. Studies of the phytoplankton of the Mississippi River, near the Prairie Island Nuclear Generating Plant 1975. In: Environmental monitoring and ecological studies program, Northern States Power 1975 annual report, Vol. I, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Barr, A. J. and J. H. Goodnight. 1972. A user's guide to the statistical analysis system. North Carolina State University, Sparks Press, Raleigh, North Carolina.

Behmer, D. J. 1969. Schooling of river carpsuckers and a population estimate. Trans. Amer. Fish. Soc. 98(3): 520-523.

Bibko, P. N., L. Wirtenan and P. E. Kueser. 1974. Preliminary studies on the effects of air bubbles and intense illumination on the swimming behavior of the striped bass (Morone saxatilis) and the gizzard shad (Dorosoma cepedianum). pp. 293-304 In: Jensen, L. D., (ed.). Proceedings of the second entrainment and intake screening workshop. Electric Power Research Institute Report No. 15. Palo Alto, California.

Bodola, A. 1966. Life history of the gizzard shad Dorosoma cepedianum (Le Sueur) in western Lake Erie. Fishery Bull. 65(2):391-425.

Britt, N. W. 1955. New methods of collecting bottom fauna from shoals or rubble bottoms of lakes and streams. Ecology 36:524-525.

Brook, A. J. 1971. Phytoplankton study. In: Environmental monitoring and ecological studies program, Northern States Power 1970 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Brook, A. J. 1972. Phytoplankton. In: Environmental monitoring and ecological studies program, Northern States Power 1971 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Brook, A. J. 1973. Phytoplankton. In: Environmental monitoring and ecological studies program, Northern States Power 1972 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Daggett, R. F. 1976. Zooplankton study. In: Environmental monitoring and ecological studies program, Northern States Power 1975 annual report, Vol. I, for the Prairie Island Generating Plant near Red Wing, Minnesota.

Daley, S. A. and J. S. Skrypek. 1964. Angler creel census of Pools 4 and 5 of the Mississippi River, Goodhue and Wabasha Counties, Minnesota in 1962-63. Minnesota Department of Conservation.

Davis, S. E. et al. 1963. The influence of oxygen concentrations on the swimming performance of juvenile Pacific salmon at various temperatures. Trans. Amer. Fish. Soc. 92(2):111-124.

Edsall, T. A. and T. G. Yocum. 1972. Review of recent technical information concerning the adverse effects of once-through cooling on Lake Michigan. U.S. Fish and Wildlife Service, Great Lakes Fisheries Laboratory, Ann Arbor, Mich.

Edwards, T. J., W. H. Hunt, L. E. Miller and J. J. Sevic. Undated. Fish impingement at four Duke Power Company steam generating facilities. Duke Power Company, Environmental Sciences Unit, Charlotte, North Carolina. Manuscript.

EPA. 1976a. Development document for best technology available for the location, design, construction and capacity of cooling water structures for minimizing adverse environmental impact. U.S. Environmental Protection Agency, Washington, D.C. (Draft).

EPA. 1976b. Guidance for determining best technology available for the location, design, construction, and capacity of cooling water intake structures for minimizing adverse environmental impact, section 316(b) P.L. 92-500. U.S. Environmental Protection Agency, Draft 2.

Fernholz, W., Work Unit Supervisor, State of Wisconsin Dept. Natural Resources. Personal communication to V. Kranz, NUS Corporation, Pittsburgh, Pa. Letter of September 23, 1975.

Finke, A. H. 1964. White bass tagging study upper Mississippi River. Wisconsin Department of Conservation, Division of Fish Management, Management Report No. 6.

Fish, M. P. 1932. Contributions to the early life histories of sixty-two species of fishes from Lake Erie and its tributary waters. Bull. U.S. Bur. Fish. 47: 293-398.

Forney, J. L. 1967. Estimates of biomass and mortality rates in a walleye population. N. Y. Fish Game J. 14: 176-192.

Gerlach, J. M. 1973. Early development of the quillback carpsucker, Carpiodes cyprinus. M.A. Thesis, Millersville State College, Millersville, Pa.

Grimes, C. B. 1975. Entrapment of fishes on intake water screens at a steam electric generating stations. Ches. Sci. 16(3):172-177.

Grotbeck, L. M. and J. L. Bechtold. 1975. Fish impingement at Monticello Nuclear Plant. J. Power Div., ASCE, Vol. 101, No. PO1, Proc. Paper 11409, pp. 69-83.

Gustafson, S. P. and P. J. Diedrich. 1976. Progress report on the Prairie Island creel survey March 1 - November 23, 1975. In: Environmental monitoring and ecological studies program, Northern States Power 1975 annual report, Vol. II, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Gustafson, S. P., J. L. Geis and P. J. Diedrich. 1976. 1975 progress report on the Prairie Island fish population study. In: Environmental monitoring and ecological studies program, Northern States Power 1975 annual report, Vol. II, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Hawkinson, B. S. 1974. Progress report on the Prairie Island creel survey May 10 - November 5, 1973. In: Environmental monitoring and ecological studies program, Northern States Power 1973 Annual Report, Vol. I, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Hawkinson, B. S. 1974. 1973 fish population study progress report of Mississippi River near Prairie Island July 1973 - February 1974. In: Environmental monitoring and ecological studies program, Northern States Power 1973 annual report, Vol. I, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Haynes, C. M. 1976. Macroinvertebrate study. In: Environmental monitoring and ecological studies program, Northern States Power 1975 annual report, Vol. I, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Hester, F. E. and Dendy, J. S. 1962. A multiplate sampler for aquatic macroinvertebrates. Trans. Amer. Fish. Soc. 91(4).

Horst, T. J. 1975. The assessment of impact due to entrainment of ichthyoplankton. In: Saila S.B. 1975. Fisheries and energy production, a symposium. D. C. Heath and Co., Lexington, Mass.

Hynes, H. B. N. 1972. The ecology of running water. University of Toronto Press.

Kerr, J. E. 1953. Studies on fish preservation at the Contra Costa Steam Plant of the Pacific Gas and Electric Company. Calif. Dept. Fish and Game Fish. Bull. 92.

Krosch, H. F. 1969. 1968 progress report on Lake St. Croix fish population study. In: Environmental monitoring and ecological studies program, Northern States Power 1968 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Lorenzen, C. J. 1967. Determination of chlorophyll and pheopigments: spectrophotometric equations. Limnol. Oceanogr. 12:343-346.

Lippson, A. J. and R. L. Moran. 1974. Manual for identification of early development stages of fishes of the Potomac River Estuary. Envir. Tech. Center, Martin Marietta Corp., Baltimore, Md. PPSP-MP-13.

May, E. B. and C. R. Gasaway. 1967. A preliminary key to the identification of larval fishes of Oklahoma with particular reference to Canton Reservoir, including a selected bibliography. Oklahoma Department of Wildlife Conservation, Oklahoma Fisheries Resource Laboratory, Bull. No. 5.

Mayhew, D. A, and H. K. Hess. 1976. Impingement of fishes and other organisms on the Prairie Island Plant intake traveling screens. In: Environmental monitoring and ecological studies program, Northern States Power 1975 annual report, Vol. I, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

McConville, D. R. 1974. Macroinvertebrate studies. In: Environmental monitoring and ecological studies program, Northern States Power 1973 annual report, Vol. I, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

McConville, D. R. 1975. Macroinvertebrate studies. In: Environmental monitoring and ecological studies program, Northern States Power 1974 annual report, Vol. I, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

McFadden, J. T. 1975. Environmental impact assessment for fish populations. pp. 89-138 In: R. K. Sharma et al. (eds.) Proceedings of the conference on the biological significance of environmental impacts. USNRC, Washington, D.C.

Meyer, F. A. 1970. Development of some larval centrarchids. Prog. Fish-Cult. 32(3):130-136.

Middlebrook, K. 1975. Zooplankton entrainment. In: Environmental monitoring and ecological studies program, Northern States Power 1974 annual report, Vol. I, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Middlebrook, K. 1976. Zooplankton entrainment. In: Environmental monitoring and ecological studies program, Northern States Power 1975 annual report, Vol. I, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Miller, E. F. 1971. Ecological studies. In: Environmental monitoring and ecological studies program, Northern States Power 1970 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Miller, E. F. 1972. Ecological studies. In: Environmental monitoring and ecological studies program, Northern States Power 1971 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Miller, E. F. 1973. Fisheries study. In: Environmental monitoring and ecological studies program, Northern States Power 1972 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Miller, R. R. 1960. Systematics and biology of the gizzard shad (Dorosoma cepedianum) and related fish. Fish. Bull. 60:371-392.

Moore, G. A. 1957. Fishes: Part 2, pp. 21-165 In: W. F. Blair, et al., Vertebrates of the United States. 2nd edition. 1968. McGraw-Hill Book Co., New York.

Moyle, J. B. 1949. Fish population concepts and management of Minnesota lakes for sport fishing. Trans. N. Am. Wildlife Conf. 14:283-294.

Mueller, K. N. 1975. Aquatic vegetation of the Prairie Island area 1974. In: Environmental monitoring and ecological studies program, Northern States Power 1974 annual report, Vol. II, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Mueller, K. N. 1976. Prairie Island aquatic vegetation study - 1975. In: Environmental monitoring and ecological studies program, Northern States Power 1975 annual report, Vol. II, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

MPCA. 1975. Minnesota's guide for biological demonstrations for administration of 316(a) and (b) for the Federal Water Pollution Control Act Amendments of 1972 and Minnesota Regulation WPC 36(u)(3). Minnesota Pollution Control Agency, Division of Water Quality.

Naplin, R. L. and J. L. Geis. 1975. 1974 progress report on the Prairie Island fish population study. In: Environmental monitoring and ecological studies program, Northern States Power 1974 annual report, Vol. II, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Naplin, R. L. and S. P. Gustafson. 1975. Progress report on the Prairie Island creel survey April 30 - December 3, 1974. In: Environmental monitoring and ecological studies program, Northern States Power 1974 annual report, Vol. II, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Nelson, W. R. 1968. Embryo and larval characteristics of sauger, walleye, and their reciprocal hybrids. Trans. Am. Fish. Soc. 97(2):167-174.

Norden, C. R. 1961. The identification of larval yellow perch, Perca flavescens, and walleye, Stizostedion vitreum. Copeia 1961 (3):282-288.

NSP. 1972. Environmental monitoring and ecological studies program, Northern States Power 1971 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

NSP. 1973. Environmental monitoring and ecological studies program, Northern States Power 1972 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

NSP. 1974. Environmental monitoring and ecological studies program, Northern States Power 1973 annual report for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Olsen, L., MPCA. Personal communication to J. Ericson, NUS Corporation, Pittsburgh, Pa. Letter of October 18, 1976.

Quirk, Lawler and Matusky. 1974. Nine Mile Point aquatic ecology studies, Vol. II, fish impingement. Niagara Mohawk Power Corporation.

Reiger, H. A., V. C. Applegate, and R. A. Ryder. 1969. The ecology and management of the walleye in western Lake Erie. Great Lakes Fish. Comm. Tech. Rep. 15.

Ricker, W. E. 1975. Handbook of computation and interpretation of statistics of fish populations. Fish. Res. Bd. Canada Bull. No. 191.

Sazaki, M., W. Heubach and J. E. Skinner. 1973. Some preliminary results on the swimming ability and impingement tolerance of young-of-the-year steelhead trout, king salmon and striped bass. Final report for Anadromous Fisheries Act Project AFS-13. Manuscript.

Scott, W. B. and E. J. Crossman, 1973. Freshwater fishes of Canada. Fish. Res. Bd. Canada Bull. No. 184.

Simonet, R. J. 1975. Macroinvertebrate study. In: Environmental monitoring and ecological studies program, Northern States Power 1974 annual report, Vol. II, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Skrypek, J. 1966. Analysis of physical and biological changes at selected sampling stations in the Mississippi River. Minnesota Department of Conservation.

Snedecor, B. W. and W. G. Cochran. 1967. Statistical methods. 6th ed. Iowa State University Press, Ames, Ia.

Snyder, D. E. 1971. Studies of larval fishes in Muddy Run Pumped Storage Reservoir near Holtwood, Pennsylvania. M.S. Thesis, Cornell University, Ithaca, N. Y.

Snyder, D. E. and M. B. M. Snyder. 1976. Identification of larvae of Notemigonus crysoleucas, Notropis spilopterus, and Pimephales promelas. J. Fish. Res. Bd. Canada 32: 000-000. (Recently submitted for publication).

Sokal, R. R. and F. J. Rohlf. 1969. Biometry. W. H. Freeman and Co., San Francisco.

Stefan, H. 1973. A preliminary evaluation of the flow through Sturgeon Lake upstream of Lock and Dam No. 3 on the Mississippi River. Prepared for John W. Gorman, Inc. and Northern States Power Company.

Sternberg, R. B. 1969. Angler creel census of Pools 4 and 5 of the Mississippi River, Goodhue and Wabasha Counties, Minnesota in 1967-68. Minnesota Department of Conservation, Division of Game and Fish. Report No. 306.

Szluha, A. 1974. Zooplankton study. In: Environmental monitoring and ecological studies program, Northern States Power 1973 annual report, Vol. I, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Szluha, A. 1975. Zooplankton study. In: Environmental monitoring and ecological studies program, Northern States Power 1974 annual report, Vol. I, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Taber, C. A. 1969. Distribution and identification of larval fishes in the Buncombe Creek Arm of Lake Texoma with observations on spawning habits and relative abundance. Ph.D.Thesis, University of Oklahoma, Norman, Oklahoma.

USAEC. 1972. Draft environmental impact statement for Indian Point Nuclear Generating Plant Unit No. 3, Consolidated Edison Company of New York, Inc. U. S. Atomic Energy Commission. Docket No. 50-286.

USAEC. 1973. Draft Environmental Statement by the United States Atomic Energy Commission Directorate of Licensing related to the proposed issuance of an operating license for the Prairie Island Nuclear Generating Plant by Northern States Power. Docket Nos. 50-282 and 50-306.

USGS. 1928-1975. Water resources data for Minnesota. Part 2. Surface water records. U. S. Geological Survey.

Vose, R. 1974. Aquatic macrophyte study. In: Environmental monitoring and ecological studies program, Northern States Power 1973 annual report, Vol. I, for the Prairie Island Nuclear Generating Plant near Red Wing, Minnesota.

Wickliff, E. L. 1953. Gizzard shad rides again. Ohio Conserv. Bull. 17:23-25.

APPENDIX 1

INTAKE VELOCITY PROFILES AT PINGP
JUNE 23 AND 28, 1976

VELOCITIES (m/sec) AT SKIMMER WALL, JUNE 23, 1976

Measured immediately in front of skimmer wall
at light posts numbered from north to south

Blowdown: 275 cfs

Depth (ft)	1	2	3	4	5	6	7	8
Surface	0.10	0.10	0.05	0.05	0.00	0.00	0.05	0.05
1	0.05	0.05	0.05	0.05	0.05	0.05	0.00	0.05
2	<0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05
3	<0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
4	<0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
5	<0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
6	<0.05	<0.05	0.05	0.05	0.05	0.05	0.10	0.05
7	<0.05	0.10	0.10	0.10	0.05	0.05	0.10	0.05
8		0.10	0.10	0.10	0.05	0.10	0.10	
9		0.10	0.10	0.15	0.10	0.10	0.10	
10		0.10	0.10	0.15	0.10	0.10	0.10	
11		0.10	0.10	0.15	0.15	0.10	0.10	
11.5							0.05	
12		0.05	0.10	0.20	0.15	0.10		
13			0.10	0.20	0.15	0.10		
14			0.10	0.15	0.15	0.15		
14.5			0.10	0.15	0.15	0.10		
15.5					0.10			

VELOCITIES (m/sec) AT BAR RACK, JUNE 23, 1976

Measured 4.5 ft in front of bar rack at 24 equidistant points numbered from east to west.

Blowdown: 275 cfs

Depth (ft)	1	2	3	4	5	6	7	8
Surface	0.30	0.40	0.30	0.30	0.30	0.30	0.25	0.35
1	0.40	0.35	0.40	0.30	0.30	0.25	0.30	0.40
2	0.40	0.40	0.40	0.30	0.35	0.30	0.30	0.30
3	0.45	0.40	0.40	0.30	0.30	0.30	0.30	0.30
4	0.50	0.40	0.35	0.30	0.30	0.30	0.30	0.30
5	0.45	0.35	0.40	0.30	0.30	0.20	0.30	0.30
6	0.40	0.35	0.30	0.30	0.20	0.20	0.20	0.15
7	0.35	0.40	0.35	0.10	0.20	0.20	0.20	0.15
8	0.30	0.30	0.25	0.10	0.20	0.25	0.10	0.10
9	0.25	0.30	0.25	0.20	0.20	0.25	0.20	0.25
10	0.25	0.30	0.25	0.20	0.25	0.20	0.20	0.30
11	0.20	0.25	0.25	0.20	0.20	0.25	0.15	0.20
11.5	0.20							
12		0.20	0.25		0.20	0.20	0.20	0.20
12.5				0.20				
13			0.20		0.30	0.10	0.20	0.20
13.5						0.10		0.10
14			0.20				0.20	
14.5			0.10				0.10	

VELOCITIES (m/sec) AT BAR RACK, JUNE 23, 1976

(Continued)

Depth (ft)	9	10	11	12	13	14	15	16
Surface	0.30	0.25	0.25	0.30	0.20	0.20	0.25	0.20
1	0.30	0.25	0.30	0.30	0.25	0.30	0.30	0.25
2	0.30	0.30	0.30	0.30	0.25	0.25	0.30	0.30
3	0.30	0.25	0.30	0.25	0.30	0.30	0.30	0.25
4	0.30	0.20	0.35	0.30	0.25	0.25	0.20	0.20
5	0.30	0.30	0.20	0.30	0.30	0.25	0.20	0.20
6	0.25	0.20	0.15	0.30	0.25	0.20	0.20	0.30
7	0.20	0.20	0.25	0.20	0.10	0.20	0.30	0.20
8	0.20	0.15	0.30	0.20	0.10	0.20	0.25	0.30
9	0.25	0.25	0.25	0.20	0.25	0.20	0.20	0.15
10	0.25	0.20	0.25	0.30	0.20	0.20	0.30	0.30
11	0.25	0.20	0.20	0.25	0.20	0.25	0.30	0.20
12	0.20	0.25	0.20	0.20	0.20	0.15	0.30	0.20
13	0.20	0.20	0.15	0.20	0.20	0.20	0.20	0.20
13.5		0.20						
14	0.10			0.10	0.10	0.20	0.20	0.10
14.5							0.10	

VELOCITIES (m/sec) AT BAR RACK, JUNE 23, 1976

(Continued)

Depth (ft)	17	18	19	20	21	22	23
Surface	0.30	0.30	0.25	0.30	0.30	0.30	0.40
1	0.30	0.30	0.30	0.30	0.35	0.40	0.35
2	0.30	0.30	0.30	0.30	0.30	0.25	0.30
3	0.30	0.30	0.30	0.35	0.40	0.30	0.30
4	0.30	0.35	0.30	0.30	0.40	0.35	0.30
5	0.30	0.25	0.20	0.35	0.40	0.30	0.30
6	0.20	0.20	0.10	0.30	0.30	0.20	0.30
7	0.25	0.25	0.20	0.25	0.30	0.25	0.25
8	0.20	0.20	0.20	0.20	0.30	0.30	0.30
9	0.20	0.30	0.15	0.30	0.20	0.20	0.30
10	0.20	0.25	0.20	0.25	0.30	0.20	0.25
11	0.20	0.20	0.20	0.30	0.30	0.20	0.20
12	0.25	0.30	0.10	0.20	0.25	0.25	0.15
12.5							0.10
13	0.20	0.20	0.20	0.25	0.25	0.15	
13.5	0.10	0.20	0.20				
14				0.25	0.20	0.20	
14.5				0.20			

VELOCITIES (m/sec) AT SKIMMER WALL, JUNE 28, 1976

Measured immediately in front of skimmer wall at light posts numbered from north to south

Blowdown: 655 cfs

Depth (ft)	1	2	3	4	5	6	7	8
Surface	0.00	0.10	0.05	0.05	0.05	0.10	0.05	0.00
1	0.00	0.15	0.10	0.05	0.05	0.05	0.10	0.05
2	0.05	0.15	0.10	0.05	0.05	0.05	0.10	0.05
3	0.05	0.15	0.05	0.05	0.05	0.10	0.05	0.00
4	0.05	0.15	0.05	0.05	0.05	0.10	0.20	0.05
5	0.05	0.10	0.10	0.10	0.10	0.10	0.15	0.05
6	0.05	0.05	0.10	0.10	0.10	0.15	0.15	0.05
7	0.05	0.05	0.15	0.10	0.10	0.15	0.15	0.05
8		0.10	0.20	0.10	0.10	0.15	0.10	
9		0.10	0.25	0.15	0.10	0.15	0.10	
10		0.20	0.25	0.20	0.15	0.15	0.15	
11		0.20	0.25	0.20	0.20	0.15	0.15	
12		0.20	0.25	0.20	0.20	0.15	0.10	
13		0.15	0.20	0.20	0.20	0.15	0.10	
13.5		0.15						
14			0.20	0.20	0.20	0.10		
15			0.20	0.15	0.10			

VELOCITIES (m/sec) AT SKIMMER WALL, JUNE 28, 1976

Measured immediately in front of skimmer wall at light posts numbered from north to south

Blowdown: 1300 cfs

Depth (ft)	1	2	3	4	5	6	7	8
Surface	0.15	0.15	0.05	0.10	0.05	0.10	0.20	0.10
1	0.15	0.20	0.05	0.05	0.05	0.10	0.20	0.05
2	0.10	0.20	0.10	0.05	0.05	0.10	0.20	0.10
3	0.05	0.10	0.10	0.10	0.10	0.10	0.20	0.10
4	0.05	0.10	0.10	0.10	0.10	0.10	0.25	0.20
5	0.05	0.10	0.15	0.15	0.10	0.15	0.25	0.15
6	0.05	0.10	0.15	0.15	0.15	0.15	0.20	0.10
7	0.05	0.15	0.15	0.20	0.20	0.20	0.20	0.10
8		0.20	0.15	0.25	0.25	0.20	0.20	
9		0.25	0.20	0.30	0.25	0.25	0.20	
10		0.25	0.25	0.30	0.30	0.25	0.20	
11		0.30	0.25	0.30	0.30	0.25	0.20	
12		0.30	0.30	0.30	0.25	0.25	0.15	
13		0.30	0.30	0.25	0.20	0.25	0.10	
13.5		0.20						
14			0.30	0.25	0.20	0.20		
15			0.25	0.20	0.20			

APPENDIX 2

NOTES ON SPAWNING AND REPRODUCTION OF 26 SPECIES OF FISH OCCURRING NEAR PINGP

APPENDIX 2

NOTES ON SPAWNING AND REPRODUCTION OF 26 SPECIES OCCURRING AT THE PINGP SITE

Species	*Amia calva* (Bowfin)
Maturation by Year - Class or Length (mm total length)	Male: III-V[6], 457; 380[5]; Female: 610[6].
Fecundity	23,600-64,000[5]
Spawning Season	Mid-May through June, possibly as early as late April (Canada)[6]; late March through May[5].
Temperature (°C)	16-19[5]
Area	Shallow vegetated waters in lakes and rivers[1]; shallow, sluggish, stagnant water up to 122cm or deeper[5].
Egg Deposition	38-76 cm diameter nets among thick vegetation hollowed out circular or elliptical depression with bottom of fibrous roots, water-soaked leaves or gravel, also under stumps, logs, and bushes. 2,000-5,000 eggs per nest; eggs attach to decaying vegetation and reeds by thread-like extensions of egg surface[5].
Type	Adhesive, darker from original creamy yellow[6]; attachment structure[5].
Water-hardened Size (mm)	2.2-3.0, capsule progressively distends to twice original size[5].
Incubation Period (days)	8-10[6]; 4-14[5].
Larvae	
Hatching Size (mm total length)	8[6]; 3-7[5]
Habits, Behavior Survival	Larvae attach to vegetation with adhesive on the tip of the snout for 7-9 days by which time they are 10-13 mm total length, young guarded by male parent for several weeks until young are about

Amia calva (cont'd.)

102 mm total length[6] ; larvae also attach to roots and lie on bottom of nest, then form tight guarded swarms, larvae 9-13 mm at yolk absorbtion, young among weeks in shallows[5].

Species	*Esox lucius* (Northern pike)
Maturation by Year - Class or Length (mm total length)	Male: I-II, 305[2]; II-III[6]; Female: II-IV, 325[2]
Fecundity	595,000,32,000[6]; 2,000-545,000[2]; 32,000[1].
Spawning Season	March through May (Canada)[6]; March to May (Michigan)[1]; February to mid-June[2].
Temperature (°C)	4.4-11.1[6]; 5-14[2].
Area	Heavily vegetated flood plains of rivers, marshes, and bays; larger lakes, often in water no deeper than 18cm[6]; shallow areas with vegetation[2]; swamps, ponds, and lakes[1]; grassy or rush beds[4].
Egg Deposition	Eggs scattered at random and attach to vegetation[6]; no nest[2]; no parental care[4]; eggs clear and amber[6].
Type	Demersal, adhesive[6]
Water-hardened Size (mm)	2.5-3.0[6]; 2.2-3.4[1].
Incubation Period (days)	12-14, 4.5 @17.8-20°C[6]
Survival	Fertility rate over 50%[6], 52-99% fertile, 64-90% egg hatch[2].
Larvae	
Hatching Size	6-7[6]; 6.5-8 with average of 7[2]; 9-10[4].
Habits, Behavior, Survival	99.8% mortality prior to young leaving spawning grounds; young attach to vegetation with adhesive glands on head for 6-10 days while consuming yolk; young grow rapidly, 43 mm by first

Esox lucius (cont'd.)

month and 152 mm by the end of first summer, young after yolk absorption feed on larger zooplankton and immature insects for 7-10 days then begin consuming small fish; by 50 mm, fish are a predominant food[6]; begin feeding at 13.3-15.1 mm, 99.6-99.9% mortality from egg to fingerling[2].

Species	*Cyprinus carpio* (Carp)
Spawning Season	Late April to mid-August (Great Lakes)[6]; mid-May through August (Wisconsin)[2]; May through mid-August (Pennsylvania)[7]; mid-May to early July (Maryland)[5]; March through August (U.S.)[5]. Late March through mid-June (Okla.)[8].
Temperature (°C)	17-28[6]; 14.5-23.4 but mostly at 18.5-20[2 & 5], 10-30 but optimal at 22[5].
Area	Weedy or grassy shallows of lakes, ponds, tributaries, swamps, flood plains, and marshes; 8-180 cm in depth[1, 2, 4, 5, 6, 8, 9].
Egg Deposition	Broadcast randomly, eggs attach frequently in clusters to weeds, grasses or roots[1, 2, 4, 5, 6, 8, 9].
Type	Adhesive[1, 2, 5, 6]
Water-hardened Size (mm)	1[6], 1.0-2.0[5].
Incubation Period (days)	3-6[6]; 3-16, 3-5 @ 20°C, 4-8 @ 17.6-18.4°C, 12-16[1]; 2-3 at 22°C[5].
Survival	High mortality[8]
Larvae	
Hatching Size (mm total length)	3-6.4[5]
Habits, Behavior, Survival	Larvae attach to or lie among vegetation after hatching[5]; most larvae remain in shallow water, few are found in deeper open water[8]; after 12 mm, total length, young appear to move from near-shore surface water to deeper water[7].

Species	Notropis hudsonius (Spottail shiner)
Spawning Season	May through July (Lake Erie)[4,6]; June to early July (Lake Erie)[2].
Temperature (°C)	20.0[2]
Area	Over sandy shoals in water 90-150 cm deep[6].
Egg Deposition	Found in algae masses along Lake Erie shore.
Fecundity (mm Total Length)	100-2600[2].

Species	*Notropis spilopterus* (Spotfin shiner)
Maturation by Year - Class or Length (mm total length)	I, 47 mm (minimum)[2]
Fecundity	225-1,580[6]
Spawning Season	Mid-May through August (New York)[6]; late May to early September (New York)[2]; late May through June (Maryland)[2]; early May to mid-September (Pennsylvania)[7].
Egg Deposition	Underside of logs and roots[6]; underside of submerged objects[9]; attached to branches and logs in clusters[2].
Type	Adhesive[6]
Larvae Habits, Behavior Survival	Larvae appear to prefer the shallow shoreline to the more open waters[7].

Species	*Notropis dorsalis* (Bigmouth shiner)
Spawning Season	Late May to early September[2]; late June to late August (Colorado)[1].
Area	Probably spawns in mid-stream[2].
Egg Deposition	Eggs probably carried by current[2].
Type	Pelagic[2]

Species	*Pimephales notatus* (Bluntnose minnow)
Maturation by Year - Class or Length (mm total length)	Male: II[6]; III[2]; Female: I[6]; I-II[2]
Fecundity	1,743-2,223 averaging 2,005[2].
Spawning Season	May to mid-August (Canada)[6]; May through August (Michigan)[2]; mid-April through August (Illinois, Pennsylvania)[2, 7]; late May to early August (Wisconsin)[1].
Temperature (°C)	21-26[2]; 27.8[4]
Area	Shallow water up to 62 cm deep, sand and gravel bottom shoals[1].
Egg Deposition	Male hollows out nest beneath stone or other object upon which the eggs are laid on the underside[6]; intermittent spawners, 200-500 eggs per spawning[2]; several broods per nest[1].
Type	Adhesive[6]
Water-hardened Size (mm)	1-1.5[6]
Incubation Period (days)	7-14[6]; 8-9 @ 21-24°C[1].
Larvae	
Hatching Size (mm total length)	5[6]
Habits, Behavior, Survival	Larvae are 12 mm 2 weeks after hatching[6].

Species	*Rhinichthys cataractae* (Longnose dace)
Fecundity	200-1,200[6]; 160-680[2].
Spawning Season	Late April through July (Canada)[6]; late April to mid-June (Maryland)[2]; late May to early September (Minnesota)[2].
Temperature (°C)	11.7 minimum[6]
Area	In riffles[6]
Egg Deposition	Over gravelly bottom, in or near *Nocomis micropogon* nests, one parent believed to guard area though no nest is built[6].
Type	Adhesive[6]
Incubation Period (days)	7-10 @ 15.6°C
Larvae Habits, Behavior, Survival	Yolk absorbed 7 days after hatching, young are pelagic and remain so for about 4 months[6].

Species	*Semotilus atromaculatus* (Creek chub)
Maturation by Year - Class or Length (mm total length)	Male: III[6]; IV[2]; Female: II[6]; III[2]
Fecundity	2,820-4,671; 4,250 average for 76-703 mm total length[1].
Spawning Season	Late April to mid-July (Canada)[6]; April to mid-May (Illinois)[2]; early March to mid-June (Iowa)[2]; mid-April to July (Michigan)[2].
Temperature (°C)	12.8 minimum[6]; 12.8-26.7[1]
Area	Small, gravelly streams in smooth water just above or below a riffle[6]; in quiet riffles or gravel bar in a lake[1].
Egg Deposition	Male creates a nest or depression (trench); eggs deposited in pit, then covered with stones and gravel, male guards nest[6]; conspicuous nests with large stone ridge and oval pit[1].
Type	Demersal[6]

Species	*Catostomus commersoni* (White sucker)
Maturation by Year - Class or Length (mm total length)	III-VIII[6]; 76 mm minimum; Male: IV-VII[2]; Female: III-IX[2]
Fecundity	20,000-139,000[6]; 775-139,000 for fish 120-510 mm total length[2]; average of 20,000-50,000 for fish 410-540 total length[1].
Spawning Season	April through mid-June (Canada)[6]; late March to mid-May (Wisconsin)[1]; early May to early July (Wisconsin)[2]; late March to mid-June (Lake Erie)[1]; April-May (Michigan)[2]; mid-March through early April (Illinois)[2]; early May through early June (New York)[1]; early March through July (U.S.)[5, 8]
Temperature (°C)	6-23[5]; usually 10-20[8].
Area	Gravelly stream, lake margins or quiet areas in blocked streams, usually shallow with gravel, sometimes in rapids[6]; in riffles over gravel[2]; shallow swift water over gravel, may spawn in lakes but not typical[1].
Egg Deposition	Eggs scattered; adhere to gravel or drift downstream[6].
Type	Pelagic, adhesive[4]; slightly adhesive until water-hardened; demersal[5].
Incubation Period (days)	8-11 @ 10-15°C; 5 @ 18°C; 7 @ 15.5-16.1°C, 11 @ 13.6°C[2]; 4 @ 21.1°C, 7 @ 15.6°C, 17-21 @ average of 10.3°C[5].
Larvae Habits, Behavior Survival	Larvae remain in gravel 1-2 weeks then migrate to lake or

Catostomus commersoni (cont'd.)

river at which time they are 12-17 mm, may be as little as 3% survival from egg to migrant larvae[6]; prolarvae lie on bottom, larvae in schools in quiet shallows[5]; 12-14 mm at first downstream movement[2]; occasionally pelagic[7].

Species	*Moxostoma anisurum* (Silver redhorse)
Maturation by Year - Class or Length (mm total length)	V[2]
Fecundity	14,190-36,340[6]
Spawning Season	April and May[2]; late May through mid-June, possibly as early as late March (Chippewa River, Canada)[6].
Temperature (°C)	13.5[2]; 13.3[6].
Egg Deposition	Swiftly flowing streams, main channel of turbid rivers in 30-91 cm of water, do not ascend tributary streams[6]; spawn upstream[4].
Type	On gravel to rubble bottoms[6].
Larvae Habits, Behavior, Survival	Young inhabit slow-moving waters over hard or soft bottoms with overhanging banks[6].

Species	*Moxostoma macrolepidotum* (Shorthead redhorse)
Maturation by Year - Class or Length (mm total length)	II-III[2]
Fecundity	13,580-29,732[6]; 13,500-27,150[5]
Spawning Season	Early April to early May (Iowa)[2]; late May through July (Canada)[6]; early April through May[2]; mid-March through June (Maryland)[5].
Temperature (°C)	11.1[6]
Area	Small rivers or streams gravelly riffles[6]; quieter upper parts of streams at least 10 m wide, also over sand bottoms[5].
Egg Deposition	Eggs scattered[6]; scattered in small lots, buried in bottom[5].

Species	*Ictalurus melas* (Black bullhead)
Maturation by Year - Class or Length (mm total length)	III, 254[2].
Fecundity	3000-6800[6]; 3000-4000[1]; 1638-6200[2].
Spawning Season	Late April through June, possibly through August[6]; June through July (Wisconsin)[1]; late May to July (Ohio)[1]; early May to July (Illinois)[1].
Temperature (°C)	21[6]; begins @ 21-25.
Area	Shallow water among moderate to heavy vegetation[6].
Egg Deposition	Female excavates nest; intermitent spawning, both parents guard and care for eggs, about 200 eggs per brood[6].
Type	Somewhat adhesive; gelatinous coat; pale cream color[6].
Water-hardened Size (mm)	3 [6]
Incubation Period (Days)	5 @ high temperature.
Larvae Habits, Behavior, Survival	Newly hatched young school in loose sphere about parent until 25 mm in length[6]; young school by day[2].

