Enclosure

Environmental Study

for

Quad Cities Nuclear Power Station

Prepared for

Exelon Nuclear

QUAD CITIES NUCLEAR STATION
316(a) Demonstration

September 2012

Prepared by HDR

QUAD CITIES NUCLEAR STATION

316(a) Demonstration Summary

TABLE OF CONTENTS

Appendix A: Description of the Mississippi River in the Vicinity of Pool 14: Hydrology, Geology, Water Quality, Biology, and Anthropogenic Influence

Appendix B: Biothermal Assessment: Prospective Demonstration

Appendix C: Retrospective Demonstration and Conclusions Regarding Protection and Propagation of a Balanced Indigenous Community under Clean Water Act Section 316(a)

Appendix D: Quad Cities Nuclear Station Operations

Appendix E: Data Collection Programs

1.0 OVERVIEW OF THE SUMMARY AND APPENDICES

1.1 Roadmap to the Summary and Appendices

This Demonstration in support of Exelon's request for a thermal variance for Quad Cities Nuclear Station (QCNS) under Section 316(a) of the Clean Water Act represents the culmination of years of extensive studies and analyses of Pool 14 of the Mississippi River and the Station's operations. These studies and analyses are discussed in detail in the documents that comprise this Demonstration. The Demonstration presents both retrospective (Appendix C) and prospective (Appendix B) analyses which show that the requested thermal variance will assure the protection and propagation of a balanced, indigenous community of shellfish, fish, and wildlife in and on Pool 14, thereby meeting the 316(a) standard for granting of the requested thermal variance.

While each of the appended documents contains important information supporting Exelon's request, this Summary and Appendices B and C are likely to be of particular interest to most readers. This Summary describes the extensive body of technical information supporting the requested thermal variance and explains the historical and legal context for the variance request. Section 1 of the Summary provides important background material, and a brief overview of the hydrothermal, biothermal, and other biological studies that were performed. Section 2 describes current and past operations at Quad Cities Nuclear Station. Section 3 discusses the legal framework applicable to determinations under Section 316(a) and identifies the biological and technical data supporting Exelon's request for a variance. Section 4 discusses the criteria used in a 316(a) Demonstration to assess whether a balanced indigenous community of shellfish, fish, and wildlife has been and will be maintained in and on the receiving water body despite the Station's thermal discharge.

Appendix A describes in detail the Mississippi River in the vicinity of Pool 14 while Appendix B and C provide prospective and retrospective biothermal assessments, respectively. Appendix D describes the operations at QCNS while Appendix E summarizes the Station's data collection programs.

1.2 Background of Proposed Alternate Thermal Standards

Construction of Quad Cities Nuclear Station began in 1967. Both units began commercial operation in early 1973, a few months after promulgation of the Clean Water Act ("CWA") National Pollutant Discharge Elimination System ("NPDES") permit program. Since the NPDES program took effect, Quad Cities Nuclear Station has held an NPDES permit. Beginning in the early 1970s and continuing through the present day, the Station has worked closely with a Technical Advisory Committee ("TAC"), called the Quad Cities Steering Committee on matters related to the Station's NPDES permit.[1]

Thermal limits in the current NPDES Permit are based on Illinois environmental regulations, and studies and demonstrations performed under Section 316(a) of the Clean Water Act. The NPDES Permit defines the mixing zone boundary as a straight line across the Mississippi River, 500 feet downstream of the diffuser pipes, and compliance with the temperature standards in the NPDES Permit is measured at the end of this mixing zone boundary. The existing thermal standards and the proposed standards under the 316(a) variance are summarized in Table 1 and described in detail on pages B-2 and B-3 of Appendix B.

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[1] The TAC is comprised of: USEPA Region V, ILEPA, USACE, USF&WS, ILDNR, IADNR, Office of IL Attorney General, Southern Illinois U. Carbondale, IL Natural History Survey, Isaac Walton League of America, United Autoworkers Union, , Mensinger Aquatic Resources, Exelon Corp., MidAmerica Energy, Dr. Roy Heidinger, Mr. James Mayhew, and Mr. Larry LaJeone.