Species	*Ictalurus nebulosus* (Brown bullhead)
Maturation by Year - Class or Length (mm total length)	III; 203-330[6].
Fecundity	2000-13000[6].
Spawning Season	Late April to July, possibly through September (Canada)[6]; May to July (Illinois)[1]; May to mid-August (Pennsylvania)[7]; May through June (Maryland)[5].
Temperature (°C)	21.1[6]; 21-25[5].
Area	Among roots of aquatic vegetation, usually near stump, rock, and trees, near shore[6]; sluggish weedy, muddy streams and lakes shallow to a several meters.
Egg Deposition	Shallow nest in bottom of mud; at times in burrows[6]; nests in open excavations in sand, gravel, or rarely mud, and often in shelter logs, rocks or vegetation, in burrows up to one meter long under roots of plants, in cavities of various objects, deposited in clusters[5].
Type	Adhesive; gelatinous, mucous coat pale cream color[6].
Water-hardened Size (mm)	3[6]
Incubation Period (Days)	6-9 @ 20.6-23.3°C[6]; 5 @ 25°C; 2 @ 20-21°C[5]; 5-14[7]; 7[1].
Larvae	
Hatching Size (mm total length)	6[6]
Habits, Behavior, Survival	Begin swimming and active feeding by 7th day after hatching, school in loose spear with parents until 51 mm total length[6]; larvae in tight mass on bottom for 6-16 days, then herded by parents for a few weeks, sometimes in schools throughout first summer among vegetation or near cover

Species	Percopis omiscomaycus (Trout-perch)
Maturation by Year - Class or Length (mm total.length)	I[6]; male 1[2]; female I-II[2].
Fecundity	240-728; averaging 349[6].
Spawning Season	Late April to June[6]; late April through May, possibly to September (Lake Erie)[6]; Lake May through August (Minnesota)[6]; late April through June[2]; late May to mid-June (Lake Erie)[2].
Temperature (°C)	16-20[2]; 19-21.4[1].
Area	Shallow rocky streams, also sand and gravel bottom in 0-1.3 m shoreline water of lakes[6]; shallow swift water over rocky or gravel bottom[1].
Type	Single 0.7 mm diameter, oil globule in fertalized egg[6]; adhesive demersal[2].
Water-hardened Size (mm)	1.36-1.85; 1.25-1.45[6].
Incubation Period (Days)	8 days at 20°C; 250 degree-days above 0°C[2].
Hatching Size (mm)	6.0[4]
Larvae Habits, Behavior, Survival	Young feed mainly on ostracods, Gammarus, Leptodora, chironomids, or zooplankton[2].

Species	Lota lota (Burbot)
Maturation by Year - Class or Length (mm total length)	III-IV, 280-480[6]; III, 343-419[2].
Fecundity	45,600-1362007[6]; 68498-1153144[2]; 160,000-670000[1].
Spawning Season	Late December through March (Canada)[6]; mid-January to March[2]; late September through March, possibly through April[1,4].
Temperature (°C)	0.6-1.7[6].
Area	30-120 cm of water over sand or gravel in shallow bays or gravel shoals 1.5-3 m deep, usually in lakes but has been known to move into rivers[6]; deep holes in streams or "Bear" deep water[1].
Egg Deposition	Spawn as a writing ball, 61 cm in diameter of 10-12 interwined and constantly moving individuals; no nest or parental care[6]; eggs scattered loose on bottom[1]; 250 eggs at a time[2].
Type	Semi-pelagic[6]; non-adhesive[1].
Water-hardened Size (mm)	1.25-1.77[6]; 1.7[1].
Incubation Period (Days)	30 @ 6.1°C; 3-4 weeks[1].

Species	*Ambloplites rupestris* (Rock bass)
Maturation by Year - Class or Length (mm total length)	II-V but typically II-III[3]; 109-267[6].
Fecundity	3,000-11,000[6]; averaging over 5,000[3].
Spawning Season	Late March through July[3]; late April to July (Lake Erie)[4]; late March to July (New York)[1]; May-June (Indiana)[1]; May to August (Pennsylvania)[7].
Temperature (°C)	15.6-21.1[6]; 20.5-26[3].
Area	Swamps to gravel shoals, very diverse[6]; near vegetation in shallow water up to 62 cm deep[1].
Egg Deposition	Male digs shallow nest up to 61 cm diameter; female spawns intermittently; male guards eggs; nest produces average of 800 larvae[6]; nests on gravel, soil, marl, in swampy places, near rocks, sticks, etc.[1]
Type	Adhesive[6].
Incubation Period (Days)	3-4 @ 20.5-21.0°C.
Larvae Habits, Behavior, Survival	Male broods young for short time; young usually inhabit protected areas only[1].

Species	*Micropterus salmoides* (Largemouth bass)
Maturation by Year - Class or Length (mm total length)	II-V, occasionally less than I[3]; male: IV-V[6]; female: III-IV[6].
Fecundity	2,000-109,314, average 7,000-94,157[3].
Spawning Season	Late March to August (Lake Erie)[4]; late March to July (New York)[1]; mid-April to July (Illinois, Missouri, New Hampshire)[3]; May (New York, Indiana)[1,3]; mid-April to early July (Wisconsin, Pennsylvania)[1,3,7]. Early April through mid-August (Okla.)[8].
Temperature (°C)	11.5-29, 14.4-23.9[3]; 17.8[1]; 16.7-18.3[6].
Area	In quiet bays among emergent vegetation, gravelly sand, marl, or solt mud in reeds, bullrushes or water lilies[6]; in shallow water, usually less than 61 cm deep, over clean sand, gravel, roots or aquatic vegetation, sometimes on fallen leaves[1,3]; usually near boulders, pilings or under sandstone ledges[3].
Egg Deposition	Nest 61-92 cm diameter; 2-20 cm deep, and 9 m apart; eggs laid over whole bottom of nest, nest guarded by male, nests produced 751-11,457 (averaging 5000-7000) larvae[6]; will not nest on silt bottoms[3]; eggs attach to stones[4]; eggs attach to roots and other objects in nests[1].
Type	Adhesive[4]; demersal, amber to pale yellow[6].
Water-hardened Size (mm)	1.5-1.7
Incubation Period (Days)	3-5[6]; 1.5-13.2, 1.5 @ 30°C, 2.9 @ 20-22.5°C; 4-43 @ 17.5%, 6.8 @ 15°C; 13.2 @ 10°C[3].
Survival	0-94%, averaging 80%, usually 92-100%[3].

Larvae	
Hatching Size (mm total length)	3[6]
Habits, Behavior, Survival	Young remain on bottom of nest for 6-7 days and rise and begin to feed at 5.9-6.3 mm total length; brood may remain together for 31 days and 15 guarded by male all or part of the time[6]; free-swimming at 6.2 mm total length; remain in nest two weeks then leave as a compact school[1,4]; survival from 90 days to fall is 58-91% from 47 days to fall is 19-100%[3].

Species	Micropterus dolomieui (Smallmouth bass)
Maturation by Year - Class or Length (mm total length)	II-IV but usually III-IV[3]; male II-IV[6]; female IV-VI.
Fecundity	5,000-14,000[6]; 2,000-20,825, averaging 5,040-13,863[3].
Spawning Season	Early May through July[6]; mid-April to early June (Ohio, Missouri)[3]; May to early July (Maryland, New York, Michigan)[3]; late May through July (Cayuga Lake)[3]; late April through July (Pennslyvania, Lake Erie)[4,7].
Temperature (°C)	16.1-18.3[6]; 15.5-17.8; 11.7-21, usually 15-21[3].
Area	Lakes and rivers; sandy, gravely or rocky bottom usually near rocks, logs, or more rarely dense vegetation[6]; usually in shallow water near overhead cover, stumps, stones, steep banks or at edges of pools, in tributatries[1,3,4,8]; along lake shores[1].
Egg Deposition	Nests, depressions, formed in clean gravel or sand with bedrock, wood debris, or clam shells on bottom[1,3,4,8]; nest circular, 30-120 cm in diameter. eggs usually attach to stones at center of nest; nest guarded by male[6].
Type	Demersal, adhesive, light amber to pale yellow[6].
Water-hardened Size (mm)	1.2-2.5[6].
Incubation Period (Days)	2.2-16[1,3,4]; 2.2 @ 75°C, 9.8 @ 12.8°C, 7 @ 15°C 3.2 @ 21.1°C[3]; 4-10[6].
Survival	55.2 - 100%, average 94.1%[3].
Larvae Hatching Size	5.6-5.9[6].

Habits, Behavior, Survival

Young guarded for 2-10 days or up to 28 days after leaving nests[3]; yolk absorbed 12 days after hatching at which time they are 8.7-9.9 mm total length and leave the nest, still guarded[6].

Species	*Lepomis macrochirus* (Bluegill)
Maturation by Year - Class or Length (mm total length)	I-II, rarely 0[3]; I[1]; female III-IV[6]; male II-III[6].
Fecundity	7,208-38,184, 4,670-224,900[6]; 2,360-81,104, means of 3,820-58,000 for fish 122-151 mm total length[3].
Spawning Season	Late April to mid-September (Wisconsin)[3]; June to mid-October (Michigan)[3]; June to July (Indiana)[1]; mid-May through August (Pennsylvania)[7]; late April through September (Illinois)[3]. Early May through late September (Okla.)[8].
Temperature (°C)	24.5[6]; 22-26, 17-32[3].
Area	Water less than 120 cm deep over variety of substrates but fine gravel or clean sand preferred, area usually exposed to sun[3].
Egg Deposition	Nests in colonies over hard bottom of sand or mud with little vegetation[1]; nest is a shallow depression 45-60 cm in diameter; guarded by male[6].
Type	Adhesive, demersal, amber[6]; very heavy[1].
Incubation Period (Days)	3.5[6]; 13.3, 3 @ 22.6°C; 1.4 @ 26.9°C; 1.3 @ 22.3°C; 2.1 @ 24°C; 1.7 @ 23.5°C in light but 1.8 in dark[3].
Survival	56% @ 22.6°C; 83% @ 26.9°C; 90% @ 27.3°C[3]; survival higher where dense vegetation is present[3].
Larvae Hatching Size (mm total length)	2-3[6].

Lepomis macrochirus

Habits, Behavior, Survival

Mortality rate of larvae is very high[6]; young free-swimming four days after hatching leave nests and remain in littoral zone until 10-12 mm when they move to limetic zone; when 21-25 mm they return to littoral zone[3]; larvae found in both limetic and littoral zones[7].

Species	Poxomis annularis (White crappie)
Maturation by Year - Class or Length (mm total length)	II-III[1]; II-IV; 152-203[6].
Spawning Season	Late April to mid-July (Ohio)[1]; mid-May through July (Pennsylvania)[7]. mid-March to mid-June (Okla.)[8]
Temperature (°C)	14-23, mostly 16-20[6].
Area	Shallow water up to 1.7 meters deep[8]; near or under overhanging ledges[1].
Egg Deposition	Eggs adhere to plants and rootlets[1,8]; clean ill-defined nests, 300 mm diameter with no depression over a variety of bottoms, nests isolated or in colonies of 35-50, 61-122 cm apart, eggs adhere to substate, especially algae and each other[6].
Type	Adhesive; demersal, colorless[6].
Water-hardened Size (mm)	0.89[6]
Incubation Period (Days)	2-2.2 @ 21.1-23.3°C[3]; 2-4.5, 4 @ 14.4°C[6].
Larvae Habits, Behavior, Survival	Larvae present in limnetic and near shore waters of Conewingo Reservoir, PA (Darrel E. Snyder); tiny young remain in nest for a very short time, sometimes only four days[6].

Species	*Pomoxis nigromaculatus* (Black crappie)
Maturation by Year - Class or Length (mm total length)	II-IV[6]
Fecundity	20,000-140,000[1]; 26,700-65,570, averaging 37,796[6]/
Spawning Season	Late April to early August (Indiana, South Dakota)[1]; late April through June[6].
Temperature (°C)	17.8[1]; 19-20[6].
Area	Shallow water, usually with bottom of fine sand or gravel[6].
Egg Deposition	Male clears shallow depression or just section of bottom of sand, gravel, or mud where there is some vegetation; nests, 20-40 cm diameter, colonial, 1.6-1.9 m apart, male guards nest[6].
Type	Adhesive, demersal, whitish, transparent[6].
Water-hardened Size (mm)	1[6]
Incubation Period (Days)	3-5[6]
Larvae Habits, Behavior, Survival	Male guards young in nest until a few days after hatching[6].

Species	*Etheostoma nigrum* (Johnny darter)
Spawning Season	May to early July[6].
Area	Shallow water, usually small streams[1].
Egg Deposition	Eggs deposited one by one on underside of rocks, 30-200 eggs at each of 5 or 6 spawning sessions, male guards territory including nest and eggs (even if eggs or rock with eggs are removed)[6]; eggs laid on under surface of submerged objects in single layer[1].
Type	Adhesive[6]; spherical[1].
Incubation Period (Days)	5-8 @ 22-24°C[6].

Species	*Perca flavescens* (Yellow perch)
Maturation by Year - Class or Length (mm total length)	Male: III[6]; Female: IV[6].
Fecundity	3,035-109,000[6].
Spawning Season	Mid-March to July (Lake Erie)[4]; mid-April through May, possibly through July;[6] mid-April through May (Lake Erie).[11]
Temperature (°C)	6.7-12.2[1]; 8.9-12.2[6]; 6.6-12.6[11]
Area	Usually over or near aquatic vegetation or brush[1]; shallows of lakes, tributary streams, sometimes over gravel or sand[6].
Egg Deposition	Eggs extruded in unique transparent, gelatinous, accordian-folded strands as long as 2.1 m and as wide as 51 to 102 mm weighing as much as a kilogram and containing 2,000 to 90,000 eggs (average: 23,000); strands undulate by water movement and adhere to bottom or submerged vegetation, eggs are easily cast ashore and lost, no parental care[6].
Type	Adhesive in gelatinous, porous strands; transparent, semi-buoyant[1].
Water-hardened Size (mm)	3.5[6]
Incubation Period (Days)	27 @ 8.3°C[1]; 8-10[6].
Larvae Hatching Size (mm total length)	5[6]
Habits, Behavior, Survival	Larvae limnetic, late May to early June (D.E. Snyder personal observations based on Conowingo Reservoir collections 1966-1971). In Oneida Lake, N.Y., larvae pelagic soon after hatching to 25.4 mm (May and June) and usually occupy upper 6 m of water column.[12]

Species	*Percina caprodes* (Logperch)
Spawning Season	Mid-March through May (Oklahoma)[8]
Area	Probably a short distance from creek mouth[4]; sandy inshore shallows[6].
Egg Deposition	Female joined by male on bottom substrate to spawn their vibration tends to bury the eggs; 10-20 eggs released with each spawning session; act repeated with other males[6].
Water-hardened Size (mm)	1.3[6]
Survival	Embryos survive 22 days @ 26°C[6].
Larvae Habits, Behavior, Survival	Larvae limnetic (D. E. Snyder)

Species	*Stizostedion vitreum* (Walleye)
Maturation by Year - Class or Length (mm total larvae)	Female: III-VI, 356,432; Male: II-IV, 279[6]; Male: II Female: III[13]
Fecundity	50,000-3,000,000[1]; 612,000 for an 801 mm specimen[6]; 72,000-110,000 per 3,178-3,405 g female[13].
Spawning Season	Mid-March to early July[1]; mid-March through April (Lake Erie)[4]; mid-April to early July[6]; April and May[11 and 13]; April (Lake Erie)[14]
Temperature (°C)	4.4-10[1]; 5.6-11.1[6]; 3.9-10.0[11].
Area	Upstream spawning runs soon after ice breaks, prefers sandy bars in shallow water spawns in water 1-3 m deep, usually on gravel or sand with good water flow[1]; rocky areas in white water below impassible falls and dams in rivers, or boulder to coarse gravel shoals of lakes.[6]
Egg Deposition	Eggs spread over bottom[1]; eggs released in shallow water[6]. Broadcast and fall into crevices in substrate.[14,17]
Type	Adhesive[1,6]; non-adhesive after water hardening[6].
Water-hardened Size (mm)	1.5-2[6]
Incubation Period (Days)	12-18[6] (at temperatures prevalent on spawning grounds)
Larvae	
Hatching Size (mm total length)	6-8.6 mm total length[6].
Habits, Behavior, Survival	Larvae begin feeding before yolk is completely absorbed; yolk absorbed rapidly; larvae disperse to upper levels of open water 10-15 days after hatching[6]. Pelagic but become demersal near end of summer.[6]

1. Breder and Rosen. 1966.
2. Carlander. 1969.
3. Carlander. Undated.
4. Fish. 1932.
5. Mansueti and Hardy. 1967.
6. Scott and Crossman. 1973.
7. Snyder. 1971.
8. Taber. 1969.
9. Trautman. 1957.
10. Snyder. 1975. Personal communication.
11. Ohio Department of Natural Resources. Undated.
12. Noble. 1968.
13. Parsons. 1972.
14. Ohio Department of Natural Resources. 1971.

APPENDIX 3

MEAN AND STANDARD DEVIATION OF DATA ON EGGS AND YOUNG FISH COLLECTED IN PINGP ENTRAINMENT STUDIES, 1975

APPENDIX 3 (Page 1 of 2)

MEAN AND STANDARD DEVIATION (S.D.) OF EGGS AND YOUNG FISH COLLECTED IN PINGP ENTRAINMENT STUDIES, 1975

Date		Bar Rack Mean	Bar Rack S.D.	Recirculation Canal Mean	Recirculation Canal S.D.	Skimmer Wall Mean	Skimmer Wall S.D.
	Eggs	0.01	0.07	0.20	0.47		
5/15-16/75	Young	4.17	5.29	5.78	4.37		
	Total	4.18	5.30	5.98	4.31		
	Eggs	1.43	2.47	0.79	1.30		
5/21-22/75	Young	71.69	70.15	141.73	70.52		
	Total	73.12	70.69	142.52	71.36		
	Eggs	27.51	34.93	2.61	1.51		
5/29-30/75	Young	100.89	134.54	30.35	14.89		
	Total	128.40	145.20	32.96	14.78		
	Eggs	3.06	3.04	0.49	0.85		
6/5-6/75	Young	7.36	9.20	7.77	10.01		
	Total	10.43	9.14	8.26	10.40		
	Eggs	0.61	1.05	0.23	0.50		
6/12-13/75	Young	12.50	34.33	1.86	2.28		
	Total	13.11	34.56	2.09	2.43		
	Eggs	3.34	4.64	1.80	1.89		
6/18-19/75	Young	14.22	19.29	8.17	4.31		
	Total	17.56	22.89	9.96	4.83		
	Eggs	1.32	1.29	0.67	0.61		
6/26-27/75	Young	60.43	117.51	15.52	16.10		
	Total	61.74	117.41	16.20	16.11		
	Eggs	0.10	0.39	0.00	0.00		
7/2-3/75	Young	5.67	14.04	6.63	5.97		
	Total	5.77	14.01	6.63	5.97		
	Eggs	0.05	0.15			0.04	0.09
7/10-11/75	Young	12.57	8.73			12.45	9.56
	Total	12.62	8.70			12.49	9.55
	Eggs	0.59	1.22			0.28	0.37
7/17-18/75	Young	2.38	1.85			2.04	1.12
	Total	2.97	2.77			2.32	1.14

APPENDIX 3 (Page 2 of 2)

Date		Bar Rack Mean	Bar Rack S.D.	Recirculation Canal Mean	Recirculation Canal S.D.	Skimmer Wall Mean	Skimmer Wall S.D.
	Eggs	0.01	0.05			0.06	0.21
7/24-25/75	Young	7.06	4.91			6.65	11.01
	Total	7.07	4.90			6.71	10.99
	Eggs	0.00	0.00			0.00	0.00
7/31-8/1/75	Young	6.78	5.27			0.96	0.82
	Total	6.78	5.27			0.96	0.82
	Eggs	0.00	0.00			0.00	0.00
8/7-8/75	Young	1.80	1.49			2.04	1.82
	Total	1.80	1.49			2.04	1.82
	Eggs	0.00	0.00			0.00	0.00
8/14-15/75	Young	2.79	4.56			3.36	5.31
	Total	2.79	4.56			3.36	5.31
	Eggs	0.00	0.00			0.00	0.00
8/21-22/75	Young	2.44	3.28			4.42	9.34
	Total	2.44	3.28			4.42	9.34
	Eggs	0.13	0.42			0.00	0.00
9/4-5/75	Young	0.15	0.44			0.02	0.11
	Total	0.28	0.57			0.02	0.11

APPENDIX 4

RESULTS OF CORRELATION ANALYSIS
OF FISH IMPINGEMENT, PLANT OPERATING
AND WATER TEMPERATURE DATA AT PINGP, 1975

Results of correlation analysis of fish impingement, plant operating and water temperature data at Prairie Island Plant during 1975.

	blkbull	chancat	whtbass	crappie	frhwdrm	rwit	rcwtrt	acw	mwa	date
Winter 1/1-3/19										
rwit	r = -0.09 p = 0.77 N.S.	r = 0.79 p = 0.003 **	r = 0.22 p = 0.51 N.S.	r = 0.52 p = 0.08 N.S.	r = 0.44 p = 0.15 N.S.	--- --- ---	r = -0.22 p = 0.51 N.S.	r = -0.28 p = 0.63 N.S.	r = 0.42 p = 0.17 N.S.	r = 0.65 p = 0.02 *
rcwtrt	r = 0.37 p = 0.24 N.S.	r = 0.02 p = 0.95 N.S.	r = 0.29 p = 0.64 N.S.	r = -0.03 p = 0.43 N.S.	r = 0.06 p = 0.85 N.S.	--- ---	--- ---	r = 0.70 p = 0.01 **	r = 0.00 p = 0.99 N.S.	r = -0.20 p = 0.53 N.S.
acw	r = 0.44 p = 0.15 N.S.	r = 0.10 p = 0.76 N.S.	r = 0.33 p = 0.30 N.S.	r = 0.22 p = 0.50 N.S.	r = 0.05 p = 0.97 N.S.	--- --- ---	--- --- ---	--- --- ---	r = 0.00 p = 0.99 N.S.	r = -0.39 p = 0.20 N.S.
mwa	r = -0.11 p = 0.73 N.S	r = 0.16 p = 0.62 N.S	r = 0.15 p = 0.64 N.S	r = 0.25 p = 0.56 N.S	r = 0.93 p = <0.01 **	--- --- ---	--- --- ---	--- --- ---	--- --- ---	r = 0.73 p = 0.01 **
Spring 3/20-6/19										
rwit	r = -0.28 p = 0.65 N.S.	r = -0.24 p = 0.57 N.S.	r = -0.04 p - 0.90 N.S.	r = -0.01 p = 0.96 N.S.	r = -0.10 p = 0.74 N.S.	--- --- ---	r = -0.21 p = 0.51 N.S.	r = -0.28 p = 0.65 N.S.	r = 0.22 p = 0.52 N.S.	r = 0.91 p = <0.01 **
rcwtrt	r = -0.25 p = 0.58 N.S.	r = 0.26 p = 0.61 N.S.	r = 0.18 p = 0.56 N.S.	r = 0.25 p = 0.58 N.S.	r = 0.47 p = 0.11 N.S.	--- --- ---	--- --- ---	r = 0.49 p = 0.08 N.S.	r = 0.33 p = 0.33 N.S.	r = -0.37 p = 0.21 N.S.
acw	r = -0.61 p = 0.02 *	r = -0.17 p = 0.58 N.S.	r = -0.16 p = 0.60 N.S.	r = -0.10 p = 0.74 N.S.	r = 0.36 p = 0.23 N.S.	--- --- ---	--- --- ---	--- --- ---	r = 0.54 p = 0.09 N.S.	r = -0.48 p = 0.10 N.S.
mwa	r = 0.47 p = 0.14 N.S.	r = -0.35 p = 0.30 N.S.	r = 0.43 p = 0.18 N.S.	r = 0.67 p = 0.02 *	r = 0.63 p = 0.04 *	--- --- ---	--- --- ---	--- --- ---	--- --- ---	r = 0.04 p = 0.90 N.S.

	blkbull	chancat	whtbass	crappie	frhwdrm	rwit	rcwtrt	acw	mwa	date
Summer 6/20-9/18										
rwit	r = 0.07 p = 0.81 N.S.	r = -0.22 p = 0.53 N.S.	r = 0.28 p = 0.65 N.S.	r = -0.05 p = 0.87 N.S.	r = -0.30 p = 0.33 N.S.	--- --- ---	r = 0.19 p = 0.53 N.S.	r = 0.38 p = 0.19 N.S.	r = 0.55 p = 0.06 N.S.	r = -0.78 p = <0.01 **
rcwtrt	r = -0.16 p = 0.60 N.S.	r = -0.22 p = 0.53 N.S.	r = 0.39 p = 0.18 N.S.	r = 0.41 p = 0.16 N.S.	r = 0.10 p = 0.75 N.S.	--- --- ---	--- --- ---	r = 0.63 p = 0.02 *	r = 0.80 p = <0.01 **	r = 0.07 p = 0.82 N.S.
acw	r = 0.17 p = 0.59 N.S.	r = 0.16 p = 0.62 N.S.	r = 0.31 p = 0.30 N.S.	r = 0.51 p = 0.07 N.S.	r = 0.36 p = 0.22 N.S.	--- --- ---	--- --- ---	--- --- ---	r = 0.46 p = 0.11 N.S.	r = 0.51 p = 0.07 N.S.
mwa	r = 0.09 p = 0.76 N.S.	r = -0.35 p = 0.24 N.S.	r = 0.51 p = 0.07 N.S.	r = 0.37 p = 0.21 N.S.	r = -0.11 p = 0.73 N.S.	--- --- ---	--- --- ---	--- --- ---	--- --- ---	r = 0.38 p = 0.20 N.S.
Fall 9/19-12/31										
rwit	r = 0.27 p = 0.65 N.S.	r = 0.57 p = 0.03 *	r = -0.09 p = 0.75 N.S.	r = 0.79 p = <0.01 **	r = 0.64 p = 0.02 *	--- --- ---	r = -0.88 p = <0.01 **	r = 0.55 p = 0.04 *	r = 0.67 p = <0.01 **	r = -0.94 p = <0.01 **
rcwtrt	r = -0.41 p = 0.14 N.S.	r = -0.37 p = 0.19 N.S.	r = 0.22 p = 0.55 N.S.	r = -0.60 p = 0.02 *	r = -0.67 p = <0.01 **	--- ---	--- ---	r = -0.40 p = 0.16 N.S.	r = -0.59 p = 0.03 *	r = 0.86 p = <0.01 **
acw	r = 0.40 p = 0.15 N.S.	r = 0.20 p = 0.50 N.S.	r = 0.16 p = 0.60 N.S.	r = 0.45 p = 0.10 N.S.	r = 0.39 p = 0.17 N.S.	--- --- ---	--- --- ---	--- --- ---	r = 0.23 p = 0.56 N.S.	r = -0.64 p = 0.02 *
mwa	r = 0.26 p = 0.62 N.S.	r = 0.79 p = <0.01 **	r = -0.04 p = 0.89 N.S.	r = 0.89 p = <0.01 **	r = 0.68 p = <0.01 **	--- --- ---	--- --- ---	--- --- ---	--- --- ---	r = -0.56 p = 0.04 *

All Seasons Combined	blkbull	chancat	whtbass	crappie	frhwdrm	rwt	rcwtrt	acw	mwa	date
rwit	r = -0.07 p = 0.61 N.S.	r = 0.10 p = 0.50 N.S.	r = 0.37 p = <0.01 **	r = 0.53 p = <0.01 **	r = 0.08 p = 0.56 N.S.	--- --- ---	r = -0.70 p = <0.01 **	r = -0.07 p = 0.60 N.S.	r = 0.63 p = <0.01 **	r = 0.28 p = 0.04 *
rcwtrt	r = 0.01 p = 0.95 N.S.	r = -0.16 p = 0.26 N.S.	r = -0.23 p = 0.10 N.S.	r = -0.44 p = <0.01 **	r = -0.30 p = 0.03 *	--- --- ---	--- --- ---	r = -0.04 p = 0.77 N.S.	r = -0.35 p = 0.02 *	r = -0.07 p = 0.61 N.S.
acw	r = -0.41 p = <0.01 **	r = 0.18 p = 0.20 N.S.	r = 0.19 p = 0.18 N.S.	r = 0.22 p = 0.11 N.S.	r = 0.29 p = 0.04 *	--- --- ---	--- --- ---	--- --- ---	r = 0.20 p = 0.16 N.S.	r = 0.03 p = 0.83 N.S.
mwa	r = 0.32 p = 0.02 *	r = -0.31 p = 0.62 N.S.	r = 0.41 p = <0.01 **	r = 0.57 p = <0.01 **	r = -0.08 p = 0.59 N.S.	--- --- ---	--- --- ---	--- --- ---	--- --- ---	r = -0.08 p = 0.57 N.S.

blkbull = black bullhead
chancat = channel catfish
whtbass = white bass

crappie = crappie spp.
frhwdrm = freshwater drum
rwit = river water inlet temperature

rcwtrt = recycle-canal water temperature
acw = average circulating water
mwa = makeup-water appropriation

N.S. = not significant
* = significant at 0.05 level
** = significant at 0.01 level
r = correlation coefficient
p = level of significance

intake modif.
circ. water

Return to KNW

STONE & WEBSTER ENGINEERING CORPORATION
P. O. BOX 5406, DENVER, COLORADO 80217

DATE	4/1/83
J. O. NO.	~~12911.09~~
P. O. NO.	E-78Y073
LTR. NO.	S-N-671
REF.	T2.2

VIA

TO
Mr. L.A. Winter
Project Manager
Northern States Power Company
Prairie Island Nuclear Generating Plant
Route 2
Welch, Minnesota 55089

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FINAL SYSTEM DESCRIPTION
MODIFY CIRCULATING WATER
INTAKE AND DISCHARGE
PRAIRIE ISLAND NUCLEAR GENERATING PLANT

Transmitted herewith for your use and files are six (6) copies of the final version of the project system description.

If you have any questions please call me.

J.E. Sells
J.E. Sells
Project Engineer

Copy to:
D.R. Brown 1/4

CLM:CMS

SWEC J.O. No. 12911.09
NSP J.O. No. E-78Y073

March 1983

MODIFY CIRCULATING WATER
INTAKE AND DISCHARGE

SYSTEM DESCRIPTION
AND
DESIGN CRITERIA

PRAIRIE ISLAND NUCLEAR GENERATING PLANT

0648B

CONTENTS

0648B

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 <u>SWEC Modified Criteria</u>

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 Mechanical

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-S00LB.

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.

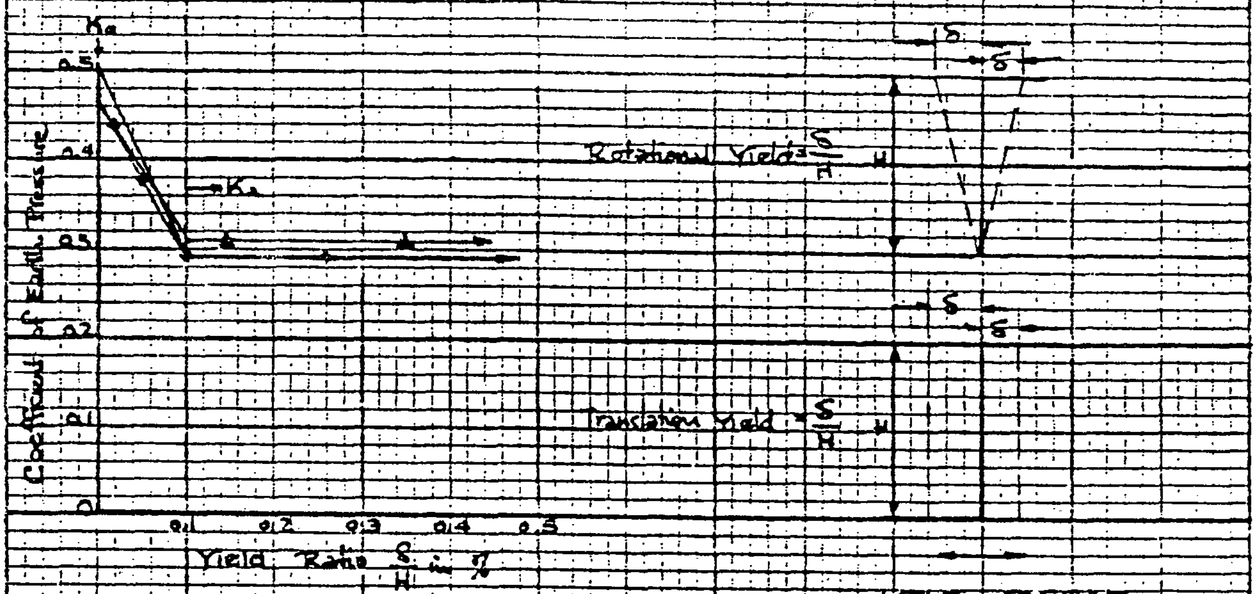
6.3.2 Valves

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

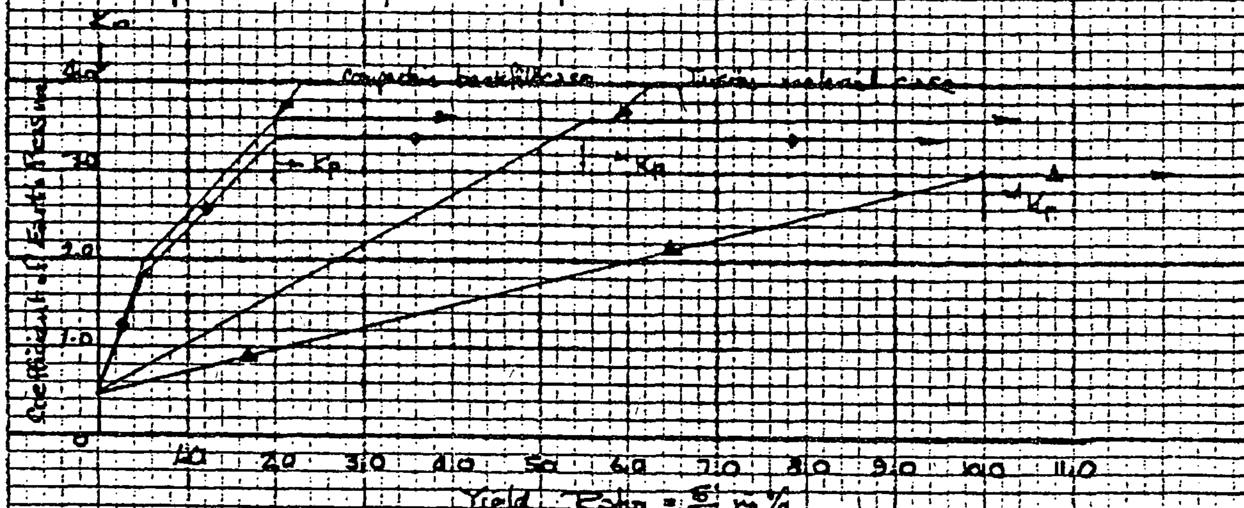
All components are visually examined while in operation every three months.



ACTIVE CASE

= 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.)

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	E.C.L 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	6	REDRAWN, ADDED PROPRIETARY & 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-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		ISSUE	DESCRIPTION
CORRECT	H.A.T. 7/7/60			
APPROVED	C.W.M. 7/7/60	STANDARD DESIGN DRAWING	STD-ME-2-2-7	
ISSUE	(7) [illegible] (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. ($LB-FT^2$)	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, $LB-FT^2$
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 <u>manually jogged</u> from the screen location whenever <u>all</u> 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 <u>automatically start with coarse screens</u> whenever <u>all</u> 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 continuously run at minimum speed with fine 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. 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 automatically start and run for 1-1/3 revolutions at approximately 20 fpm whenever all 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 stop whenever any 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. Fine Screen Larvae Removal Pump - Typical for Two
(Ref. drawing NF-92780-4)

1. The fine screen larvae removal pump (CT-045-1031, 1032) 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-91800-27, 32) is in the RUN position.

   b. Motor circuit breaker closed.

   c. Motor thermal overload reset.

2. The fine screen larvae removal pump will manually stop whenever any 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. Fine Screen Trash Removal Pump - Typical for Two
(Re. drawing NF-92780-3)

1. The fine screen trash removal pump (CT-045-1021, 1022) 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-91800-25, 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 stop whenever any 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. Coarse Screen Fish and Trash Removal Pump Discharge Valves - 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 manually open from the control board in the intake screenhouse whenever all of the following conditions are satisfied.

   a. The valve selector switch (CS-91800-16, 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 manually close from the control board in the intake screenhouse whenever all of the following conditions are satisfied.

   a. The valve selector switch (CS-91800-16, 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 automatically open from the control board in the intake screenhouse whenever all of the following conditions are satisfied.

   a. The valve selector switch (CS-91800-16, 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 Automatically close from the control board in the intake screenhouse whenever all of the following conditions are satisfied.

   a. The valve selector switch (CS-91800-16, 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. Fine Screen Trash Removal Pump Discharge Valve - Typical of two (MV-91200, MV-91201)
(Ref. drawing NF-92780-3)

1. The fine screen trash 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-91800-15, 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 satisified:

   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:

$$Q_T=(K_5\ I_5 + K_6\ I_6 + K_7\ I_7 + K_8\ I_8)\ [h_{DIS}-h_{INT}]$$

PRAIRIE ISLAND NUCLEAR GENERATING PLANT
ENVIRONMENTAL MONITORING
AND
ECOLOGICAL STUDIES PROGRAM

2006 ANNUAL REPORT

Prepared for
Northern States Power Company d/b/a Xcel Energy
Minneapolis, Minnesota

By
Environmental Services
Water Quality Department

TABLE OF CONTENTS

SECTION I

PRAIRIE ISLAND NUCLEAR GENERATING PLANT ENVIRONMENTAL MONITORING PROGRAM 2006 ANNUAL REPORT

WATER TEMPERATURE AND FLOW

Report
by
B. D. Giese

Environmental Services
Water Quality Department

WATER TEMPERATURE AND FLOW

INTRODUCTION AND METHODS

The Mississippi River is the source-water body for circulating and cooling water systems at the Prairie Island Nuclear Generating Plant (PINGP). This report presents daily plant operating hours, river inlet temperatures, site discharge temperatures and flows (blowdown). Site discharge temperatures are determined by thermocouples located downstream at U.S. Army Corps of Engineers Lock and Dam 3. Plant inlet (ambient river) temperatures are determined by remote sensors located in Sturgeon Lake, and the main channel at Diamond Bluff. Inlet temperatures are also recorded from thermocouples located in front of the intake screenhouse, which are maintained for back-up. Data presented in this report are for environmental studies comparison, and are not intended as NPDES temperature compliance reporting.

Also presented in this 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.

RESULTS AND DISCUSSION

Daily average river inlet and site discharge temperature data are presented by month in Table 1. Daily Mississippi River flows recorded at Lock and Dam 3 ranged from 2,400 to 65,100 cfs in 2006 (Table 2). Daily mean site discharge flow (blowdown) from the PINGP external circulating water log ranged from 141 to 1,208 cfs (Table 1).

PINGP withdrew an annual average of 4.5 percent of the Mississippi River flow during 2006 (Table 3). Table 4 shows the monthly average Mississippi River flows for the years 1985 through 2006. The average river flow in 2006 was 17,800 cfs, which was lower than the average river flow of 22,100 cfs for years 1985-2005. The range of annual average river flows is 8,709 cfs in 1988 to 37,772 cfs in 1986.

Table 1. **Monthly ambient river inlet temperatures, and site discharge temperatures and flows, with recorded operating hours for Units 1 and 2 at PINGP in 2006**

DATE **JANUARY**	OPERATING HOURS UNIT 1	UNIT 2	RIVER INLET TEMP. (°F)	SITE DISCHARGE TEMP. (°F)	MEAN SITE DISCHARGE FLOW (BLOWDOWN-CFS)
1	24	24	33.5	34.7	802
2	24	24	34.4	35.0	802
3	24	24	34.7	35.4	808
4	24	24	35.2	34.8	808
5	24	24	34.6	35.4	808
6	24	24	34.5	34.7	808
7	24	24	33.9	34.9	808
8	24	24	34.5	35.3	808
9	24	24	34.0	35.4	808
10	24	24	32.6	34.2	808
11	24	24	32.6	34.1	808
12	24	24	33.5	34.6	808
13	24	24	34.1	34.5	808
14	24	24	32.9	34.4	808
15	24	24	33.4	34.2	815
16	24	24	33.9	34.9	815
17	24	24	32.7	33.7	616
18	24	24	32.3	33.2	528
19	24	24	33.1	33.4	488
20	24	24	33.4	33.9	488
21	24	24	32.6	33.8	488
22	24	24	32.7	33.9	624
23	24	24	32.1	34.1	815
24	24	24	33.8	34.6	815
25	24	24	32.7	34.2	815
26	24	24	32.3	34.2	815
27	24	24	34.5	35.2	815
28	24	24	32.7	35.9	815
29	24	24	35.6	35.9	815
30	24	24	34.9	36.0	815
31	24	24	35.6	36.1	815
	MONTHLY MINIMUM		32.1	33.2	488
	MONTHLY MAXIMUM		35.6	36.1	815
	MONTHLY MEAN		33.7	34.7	758

Table 1. **Monthly ambient river inlet temperatures, and site discharge temperatures and flows, with recorded operating hours for Units 1 and 2 at PINGP in 2006**

DATE **FEBRUARY**	OPERATING HOURS UNIT 1	 UNIT 2	RIVER INLET TEMP. (°F)	SITE DISCHARGE TEMP. (°F)	MEAN SITE DISCHARGE FLOW (BLOWDOWN-CFS)
1	24	24	35.9	36.2	815
2	24	24	35.0	35.6	828
3	24	24	35.1	35.8	815
4	24	24	33.0	33.9	815
5	24	23.5	32.2	33.6	828
6	24	0	32.1	32.7	413
7	24	0	32.6	33.0	413
8	24	0	32.2	33.1	413
9	24	0	32.1	33.0	413
10	24	0	31.9	33.1	413
11	24	0	32.5	33.1	392
12	24	0	32.5	33.0	392
13	24	0	31.9	33.1	360
14	24	0	32.7	33.0	413
15	24	0	32.5	33.0	413
16	24	0	32.4	32.9	423
17	24	0	32.3	32.8	402
18	24	0	31.5	33.3	402
19	24	0	31.3	32.8	540
20	24	0	31.7	32.8	475
21	24	21	31.8	33.0	500
22	24	24	32.3	33.7	855
23	24	24	32.5	33.9	869
24	24	24	32.2	34.0	869
25	24	24	31.9	34.4	869
26	24	24	31.8	34.8	869
27	24	24	33.1	35.0	869
28	24	24	32.5	35.0	869
	MONTHLY MINIMUM		31.3	32.7	360
	MONTHLY MAXIMUM		35.9	36.2	869
	MONTHLY MEAN		32.6	33.7	605

Table 1. **Monthly ambient river inlet temperatures, and site discharge temperatures and flows, with recorded operating hours for Units 1 and 2 at PINGP in 2006**

DATE **MARCH**	OPERATING HOURS UNIT 1	UNIT 2	RIVER INLET TEMP. (°F)	SITE DISCHARGE TEMP. (°F)	MEAN SITE DISCHARGE FLOW (BLOWDOWN-CFS)
1	24	24	31.3	35.4	869
2	24	24	34.6	36.0	869
3	24	24	34.3	35.9	889
4	24	24	33.7	36.6	855
5	24	24	35.5	36.6	855
6	24	24	34.8	35.9	855
7	24	24	35.6	36.4	855
8	24	24	36.4	37.2	855
9	24	24	36.6	37.8	869
10	24	24	36.2	38.3	815
11	24	24	38.7	40.2	815
12	24	24	38.4	39.2	882
13	24	24	35.3	36.4	882
14	24	24	34.0	35.2	838
15	24	24	34.0	35.0	815
16	24	24	34.7	35.0	822
17	24	24	33.6	34.8	822
18	24	24	34.8	35.8	822
19	24	24	35.1	36.4	855
20	24	24	36.7	37.3	842
21	24	24	35.9	37.1	849
22	24	24	36.0	36.7	849
23	24	24	38.3	38.3	849
24	24	24	38.3	38.6	849
25	24	24	38.7	39.2	849
26	24	24	38.4	39.5	846
27	24	24	39.6	40.4	869
28	24	24	38.8	40.2	869
29	24	24	40.7	41.9	875
30	24	24	42.6	43.9	875
31	24	24	41.8	43.8	875
	MONTHLY MINIMUM		31.3	34.8	815
	MONTHLY MAXIMUM		42.6	43.9	889
	MONTHLY MEAN		36.6	37.8	853

Table 1. Monthly ambient river inlet temperatures, and site discharge temperatures and flows, with recorded operating hours for Units 1 and 2 at PINGP in 2006

DATE APRIL	OPERATING HOURS UNIT 1	UNIT 2	RIVER INLET TEMP. (°F)	SITE DISCHARGE TEMP. (°F)	MEAN SITE DISCHARGE FLOW (BLOWDOWN-CFS)
1	24	24	41.4	42.5	875
2	*23	*23	41.6	42.6	869
3	24	24	39.9	41.7	862
4	24	24	39.6	42.0	882
5	24	24	39.7	42.7	862
6	24	24	41.7	43.4	862
7	24	24	42.5	44.6	862
8	24	24	42.3	44.5	862
9	24	24	43.6	46.1	869
10	24	24	45.5	47.8	869
11	24	24	47.5	50.0	869
12	24	24	49.2	52.2	869
13	24	24	49.9	52.6	822
14	24	24	51.6	54.8	684
15	24	24	52.4	54.7	291
16	24	24	53.5	55.5	291
17	24	24	53.8	55.6	291
18	24	24	54.5	56.5	267
19	24	24	56.0	57.4	144
20	24	24	55.3	56.8	141
21	24	24	54.9	56.8	291
22	24	24	54.5	56.2	283
23	24	24	55.7	56.7	267
24	24	24	57.2	62.1	299
25	24	24	55.0	56.6	283
26	24	24	56.4	57.4	291
27	24	24	56.7	58.1	291
28	24	24	58.2	58.8	275
29	3.6	24	56.8	57.3	283
30	0	24	56.1	56.6	275

* Daylight savings

MONTHLY MINIMUM	39.6	42.0	141
MONTHLY MAXIMUM	58.2	58.8	882
MONTHLY MEAN	50.1	52.0	539

Table 1. Monthly ambient river inlet temperatures, and site discharge temperatures and flows, with recorded operating hours for Units 1 and 2 at PINGP in 2006

DATE MAY	OPERATING HOURS UNIT 1	UNIT 2	RIVER INLET TEMP. (°F)	SITE DISCHARGE TEMP. (°F)	MEAN SITE DISCHARGE FLOW (BLOWDOWN-CFS)
1	0	24	55.7	56.3	291
2	0	24	56.2	56.4	291
3	0	24	57.8	57.8	291
4	0	24	56.8	57.5	283
5	0	24	55.6	55.8	283
6	0	24	55.7	56.4	283
7	0	24	56.6	57.9	283
8	0	24	57.9	58.2	283
9	0	24	58.9	59.6	283
10	0	24	59.5	59.4	283
11	0	24	59.1	59.2	283
12	0	24	56.1	56.7	283
13	0	24	55.5	55.6	283
14	0	24	54.7	55.7	283
15	0	24	56.3	55.9	283
16	0	24	56.6	57.9	283
17	0	24	58.2	59.1	283
18	0	24	58.1	60.1	299
19	0	24	59.0	60.3	299
20	0	24	59.5	61.8	299
21	0	24	59.6	60.7	299
22	0	24	60.1	60.9	299
23	0	24	60.6	62.9	291
24	0	24	62.8	64.6	291
25	0	24	64.7	66.2	299
26	0	24	66.5	67.4	275
27	0	24	68.2	70.0	283
28	0	24	68.9	71.2	291
29	0	24	72.5	72.4	291
30	0	24	72.4	74.0	291
31	0	24	73.5	74.4	275
	MONTHLY MINIMUM		54.7	55.7	275
	MONTHLY MAXIMUM		73.5	74.4	299
	MONTHLY MEAN		60.4	61.4	288

Table 1. Monthly ambient river inlet temperatures, and site discharge temperatures and flows, with recorded operating hours for Units 1 and 2 at PINGP in 2006

DATE JUNE	OPERATING HOURS UNIT 1	UNIT 2	RIVER INLET TEMP. (°F)	SITE DISCHARGE TEMP. (°F)	MEAN SITE DISCHARGE FLOW (BLOWDOWN-CFS)
1	0	24	74.9	75.6	384
2	0	24	74.7	75.8	396
3	0	24	75.2	75.9	396
4	0	24	75.2	74.9	384
5	0	24	73.7	74.6	396
6	15.9	24	74.1	74.4	396
7	24	24	75.1	76.1	396
8	24	24	75.8	76.6	434
9	24	24	74.6	74.4	423
10	24	24	70.5	71.1	392
11	24	24	67.1	69.4	392
12	24	24	68.9	68.5	392
13	24	24	69.8	71.1	392
14	24	24	71.6	72.3	392
15	24	24	71.2	72.0	392
16	24	24	71.6	72.8	760
17	24	24	73.3	74.4	760
18	24	24	74.2	75.4	760
19	24	24	73.3	74.9	768
20	24	24	73.3	74.0	760
21	24	24	73.7	74.1	760
22	24	24	74.0	74.3	760
23	24	24	74.0	73.9	760
24	24	24	74.3	74.4	760
25	24	24	73.3	73.7	760
26	24	24	73.3	73.5	768
27	24	24	74.0	74.3	776
28	24	24	73.0	74.3	768
29	24	24	74.5	74.7	760
30	24	24	75.0	75.9	760
	MONTHLY MINIMUM		67.1	69.4	384
	MONTHLY MAXIMUM		75.8	76.6	776
	MONTHLY MEAN		73.2	73.9	580

Table 1. Monthly ambient river inlet temperatures, and site discharge temperatures and flows, with recorded operating hours for Units 1 and 2 at PINGP in 2006

DATE JULY	OPERATING HOURS UNIT 1	OPERATING HOURS UNIT 2	RIVER INLET TEMP. (°F)	SITE DISCHARGE TEMP. (°F)	MEAN SITE DISCHARGE FLOW (BLOWDOWN-CFS)
1	24	24	76.0	77.4	869
2	24	24	77.0	77.9	1180
3	24	24	77.3	79.3	1180
4	24	24	77.6	78.4	1180
5	24	24	76.2	77.9	1180
6	24	24	75.9	78.2	1194
7	24	24	77.1	78.6	1194
8	24	24	77.4	78.7	1194
9	24	24	77.2	78.9	1194
10	24	24	77.0	78.6	1194
11	24	24	78.2	79.6	1194
12	24	24	77.6	79.2	1194
13	24	24	78.7	81.0	1194
14	24	24	78.6	82.1	1194
15	24	24	80.2	81.7	1194
16	24	24	81.6	83.0	1194
17	24	24	80.7	82.7	1194
18	24	24	79.8	81.6	1194
19	24	24	79.6	81.4	1194
20	24	24	77.3	79.8	1194
21	24	24	78.0	80.0	1194
22	24	24	77.7	78.9	1194
23	24	24	77.4	79.8	1194
24	24	24	78.9	81.3	1194
25	24	24	78.9	81.4	1194
26	24	24	80.1	81.9	1194
27	24	24	80.8	82.8	1194
28	24	24	81.3	83.8	1194
29	24	24	83.2	85.8	1194
30	24	24	83.5	85.2	1194
31	24	24	82.7	83.6	1194
	MONTHLY MINIMUM		75.9	78.2	869
	MONTHLY MAXIMUM		83.5	85.2	1194
	MONTHLY MEAN		78.8	80.7	1182

Table 1. Monthly ambient river inlet temperatures, and site discharge temperatures and flows, with recorded operating hours for Units 1 and 2 at PINGP in 2006

DATE AUGUST	OPERATING HOURS UNIT 1	UNIT 2	RIVER INLET TEMP. (°F)	SITE DISCHARGE TEMP. (°F)	MEAN SITE DISCHARGE FLOW (BLOWDOWN-CFS)
1	24	24	84.0	85.1	1194
2	24	24	78.3	82.4	1194
3	24	24	81.6	81.8	1194
4	24	24	80.3	82.6	1194
5	24	24	80.1	81.8	1194
6	24	24	79.5	81.1	1194
7	24	24	79.1	80.6	1194
8	24	24	78.6	80.2	1194
9	24	24	77.9	80.3	1194
10	24	24	78.1	79.7	1194
11	24	24	78.1	80.1	1208
12	24	24	77.2	79.7	1194
13	24	24	77.4	79.1	1194
14	24	24	75.8	77.5	1194
15	24	24	75.9	77.5	1194
16	24	24	76.2	78.4	1194
17	24	24	75.9	78.6	1194
18	24	24	75.3	77.5	1194
19	24	24	75.2	77.4	1194
20	24	24	74.9	76.7	1194
21	24	24	74.9	78.0	1194
22	24	24	75.3	78.3	1194
23	24	24	75.3	77.9	1194
24	24	24	75.5	77.3	1194
25	24	24	73.5	74.9	1194
26	24	24	72.6	74.1	1194
27	24	24	73.4	75.1	1194
28	24	24	73.8	76.2	1194
29	24	24	72.2	74.8	1194
30	24	24	73.5	75.7	1194
31	24	24	73.4	75.8	1194
	MONTHLY MINIMUM		72.2	74.8	1194
	MONTHLY MAXIMUM		84.0	85.1	1208
	MONTHLY MEAN		76.5	78.6	1194

Table 1. **Monthly ambient river inlet temperatures, and site discharge temperatures and flows, with recorded operating hours for Units 1 and 2 at PINGP in 2006**

DATE **SEPTEMBER**	OPERATING HOURS UNIT 1	UNIT 2	RIVER INLET TEMP. (°F)	SITE DISCHARGE TEMP. (°F)	MEAN SITE DISCHARGE FLOW (BLOWDOWN-CFS)
1	24	24	72.9	76.1	1194
2	24	24	72.4	75.3	1180
3	24	24	73.2	75.3	1180
4	24	24	71.4	73.7	1194
5	24	24	72.0	74.5	1194
6	24	24	72.8	75.1	1194
7	24	24	72.7	75.4	1194
8	24	24	73.4	75.4	1194
9	24	24	70.8	72.4	1194
10	24	24	68.7	71.4	1194
11	24	24	66.7	69.3	1194
12	24	24	65.1	67.3	1180
13	24	24	64.8	66.8	1180
14	24	24	65.2	68.3	1180
15	24	24	65.7	69.2	1180
16	24	24	66.3	69.6	1180
17	24	24	67.6	70.4	1180
18	24	24	66.4	67.9	1152
19	24	24	64.1	64.4	1138
20	24	24	61.5	64.2	1138
21	24	24	61.5	65.1	1138
22	24	24	60.1	62.9	1152
23	24	24	59.5	60.9	1152
24	24	24	60.1	60.6	1152
25	24	24	60.3	63.2	1152
26	24	24	60.6	63.4	1152
27	24	24	61.3	63.0	1152
28	24	24	60.3	61.3	1152
29	24	24	59.6	61.7	1152
30	24	24	58.9	60.6	1012
	MONTHLY MINIMUM		58.9	60.6	1012
	MONTHLY MAXIMUM		73.4	75.4	1194
	MONTHLY MEAN		65.9	68.2	1166

Table 1. **Monthly ambient river inlet temperatures, and site discharge temperatures and flows, with recorded operating hours for Units 1 and 2 at PINGP in 2006**

DATE OCTOBER	OPERATING HOURS UNIT 1	UNIT 2	RIVER INLET TEMP. (°F)	SITE DISCHARGE TEMP. (°F)	MEAN SITE DISCHARGE FLOW (BLOWDOWN-CFS)
1	24	24	59.1	60.9	1012
2	24	24	61.1	63.3	1166
3	24	24	62.2	64.5	1180
4	24	24	62.2	65.1	1180
5	24	24	61.2	64.0	1180
6	24	24	60.6	63.4	1180
7	24	24	60.0	61.9	1180
8	24	24	60.4	62.2	1180
9	24	24	59.3	60.8	1194
10	24	24	57.8	59.4	1194
11	24	24	56.9	57.9	1194
12	24	24	52.2	53.7	1194
13	24	24	49.8	50.9	1194
14	24	24	47.4	48.5	1082
15	24	24	46.7	49.1	1082
16	24	24	49.2	51.7	1110
17	24	24	48.8	52.2	1110
18	24	24	49.8	50.6	1110
19	24	24	49.0	50.7	1110
20	24	24	49.4	51.6	1124
21	24	24	49.0	51.8	1082
22	24	24	46.7	49.3	1082
23	24	24	46.9	49.2	1068
24	24	24	45.2	48.8	1124
25	24	24	45.3	49.5	1124
26	24	24	46.1	49.1	1124
27	24	24	45.6	49.1	1124
28	24	24	45.8	49.6	1124
29	*25	*25	46.2	49.4	1124
30	24	24	46.5	50.1	1124
31	24	24	45.0	48.7	1124
* Daylight savings					
	MONTHLY MINIMUM		45.0	48.7	1012
	MONTHLY MAXIMUM		62.2	65.1	1194
	MONTHLY MEAN		52.0	54.4	1135

Table 1. **Monthly ambient river inlet temperatures, and site discharge temperatures and flows, with recorded operating hours for Units 1 and 2 at PINGP in 2006**

DATE NOVEMBER	OPERATING HOURS UNIT 1	UNIT 2	RIVER INLET TEMP. (°F)	SITE DISCHARGE TEMP. (°F)	MEAN SITE DISCHARGE FLOW (BLOWDOWN-CFS)
1	24	24	43.5	47.4	1110
2	24	24	42.1	45.4	1110
3	24	24	39.8	43.8	1082
4	24	24	41.7	44.5	967
5	24	24	41.8	45.4	967
6	24	24	42.2	46.6	973
7	24	24	44.0	47.5	967
8	24	24	45.6	49.4	973
9	24	24	46.3	50.8	973
10	24	24	45.1	47.7	973
11	24	24	43.8	47.2	973
12	24	24	42.6	47.5	973
13	24	24	42.3	45.3	973
14	24	20.3	39.8	44.7	973
15	24	0	40.9	42.4	955
16	24	0	41.7	42.1	880
17	24	0	39.0	42.3	880
18	24	0	41.3	41.7	392
19	24	0	39.5	41.3	392
20	24	0	39.2	40.5	392
21	24	0	40.4	41.5	392
22	24	0	40.5	41.9	392
23	24	0	40.3	41.8	392
24	24	0	41.5	42.6	381
25	24	0	40.7	42.7	381
26	24	0	40.4	41.8	381
27	24	0	41.9	42.4	392
28	24	0	42.2	43.7	392
29	24	0	41.4	42.3	392
30	24	0	37.3	38.1	381
		MONTHLY MINIMUM	37.3	38.1	381
		MONTHLY MAXIMUM	46.3	50.8	1110
		MONTHLY MEAN	41.6	44.1	725

Table 1. **Monthly ambient river inlet temperatures, and site discharge temperatures and flows, with recorded operating hours for Units 1 and 2 at PINGP in 2006**

DATE DECEMBER	OPERATING HOURS UNIT 1	UNIT 2	RIVER INLET TEMP. (°F)	SITE DISCHARGE TEMP. (°F)	MEAN SITE DISCHARGE FLOW (BLOWDOWN-CFS)
1	24	0	36.3	37.0	373
2	24	0	35.0	36.1	373
3	24	0	33.2	35.2	361
4	24	0	33.4	36.1	338
5	24	0	32.9	35.1	350
6	24	0	32.4	34.7	361
7	24	0	32.8	35.0	361
8	24	0	32.4	34.8	361
9	24	0	33.2	34.7	361
10	24	0	34.3	34.9	361
11	24	0	34.6	36.0	361
12	24	0	35.7	35.8	525
13	24	0	34.9	36.3	660
14	24	21	35.0	36.6	660
15	24	24	36.0	36.3	660
16	24	24	35.4	37.6	660
17	24	24	34.8	38.1	684
18	24	24	34.6	36.6	684
19	24	24	34.4	36.8	684
20	24	24	35.2	39.1	684
21	24	24	35.7	38.8	708
22	24	24	36.0	37.9	720
23	24	24	36.2	38.3	760
24	24	24	35.1	38.1	760
25	24	24	35.6	36.9	768
26	24	24	35.2	37.2	768
27	24	24	34.9	38.0	768
28	24	24	35.6	39.4	768
29	24	24	36.3	39.1	768
30	24	24	36.7	38.2	768
31	24	24	37.6	38.7	760
	MONTHLY MINIMUM		32.4	34.7	338
	MONTHLY MAXIMUM		37.6	38.7	768
	MONTHLY MEAN		34.9	36.9	586

Table 2 Daily 2006 Mississippi River Discharge Flow rate (cfs) at Lock Dam 3

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	18100	19300	13800	38500	33900	28300	14800	6300	4700	8400	6300	8400
2	18500	22800	13700	36200	34300	26400	13700	15000	5500	8300	7900	8400
3	18500	22600	14000	36900	35000	25500	12500	17400	6300	8200	7700	4700
4	18400	24300	13800	42200	36400	24200	11500	11900	10000	6900	6900	3200
5	19300	23400	13200	48200	38000	23100	11500	6700	8300	6800	6900	3700
6	19800	22300	13600	54600	39900	21800	9600	5300	5400	6800	6900	4600
7	19000	21400	14100	59700	41800	23000	9000	9700	5500	5400	6900	4500
8	18800	21400	14200	63100	43500	21300	9100	10300	7100	7000	6200	4500
9	18900	21100	16000	64300	45300	18800	10500	6900	7500	9200	7100	6900
10	18600	20200	15800	64700	47200	18800	8900	7000	4600	6900	8500	7800
11	18500	20100	15600	65100	48400	18500	7600	6900	4700	5500	8400	7100
12	17600	20300	17100	65100	49000	20300	7700	3900	5500	7100	4600	7300
13	18100	19600	21001	64500	48800	20000	8300	9000	5500	6900	6200	8100
14	19000	18000	24100	63600	48700	20100	3200	6900	5400	6400	6900	7900
15	17800	18300	22800	62500	48400	20700	7000	6900	4700	6300	7000	7200
16	18100	18300	22500	61800	48300	19100	7000	5400	4600	5500	7700	7000
17	19200	17600	22800	60600	48200	18600	7000	4700	6100	7000	7700	7200
18	18400	11600	23500	58900	48000	22200	6200	5500	7600	9400	7000	7300
19	17500	12300	23500	56900	47300	21900	5400	5500	7000	9800	7000	7700
20	17400	13600	23300	54400	46400	23700	7000	6100	3100	6100	7800	7500
21	17300	13800	23200	51500	45000	25000	6900	6100	3200	8400	6900	6800
22	16600	14300	23400	49200	43500	24900	6200	5400	6100	9000	6800	8100
23	16600	15800	24000	46900	41900	23800	6200	5400	11300	6800	6900	8900
24	15800	15700	24100	44500	38000	23300	5500	6900	8300	6900	6900	7400
25	15900	16500	24100	42600	36100	22300	6900	10200	6900	6200	7000	7200
26	15400	15900	23500	40700	33400	20700	6900	11500	7800	7000	7000	7100
27	15200	14800	23700	38600	32600	19300	6900	7400	9300	7800	7000	6500
28	15600	13900	24700	36900	32100	17700	6200	7500	8400	7800	7500	6400
29	17100		27700	35200	31200	16500	3900	6200	6900	6900	7800	6600
30	18000		31700	34500	31000	15500	2400	7000	6300	6900	8600	6800
31	18500		35500		29300		6300	6200		7200		7100
MIN	15200	11600	13200	34500	29300	15500	2400	3900	3100	5400	4600	3200
MAX	19800	24300	35500	65100	49000	28300	14800	17400	11300	9800	8600	8900
MEAN	17800	18200	20800	51400	41000	21500	7800	7600	6500	7300	7100	6800
YEAR MAX		65100										
YEAR MIN		2400										

Table 3 2006 Percentage of mean monthly Mississippi River flow entering the Xcel Energy Prairie Island Generating Plant intake

Month	Mean Plant Flow (cfs)	Mean River Flow (cfs)	Percentage of Mean River Flow Entering the Plant Intake
January	758	17800	4.3%
February	605	18200	3.3%
March	853	20800	4.1%
April	539	51400	1.0%
May	288	41000	0.7%
June	580	21500	2.7%
July	1182	7800	15.2%
August	1194	7600	15.7%
September	1166	6500	17.9%
October	1135	7300	15.5%
November	725	7100	10.2%
December	586	6800	8.6%
Averages	801	17800	4.5%

Table 4. Mean Monthly Mississippi River Flow for 1985 - 2006, in cubic feet per second (cfs).

Month	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996
January	17,800	9,900	6,700	9,229	10,932	11,271	8,974	10,790	9,806	14,823	14,826
February	18,200	11,600	6,700	7,871	10,104	10,471	9,548	12,589	14,911	13,954	15,041
March	20,800	14,700	15,000	13,210	11,497	10,948	22,219	17,897	26,574	24,177	24,474
April	51,400	44,700	24,700	25,613	40,657	112,703	15,570	42,013	51,477	106,073	57,517
May	41,000	31,000	19,400	42,194	33,974	82,661	18,839	47,426	22,681	39,316	46,535
June	21,500	39,200	46,000	27,413	26,323	53,177	22,070	34,423	25,690	19,487	33,790
July	7,800	21,900	19,500	32,739	34,597	23,981	21,052	27,548	26,477	36,119	23,732
August	7,600	9,800	10,600	10,084	29,065	12,164	10,026	24,432	10,742	28,074	13,303
September	6,500	15,200	19,200	7,087	24,513	9,193	6,687	18,013	7,060	16,663	9,300
October	7,300	35,900	19,500	6,771	28,600	9,577	6,790	14,200	12,597	14,155	11,403
November	7,100	19,200	21,900	8,167	18,467	11,040	17,463	13,243	19,773	14,160	23,353
December	6,800	19,100	12,300	8,310	12,135	13,813	9,558	9,671	15,645	12,694	18,716
Averages	**17,800**	**22,700**	**18,500**	**16,557**	**23,405**	**30,083**	**14,066**	**22,687**	**20,286**	**28,308**	**24,333**

Month	1995	1994	1993	1992	1991	1990	1989	1988	1987	1986	1985
January	11,365	13,090	9,326	15,658	5,542	4,965	6,294	7,303	13,758	13,710	12,526
February	9,371	12,611	8,936	13,978	5,879	4,889	6,529	7,634	12,586	12,804	10,239
March	29,061	28,542	12,513	43,661	15,081	17,484	11,300	14,810	17,287	24,790	32,265
April	48,507	40,830	55,473	32,668	34,268	12,842	33,264	21,463	20,267	84,870	45,317
May	45,135	47,548	48,571	25,474	44,753	22,310	24,287	13,119	13,655	81,242	43,518
June	30,667	26,913	65,377	17,920	44,960	31,610	13,237	4,667	14,573	37,043	30,105
July	27,323	29,403	84,123	28,985	33,856	20,323	7,690	2,903	11,674	34,684	25,676
August	29,129	19,971	41,135	14,532	21,535	16,322	4,658	5,103	10,477	30,813	18,226
September	19,860	21,203	30,717	15,686	25,182	9,923	8,307	6,080	7,183	41,957	29,665
October	31,061	25,581	19,516	15,374	15,458	11,135	6,358	7,019	7,771	49,319	39,590
November	30,703	20,173	18,773	19,076	22,467	9,903	6,793	7,919	8,693	24,260	21,337
December	17,494	14,432	16,490	12,126	20,503	6,184	4,961	6,487	9,016	17,774	16,094
Averages	**27,473**	**25,025**	**34,246**	**21,262**	**24,124**	**13,991**	**11,140**	**8,709**	**12,245**	**37,772**	**27,047**

Note: Mean monthly river flow data for the years 1985, 1990, 1991 and 1992 have been adjusted to reflect the averages found in Table 2 of the corresponding annual report for each year.

SECTION II

PRAIRIE ISLAND NUCLEAR GENERATING PLANT
ENVIRONMENTAL MONITORING PROGRAM
2006 ANNUAL REPORT

SUMMARY OF THE 2006 FISH POPULATION STUDY

Report
by
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Environmental Services
Water Quality Department

SUMMARY OF THE 2006 FISH POPULATION STUDY

INTRODUCTION

To fulfill part of the continuing environmental monitoring requirements of the Prairie Island Nuclear Generating Plant, (PINGP), the Mississippi River fisheries population was sampled near Red Wing, Minnesota, May through October, 2006. 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 1). 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" (Hawkinson 1973). Presently, the objective is to monitor and assess the status of the fishery in the vicinity of the PINGP (Mueller 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.

METHODS AND MATERIALS

Fish were collected using a Smith-Root SR-18 Electrofishing boat equipped with a 5.0 GPP electrofishing unit (Figure 6). The power source was 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 annode 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 occurred during daylight hours with a pulsed direct current. Due to the constantly changing river conditions, Electrofisher output was varied to enhance the effectiveness.

Sampling was done monthly, May through October, within four established sectors of the study area (Figures 1-5). 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 was recorded from a digital timer, which only tallied the seconds that the electrical field was energized. A run was terminated after approximately 450 seconds shocking time or when the end of the prescribed run was reached.

Stunned fish were captured with one-inch stretch mesh landing nets equipped with eight-foot insulated handles. Fish were placed in live-wells, supplied with river water constantly, until the end of each run. At the end of each run fish were 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.

Electrofishing CPUE was computed as numbers of fish per hour for each sector. Length frequencies in 20 millimeter intervals were calculated for all fish species. Length-weight relationships were calculated using the length-weight formula:

$$\log W = \log a + b \log L,$$

where W is the weight in grams, a is the y axis intercept, b is the slope of the regression line, and L is the total length in millimeters.

RESULTS

Initial PINGP preoperational annual environmental reports simply listed all data collected without discussion or analysis (NSP 1972). Individual species were not discussed, due to the amount of data collected during initial sampling efforts. Representative species were selected in 1975 for abundance comparisons based on electrofishing data (Gustafson et. al. 1975), modified in 1986 after seining was eliminated (Donkers 1986), and in 1989 smallmouth and largemouth bass were added as they "have been seen more frequently in the electrofishing catch during recent years in the PINGP study area" (Mueller 1989).