Table 1. Existing and Proposed Alternative Thermal Standards for Quad Cities Nuclear Station

End of Mixing Zone Temperature Criterion[1]			
Month	**Excursion Threshold Temperature[2]**	**Current** Maximum Excursion Temperature	**Proposed** Maximum Excursion Temperature
January	45°F	48°F	No Change
February	45°F	48°F	No Change
March	57°F	60°F	No Change
April	68°F	71°F	No Change
May	78°F	81°F	No Change
June	85°F	88°F	No Change
July	86°F	89°F	91°F
August	86°F	89°F	91°F
September	85°F	88°F	90°F
October	75°F	78°F	No Change
November	65°F	68°F	No Change
December	52°F	55°F	No Change

Temperature Tacking Method		**Allowable Excursion Hours**	
Current	**Proposed**	**Current**	**Proposed**
Rolling 12-month basis	Calendar year basis (January to December)	1% (87.6 hours)	2.5% (219 hours) of which 1.5% (131.4 hours) may cause 5 °F increases in July, August and September.

[1] The NPDES Permit defines the mixing zone boundary as a straight line across the Mississippi River, 500 feet downstream of the diffuser pipes.

[2] No change in these values is proposed.

1.2.1 Excursion Hours

The Clean Water Act requires that an applicant for a thermal variance (or alternate thermal standards) demonstrate that the generally applicable standards are more stringent than necessary to assure the protection and propagation of a balanced indigenous population [community] of shellfish, fish, and wildlife in and on the body of water into which the discharge is to be made. Many of the studies that comprise this Demonstration were conducted to evaluate increasing the number of excursion hours available to QCNS on an annual basis from 1% (87.6 hours) to 3% (262.8 hours). As shown in this Demonstration (based on comprehensive biological, historical, and hydrothermal evaluations), the fish and shellfish populations in Pool 14 will be adequately protected if the Station is allowed an increase of excursion hours from 1% to 3%.

However, during the 28-year QCNS open cycle operating history the Station never utilized more than approximately 2.5% excursion hours during a summer season.[2] That occurred during the summers of 2006 and 2012. For that reason, rather than seeking an excursion hour increase to 3%, Exelon is limiting its request to 2.5% excursion hours (219 hours). It follows that a 2.5% standard, being more stringent than the 3% standard on which many of the analyses in this Demonstration are based, will also "assure the protection and propagation of a balanced indigenous community of shellfish and fish" in Pool 14.

1.2.2 Zone of Passage

The portions of cross-sectional area or volume of flow of the receiving steam not included in a mixing zone is termed the zone of passage (ZOP). Illinois regulation provides that the ZOP contain at least 75% of the cross-sectional area or volume of flow. In 1978, the Illinois Pollution Control Board determined that Station discharges were not reasonably expected to cause significant ecological damage to the river. As a result, the Station has not restricted plant operations for ZOP purposes.

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[2] During March 2012, record breaking air temperatures caused the upstream water temperature at Lock and Dam 13 to reach and exceed the monthly excursion temperature threshold of 57 °F. As a result, during the period March 18 through March 29, 2012 QCNS used a total of 223.5 excursion hours, 168.9 of which were accumulated under a provisional variance. During the summer of 2012 (June – September) 219 (2.5%) excursion hours were used.

Modeling studies (Jain, 2002) have quantified the relationship between river flow and the zone of passage. Table C-1 (Appendix C) shows that based on Jain's modeling studies, with the plant operating at full capacity, the ZOP will be less than 75% at a river flow of 16,400 cfs. Flow records indicate that over the past 26 years, river flows have been less than 16,400 cfs on 209 days with only 25 of those days occurring during March, April, May, or October, the biologically important months in terms of fish movement (Haas, 2011). The retrospective analysis in Appendix C demonstrates that these historical episodes when ZOP has been less than 75% have not caused appreciable harm to the biological indigenous community in Pool 14. The prospective analysis (Appendix B Section 1.1) demonstrates that a ZOP of 66% will be protective of the BIC in the future. To assure that a ZOP of 66% or higher will be maintained, Exelon has committed to derating of QCNS when river flows reach levels that are predicted to result in ZOP values of 66% or less (Section 2.9.3 of Appendix C).