Electrofishing collection methods changed before the 1982 sampling season. The mesh size of the dip nets was increased to one inch stretch mesh. The larger mesh size enabled small adult fish and some young of the year fish of certain species to avoid collection. Currently, individual gizzard shad, freshwater drum, and white bass less than 160 mm are not collected. Also, logperch and cyprinids (other than carp) are no longer collected, due to their small size (Donkers 1987). Therefore, a direct comparison of electrofishing CPUE prior to 1982 is inappropriate to later years.

Species collected in 2006 are compared to previous years in Table 1. A total of 7,124 fish, comprising 38 species, was collected in the 2006 survey (Table 2).

All species collected in 2006 are ranked according to electrofishing CPUE and listed in Table 2. Summaries for selected species (Tables 3-9) are based on electrofishing and trapnetting data for years 1977 through 1987, and on electrofishing data only for years 1988 through 2006, since trapnetting was discontinued after 1987 (Orr 1988). Annual CPUE for selected species is compared to previous years (Figures 15-22), by sector (Figures 23-30), and by date (Figures 31-38).

The top three abundant species, based on CPUE, was determined for each sector.

Sector One;	shorthead redhorse, carp, freshwater drum
Sector Two;	carp, bluegill, freshwater drum
Sector Three;	white bass, smallmouth bass, carp
Sector Four;	white bass, freshwater drum, gizzard shad
Overall CPUE Average;	carp, white bass, freshwater drum

Table 10 summarizes the percent contribution of historically predominant species in the annual catch. Length frequency distributions for selected species are illustrated by sector in Figures 7 through 14.

DISCUSSION

When dealing with a large river environment, a high degree of natural variability exists in habitat conditions and therefore, in fish distribution. Palmquist (1982) proposed the wide range in species abundance between study sectors was largely due to habitat preferences of a species rather than PINGP induced. A high degree of variability in species abundance exists within sectors from year to year. Differences in collection efficiency and year class strengths may explain this variability.

A qualitative and quantitative discussion for selected species, with respect to other years, includes: 1) CPUE, 2) rank, 3) percent composition of catch, 4) population condition as depicted by length-weight regression analysis, and 5) mean length.

Average mean length was calculated by splitting the length data for each species into 20 mm intervals and multiplying the number of fish in each interval by the median length of that interval (Example: The number of fish in the 260-279 mm interval was multiplied by 270 mm). Interval totals were summed, divided by the total number of fish, and rounded to the nearest 10 mm.

GIZZARD SHAD

Electrofishing CPUE for gizzard shad decreased from 17.60 fish/hr in 2004 to 14.06 fish/hr in 2005 to 7.91 in 2006 (Figure 15). CPUE decreased in all sectors from 2005 to 2006 (Figure 23). CPUE was also examined for each sampling month for 2006, with the highest occurring in Sector 4 in May (Figure 31).

Shad ranked eighth in 2006 (Table 2), and presently comprise five percent of the catch (Table 10). The general condition of gizzard shad, 2.854, falls into the range of previous years, 2.388 to 3.934 from 1982-2005 (Table 3). Carlander (1969) sites a population in Canton Lake, Oklahoma with a range in total fish length of 173 to 335 mm and a regression slope of 3.066 which compares well to the fish in this study. The mean length for gizzard shad (340 mm) decreased from 2005 (Table 3). The length frequency data indicates a range of approximately 170-470 mm, with peaks occurring at approximately 240 and 350 mm (Figure 7).

FRESHWATER DRUM

Freshwater Drum CPUE for 2006, (16.61 fish/hour) decreased from 32.02 fish/hr in 2005, and was the lowest CPUE since 1996 (Figure 16). CPUE was lower in all sectors when comparing 2006 to 2005 (Figure 24). The highest CPUE in a sector for any month occurred in Sector 4 in May (Figure 32).

Freshwater drum CPUE ranked third in 2006 (Table 2). Presently, adult freshwater drum comprise 11 percent of the catch (Table 4).

The general condition of freshwater drum has remained relatively stable, as depicted by a regression slope of 3.258 in 2006, in comparison to a range of slopes of 2.598 to 3.276 from previous years of the study (Table 4). The mean length for freshwater drum was approximately 320 mm in 2006 (Table 4). The length frequency data for freshwater drum suggest that a peak occurs at approximately 310 mm (Figure 8).

SHORTHEAD REDHORSE

Electrofishing CPUE for shorthead redhorse has ranged from 7.07 to 25.94 fish/hour (Figure 17). CPUE for 2006 (14.38 fish/hr) is slightly higher than 2005, but is still low compared to values from the last 10 years (Table 5). Historically, the CPUE within each sector is highly variable (Figure 25). The 2006 CPUE is also variable between sectors, ranging from 23.00 fish/hour in Sector 3, to 7.71 fish/hour in Sector 4 (Table 2). CPUE for each sector is highly variable during the collection year, with the highest CPUE occurring in Sector 3 in September (Figure 33).

Shorthead redhorse ranked fourth in 2006 (Table 2), comprising ten percent of the catch (Table 5).

The general condition of shorthead redhorse has remained relatively stable, as depicted by a regression slope of 2.772 in 2006, in comparison to a range of slopes of 2.571 to 3.041 from previous years of the study (Table 5). The length-weight regression slope of shorthead redhorse in the vicinity of Prairie Island is about the same as that of another population of Upper Mississippi River shorthead redhorse as reported by Carlander (1969) as having a slope of 2.83. The mean length for shorthead redhorse at Prairie Island was approximately 370 mm in 2006 (Table 5). The length frequency data show that the main peaks occur at approximately 230, 320 and 400 mm (Figure 9).

WHITE BASS

Electrofishing CPUE for white bass in 2006 (16.71 fish/hr) is the lowest recorded since 1994 (Table 6 and Figure 18). CPUE decreased in all four sectors when comparing 2006 to 2005 (Figure 26). A large difference is evident when comparing CPUE upstream of Lock and Dam 3 to downstream of Lock and Dam 3 (Table 2). Overall CPUE appears cyclic (Figure 18) with year to year variability within each sector (Figure 26). Highest CPUE for any month sampled, occurred in Sector 3 in May with 80+ fish/hr (Figure 34).

White bass ranked second in 2006 (Table 2). Presently, white bass comprise 12 percent of the catch (Table 10).

The general condition of white bass has remained relatively stable, as depicted by a regression slope of 2.886 in 2006, in comparison to a range of slopes of 2.441 to 3.085 from previous years of the study (Table 6). The mean length for white bass is similar to the last ten years (Table 6). The length frequency data shows that peaks occur for white bass at approximately 330 and 380 mm, with a smaller peak at approximately 250 mm (Figure 10).

WALLEYE

Electrofishing CPUE for walleye in 2006 (2.77 fish/hour), although slightly higher than 2005, is still low compared to the last 10 years (Figure 19). CPUE increased in all sectors, except Sector 2, when comparing 2006 to 2005 (Figure 27). The highest CPUE for any sector in any month was Sector 3 in October (Figure 35).

Walleye ranked 13th in 2006 in overall catch abundance (Table 2). Presently, adult walleye comprise two percent of the catch (Table 7).

The general condition of walleye has remained relatively stable, as depicted by a regression slope of 3.352 in 2006, in comparison to a range of slopes of 2.852 to 3.318 from previous years of the study (Table 7). The mean length for walleye is the same as 2005, which was the highest recorded since the study began (Table 7). The length-frequency relationship indicates a main peak occurring at approximately 500 mm (Figure 11).

SAUGER

Electrofishing CPUE for sauger was the lowest recorded since 1990 (Table 8 and Figure 20). Sauger CPUE decreased in all sectors in 2006, compared to 2005 (Figure 28). Sector 3 had the highest CPUE in September of any sector in any month (Figure 36).

Sauger ranked twelfth in 2006 (Table 2), comprising two percent of the catch (Table 8).

The general condition of sauger has remained relatively stable, as depicted by a regression slope of 3.042 in 2006, in comparison to a range of slopes of 2.648 to 3.356, in previous years of the study (Table 8). The mean length for sauger was approximately 280 mm in 2006 (Table 8). The length frequency data exhibit a range from 150-510 mm, with peaks occurring at approximately 200, 300, 360 and 400 mm (Figure 12).

SMALLMOUTH BASS

Electrofishing CPUE for smallmouth bass appears cyclic with the peak CPUE (17.02 fish/hour) occurring in 2000, while 2006 CPUE was 13.39 fish/hr (Figure 21). CPUE in Sectors 1-4 appear cyclic (Figure 29) with curves appearing similar in shape to the curve for all sectors combined shown in Figure 21. The highest CPUE occurred in Sector 3, in September (Figure 37).

Smallmouth bass ranked fifth in 2006 (Table 9), comprising nine percent of the catch. Smallmouth bass have a length frequency range of approximately 80-450 mm, with peaks occurring at approximately 200 and 300 mm (Figure 13).

LARGEMOUTH BASS

Largemouth bass CPUE for 2006, (8.57 fish/hour), is the highest recorded since the study began (Figure 22). This was probably due to the extreme low flows and low water levels in pool 4 during August, September and October, which may have forced largemouth out of the backwater areas. The CPUE for Sector 1 was virtually zero for all sampling dates, while Sectors 2-4 have a little more variability (Figure 30). The highest CPUE occurred in Sector 3 in September (Figure 38).

Largemouth bass ranked seventh in 2006, which is the highest ranking since the study began (Table 9), comprising six percent of the catch. Historically, largemouth bass rank has varied greatly, ranging from 9th to 20th (Table 9).

The length frequency data indicates a range of 1340-460 mm, with peaks occurring at 220, and 320 mm (Figure 14).

GENERAL

The ten most abundant species collected during 2006 in descending order, based on average CPUE for all sectors combined were: 1) carp, 2) white bass, 3) freshwater drum, 4) shorthead redhorse, 5) smallmouth bass, 6) bluegill, 7) largemouth bass, 8) gizzard shad, 9) black crappie, and 10) silver redhorse (Table 2).

Total average CPUE for all species and sectors combined decreased from 193.89 fish/hr in 2003, to 174.73 fish/hr in 2004 to 148.66 in 2005 to 145.06 in 2006 (Table 2).

LITERATURE CITED

Carlander, K. D. 1969. Handbook of Freshwater Fisheries Biology. Volume One. The Iowa State University Press, Ames, Iowa.

Carlander, K. D. 1977. Handbook of Freshwater Fisheries Biology. Volume Two. The Iowa State University Press, Ames, Iowa.

Donkers, C. A. 1986. Summary of the 1986 fish population study. IN: Prairie Island Nuclear Generating Plant Environmental Monitoring Program 1985 Annual Report. Northern States Power Company, Minneapolis, MN.

Donkers, C. A. 1987. Summary of the 1987 fish population study. IN: Prairie Island Nuclear Generating Plant Environmental Monitoring Program 1987 Annual Report. Northern States Power Company, Minneapolis, MN.

Giese, B. D. and Mueller, K. N. 2005. Summary of the 2005 fish population study. IN: Prairie Island Island Nuclear Generating Plant Environmental Monitoring Program 2005 Annual Report. Northern States Power Company, Minneapolis, MN.

Gustafson, S. P., J. L. Geise, and P. J. Diedrich. 1975. 1975 Progress Report on the Prairie Island Fish Population Study. IN: Environmental Monitoring and Ecological Studies Program, Prairie Island Nuclear Generating Plant, 1975 Annual Report. Northern States Power Company, Minneapolis, MN.

Hawkinson, B. W. 1973. 1973 Fish Population Study Progress Report of the Mississippi River Near Prairie Island July 1973-February 1974. IN: Environmental Monitoring and Ecological Studies Program, Prairie Island Nuclear Generating Plant, 1973 Annual Report. Northern States Power Company, Minneapolis, MN.

Mueller, K. N. 1989. Summary of the 1989 fish population study. IN: Prairie Island Nuclear Generating Plant Environmental Monitoring Program 1989 Annual Report. Northern States Power Company, Minneapolis, MN.

Mueller, K. N. 1994. Summary of the 1994 fish population study. IN: Prairie Island Nuclear Generating Plant Environmental Monitoring Program 1994 Annual Report. Northern States Power Company, Minneapolis, MN.

NSP. 1972. Environmental Monitoring and Ecological Studies Program for the Prairie Island Nuclear Generating Plant Near Red Wing, Minnesota. Prepared by: engineering Vice Presidential Staff Department, Northern States Power Company. February 1, 1970, revised May 1, 1972. Northern States Power Company, Minneapolis, MN.

Orr, D. J. 1988. Summary of the 1988 fish population study. IN: Prairie Island Nuclear Generating Plant Environmental Monitoring Program 1981 Annual Report. Northern States Power Company, Minneapolis, MN.

Palmquist, P. R. 1982. Summary of the 1982 fish population study. IN: Prairie Island Nuclear Generating Plant Environmental Monitoring Program 1982 Annual Report. Northern States Power Company, Minneapolis, MN.

Figure 1

PRAIRIE ISLAND FISHERIES POPULATION - STUDY AREA

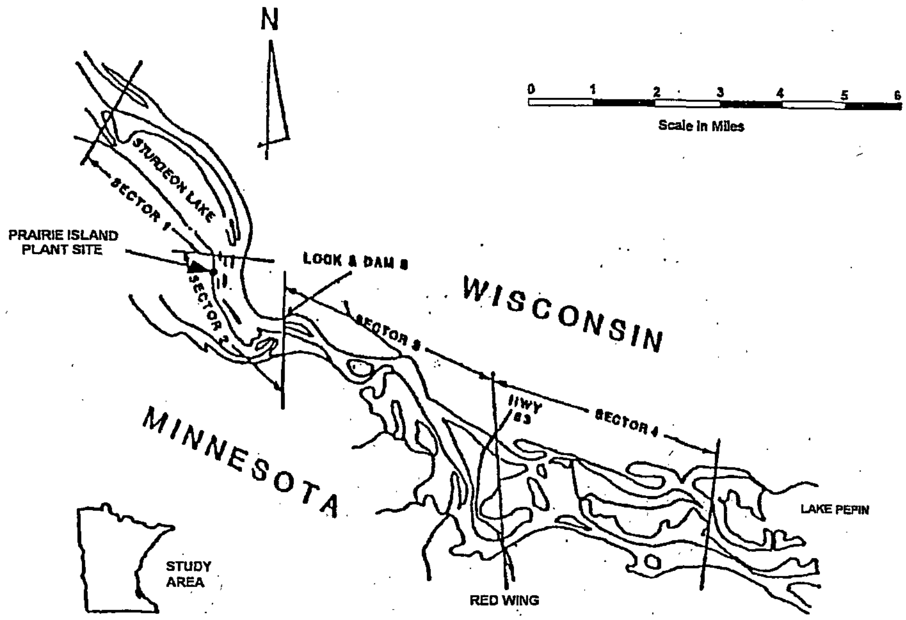


FIGURE 2.

PRAIRIE ISLAND FISHERIES POPULATION STUDY

Sampling Locations
Upstream
Sec 1 Runs 1-20

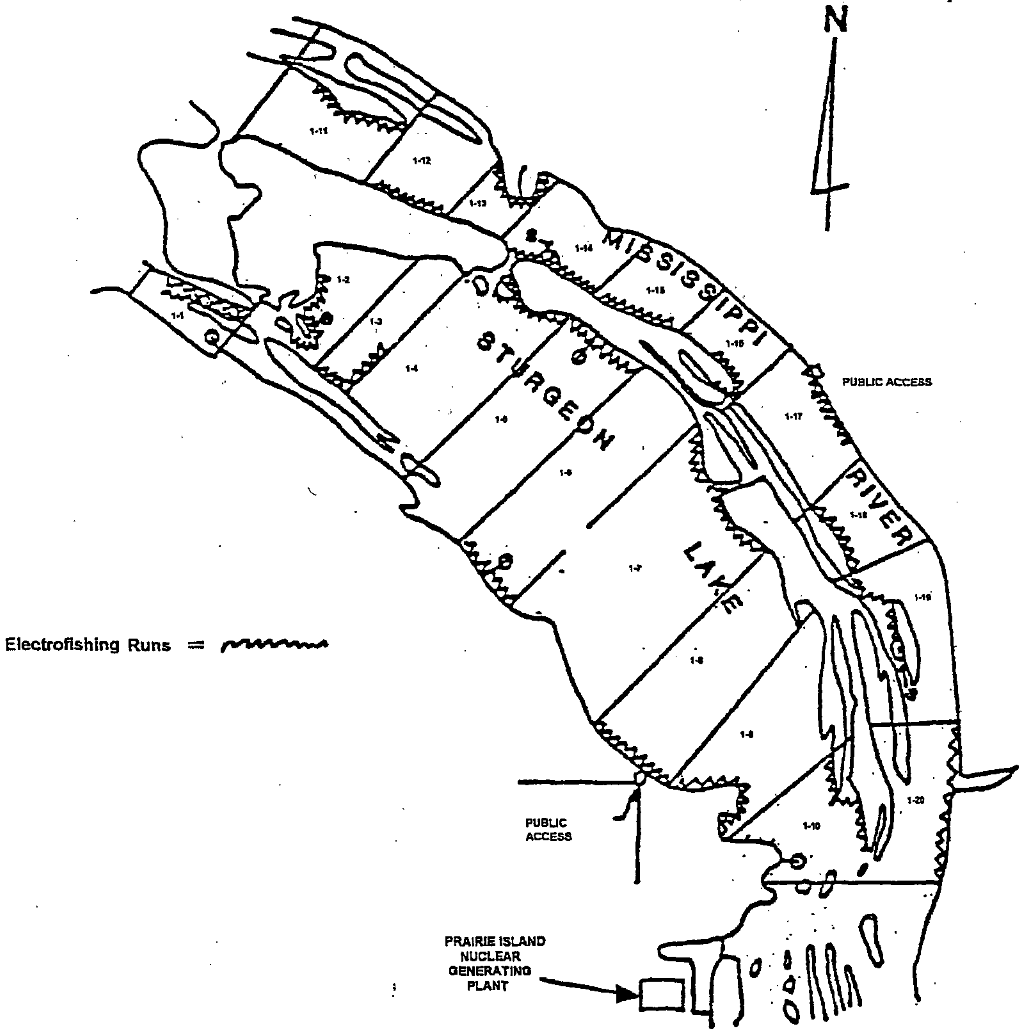


Figure 3.

PRAIRIE ISLAND FISHERIES POPULATION STUDY
Sampling Locations
Plant Area
(Sec 2 Runs 1-10)

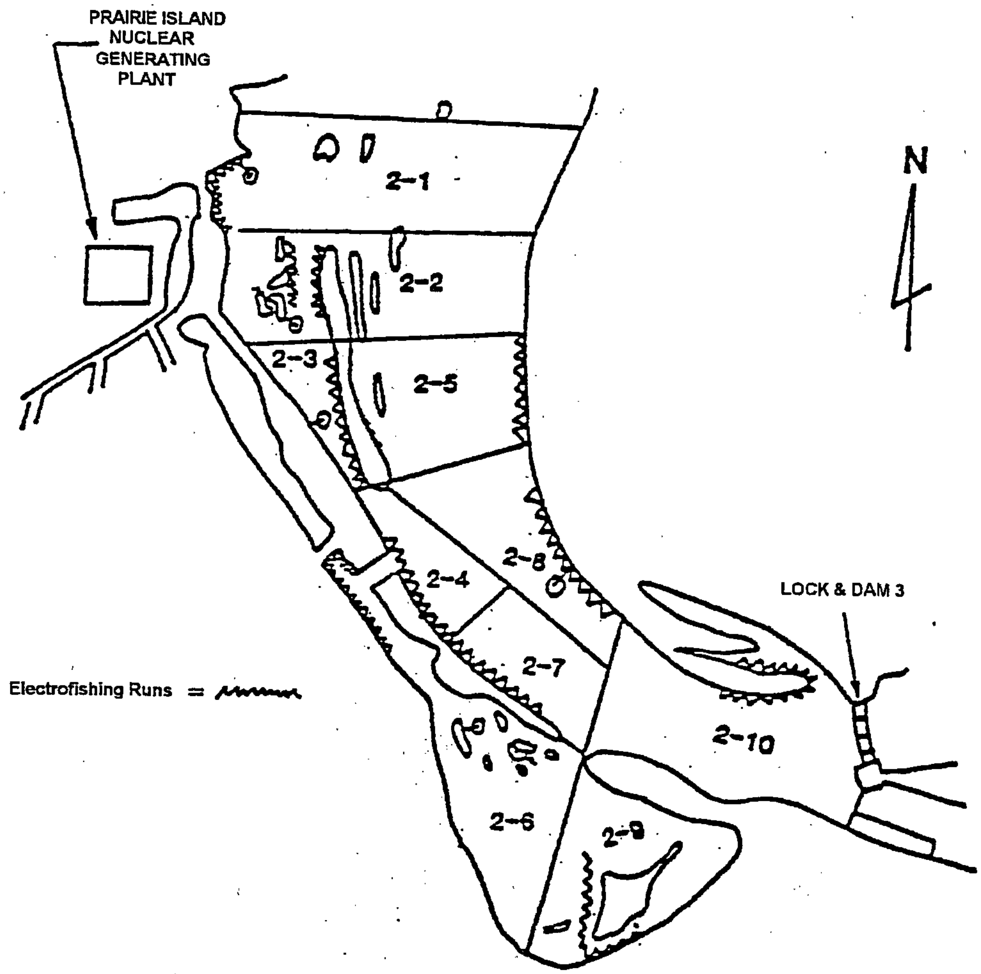
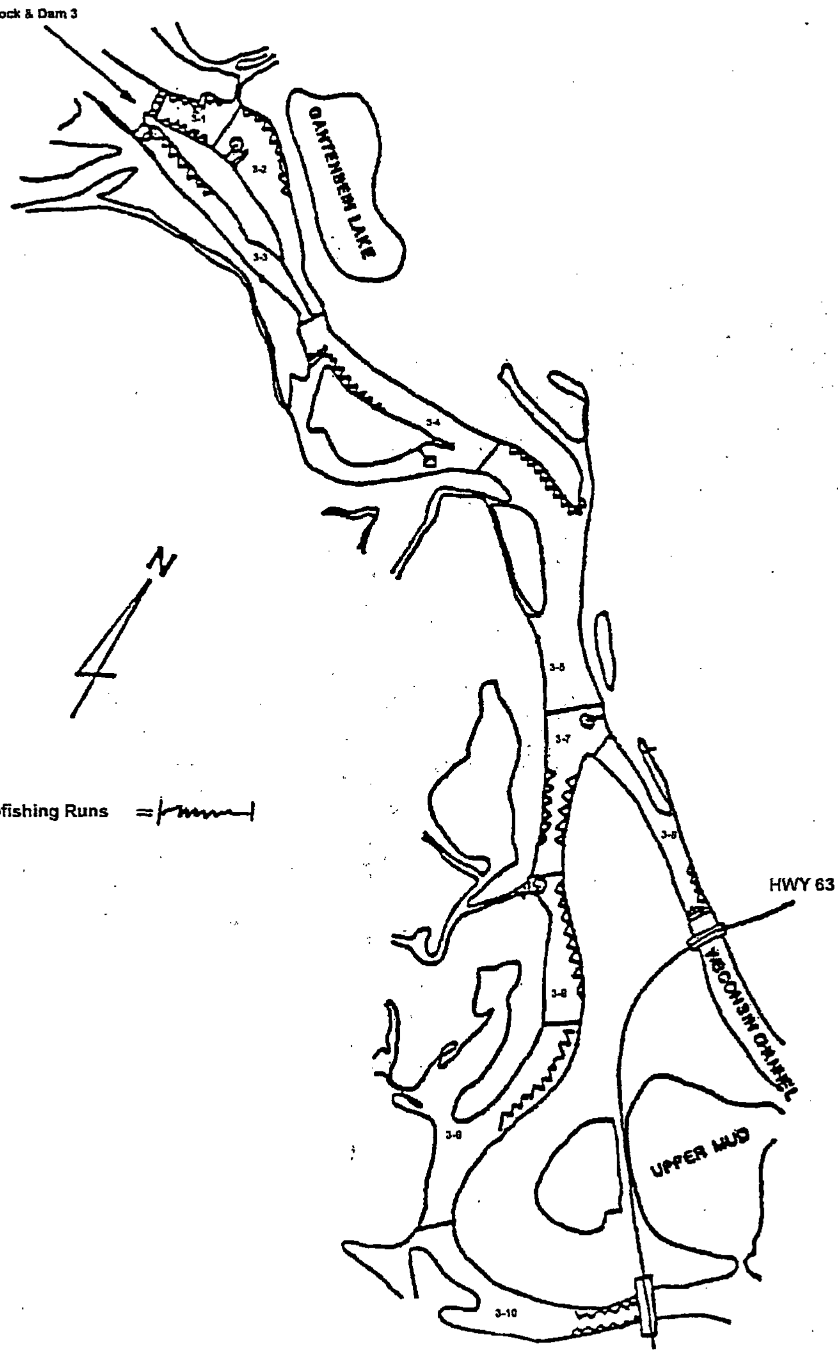


Figure 4.

PRAIRIE ISLAND FISHERIES POPULATION STUDY

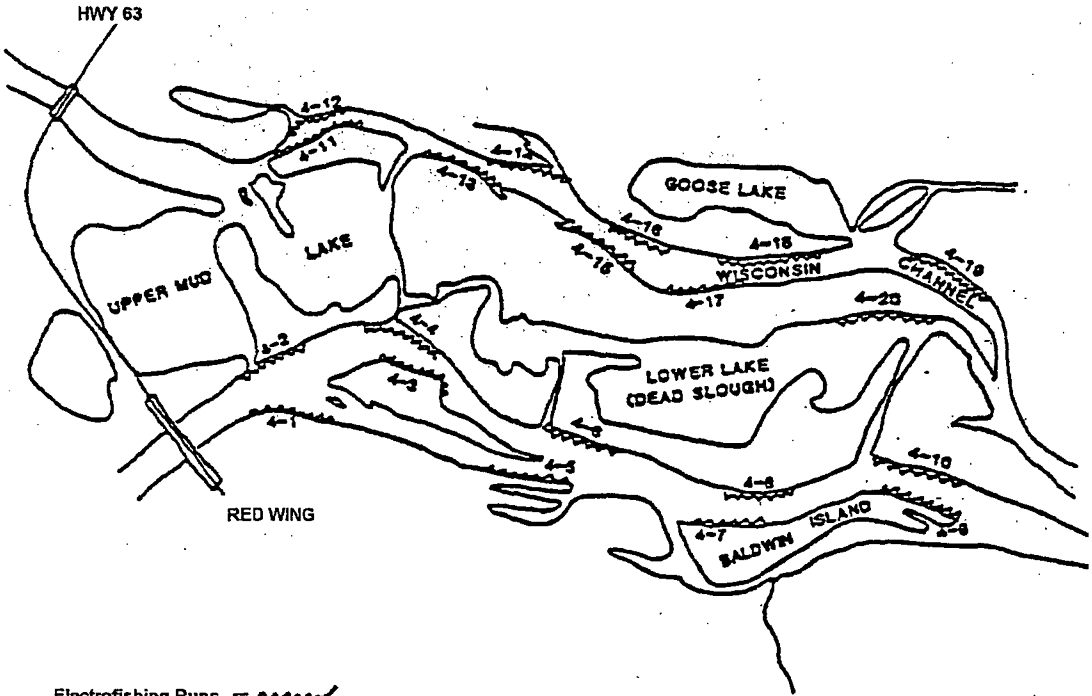
Sampling Locations
Downstream
(Sec 3 Runs 1-10)



Electrofishing Runs =

Figure 5.

PRAIRIE ISLAND FISHERIES POPULATION STUDY
Sampling Locations
Downstream
(Sec 4 Runs 1-20)



Electrofishing Runs =

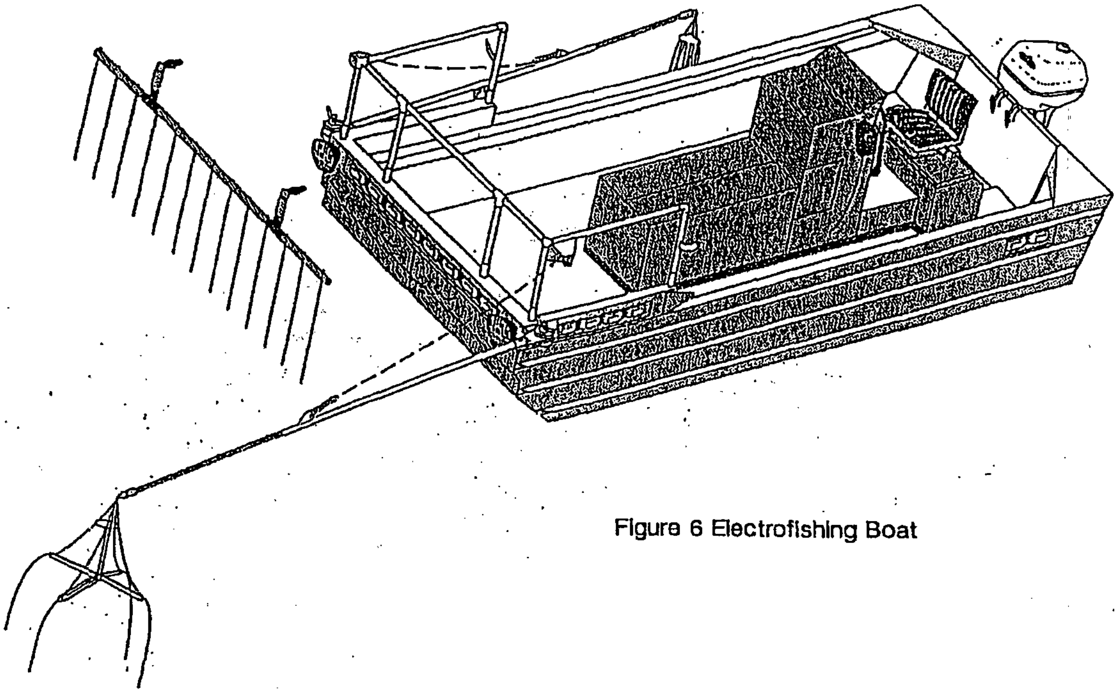


Figure 6 Electrofishing Boat

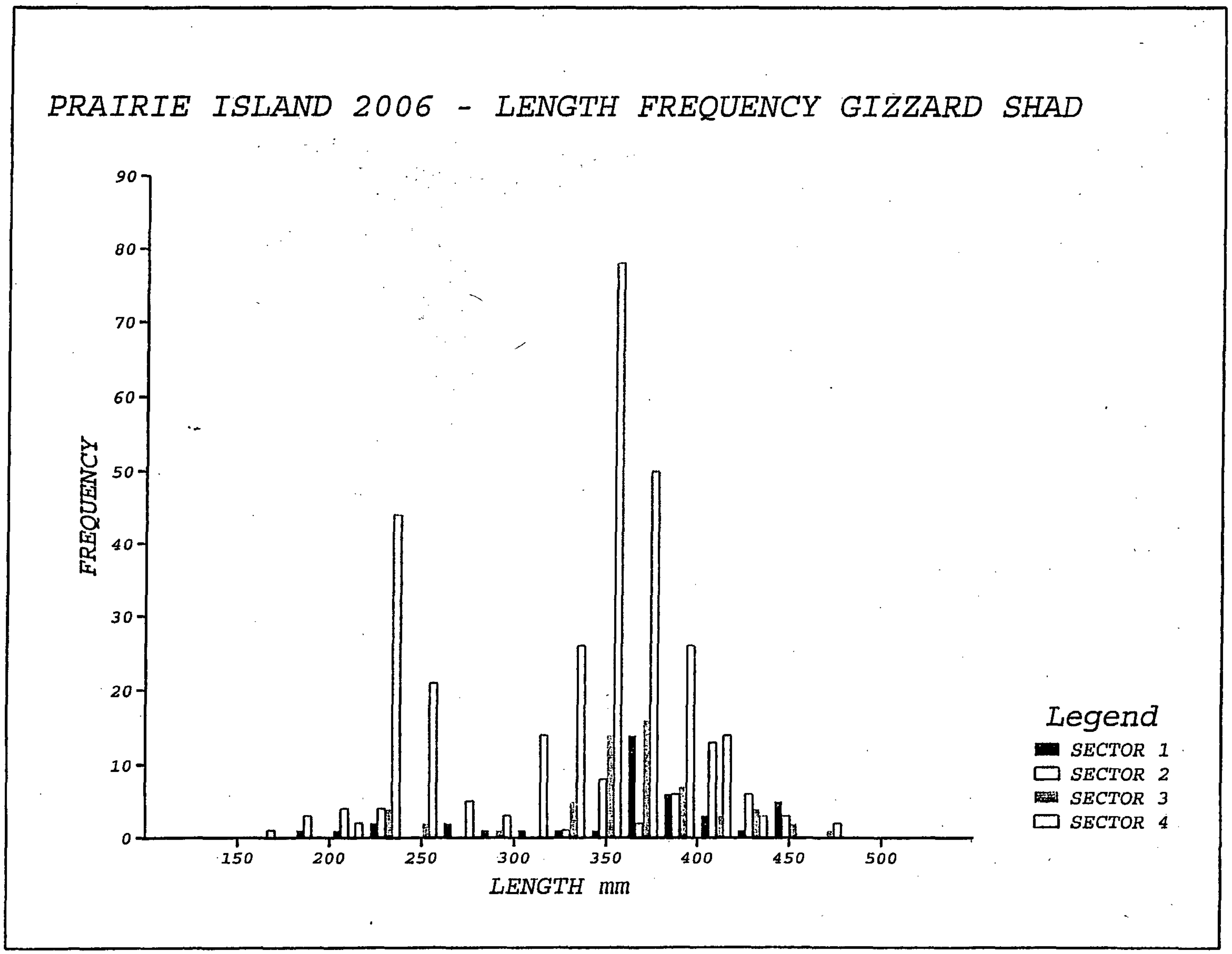

PRAIRIE ISLAND 2006 - LENGTH FREQUENCY GIZZARD SHAD
FREQUENCY
0
10
20
30
40
50
60
70
80
90
150
200
250
300
350
400
450
500
LENGTH mm
Legend
SECTOR 1
SECTOR 2
SECTOR 3
SECTOR 4

Figure 7

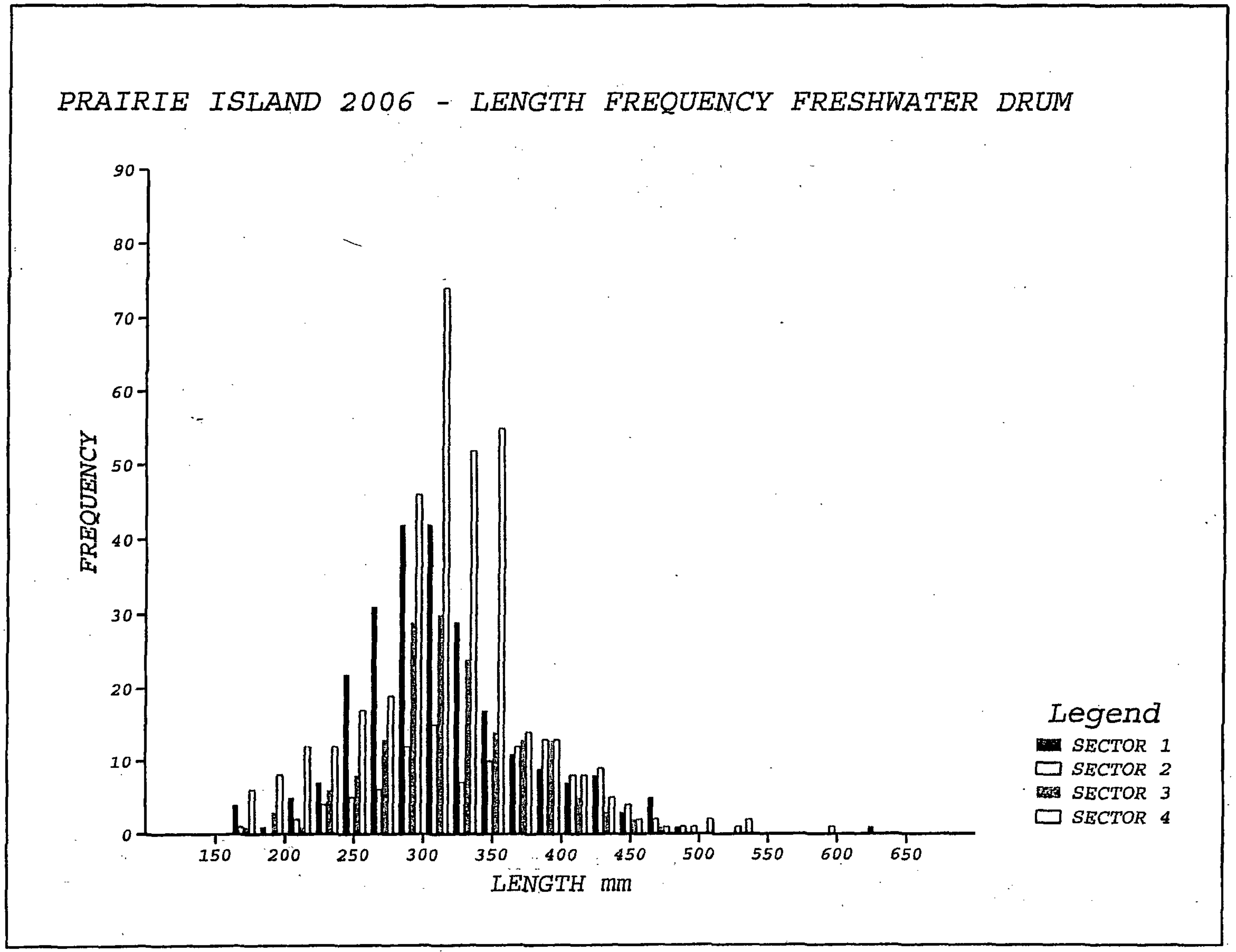

PRAIRIE ISLAND 2006 - LENGTH FREQUENCY FRESHWATER DRUM
FREQUENCY
0
10
20
30
40
50
60
70
80
90
150
200
250
300
350
400
450
500
550
600
650
LENGTH mm
Legend
SECTOR 1
SECTOR 2
SECTOR 3
SECTOR 4

Figure 8

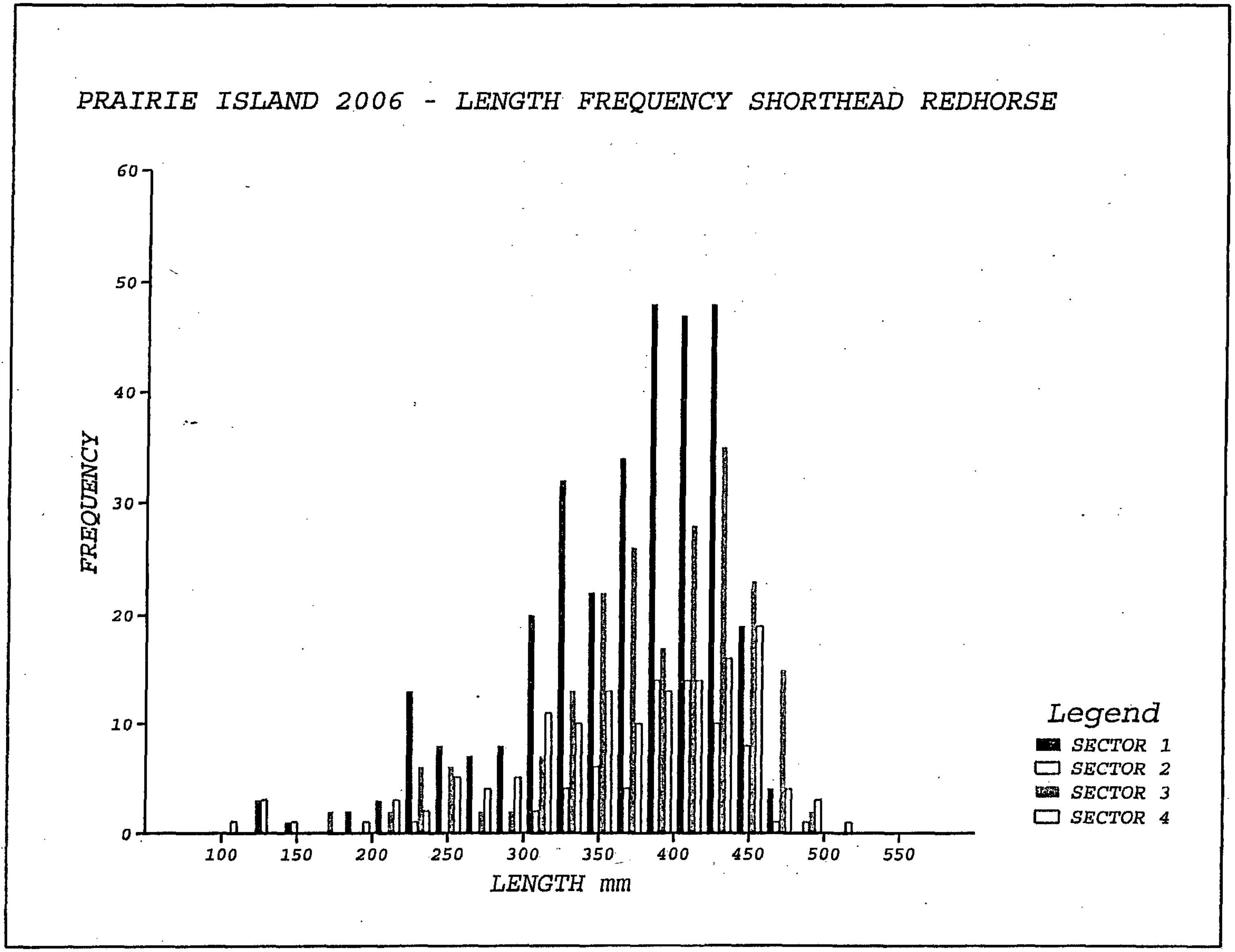
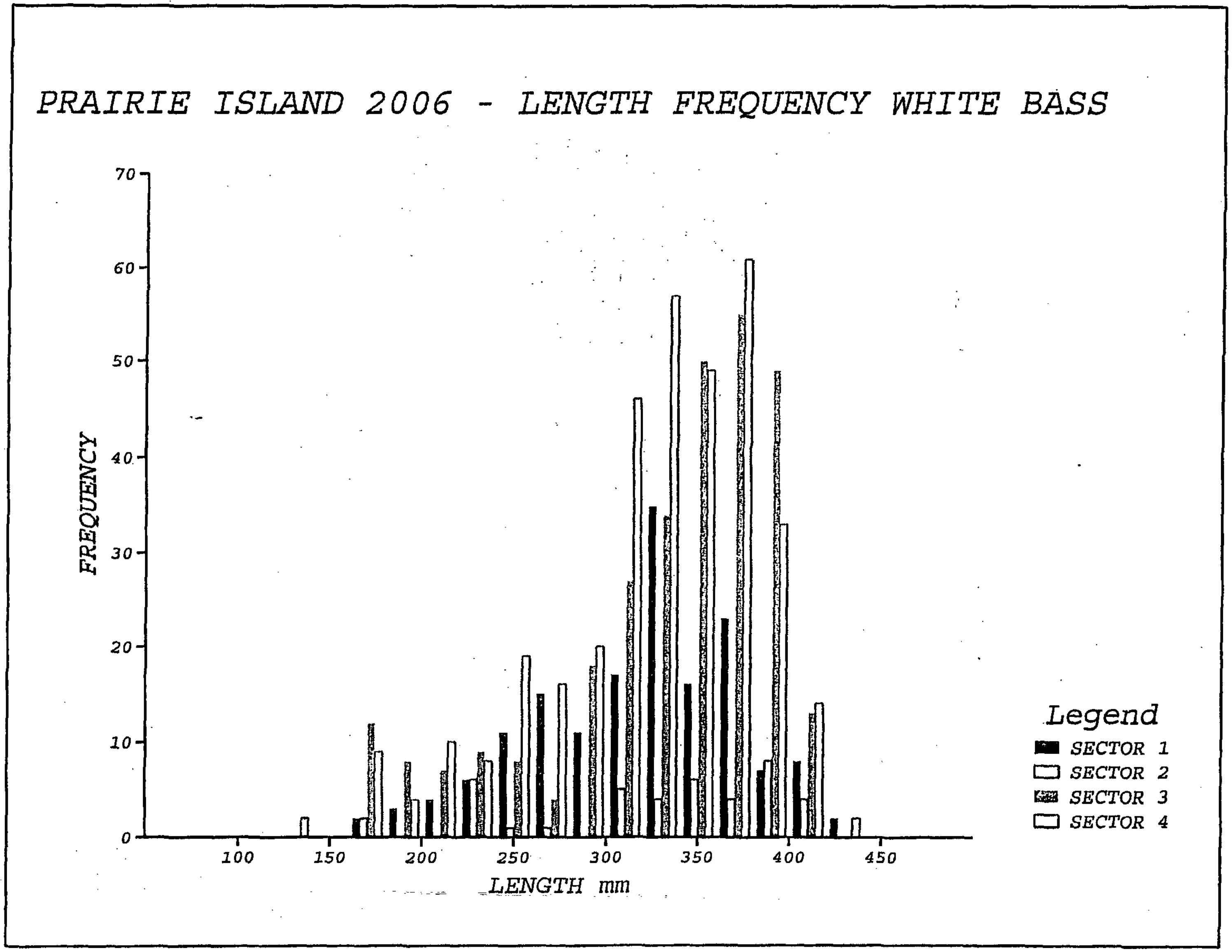

PRAIRIE ISLAND 2006 - LENGTH FREQUENCY SHORTHEAD REDHORSE
FREQUENCY
0
10
20
30
40
50
60
100
150
200
250
300
350
400
450
500
550
LENGTH mm
Legend
SECTOR 1
SECTOR 2
SECTOR 3
SECTOR 4

Figure 9



PRAIRIE ISLAND 2006 - LENGTH FREQUENCY WHITE BASS
FREQUENCY
70
60
50
40
30
20
10
0
100
150
200
250
300
350
400
450
LENGTH mm
Legend
SECTOR 1
SECTOR 2
SECTOR 3
SECTOR 4

Figure 10

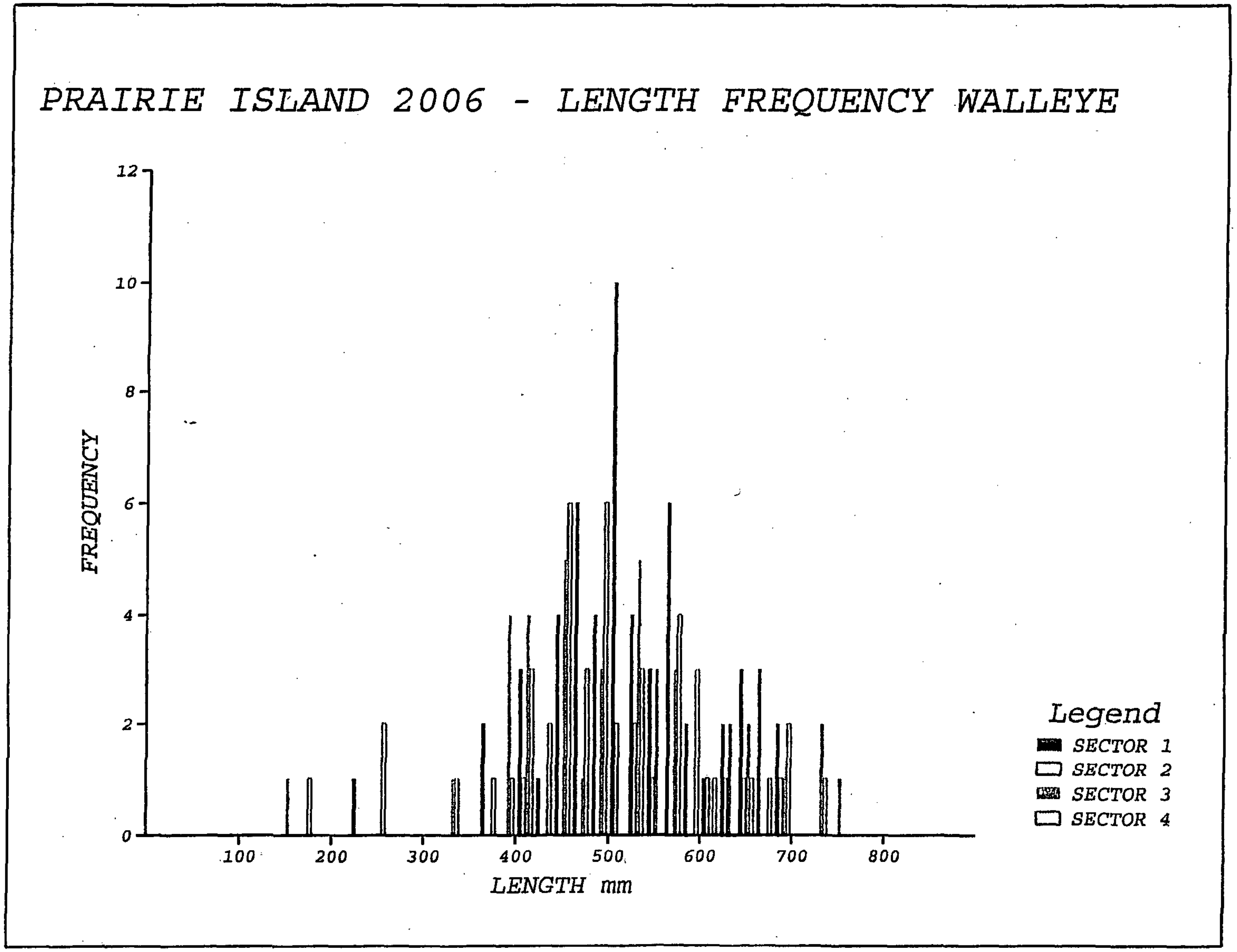

PRAIRIE ISLAND 2006 - LENGTH FREQUENCY WALLEYE
FREQUENCY
0
2
4
6
8
10
12
100
200
300
400
500
600
700
800
LENGTH mm
Legend
SECTOR 1
SECTOR 2
SECTOR 3
SECTOR 4

Figure 11

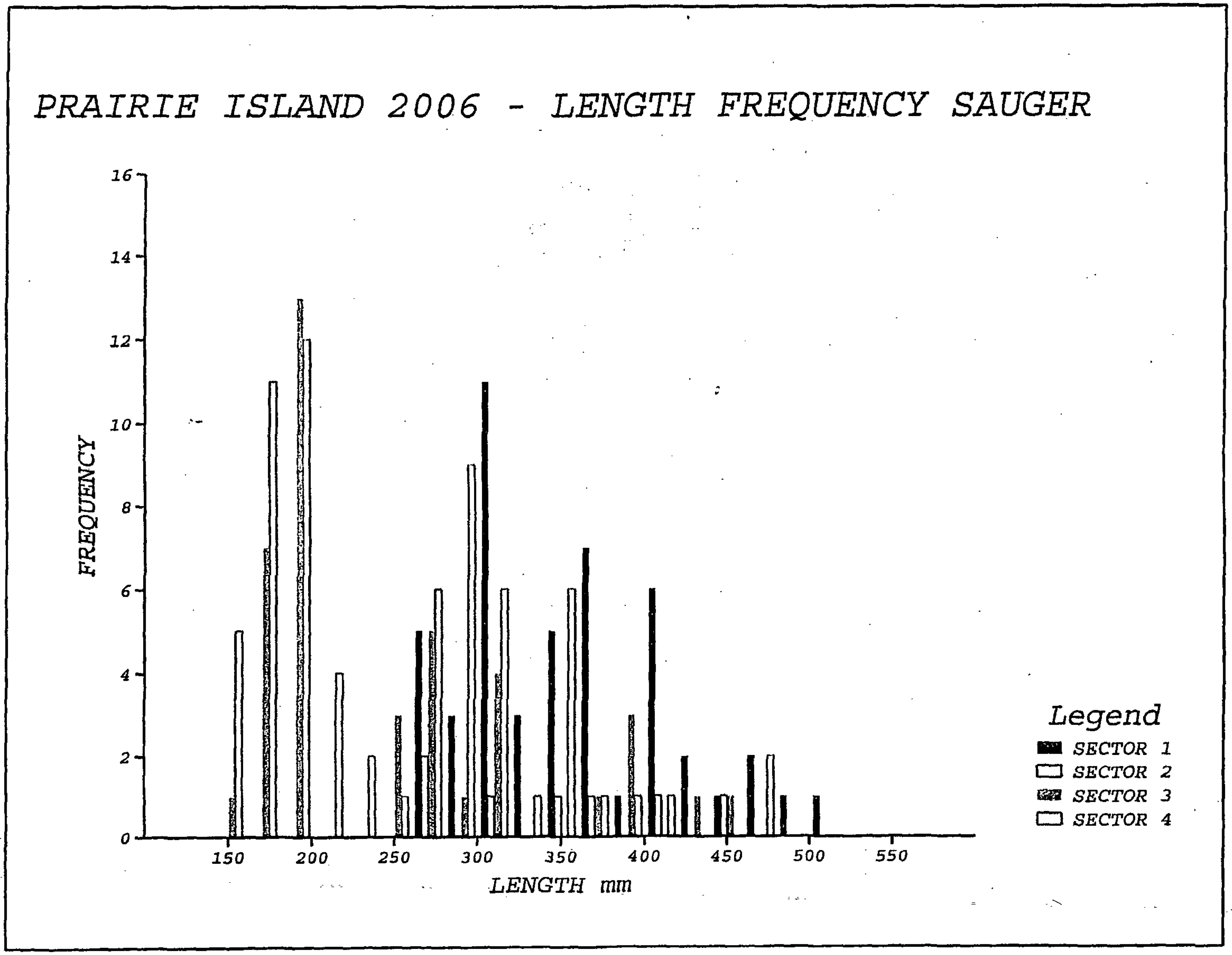

PRAIRIE ISLAND 2006 - LENGTH FREQUENCY SAUGER
FREQUENCY
0
2
4
6
8
10
12
14
16
150
200
250
300
350
400
450
500
550
LENGTH mm
Legend
SECTOR 1
SECTOR 2
SECTOR 3
SECTOR 4

Figure 12

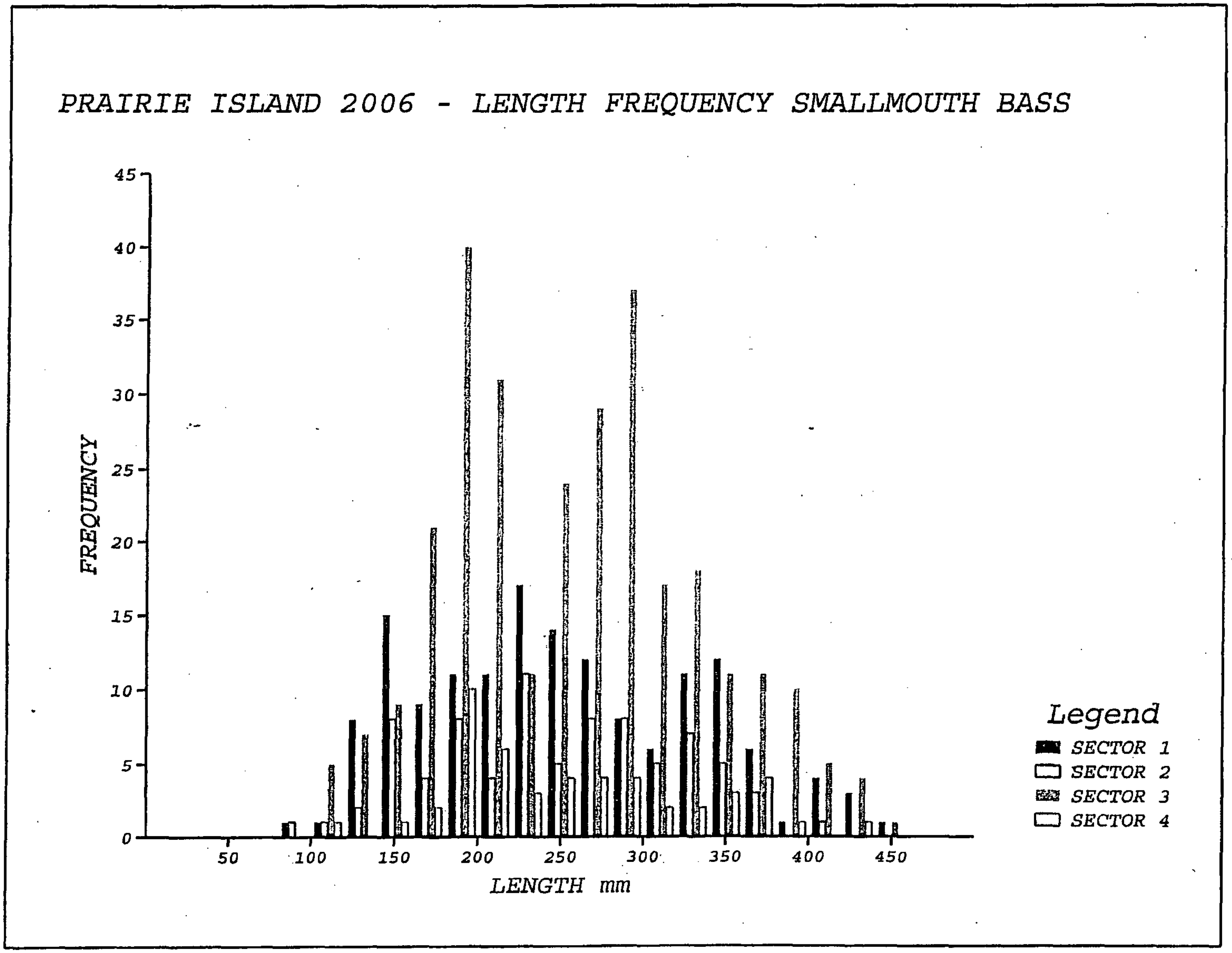

PRAIRIE ISLAND 2006 - LENGTH FREQUENCY SMALLMOUTH BASS
FREQUENCY
45
40
35
30
25
20
15
10
5
0
50
100
150
200
250
300
350
400
450
LENGTH mm
Legend
SECTOR 1
SECTOR 2
SECTOR 3
SECTOR 4

Figure 13

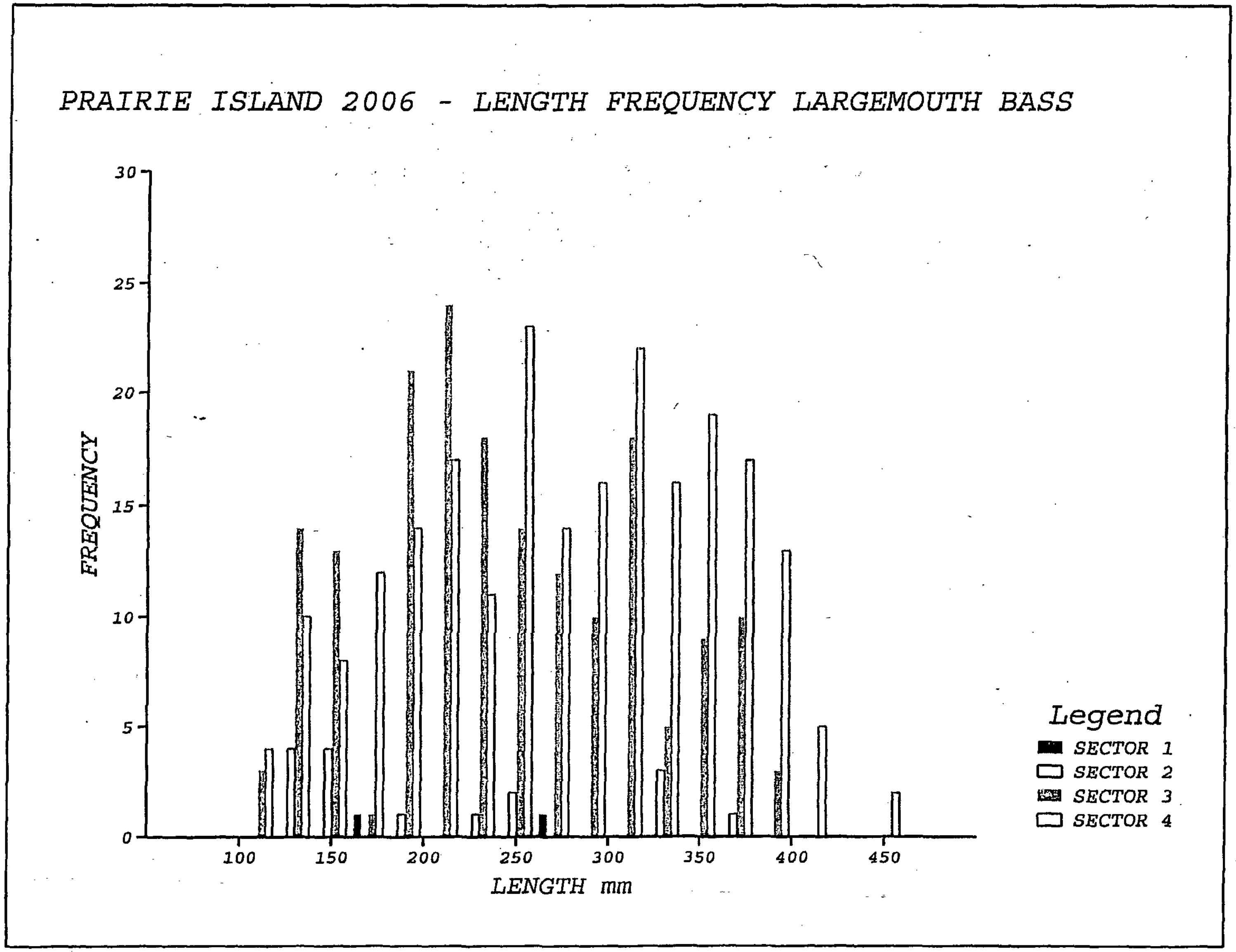

PRAIRIE ISLAND 2006 - LENGTH FREQUENCY LARGEMOUTH BASS
FREQUENCY
30
25
20
15
10
5
0
100
150
200
250
300
350
400
450
LENGTH mm
Legend
SECTOR 1
SECTOR 2
SECTOR 3
SECTOR 4

Figure 14

Figure 15. Electrofishing CPUE (fish/hour) for Gizzard shad for years 1982-2006 in the vicinity of PINGP.

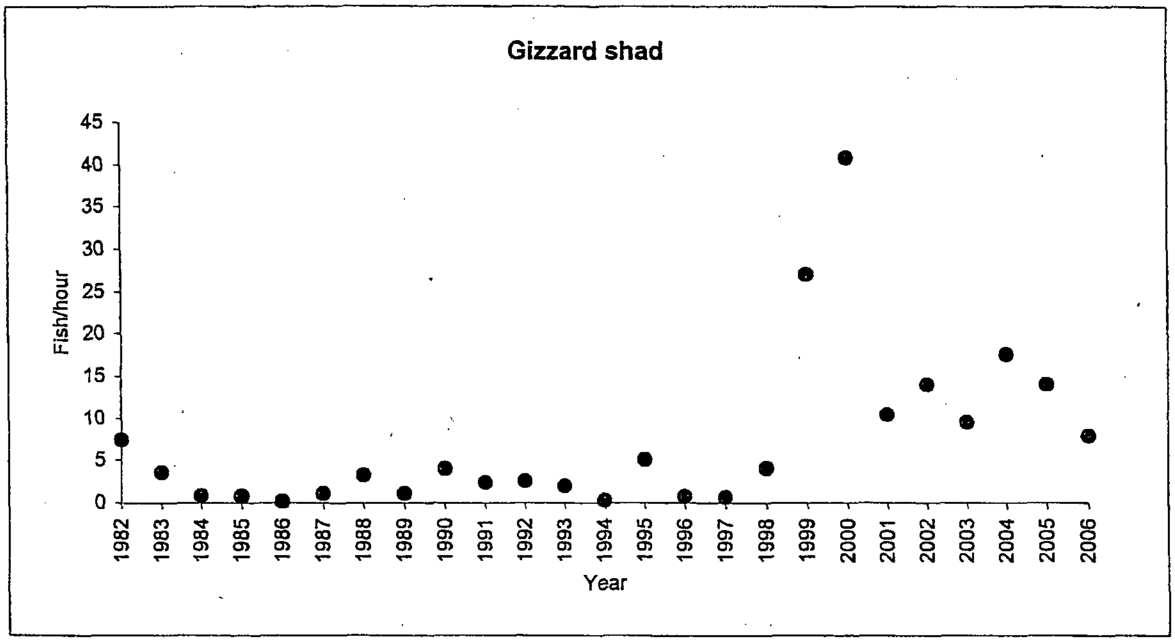


Figure 16. Electrofishing CPUE (fish/hour) for Freshwater drum for years 1982-2006 in the vicinity of PINGP.

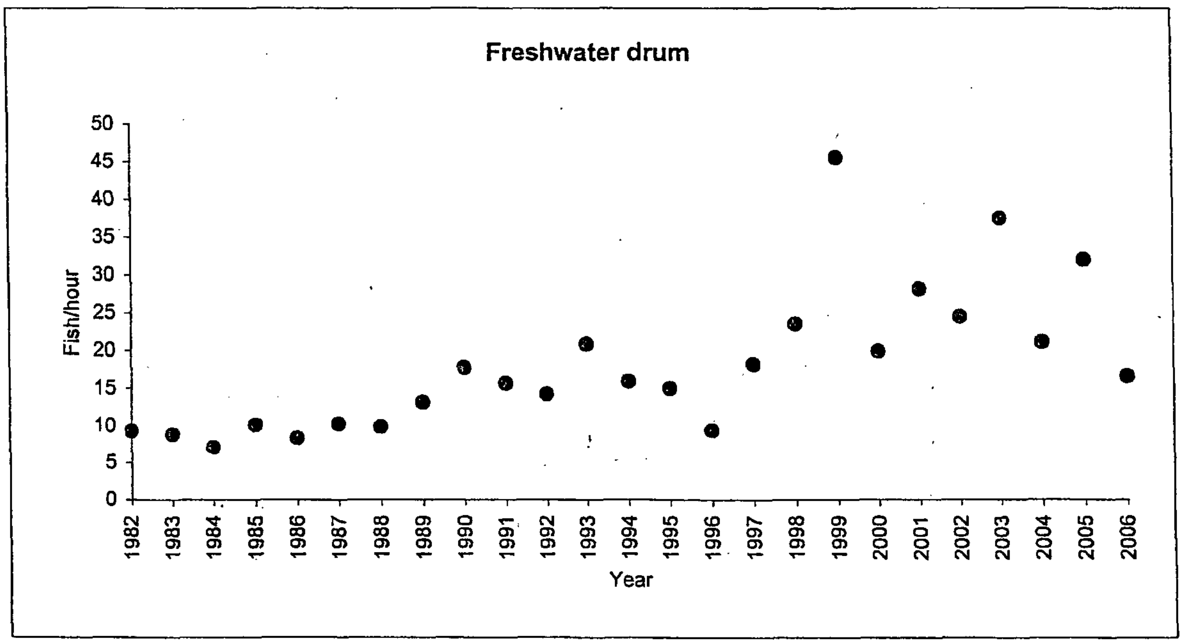


Figure 17. Electrofishing CPUE (fish/hour) for Shorthead redhorse for years 1982-2006 in the vicinity of PINGP.

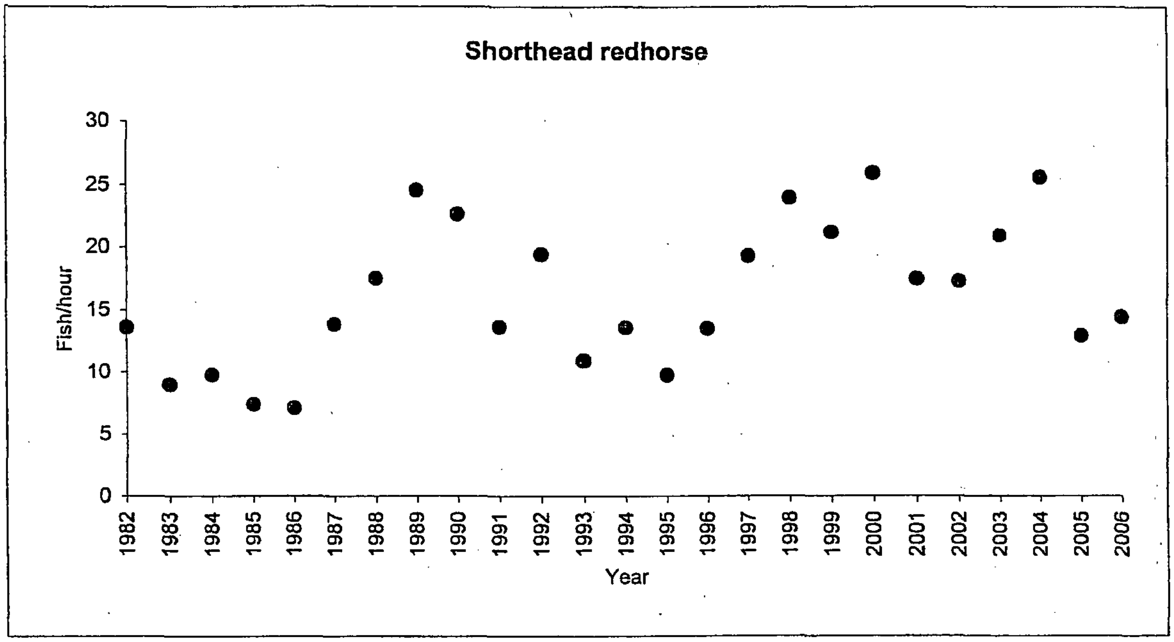


Figure 18. Electrofishing CPUE (fish/hour) for White bass for years 1982-2006 in the vicinity of PINGP.