1.2.3 Twelve –month Tracking of Excursion Hours

Exelon is requesting that it be allowed to track excursion hours on a calendar year basis instead of over a 12-month rolling period. This change in the way in which excursion hours are tracked should have no biological consequence or impact. Excursion hours have been tracked at QCNS for the past 28 years (1983-2011). During that time, excursion hours have occurred exclusively during the March-August period. There is virtually no possibility that Exelon would use excursion hours in December or January, that is, at the end of one calendar year and the beginning of another. Thus, there should be no concern that tracking excursion hours at QCNS would result in allowing the plant to use two years of allotted hours over a two or three month contiguous period.

1.3 Exelon's Contributions to the Well-Being of Pool 14

Recognizing the value of the Mississippi River Pool 14 ecosystem, Exelon is committed to maintaining and improving the health of the Pool. Some of the specific actions Exelon has taken and is taking to address the health of Pool 14 include:

- Operation of Fish Hatchery/Stocking Program
- Long-Term Aquatic Monitoring Program
- Freshwater Mussel Monitoring Program
- Zebra Mussel Monitoring Program.

1.4 Summary of data collection and analyses

The Station, a team of distinguished scientists[3], and the TAC have worked together to identify and implement the data collection, study, and analysis requirements for considering possible impacts on Pool 14 from Station operations. The focus of the work regarding Pool 14 has been to:

- Analyze current and historical background conditions
- Identify and analyze trends in fish abundance
- Analyze historic and future impacts of Quad Cities Nuclear Station
- Identify and evaluate the freshwater mussel community.

A substantial body of data and analyses utilizing sophisticated, state-of-the-science analytical tools has resulted from these efforts. Some of this information has been presented to and discussed with Illinois Environmental Protection Agency ("ILEPA"), USEPA Region V, Illinois Department of Natural Resources ("ILDNR"), Iowa Department of Natural Resources ("IADNR"), and the TAC. Some of the analyses underlying prior submittals have now been refined, updated, and/or revised. New data and analyses are described in this Summary and are presented in detail in the accompanying Appendices. For a description of the studies that have been performed by the Station see Appendix E.

Data has been collected since 1984 by HDR Engineering, Inc. ("HDR"), the Iowa Institute of Hydraulic Research (IIHR), and Ecological Specialists, Inc. (ESI). Analyses of available data collected by HDR, ESI, and other individuals and organizations, as well as comprehensive literature reviews have been performed by HDR, Forrest Holly[4] and Heidi Dunn (ESI)[5]. These efforts include extensive hydrothermal modeling of Pool 14 which provides important input to the biothermal assessment model developed and applied by HDR to determine the effects of the Station's thermal discharge on fish in the Mississippi River.

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[3] The team includes: HDR Inc., Southern Illinois University, Forrest Holly and Associates, and Ecological Specialists Inc.

[4] Forrest Holly formerly of IIHR and now of Forrest Holly & Associates

[5] Ms. Dunn is President of Environmental Specialists, Inc.

The Station's 316(a) variance application and supporting demonstrations are predicated on this substantial body of data and analyses. The primary data sources are described below.

1.4.1 Water Quality

Sullivan et al. (2002) compiled Upper Mississippi River (UMR) water quality data from federal, state and local agencies that conducted monitoring on the river over the period 1980-2008. Three sites from Pool 14 are included in these data. The major objectives of this effort were to increase coordination and cooperation among monitoring agencies, develop a unified database of relevant water quality information, and to use these data to produce an assessment of the UMR water quality.

1.4.2 Thermal Surveys

Several thermal studies have been conducted in Pool 14 throughout the history of Quad Cities Nuclear Station including a combination of vertical thermal profiling and infrared aerial photography which were used to calibrate the hydrothermal model described in the next section.

1.4.3 Hydrothermal Modeling

IIHR Hydroscience & Engineering simulated the Station's thermal plume using a three-dimensional (3-D) Computational Fluid Dynamics (CFD) model. The IIHR modeling effort included the following major components (as detailed in the IIHR Report, 2004):

1. Inclusion of relevant river-training structures, namely wing dams and the cross-channel closure dam in the Steamboat Slough, in the model bathymetry to better reflect real-world conditions. The resultant model grid contained nearly two million points.

2. Simulation of conditions corresponding to the HDR September 2003 thermal survey field effort, which validated the model's ability to predict the observed thermal conditions.

3. Simulation of station operations at maximum power for a series of relatively low Mississippi River flows.

4. Provision of temperature, depth, and velocity results from the multiple simulations to HDR to serve as input for the biothermal model.