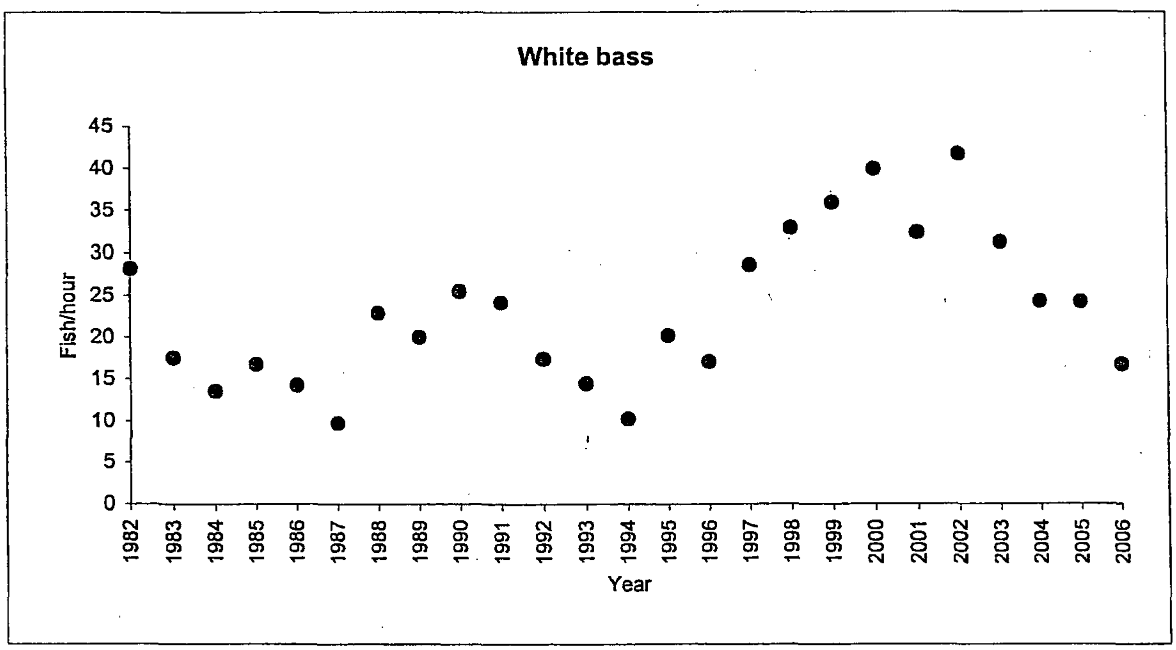


Figure 19. Electrofishing CPUE (fish/hour) for Walleye for years 1982-2006 in the vicinity of PINGP.

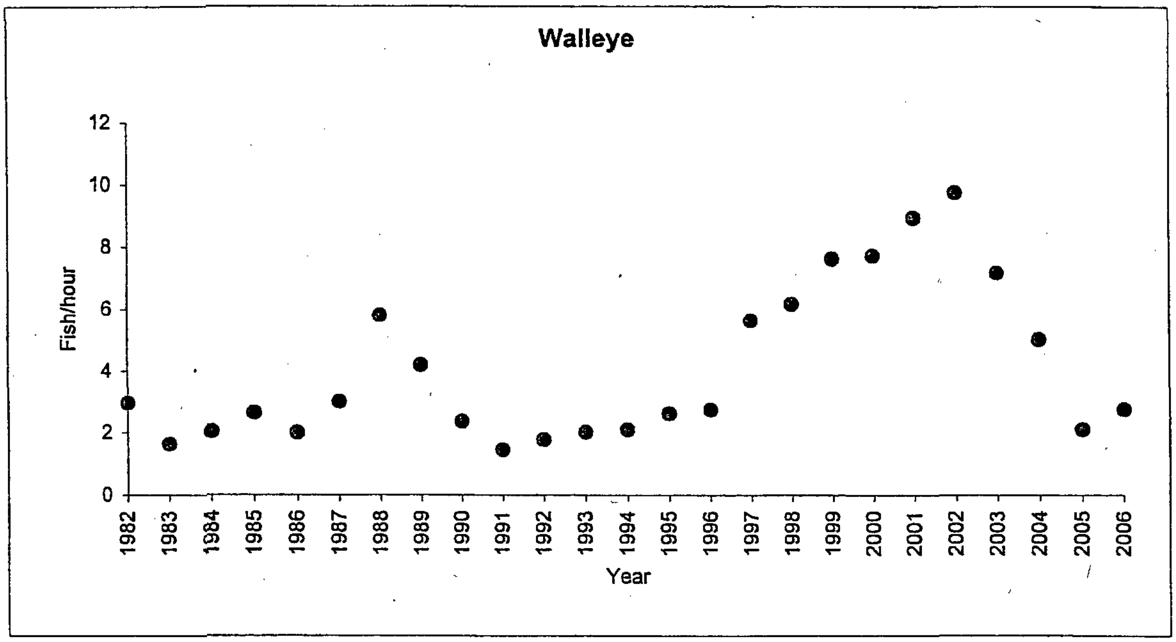


Figure 20. Electrofishing CPUE (fish/hour) for Sauger for years 1982-2006 in the vicinity of PINGP.

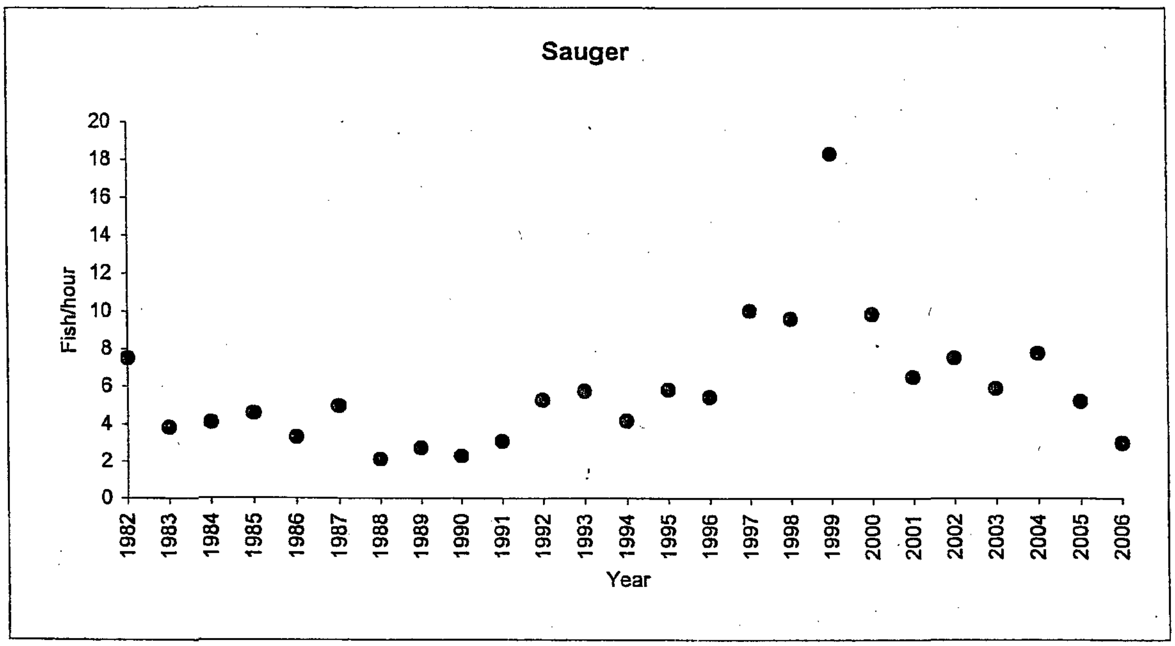


Figure 21. Electrofishing CPUE (fish/hour) for Smallmouth bass for years 1982-2006 in the vicinity of PINGP.

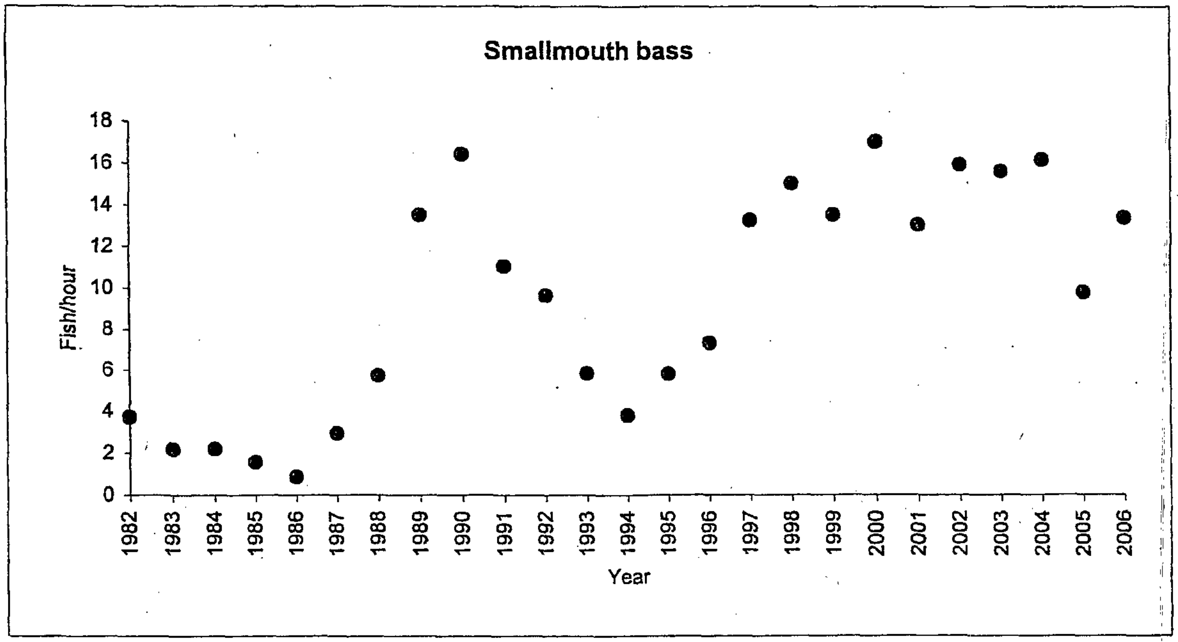


Figure 22. Electrofishing CPUE (fish/hour) for Largemouth bass for years 1982-2006 in the vicinity of PINGP.

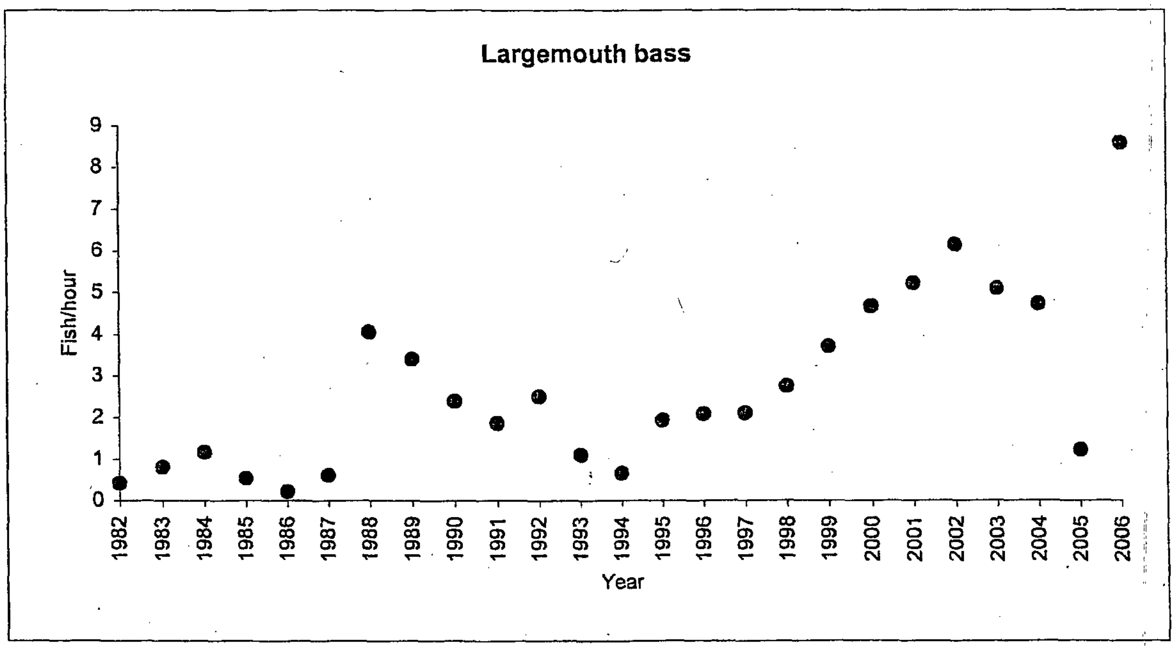


Figure 23. Electrofishing CPUE (fish/hour) by sector for Gizzard shad for years 1982-2006 in the vicinity of PINGP.

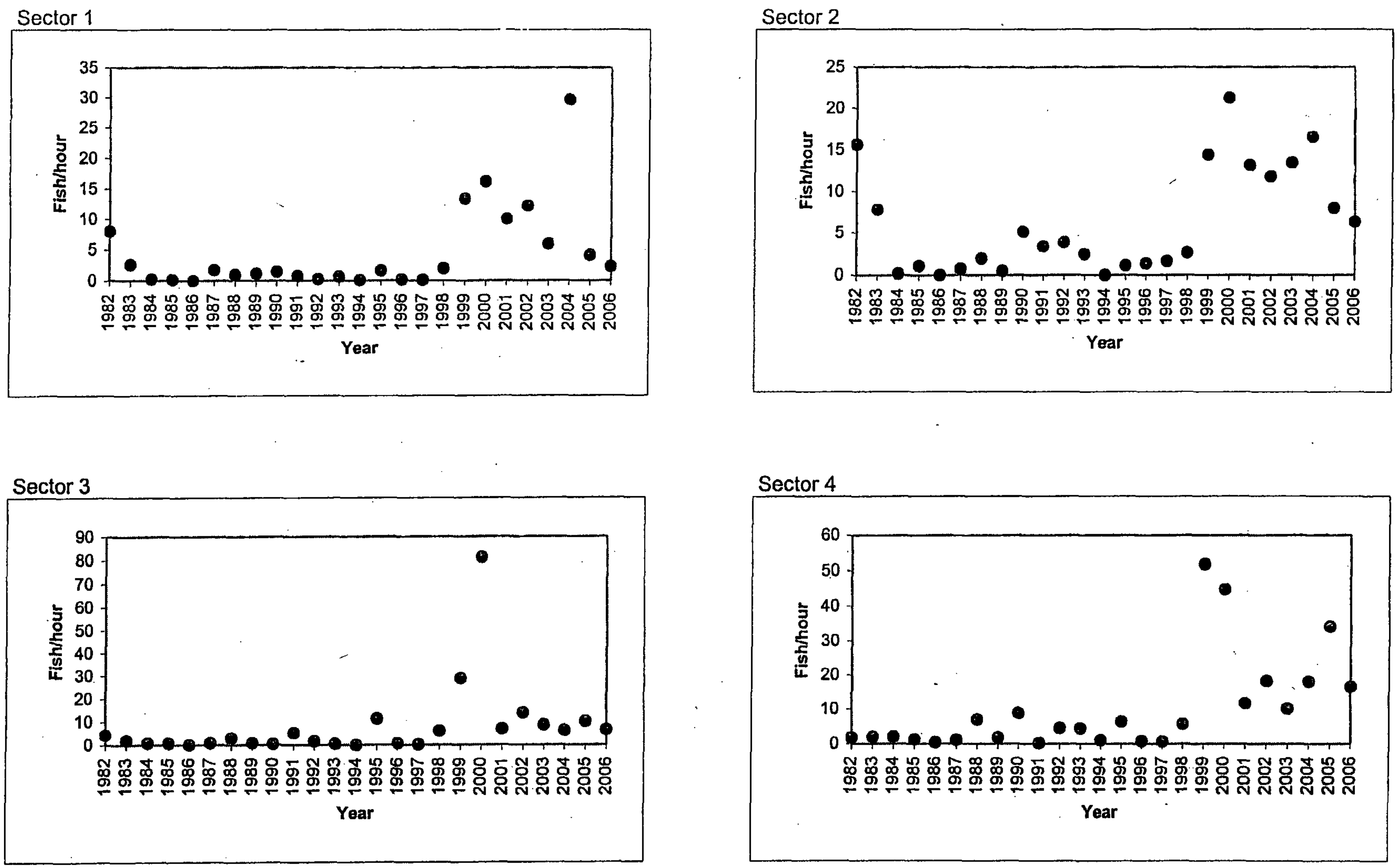
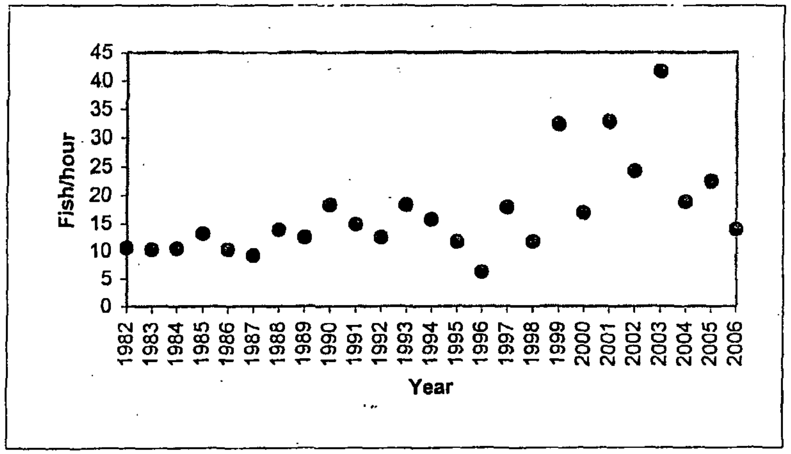
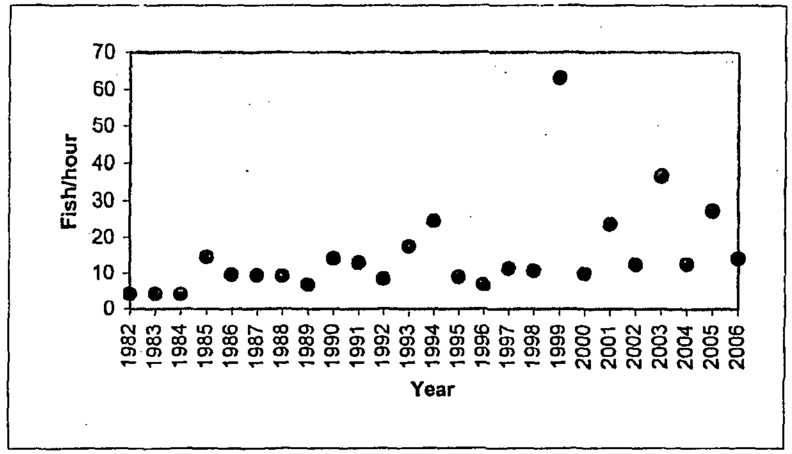


Figure 24. Electrofishing CPUE (fish/hour) by sector for Freshwater drum for years 1982-2006 in the vicinity of PINGP.

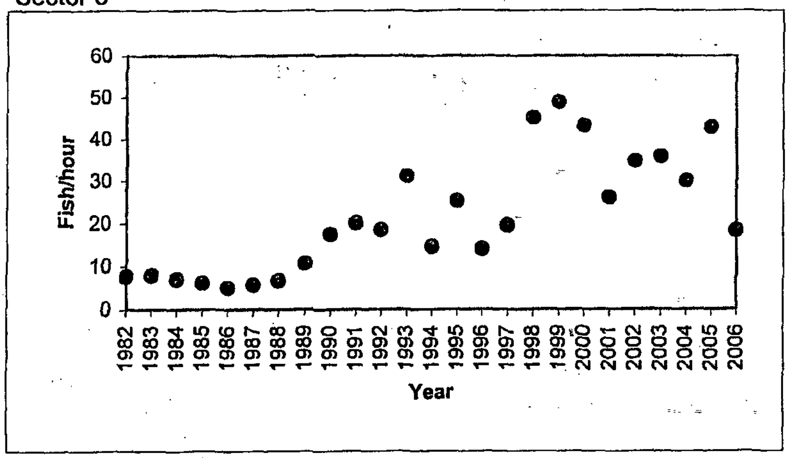
Sector 1



Sector 2



Sector 3



Sector 4

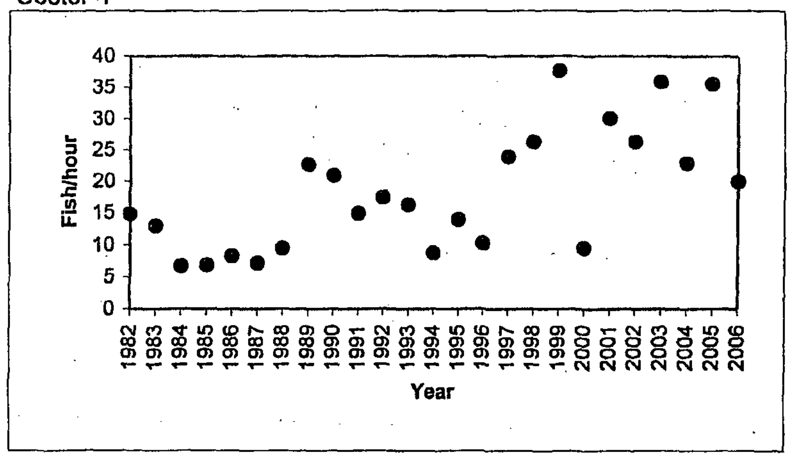


Figure 25. Electrofishing CPUE (fish/hour) by sector for Shorthead redhorse for the years 1982-2006 in the vicinity of PINGP.

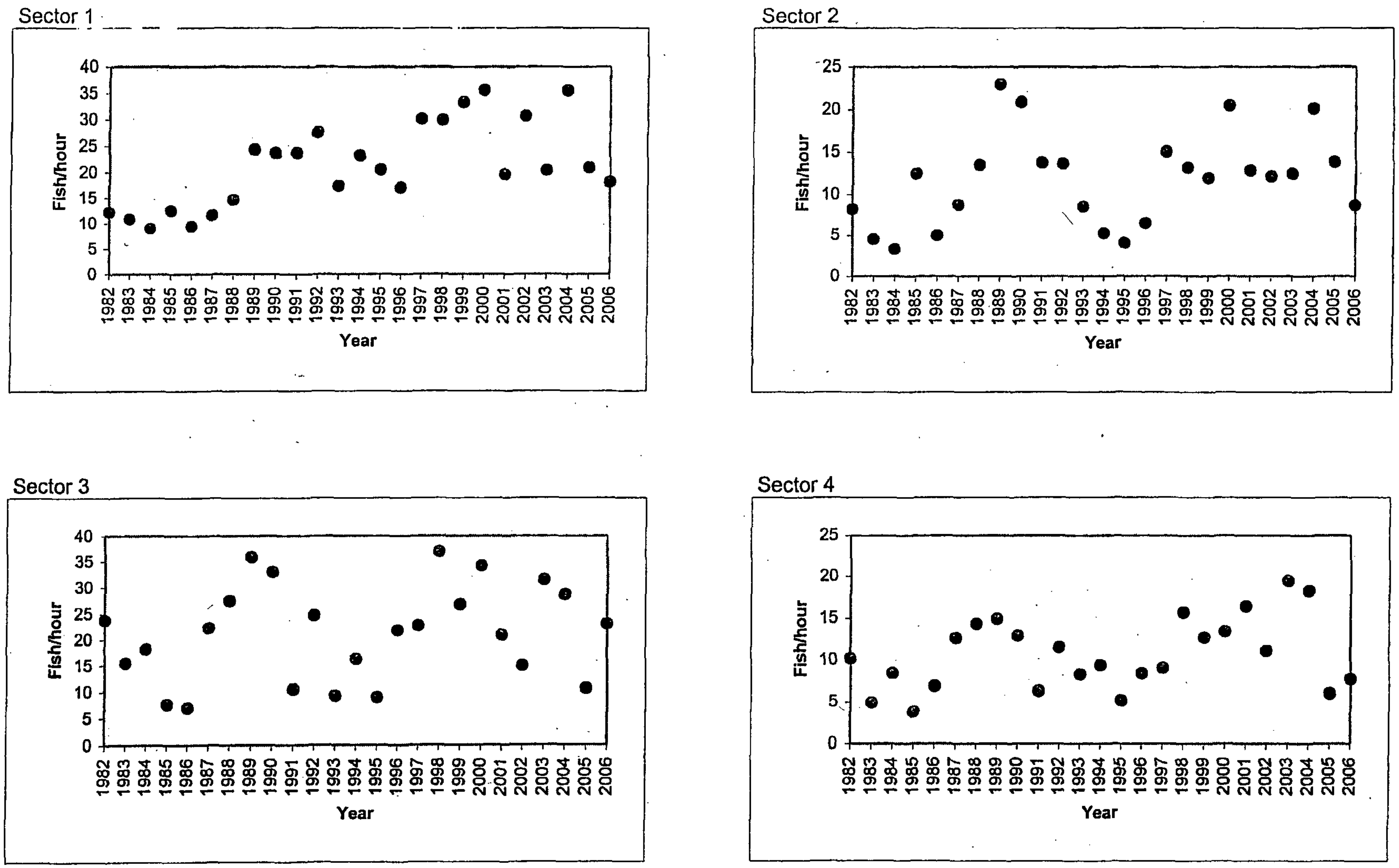


Figure 26. Electrofishing CPUE (fish/hour) by sector for White bass for years 1982-2006 in the vicinity of PINGP.

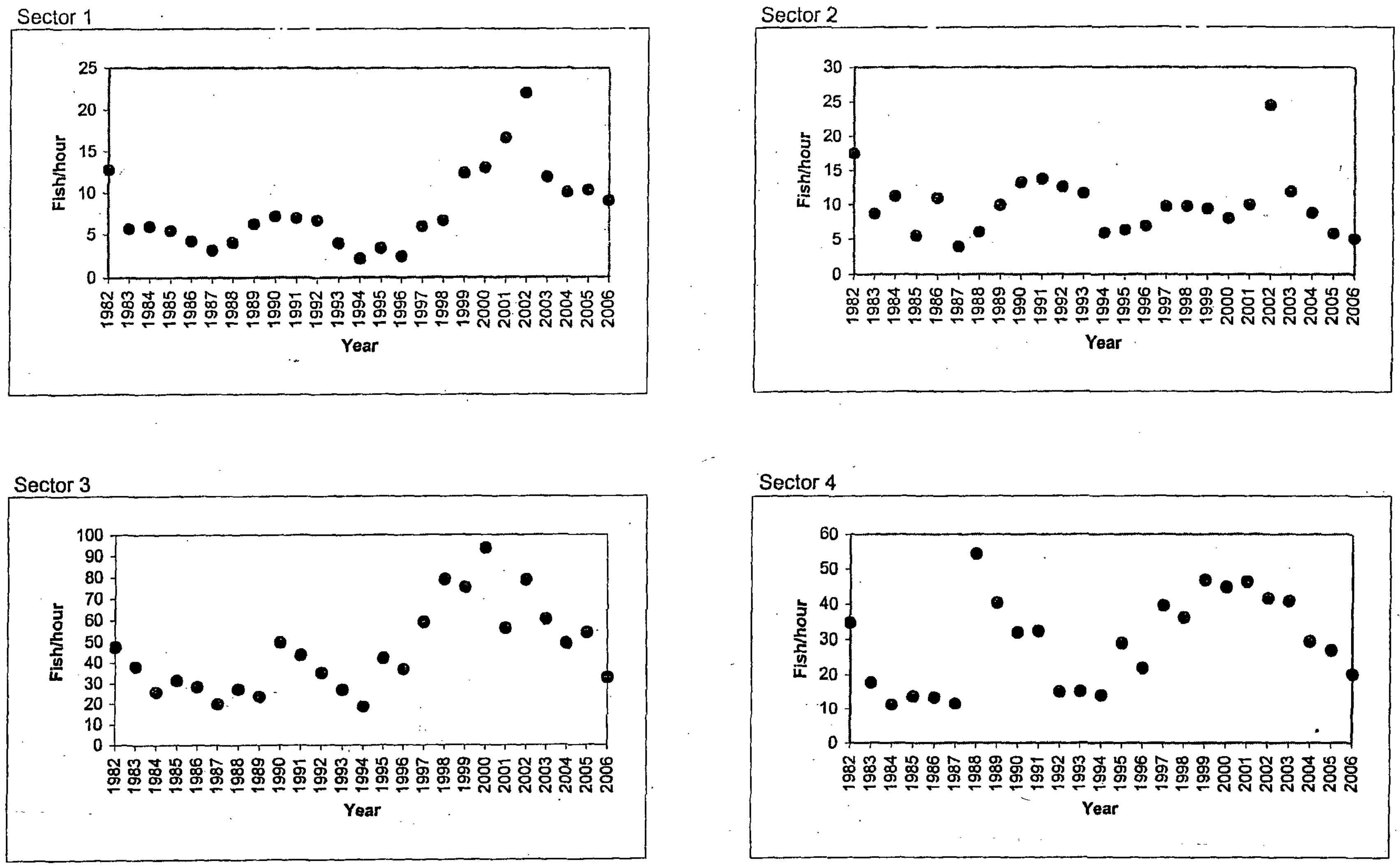
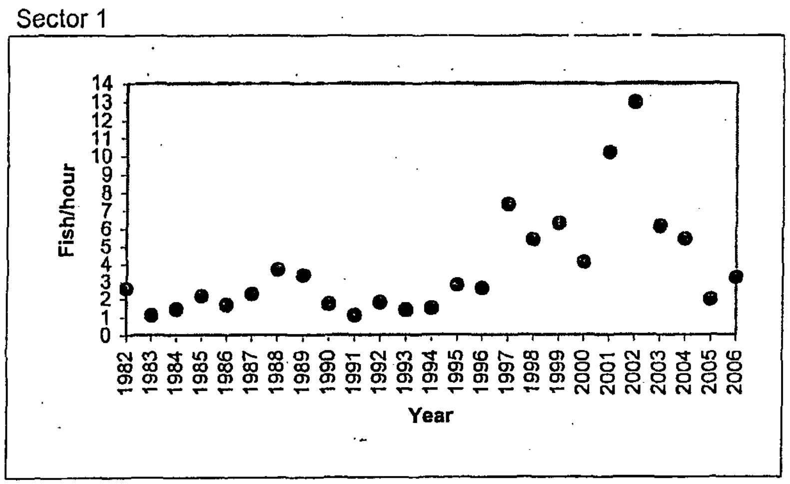
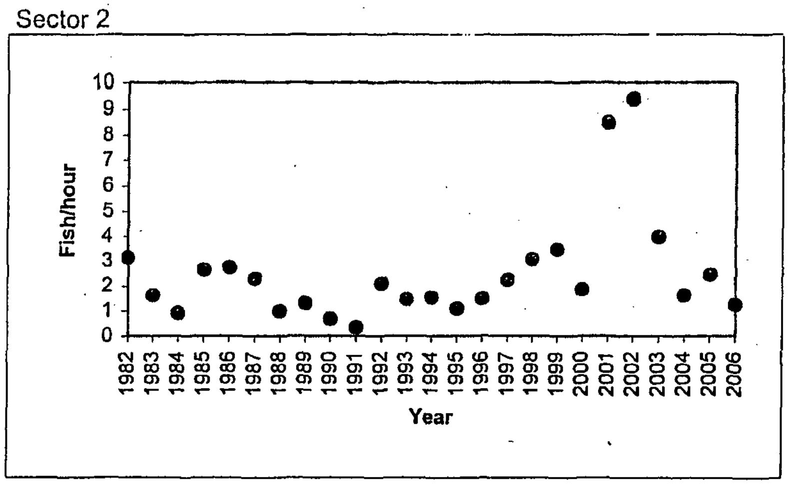
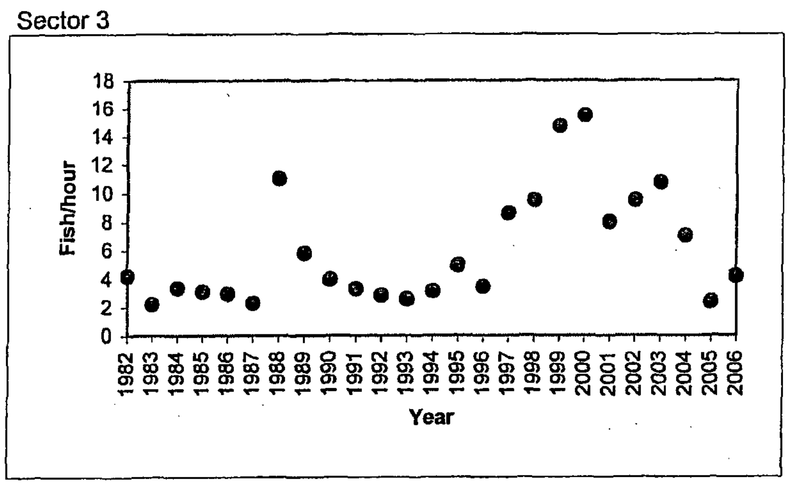


Figure 27. Electrofishing CPUE (fish/hour) by sector for Walleye for years 1982-2006 in the vicinity of PINGP.