5. Supplemental thermal analysis was conducted to relate measured sediment temperatures to the hydrothermal modeling (July 2007).

1.4.4 Phytoplankton

Phytoplankton studies were conducted in conjunction with and at the same locations as zooplankton studies from August 1972 through August 1973. During this period, both reactor units were in the open cycle operation mode with the two diffuser pipes employed to diffuse waste heat into the river (ComEd, 1975).

Composite phytoplankton samples were collected, preserved, and transported to a laboratory where abundance, biomass, chlorophyll *a,* and carbon fixation rates were determined. Analysis of variance was performed to identify differences in phytoplankton productivity between the intake and discharge locations and between river locations above and below the diffuser pipe discharge system.

1.4.5 Zooplankton

Zooplankton entrainment studies were conducted at Quad Cities Nuclear Station from mid-September 1972 through early August 1973, a period during which the full thermal, mechanical and chemical stresses of entrainment could be assessed, because both reactor units were in operation in the open cycle mode with the two diffuser pipes employed to diffuse waste heat into the river (ComEd, 1975).

Samples were also collected with a filter-pump system near the surface at the Station intake and from the discharge bay where condenser water entered the diffuser pipes. River locations were sampled about 1,600 feet upstream of and at approximately 375, 4,000, and 8,000 feet downstream of the diffuser pipes (ComEd, 1975).

1.4.6 Benthic Macroinvertebrates

Drifting invertebrates were sampled monthly from late March to early July 1972, primarily at the edge of the channel offshore of the station. In 2004, Exelon established a monitoring program using quantitative and qualitative techniques for freshwater unionids near the Station's thermal discharge diffuser. The program includes monitoring three beds both upstream and downstream of the diffuser pipes in July and October. These three beds were last monitored in 2008. All of these mussel sampling programs were conducted via scuba by Ecological Specialists, Inc.

Quantitative samples are collected to estimate density, relative abundance, age structure and mortality, parameters used for spatial and temporal comparisons of unionid communities for management and impact analysis. A standard quantitative sample consists of 90 0.25 m^2, 15-cm deep quadrat samples taken randomly within the bed using GIS, which are then plotted on a GPS Depthfinder. All materials are hoisted to the boat in a 6-mm bag where the contents are removed and identified accordingly.

Qualitative sampling is a visual and tactile search for unionids and by design is often biased towards large and sculptured animals. The diver takes a 5-minute interval to collect all mussels at a location along with pertinent water quality information. Usually 25 sites are selected for sampling within the bed.

1.4.7 Ichthyoplankton

Ichthyoplankton (fish eggs and larvae) were studied intensively in the vicinity of the Station from 1975 through 1985. The design of the program used after the return to open cycle cooling in 1984 included sampling three locations (near Illinois bank, main channel, and near Iowa bank) on a transect that extended from a point upstream of the intake channel on the Illinois bank to a point upstream of the confluence of the Wapsipinicon River on the Iowa shoreline. Samples were collected one meter below the surface and one meter above the bottom at each river location and were also collected one meter below the surface at one location in the discharge bay. Samples were collected in quadruplicate at each location on a weekly basis for a period of 16 weeks beginning in mid-April. A total of 448 samples were collected annually during 1984 and 1985.

1.4.8 Finfish

The Quad Cities Pool 14 fish monitoring program currently contains four different study plans:

- Adult and juvenile fish long-term monitoring.
- Freshwater drum life history and population dynamics study.
- Channel catfish, flathead catfish, walleye and sauger studies.
- Stocking assessment.

Each program is described briefly in the sections that follow.

1.4.8.1 Adult and juvenile fish long-term monitoring

Adult and juvenile fish monitoring has been conducted in Pool 14 in the area of the Station since 1971. The program was modified several times during the 1971-1977 period to address specific objectives related to Station operation. In 1978, results of the previous years' studies were reviewed and those sampling techniques (electrofishing and trawling) and sample locations that had the greatest continuity since 1971 were selected to be included in the long-term monitoring program. Locations were selected based on their continuity to evaluate trends in the species composition and dominant species of Pool 14. At the suggestion of the IADNR, an additional collection method (haul seine) was added to provide relative abundance estimates for several species deemed not to have been adequately collected in previous studies. The haul seine also provides a means of sampling for several species utilizing the side channel and slough habitats. Population estimates of catfish using hoop nets were added in 1982 as an additional component. The entire data base (1971-1994) was re-evaluated in 1995 and it was determined that bottom trawling and hoop netting were not providing new insights regarding the structure of the fish community or the plant's effect on it. Consequently, both these elements were deleted from the program beginning with the 1996 sampling year.