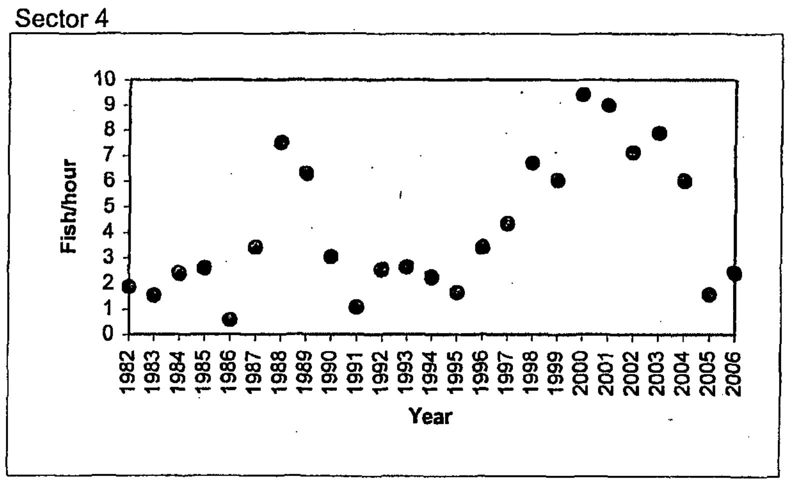


Figure 28. Electrofishing CPUE (fish/hour) by sector for Sauger for years 1982-2006 in the vicinity of PINGP

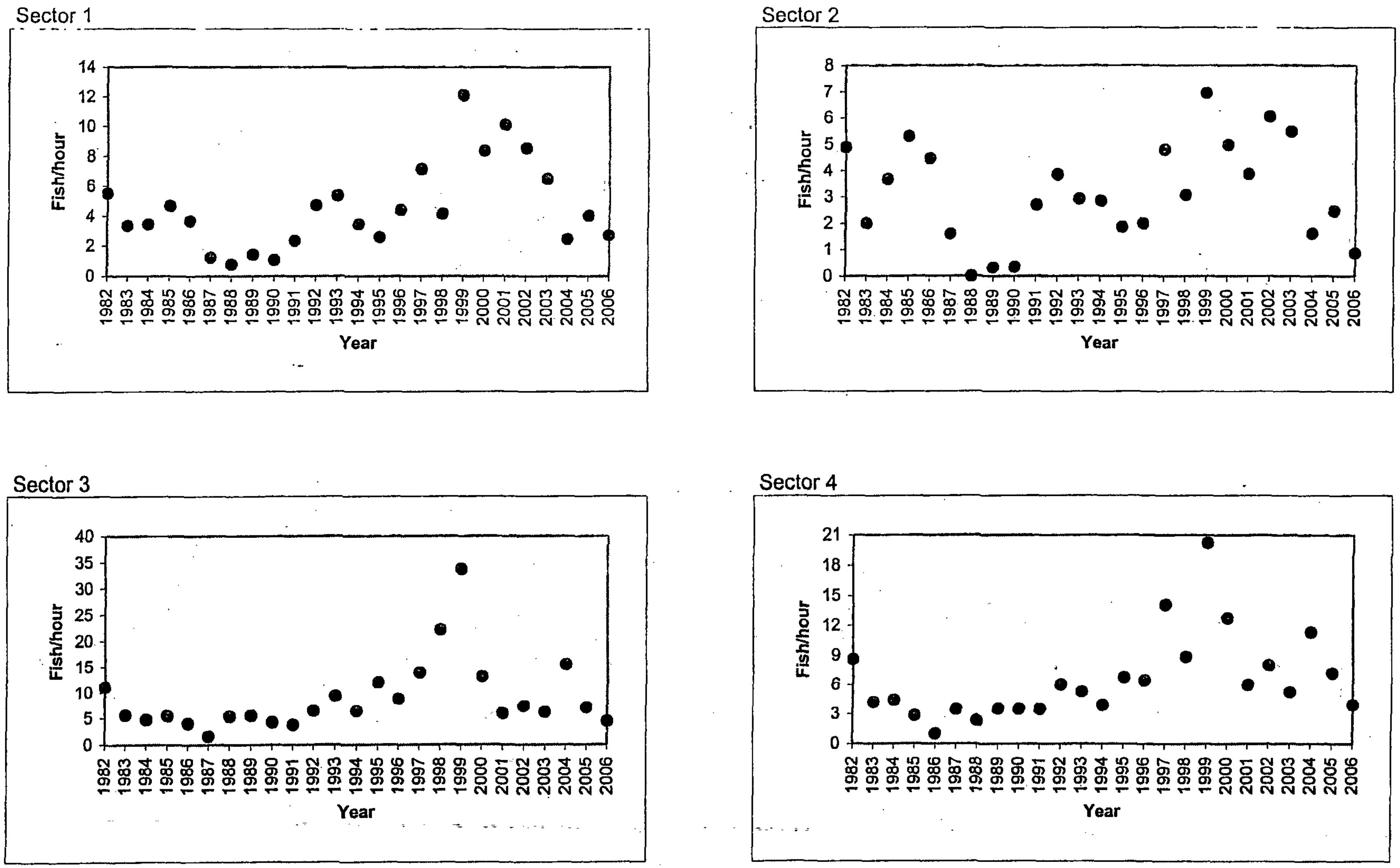
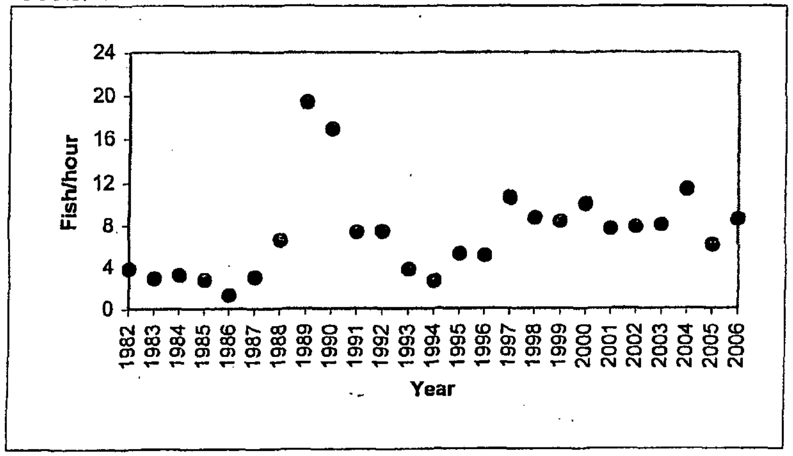
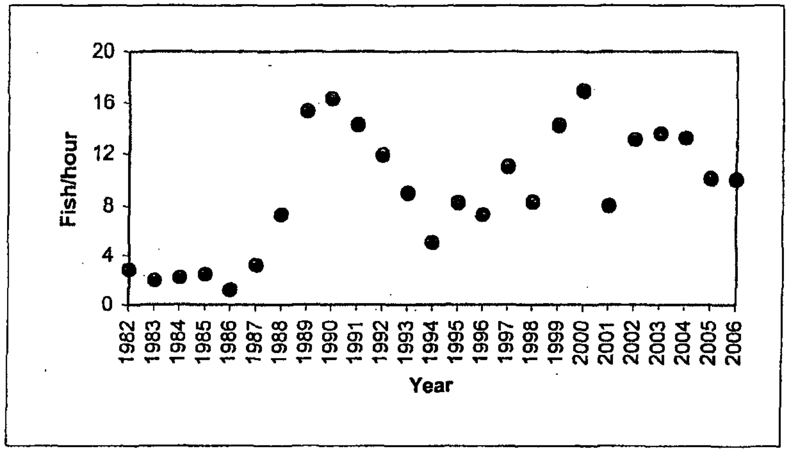


Figure 29. Electrofishing CPUE (fish/hour) by sector for Smallmouth bass for years 1982-2006 in the vicinity of PINGP.

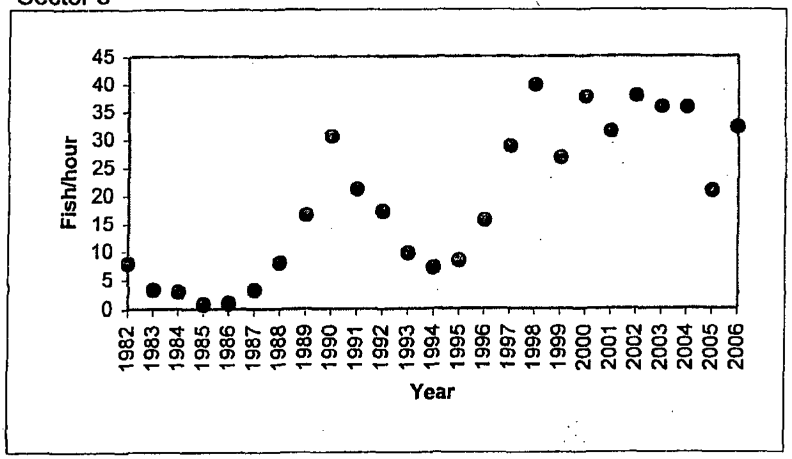
Sector 1



Sector 2



Sector 3



Sector 4

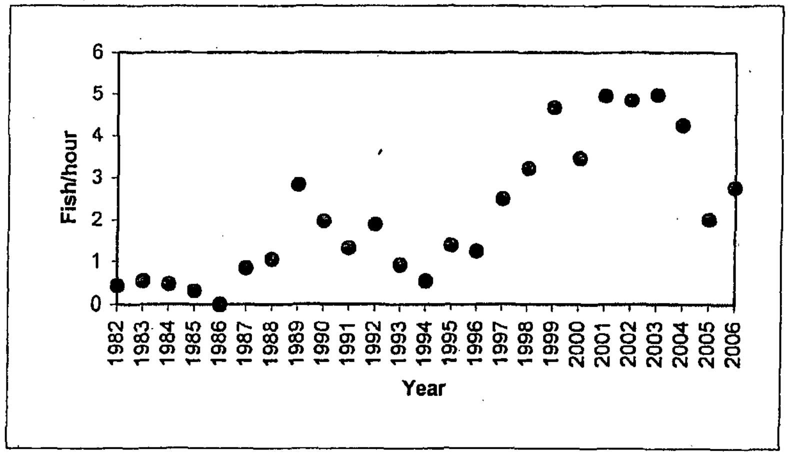
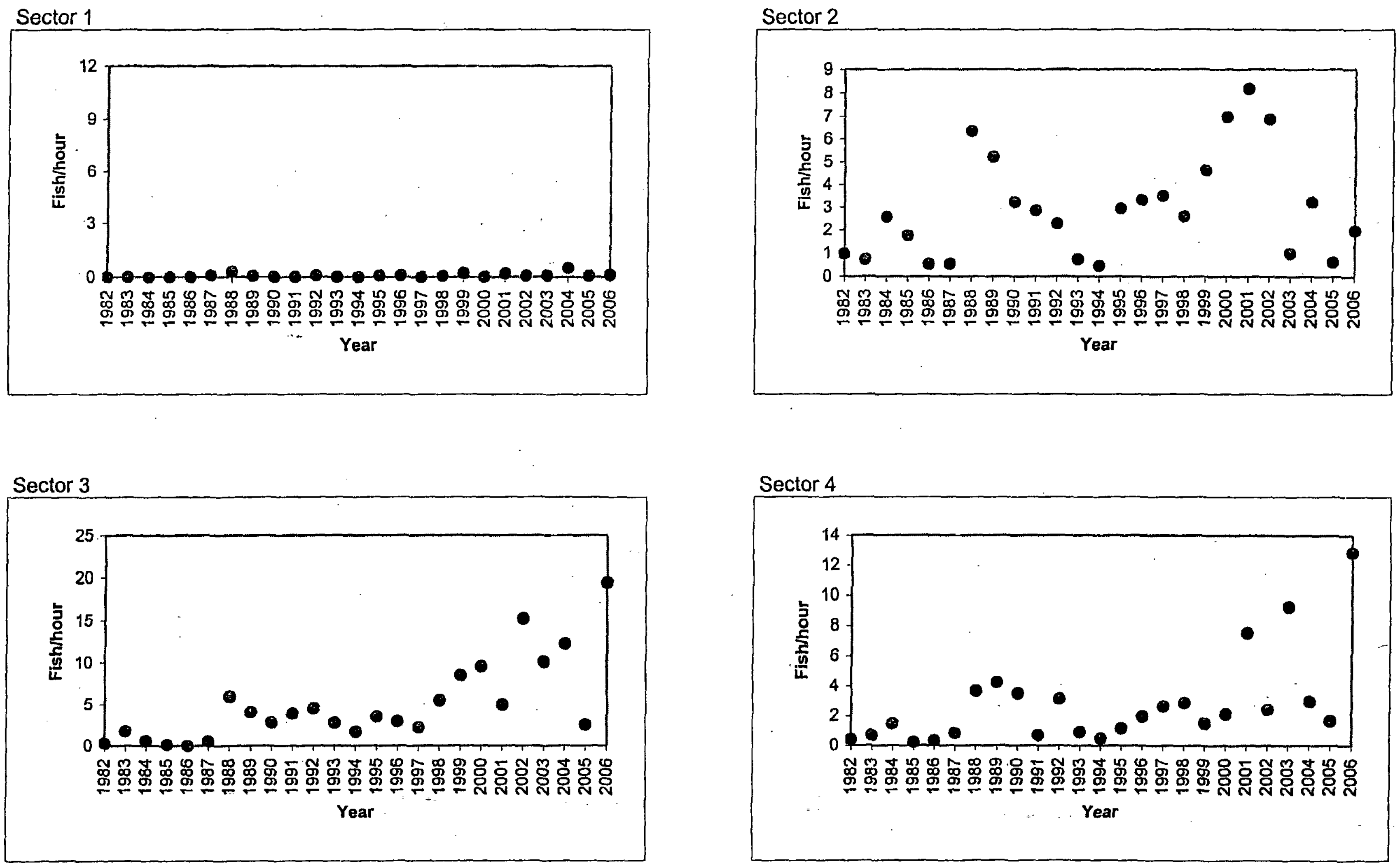
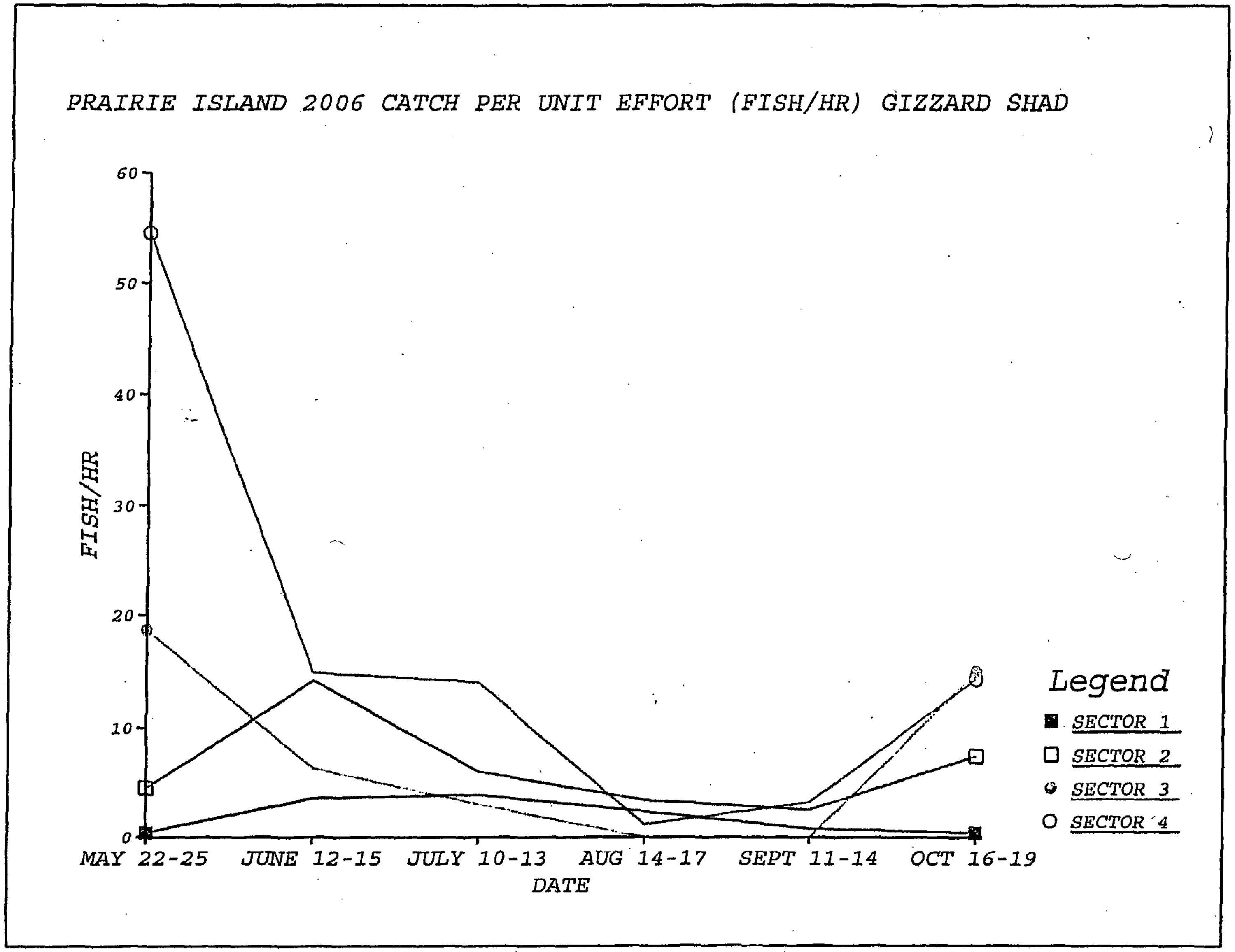


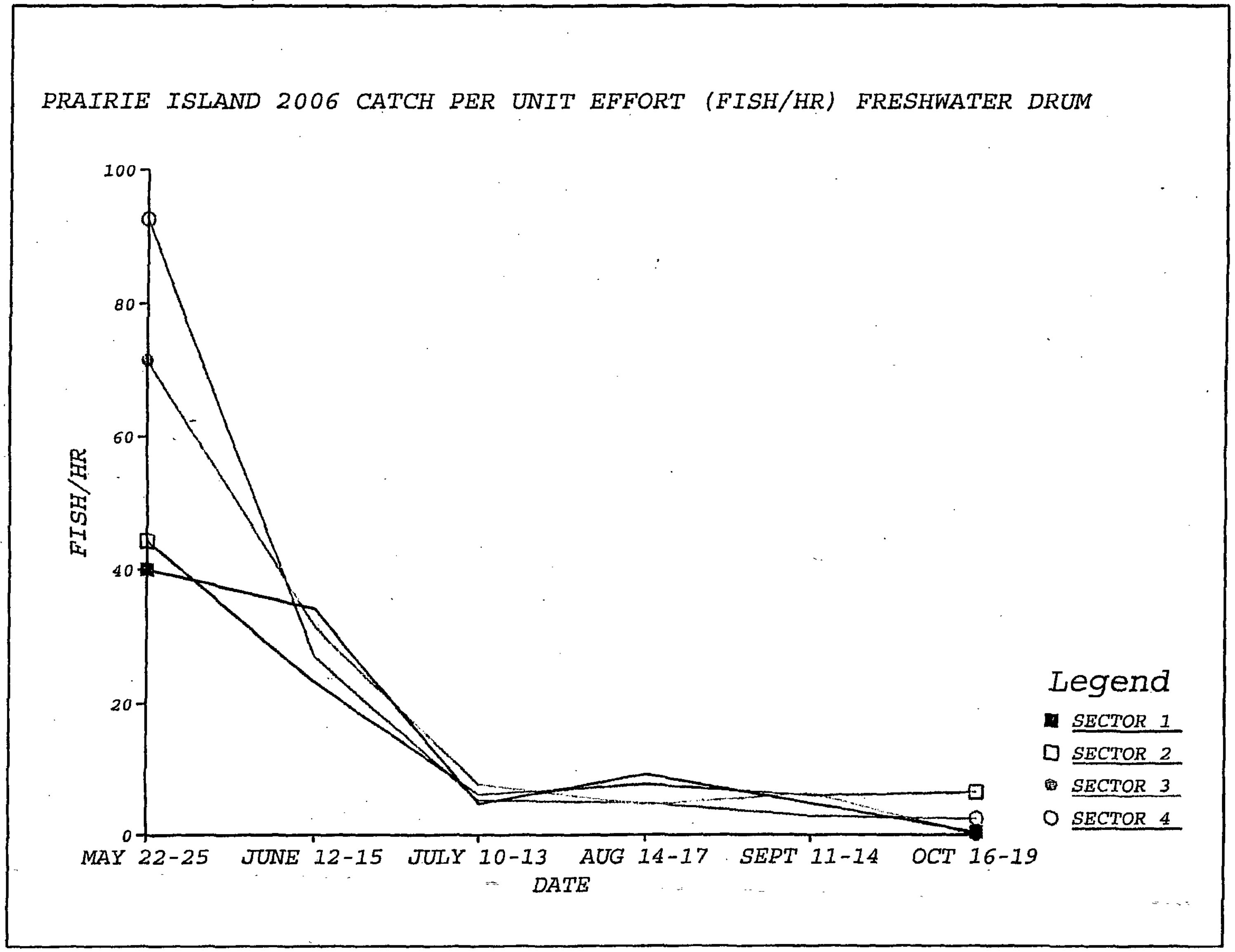
Figure 30. Electrofishing CPUE (fish/hour) by sector for Largemouth bass for years 1982-2006 in the vicinity of PINGP.





PRAIRIE ISLAND 2006 CATCH PER UNIT EFFORT (FISH/HR) GIZZARD SHAD
FISH/HR
60
50
40
30
20
10
0
MAY 22-25
JUNE 12-15
JULY 10-13
AUG 14-17
SEPT 11-14
OCT 16-19
DATE
Legend
SECTOR 1
SECTOR 2
SECTOR 3
SECTOR 4

Figure 31



PRAIRIE ISLAND 2006 CATCH PER UNIT EFFORT (FISH/HR) FRESHWATER DRUM
100
80
60
40
20
0
FISH/HR
MAY 22-25
JUNE 12-15
JULY 10-13
AUG 14-17
SEPT 11-14
OCT 16-19
DATE
Legend
SECTOR 1
SECTOR 2
SECTOR 3
SECTOR 4

Figure 32

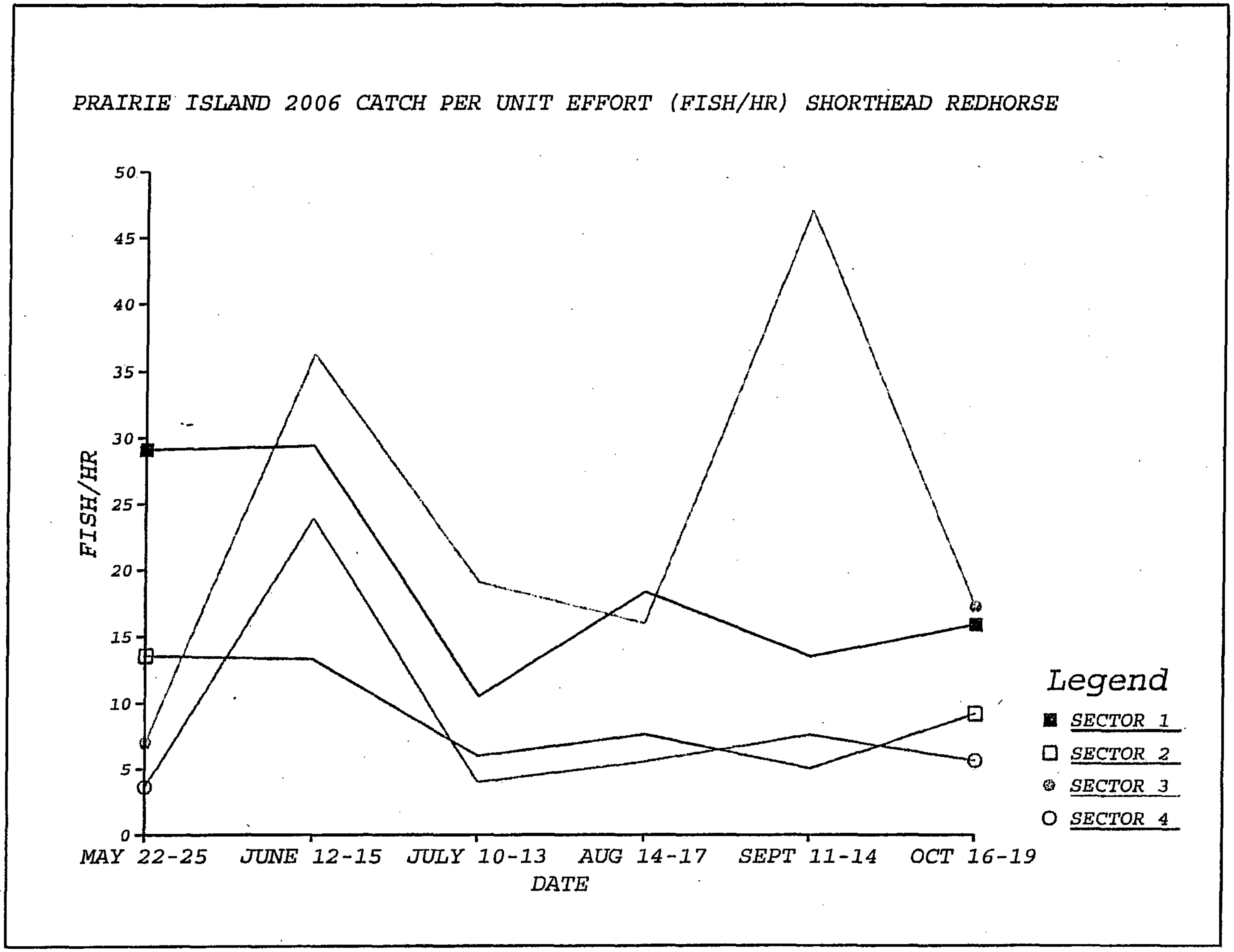

PRAIRIE ISLAND 2006 CATCH PER UNIT EFFORT (FISH/HR) SHORTHEAD REDHORSE
FISH/HR
0
5
10
15
20
25
30
35
40
45
50
MAY 22-25
JUNE 12-15
JULY 10-13
AUG 14-17
SEPT 11-14
OCT 16-19
DATE
Legend
SECTOR 1
SECTOR 2
SECTOR 3
SECTOR 4

Figure 33

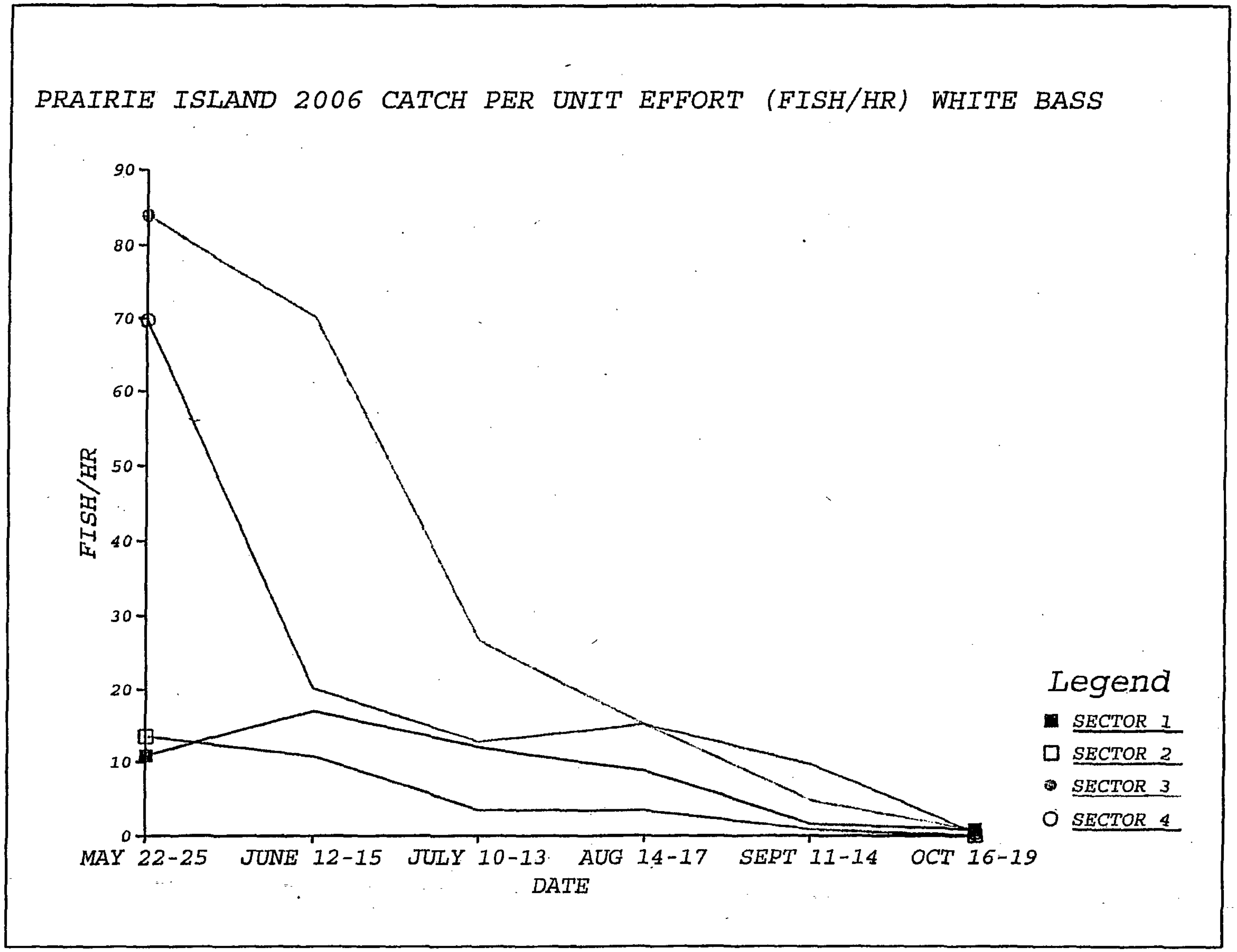

PRAIRIE ISLAND 2006 CATCH PER UNIT EFFORT (FISH/HR) WHITE BASS
FISH/HR
90
80
70
60
50
40
30
20
10
0
MAY 22-25
JUNE 12-15
JULY 10-13
AUG 14-17
SEPT 11-14
OCT 16-19
DATE
Legend
SECTOR 1
SECTOR 2
SECTOR 3
SECTOR 4

Figure 34

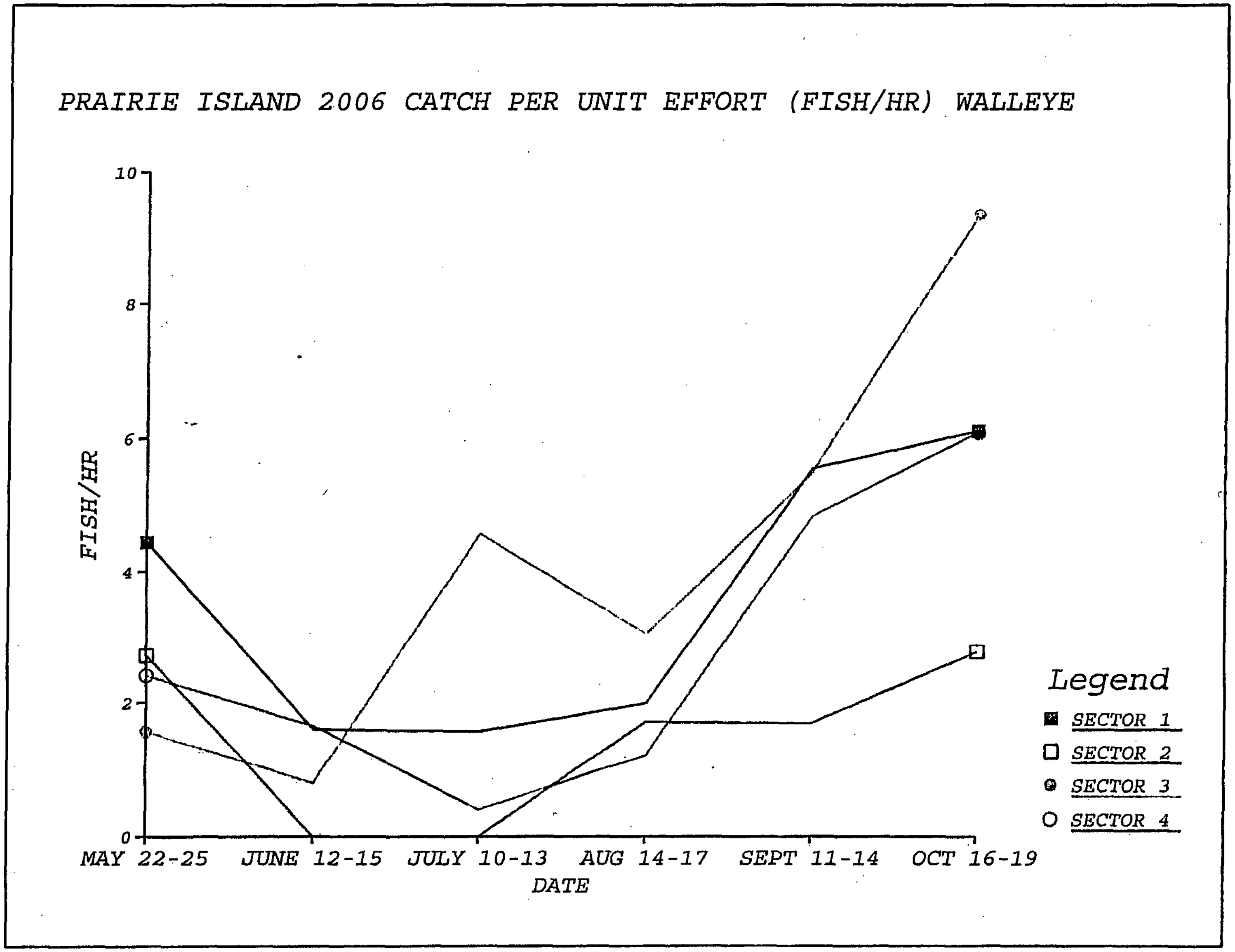
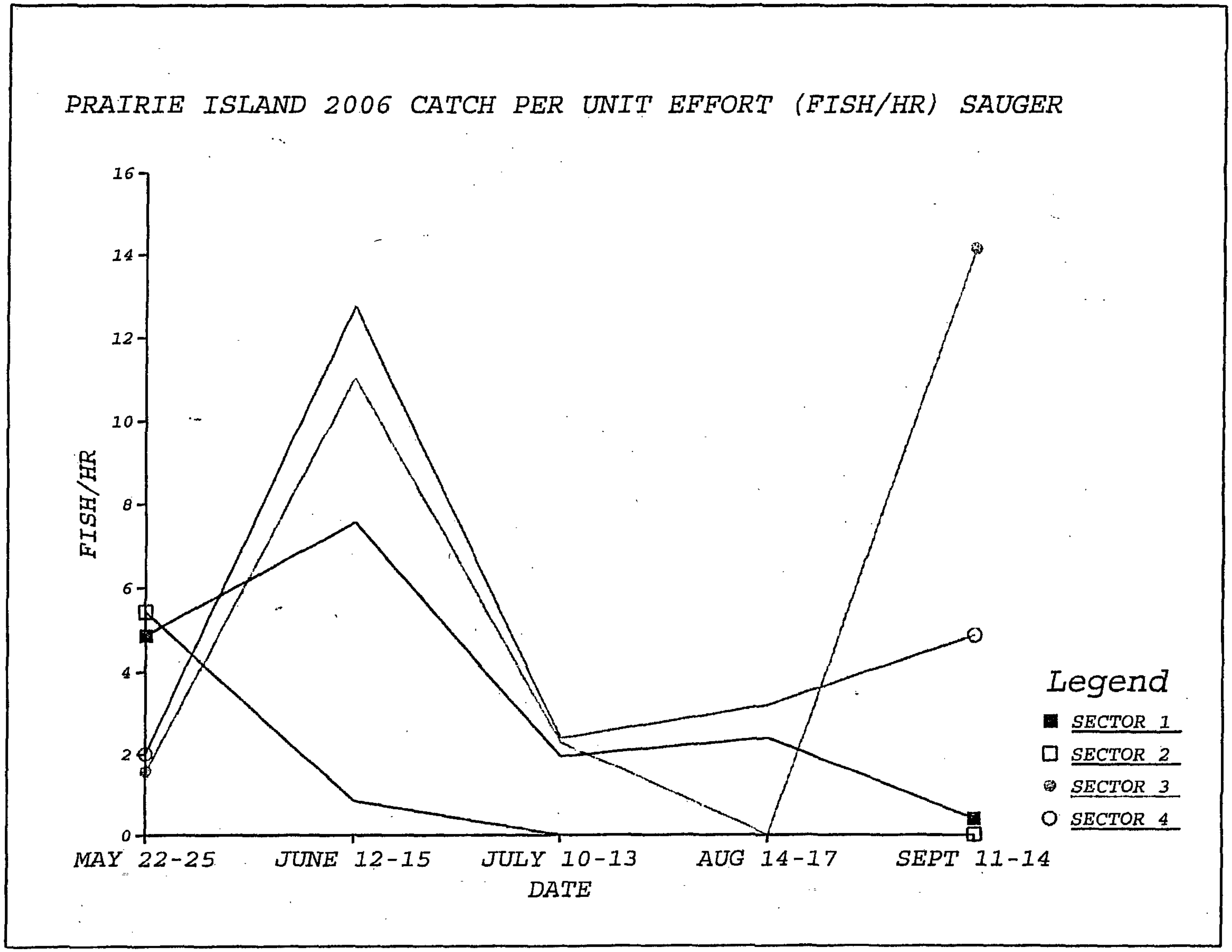
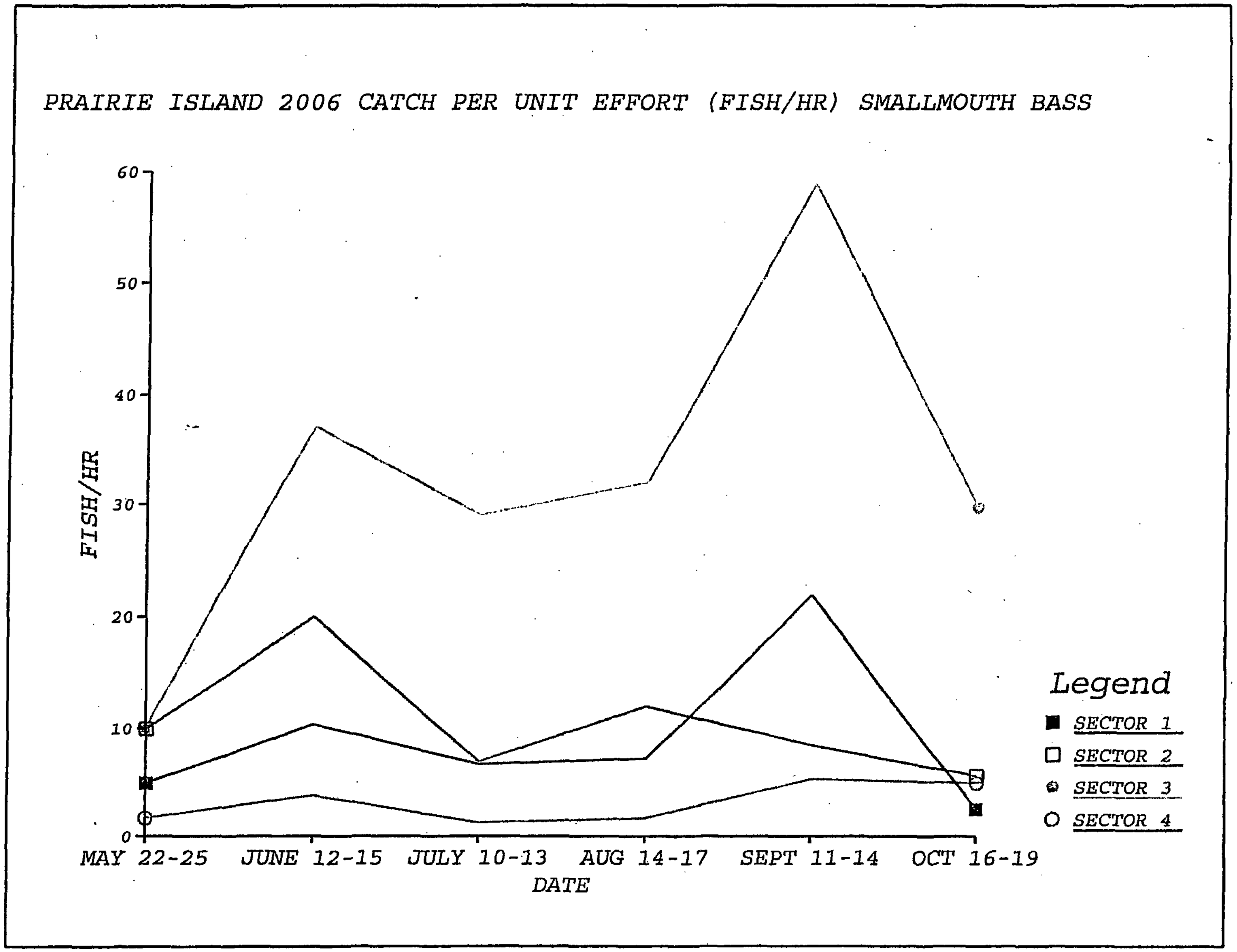