1.4.8.2 Freshwater Drum Life History and Population Dynamics Study

In 1978, at the recommendation of the ILDNR, freshwater drum was selected for intensive study to determine whether Station operation may be affecting population levels and growth of this species in Pool 14. Freshwater drum were the subject of this focused study because it is the only species in Pool 14 that has a truly planktonic egg stage and its larvae frequently represent the greatest percentage of ichthyoplankton drift resulting in the potential for population level effects if high percentages of its early life history stages are being lost through entrainment. Impingement also has the potential to affect population levels because freshwater drum has had the second highest impingement rate at the Station (Hazleton Environmental Sciences, 1979).

Since 1978, a variety of population parameters have been studied including standing stock, age class distribution, annual growth rates, fecundity, total annual mortality, and impingement exploitation rates. Refinements and adjustments to the freshwater drum life history program have been made during the past 31 years.

The most recent modification to the freshwater drum life history program occurred in 1993. The fecundity analysis portion of the study was deleted on the basis that ten years of data were more than adequate to determine mean fecundity for the species and that no measurable changes in fecundity had occurred as a result of Station operation.

1.4.8.3 Channel Catfish, Flathead Catfish, Walleye/Sauger Studies

Spring hoop and lead net studies conducted from 1982 to the present and directed toward freshwater drum life history and population assessments have also yielded considerable numbers of channel and flathead catfish. Consequently, ongoing life history studies were amended in 1983 to include a tagging study for channel and flathead catfish aimed at monitoring the extent of their movement and to provide an estimate of their standing crop in those same areas surveyed for freshwater drum. The tagging studies have not been conducted since 1995. However, both species continue to be monitored as part of the freshwater drum studies. Based on 25 years of monitoring, population levels and standing crop of both species have increased in Pool 14.

As a further supplement to the freshwater drum life history study and the catfish population study, a tagging program for walleye and sauger was initiated in 1984. The addition of this program to the monitoring effort was prompted by ILDNR's interest in habitat preference and utilization by walleye and sauger, and the need to develop a database on walleye in anticipation of future stocking activities in Pool 14. Too few fish of either species have been captured to date to satisfy program objectives.

1.4.8.4 Fall Stock Assessment

In 1984, under the auspices of the IADNR and the ILDNR, the inactive spray canal surrounding the Station was converted into a game fish production facility through a grant to Southern Illinois University. Species chosen for rearing were hybrid striped bass and walleye, with annual stocking objectives of 175,000 advanced fingerlings of each species for Pools 13 & 14. Production of both species has been variable from year to year, but since 1984 in excess of 4.5 million walleye and 700,000 hybrid striped bass fingerlings have been stocked in the Mississippi River.

As a result of past stocking in Pool 14 and to provide information for future stockings, the standard monitoring program was expanded to include additional analyses and sampling. Several basic elements of the long-term fisheries monitoring program (electrofishing, hoop netting and haul seining) document the relative contributions of these stocking efforts in habitats near Quad Cities Nuclear Station. However, both hybrid striped bass and walleye utilize tailwater areas both upstream and downstream from the Station rather extensively and historic monitoring programs had not included these areas. Dialogue with IADNR and ILDNR resulted in the addition of a special fall tailwater electrofishing survey to the 1984 monitoring program. That effort was expanded over a broader time frame in 1985 and continues through the present.

1.5 The comprehensive biological and hydrothermal evaluations justify granting a thermal variance

As discussed in more detail below, issuance of a 316(a) variance requires that Exelon demonstrate that future operations of Quad Cities Nuclear Station in accordance with the proposed alternative thermal standard set forth in Table 1 will assure the protection and propagation of a balanced indigenous community (BIC) of fish, wildlife, and shellfish.