PRAIRIE ISLAND 2006 CATCH PER UNIT EFFORT (FISH/HR) WALLEYE
10
8
6
4
2
0
FISH/HR
MAY 22-25
JUNE 12-15
JULY 10-13
AUG 14-17
SEPT 11-14
OCT 16-19
DATE
Legend
SECTOR 1
SECTOR 2
SECTOR 3
SECTOR 4

Figure 35



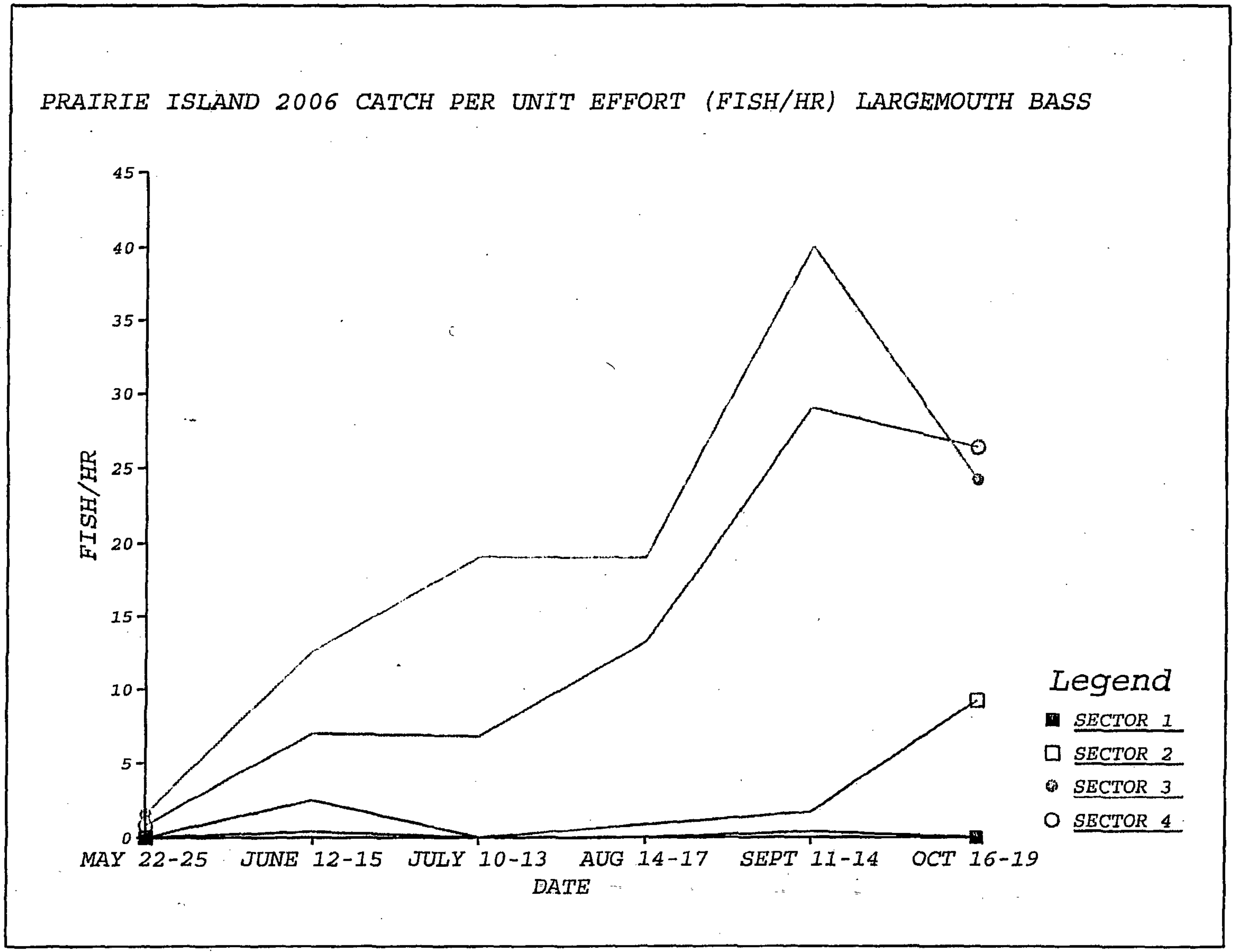
PRAIRIE ISLAND 2006 CATCH PER UNIT EFFORT (FISH/HR) SAUGER
16
14
12
10
8
6
4
2
0
FISH/HR
MAY 22-25
JUNE 12-15
JULY 10-13
AUG 14-17
SEPT 11-14
DATE
Legend
SECTOR 1
SECTOR 2
SECTOR 3
SECTOR 4

Figure 36



PRAIRIE ISLAND 2006 CATCH PER UNIT EFFORT (FISH/HR) SMALLMOUTH BASS
60
50
40
30
20
10
0
FISH/HR
MAY 22-25
JUNE 12-15
JULY 10-13
AUG 14-17
SEPT 11-14
OCT 16-19
DATE
Legend
SECTOR 1
SECTOR 2
SECTOR 3
SECTOR 4

Figure 37



PRAIRIE ISLAND 2006 CATCH PER UNIT EFFORT (FISH/HR) LARGEMOUTH BASS
45
40
35
30
25
20
15
10
5
0
FISH/HR
MAY 22-25
JUNE 12-15
JULY 10-13
AUG 14-17
SEPT 11-14
OCT 16-19
DATE
Legend
SECTOR 1
SECTOR 2
SECTOR 3
SECTOR 4

Figure 38

Table 1. Species of fish captured In the Mississippi River in the vicinity of the Prairie Island Nuclear Generating Plant 1983-2006.

Species	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	OO	O1	O2	O3	O4	O5	O6
Chestnut lamprey Ichthyomyzon castaneus	x	x							x	x			x			x	x		x	x	x			x
Silver lamprey Icthyomyzon unicuspus					x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
Paddlefish Polyodon spathula															x								x	
Longnose gar Lepisosteus osseus	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 Lepisosteus platostomus	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Bowfin Amia calva	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
American eel Anguilla rostrata	x	x		x	x	x	x	x	x	x	x	x	x	x			x	x		x			x	
Gizzard shad Dorosoma cepedianum	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Goldeye Hiodon alosoides	x		x		x	x					x			x	x	x	x				x	x	x	
Mooneye Hiodon tergisus	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Brown trout Salmo trutta				x									x		x		x		x	x	x		x	x
Northern pike Esox lucius	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Musky Esox masquinongy																		x	x			x		
Carp Cyprinus carpio	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Carpsucker Species Carpiodes species		x					x																	
River carpsucker Carpiodes carpio	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 Carpiodes cyprinus	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 Carpiodes velifer			x	x	x	x	x	x	x	x	x	x	x	x	x					x	x	x	x	
White sucker Catostomus commersoni	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x		x

Table 1 (cont.) Species of fish captured In the Mississippi River in the vicinity of the Prairie Island Nuclear Generating Plant 1983-2006.

Species	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	OO	O1	O2	O3	O4	O5	O6
Blue sucker Cycleptus elongatus	x			x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Northern hogsucker Hypentelium nigricans	x														x			x						
Smallmouth buffalo Ictiobus bubalus	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 Ictiobus cyprinellus	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Spotted sucker Minytrema melanops	x	x		x		x	x			x												x	x	x
Silver redhorse Moxostoma anisurum	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 Moxostoma carinatum		x	x		x		x	x	x	x		x	x			x	x	x	x	x	x	x	x	x
Golden redhorse Moxostoma erythrurum	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 Moxostoma valenciennesi		x		x		x		x							x	x			x		x			
Shorthead redhorse Moxostoma macrolepidotum	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 bullhead Ictalurus melas	x	x	x	x	x	x				x							x	x		x				
Yellow bullhead Ictalurus natalis					x	x	x					x	x											
Brown bullhead Ictalurus nebulosus	x																							
Channel catfish Ictalurus punctatus	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Flathead catfish Pylodictus olivaris	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Burbot Lota lota	x	x			x					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
White bass Marone chrysops	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Rock bass Ambloplites rupestris	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 Lepommis cyanellus	x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Table 1 (cont.) Species of fish captured In the Mississippi River in the vicinity of the Prairie Island Nuclear Generating Plant 1983-2006.

Species	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	OO	O1	O2	O3	O4	O5	O6
Pumpkinseed Lepomis gibbosus							x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Orangespotted sunfish Lepomis humilis																x		x	x			x		x
Bluegill Lepomis macrochirus	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 Micropterus dolomieui	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 Micropterus salmoides	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 Pomoxis annularis	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 Pomoxis nigromaculatus	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Yellow perch Perca flavens	x	x	x		x	x	x	x	x	x	x	x	x		x	x	x		x	x	x	x	x	x
Sauger Sander canadense	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 Sander vitreum	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 S. vitreum x S. canadense															x	x	x		x	x	x	x	x	
Freshwater drum Aplodinotus grunniens	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Lake sturgeon Acipenser fulvescens																					x			

Table 2. Electrofishing CPUE (fish/hour) for each sector in the vicinity of PINGP and total number of each species collected during 2006. Species are listed in descending order according to average CPUE.

Rank	Species	Sector 1	Sector 2	Sector 3	Sector 4	Average	Number collected
1	Carp	17.50	31.71	29.08	15.20	23.37	1091
2	White bass	9.09	5.08	32.51	20.15	16.71	845
3	Freshwater drum	13.92	14.12	18.36	20.03	16.61	873
4	Shorthead redhorse	18.13	8.67	23.00	7.71	14.38	731
5	Smallmouth bass	8.58	10.03	32.18	2.76	13.39	571
6	Bluegill	0.91	15.85	20.02	13.13	12.48	553
7	Largemouth bass	0.11	1.98	19.35	12.84	8.57	416
8	Gizzard shad	2.22	6.32	6.52	16.58	7.91	437
9	Black crappie	0.74	2.48	2.99	11.86	4.52	266
10	Silver redhorse	4.32	3.59	2.88	4.03	3.70	201
11	Quillback carpsucker	1.99	5.20	2.43	3.86	3.37	166
12	Sauger	2.73	0.87	4.42	3.92	2.98	163
13	Walleye	3.24	1.24	4.20	2.42	2.77	147
14	Flathead catfish	1.36	2.73	5.31	1.44	2.71	119
15	Channel catfish	1.31	6.81	1.11	0.52	2.44	97
16	Smallmouth buffalo	1.71	2.73	1.99	1.38	1.95	94
17	Green sunfish	0.17	4.58	1.00	0.17	1.48	52
18	White crappie	0.06	2.35	0.00	1.79	1.05	51
19	Bowfin	0.06	0.00	0.44	2.36	0.71	46
20	Mooneye	1.42	0.25	0.11	0.23	0.50	32
21	Bigmouth buffalo	0.28	0.25	0.77	0.58	0.47	24
22	Blue sucker	0.51	0.37	0.55	0.17	0.40	20
23	Longnose gar	0.57	0.62	0.33	0.00	0.38	18
24	Shortnose gar	0.00	0.25	0.89	0.17	0.33	13
25	Northern pike	0.11	0.00	0.22	0.92	0.31	20
26	Silver lamprey	0.46	0.25	0.44	0.00	0.29	14
27	River carpsucker	0.11	0.25	0.33	0.23	0.23	11
28	Rock bass	0.06	0.12	0.22	0.40	0.20	11
29	Golden redhorse	0.17	0.00	0.33	0.29	0.20	11
30	Burbot	0.00	0.00	0.55	0.00	0.14	5
31	Yellow perch	0.06	0.12	0.11	0.12	0.10	5
32	White sucker	0.06	0.00	0.11	0.23	0.10	6
33	River redhorse	0.28	0.00	0.11	0.00	0.10	6
34	Pumpkinseed	0.00	0.12	0.11	0.12	0.09	4
35	Orange spotted sunfish	0.00	0.12	0.11	0.00	0.06	2
36	Brown trout	0.00	0.00	0.11	0.00	0.03	1
37	Chestnut lamprey	0.00	0.00	0.11	0.00	0.03	1
38	Spotted sucker	0.06	0.00	0.00	0.00	0.01	1
	Totals	92.27	129.06	213.32	145.59	145.06	7124

Table 3. Fisheries summary for Gizzard shad 1977-2006.

YEAR	ELECTRO CPUE Fish/hr	TRAPNET CPUE Fish/hr	CATCH COMP (%)	N	MEAN LENGTH	LENGTH WEIGHT REGRESSION
1977	7.92	0.61	4	135	NA	LOG W=3.101 LOG L-5.163
1978	10.20	0.20	5	73	NA	LOG W=3.068 LOG L-5.078
1979	1.81	0.06	1	NA	NA	NA
1980	10.83	0.14	7	NA	NA	NA
1981	23.03	0.38	9	917	216	LOG W=2.748 LOG L-4.348
1982	7.39	0.09	3	276	329	LOG W=2.917 LOG L-4.741
1983	3.57	0.26	2	155	355	LOG W=3.029 LOG L-5.049
1984	0.84	0.08	1	48	281	LOG W=2.684 LOG L-4.171
1985	0.81	0.01	1	31	325	LOG W=2.388 LOG L-3.431
1986	0.14	0.06	<1	13	274	LOG W=3.248 LOG L-5.634
1987	1.08	0.05	1	55	256	LOG W=3.030 LOG L-5.046
1988	3.25	NA	3	139	288	LOG W=2.629 LOG L-4.015
1989	1.07	NA	<1	47	323	LOG W=3.025 LOG L-5.021
1990	3.99	NA	3	170	326	LOG W=2.956 LOG L-4.857
1991	2.39	NA	4	198	338	LOG W=2.601 LOG L-3.940
1992	1.82	NA	1.8	91	357	LOG W=3.459 LOG L-6.127
1993	1.99	NA	1.9	62	375	LOG W=2.920 LOG L-4.728
1994	0.28	NA	<1	14	394	LOG W=3.371 LOG L-5.955
1995	5.10	NA	4	204	272	LOG W=2.625 LOG L-4.073
1996	0.76	NA	<1	27	330	LOG W=3.275 LOG L-5.666
1997	0.66	NA	<1	23	400	LOG W=3.934 LOG L-7.373
1998	4.07	NA	2	176	260	LOG W=3.104 LOG L-5.218
1999	27.12	NA	12	1222	290	LOG W=2.981 LOG L-4.988
2000	40.85	NA	17	1634	290	LOG W=3.274 LOG L-5.697
2001	10.43	NA	6	455	340	LOG W=3.767 LOG L-6.967
2002	14.02	NA	7	612	350	LOG W=3.200 LOG L-5.518
2003	9.51	NA	5	373	380	LOG W=3.469 LOG L-6.198
2004	17.60	NA	10	859	290	LOG W=2.863 LOG L-4.607
2005	14.06	NA	9	682	350	LOG W=3.072 LOG L-5.147
2006	7.91	NA	5	437	340	LOG W=2.854 LOG L-4.585

Table 4. Fisheries summary for Freshwater drum 1977-2006.

YEAR	ELECTRO CPUE Fish/hr	TRAPNET CPUE Fish/hr	CATCH COMP (%)	N	MEAN LENGTH	LENGTH WEIGHT REGRESSION
1977	7.49	5.27	13	569	NA	LOG W=2.947 LOG L-4.756
1978	11.97	6.28	17	422	NA	LOG W=2.911 LOG L-4.710
1979	7.47	5.22	21	360	NA	LOG W=3.068 LOG L-5.100
1980	5.89	3.83	18	520	NA	LOG W=3.052 LOG L-5.026
1981	30.88	4.76	12	1146	267	LOG W=2.891 LOG L-4.625
1982	9.30	11.00	24	2225	293	LOG W=2.888 LOG L-4.625
1983	8.80	8.18	22	1626	287	LOG W=3.001 LOG L-4.927
1984	7.07	6.21	20	1212	288	LOG W=2.598 LOG L-3.919
1985	10.15	7.92	31	1712	293	LOG W=2.846 LOG L-4.452
1986	8.33	0.39	22	856	310	LOG W=3.089 LOG L-5.139
1987	10.29	3.75	16	940	312	LOG W=2.874 LOG L-4.603
1988	9.85	NA	8	419	280	LOG W=2.722 LOG L-4.205
1989	13.17	NA	11	570	294	LOG W=2.908 LOG L-4.707
1990	17.70	NA	13	724	297	LOG W=3.008 LOG L-4.957
1991	15.68	NA	12	596	305	LOG W=2.955 LOG L-4.824
1992	14.23	NA	11	539	320	LOG W=2.967 LOG L-4.829
1993	20.83	NA	18	584	334	LOG W=3.063 LOG L-5.053
1994	15.92	NA	14	495	332	LOG W=3.072 LOG L-5.086
1995	14.96	NA	12	605	317	LOG W=3.124 LOG L-5.243
1996	9.33	NA	8	374	300	LOG W=3.061 LOG L-5.093
1997	18.18	NA	10	812	300	LOG W=3.090 LOG L-5.159
1998	23.47	NA	11	983	320	LOG W=3.171 LOG L-5.344
1999	45.53	NA	17	1745	320	LOG W=3.138 LOG L-5.289
2000	19.88	NA	8	776	310	LOG W=3.077 LOG L-5.161
2001	28.17	NA	15	1279	330	LOG W=3.212 LOG L-5.480
2002	24.45	NA	12	1062	320	LOG W=3.155 LOG L-5.346
2003	37.51	NA	19	1595	350	LOG W=3.276 LOG L-5.637
2004	21.12	NA	12	928	310	LOG W=3.080 LOG L-5.131
2005	32.02	NA	22	1342	330	LOG W=3.129 LOG L-5.238
2006	16.61	NA	11	873	320	LOG W=3.258 LOG L-5.546

Table 5. Fisheries summary for Shorthead redhorse 1977-2006.

YEAR	ELECTRO CPUE Fish/hr	TRAPNET CPUE Fish/hr	CATCH COMP (%)	N	MEAN LENGTH	LENGTH WEIGHT REGRESSION
1977	5.39	1.58	5	259	NA	LOG W=2.902 LOG L-4.691
1978	2.96	1.09	4	125	NA	LOG W=2.978 LOG L-4.917
1979	2.08	0.45	3	67	NA	LOG W=3.041 LOG L-5.090
1980	6.08	0.70	7	137	NA	LOG W=2.894 LOG L-4.678
1981	11.67	1.34	7	686	376	LOG W=2.791 LOG L-4.428
1982	13.56	0.92	7	675	392	LOG W=2.814 LOG L-4.496
1983	8.96	0.79	6	454	387	LOG W=2.849 LOG L-4.590
1984	9.74	0.51	7	435	386	LOG W=2.571 LOG L-3.840
1985	7.36	0.51	7	374	389	LOG W=2.787 LOG L-4.415
1986	7.07	0.19	8	319	398	LOG W=2.911 LOG L-4.730
1987	13.80	1.24	12	722	403	LOG W=2.860 LOG L-4.608
1988	17.48	NA	13	667	381	LOG W=2.696 LOG L-4.176
1989	24.52	NA	17	902	370	LOG W=2.792 LOG L-4.448
1990	22.60	NA	14	838	361	LOG W=2.825 LOG L-4.544
1991	13.58	NA	11	538	355	LOG W=2.784 LOG L-4.443
1992	19.35	NA	14	721	403	LOG W=2.841 LOG L-4.587
1993	10.86	NA	10	332	382	LOG W=3.011 LOG L-4.991
1994	13.51	NA	14	505	389	LOG W=2.872 LOG L-4.655
1995	9.67	NA	8	450	364	LOG W=2.925 LOG L-4.808
1996	13.42	NA	11	551	380	LOG W=2.897 LOG L-4.719
1997	19.21	NA	10	833	350	LOG W=2.982 LOG L-4.960
1998	23.94	NA	12	1047	360	LOG W=2.982 LOG L-4.960
1999	21.17	NA	9	931	350	LOG W=3.016 LOG L-5.050
2000	25.94	NA	11	1099	360	LOG W=2.905 LOG L-4.760
2001	17.43	NA	9	777	370	LOG W=3.039 LOG L-5.101
2002	17.23	NA	9	781	370	LOG W=2.954 LOG L-4.892
2003	20.92	NA	11	878	390	LOG W=3.033 LOG L-5.071
2004	25.63	NA	15	1141	360	LOG W=2.948 LOG L-4.855
2005	12.85	NA	9	562	350	LOG W=2.833 LOG L-4.544
2006	14.38	NA	10	731	370	LOG W=2.772 LOG L-4.375

Table 6. Fisheries summary for White bass 1977-2006.

YEAR	ELECTRO CPUE Fish/hr	TRAPNET CPUE Fish/hr	CATCH COMP (%)	N	MEAN LENGTH	LENGTH WEIGHT REGRESSION
1977	7.76	6.73	19	565	NA	LOG W=2.441 LOG L-3.529
1978	7.11	5.67	17	369	NA	LOG W=2.956 LOG L-4.813
1979	3.49	3.02	13	217	NA	LOG W=3.055 LOG L-5.057
1980	2.48	1.97	9	183	NA	LOG W=3.064 LOG L-5.022
1981	30.88	5.39	20	1996	240	LOG W=2.842 LOG L-4.498
1982	28.11	0.07	18	1722	286	LOG W=2.909 LOG L-4.677
1983	17.50	4.52	17	1277	300	LOG W=3.041 LOG L-5.021
1984	13.53	2.89	15	435	304	LOG W=2.571 LOG L-3.840
1985	16.75	1.39	14	768	308	LOG W=2.773 LOG L-4.337
1986	14.23	1.63	18	732	325	LOG W=2.926 LOG L-4.716
1987	9.70	1.44	10	589	321	LOG W=3.027 LOG L-4.958
1988	22.90	NA	20	1009	242	LOG W=2.855 LOG L-4.525
1989	20.00	NA	15	819	266	LOG W=2.945 LOG L-4.765
1990	25.49	NA	16	941	295	LOG W=2.913 LOG L-4.697
1991	24.15	NA	18	886	310	LOG W=2.911 LOG L-4.696
1992	17.36	NA	11	577	338	LOG W=2.967 LOG L-4.829
1993	14.42	NA	12	390	328	LOG W=2.939 LOG L-4.750
1994	10.20	NA	10	360	339	LOG W=2.911 LOG L-4.671
1995	20.16	NA	16	809	267	LOG W=3.026 LOG L-4.975
1996	16.99	NA	14	660	320	LOG W=3.066 LOG L-5.068
1997	28.53	NA	15	1159	300	LOG W=3.054 LOG L-5.038
1998	32.90	NA	16	1314	320	LOG W=3.085 LOG L-5.106
1999	35.91	NA	14	1461	300	LOG W=3.011 LOG L-4.942
2000	39.90	NA	16	1602	320	LOG W=2.963 LOG L-4.830
2001	32.37	NA	17	1436	320	LOG W=2.967 LOG L-4.821
2002	41.69	NA	21	1656	320	LOG W=3.042 LOG L-5.013
2003	31.22	NA	16	1272	330	LOG W=2.977 LOG L-4.829
2004	24.29	NA	14	1011	310	LOG W=3.029 LOG L-4.960
2005	24.21	NA	16	982	330	LOG W=2.947 LOG L-4.742
2006	16.71	NA	12	845	330	LOG W=2.886 LOG L-4.594

Table 7. Fisheries summary for Walleye 1977-2006.

YEAR	ELECTRO CPUE Fish/hr	TRAPNET CPUE Fish/hr	CATCH COMP (%)	N	MEAN LENGTH	LENGTH WEIGHT REGRESSION
1977	1.36	0.37	1	20	NA	LOG W=3.137 LOG L-5.377
1978	1.54	0.96	2	28	NA	LOG W=3.056 LOG L-5.197
1979	1.57	0.31	2	34	NA	LOG W=3.225 LOG L-5.640
1980	1.20	0.13	1	22	NA	LOG W=3.250 LOG L-5.693
1981	3.53	0.39	2	189	335	LOG W=3.082 LOG L-5.240
1982	2.96	0.16	1	135	415	LOG W=3.097 LOG L-5.293
1983	1.63	0.21	1	90	432	LOG W=3.095 LOG L-5.295
1984	2.04	0.11	2	93	378	LOG W=2.852 LOG L-4.615
1985	2.64	0.13	2	119	413	LOG W=3.159 LOG L-5.461
1986	1.99	0.15	2	101	404	LOG W=3.085 LOG L-5.269
1987	3.00	0.09	2	132	386	LOG W=3.151 LOG L-5.446
1988	5.80	NA	5	234	450	LOG W=3.103 LOG L-5.272
1989	4.19	NA	3	173	408	LOG W=3.140 LOG L-5.379
1990	2.36	NA	2	95	420	LOG W=3.214 LOG L-5.594
1991	1.44	NA	1	52	477	LOG W=3.318 LOG L-5.870
1992	2.30	NA	1	82	403	LOG W=3.257 LOG L-5.727
1993	2.00	NA	2	60	465	LOG W=3.001 LOG L-5.020
1994	2.11	NA	2	74	439	LOG W=3.261 LOG L-5.720
1995	2.63	NA	2	107	333	LOG W=3.208 LOG L-5.586
1996	2.75	NA	2	118	360	LOG W=3.159 LOG L-5.467
1997	5.63	NA	3	248	400	LOG W=3.215 LOG L-5.617
1998	6.16	NA	3	272	420	LOG W=3.148 LOG L-5.440
1999	7.63	NA	3	308	440	LOG W=3.238 LOG L-5.690
2000	7.72	NA	3	325	460	LOG W=3.250 LOG L-5.717
2001	8.93	NA	5	399	400	LOG W=3.296 LOG L-5.837
2002	9.75	NA	5	415	390	LOG W=3.257 LOG L-5.744
2003	7.18	NA	4	304	450	LOG W=3.253 LOG L-5.726
2004	5.02	NA	3	232	440	LOG W=3.175 LOG L-5.494
2005	2.11	NA	1	86	510	LOG W=3.225 LOG L-5.633
2006	2.77	NA	2	147	510	LOG W=3.352 LOG L-5.964

Table 8. Fisheries summary for Sauger 1977-2006.

YEAR	ELECTRO CPUE Fish/hr	TRAPNET CPUE Fish/hr	CATCH COMP (%)	N	MEAN LENGTH	LENGTH WEIGHT REGRESSION
1977	0.77	0.40	1	20	NA	LOG W=2.984 LOG L-4.991
1978	2.43	0.38	2	38	NA	LOG W=3.100 LOG L-5.354
1979	1.57	0.30	2	24	NA	LOG W=3.009 LOG L-5.158
1980	1.79	0.17	2	16	NA	LOG W=3.169 LOG L-5.509
1981	7.28	0.29	4	NA	NA	NA
1982	7.50	0.17	4	329	256	LOG W=2.864 LOG L-4.773
1983	3.80	0.25	3	188	285	LOG W=3.013 LOG L-5.144
1984	4.07	0.19	3	182	262	LOG W=2.648 LOG L-4.202
1985	4.57	0.21	4	199	283	LOG W=2.996 LOG L-5.019
1986	3.29	0.24	4	178	294	LOG W=3.336 LOG L-5.936
1987	4.94	0.12	2	114	262	LOG W=3.177 LOG L-5.556
1988	2.10	NA	2	79	236	LOG W=2.683 LOG L-4.285
1989	2.70	NA	2	104	237	LOG W=3.208 LOG L-5.639
1990	2.29	NA	2	92	291	LOG W=3.070 LOG L-5.277
1991	3.07	NA	2	117	308	LOG W=3.155 LOG L-5.507
1992	5.24	NA	4	196	297	LOG W=3.029 LOG L-5.191
1993	5.71	NA	5	168	262	LOG W=2.950 LOG L-4.976
1994	4.16	NA	4	145	280	LOG W=3.153 LOG L-5.484
1995	5.80	NA	5	233	243	LOG W=3.090 LOG L-5.369
1996	5.41	NA	5	228	270	LOG W=3.142 LOG L-5.475
1997	9.99	NA	5	437	270	LOG W=3.065 LOG L-5.294
1998	9.57	NA	5	386	250	LOG W=3.190 LOG L-5.596
1999	18.26	NA	7	756	260	LOG W=3.262 LOG L-5.788
2000	9.81	NA	4	435	280	LOG W=3.306 LOG L-5.892
2001	6.47	NA	3	308	310	LOG W=3.356 LOG L-6.015
2002	7.50	NA	4	329	280	LOG W=3.350 LOG L-6.018
2003	5.86	NA	3	247	300	LOG W=3.281 LOG L-5.842
2004	7.75	NA	4	333	270	LOG W=3.232 LOG L-5.678
2005	5.20	NA	3	233	290	LOG W=3.163 LOG L-5.505
2006	2.98	NA	2	163	280	LOG W=3.042 LOG L-5.203

Table 9. Smallmouth and largemouth bass electrofishing CPUE (fish/hr) and rank, 1981-2006.

	Smallmouth Bass		Largemouth Bass	
Year	CPUE	Rank	CPUE	Rank
1981	4.65	9	0.58	20
1982	3.72	7	0.41	18
1983	2.17	8	0.80	11
1984	2.19	7	1.16	11
1985	1.56	8	0.54	15
1986	0.85	9	0.21	20
1987	2.94	7	0.61	16
1988	5.72	7	4.06	9
1989	13.52	4	3.40	10
1990	16.44	5	2.39	9
1991	11.03	5	1.87	11
1992	9.61	5	2.50	11
1993	5.80	6	1.10	14
1994	3.83	7	0.65	15
1995	5.81	5	1.93	12
1996	7.31	5	2.08	10
1997	13.23	5	2.10	15
1998	15.01	5	2.75	14
1999	13.51	7	3.71	13
2000	17.02	6	4.67	11
2001	13.01	5	5.21	11
2002	15.91	5	6.14	11
2003	15.59	5	5.09	11
2004	16.15	6	4.73	10
2005	9.77	6	1.22	17
2006	13.39	5	8.57	7

Table 10. Species composition expressed as % of total annual catches for PINGP fisheries studies, electrofishing and trapnetting combined for 1981-1987, and electrofishing only for 1988 through 2006.

Year	Carp	White bass	Freshwater Drum	Sauger	Black Crappie	Shorthead Redhorse	Walleye	Gizzard Shad	Total %
1981	17	20	12	4	15	7	2	9	86
1982	23	18	24	4	9	7	1	3	89
1983	18	17	22	3	16	6	1	2	85
1984	26	15	20	3	12	7	2	1	86
1985	20	14	31	4	9	7	2	1	87
1986	21	18	22	4	9	8	2	<1	84
1987	27	10	16	2	11	12	2	1	81
1988*	23	20	8	2	3	13	5	3	77
1989*	20	15	11	2	1	17	3	<1	70
1990*	20	16	13	1	<1	14	1	3	69
1991*	24	18	12	2	1	11	1	4	73
1992*	26	12	11	4	1	14	2	2	72
1993*	28	12	18	5	<1	10	2	2	76
1994*	34	10	14	4	<1	14	2	<1	78
1995*	30	16	12	5	1	8	2	4	78
1996*	34	14	8	5	2	11	2	<1	76
1997*	29	15	10	5	1	10	3	<1	73
1998*	23	16	11	5	2	12	3	2	74
1999*	17	14	17	7	3	9	3	12	82
2000*	16	16	8	4	2	11	3	17	77
2001*	15	17	15	3	2	9	5	6	72
2002*	14	21	12	4	2	9	5	7	74
2003*	13	16	19	3	1	11	4	5	72
2004*	14	14	12	4	1	15	3	10	73
2005*	14	16	22	3	<1	9	1	9	74
2006*	16	12	11	2	3	10	2	5	61

*Electrofishing only