To evaluate the Station's historic and prospective impacts on Pool 14, a number of comprehensive, state-of-the-science studies were conducted. The various comprehensive analyses confirm that the Station's operations have caused no prior appreciable harm to the BIC (Appendix C) and that future operations under the proposed alternative thermal standard will be protective of the BIC (Appendix B). As is shown by this Demonstration, operation of the Station under the alternative thermal standard proposed in Table 1 will adequately safeguard the populations of Pool 14. Accordingly, issuance of the requested alternative thermal standard as set forth in Section 2 of this summary is warranted.

2.0 DESCRIPTION OF QUAD CITIES NUCLEAR STATION OPERATIONS: PAST, PRESENT, FUTURE

2.1 Introduction

Construction of Quad Cities Nuclear Station began in the late 1960s on approximately 920 acres in Rock Island County, Illinois on the east bank of the Mississippi River, approximately three miles north of Cordova, Illinois, 20 miles northeast of the Quad Cities Metropolitan Area of Davenport, Iowa, Rock Island, Moline, and East Moline, Illinois and seven miles southwest of Clinton, Iowa. The Station is located on Pool 14 of the Mississippi River, at approximate River Mile 506.5 above the confluence of the Ohio River.

Quad Cities Nuclear Station is designed to operate 24 hours a day, seven days a week, with two generating units. Each unit's maximum power level is 2,957 megawatts thermal (MWt), for a combined thermal output of 5,914 MWt. This level of MWt will not be increased as a result of issuance of a revised ATS (see Appendix D, page D-2 for further discussion). Steam, which is produced at high temperature and pressure in the boiler, is exhausted from the turbine of each generating unit and condensed using non-contact cooling water from the Mississippi River. After passing through the condensers, cooling water from Units 1 and 2 mixes and then exits to the discharge canal. The Station also withdraws a small amount of service water. The condensers for Units 1 and 2 are treated daily with sodium hypochlorite to control the growth of micro-fouling organisms. The Station's NPDES permit allows for biocide treatment of each unit's circulating water system (condenser cooling) a with sodium bromide and/or sodium hypochlorite with a maximum instantaneous total residual chlorine/total residual oxidant (TRC/TRO) concentration of 0.05 ppm discharged to the river. Sodium hypochlorite is normally used as the sole biocide for treatment of the circulating water system. Circulating water is also continuously treated with a scale inhibitor 365 days per year.

The history of operations at Quad Cities Nuclear Station since commercial startup in 1972 is summarized below.

2.1.1 1972-1974 (May): Open Cycle Cooling with Shoreline-Jet Side Canal/Diffusers

The Station began operation in January 1972, when low power testing was initiated. Following low power testing, in early April 1972, startup testing began and was continued until August 1972. From January until August 1972, cooling water was withdrawn from the Mississippi River, circulated through the condenser cooling system, and discharged through a shoreline-jet discharge canal (the current discharge bay was open to the river, west of the lift Station).

A diffuser system was installed in the Mississippi River in 1972 as an interim mode of discharge until the spray canal (closed-cycle cooling) was completed. This diffuser system consists of two 16-foot diameter multi-riser manifolds that are buried in the riverbed. Open cycle, two-pipe diffuser operation began in August 1972, at which time the use of the side-jet discharge was permanently discontinued. The diffuser mode of operation continued until May 1, 1974.

2.1.2 1974/75-1979: Closed Cycle Cooling

In accordance with an agreement signed in 1972, operation of the spray canal commenced on May 1, 1974, with the Station operating with the equivalent of one unit discharging cooling water to the canal and one unit discharging directly to the river. This mode of operation continued until May 1, 1975, when cooling water from both units was routed to the canal (closed-cycle). Electrical energy to operate the spray canal (328 spray pumps and 5 lift pumps) required approximately 29 MW. Similarly, the warm water returning from the spray canal reduced turbine efficiency and resulted in significant loss of production of electricity during summer months. Due to these combined losses of electricity available to the grid during operation of the spray canal during the summer months, Commonwealth Edison sought relief from operating in the closed-cycle mode. Closed-cycle operation continued until August 2, 1979.

2.1.3 1979-1983: Partial Open Cycle Cooling

On August 2, 1979, the Station received a new NPDES permit that allowed partial open-cycle operation of the condenser cooling system at times when the temperature of the water returning from the spray canal to the intake exceeded 93°F. Operation of the Station in the partial open-cycle mode was also subject to an interim modification, effective August 27, 1979, to the closed-cycle agreement which allowed the Station to operate in partial open-cycle mode to avoid substantial capacity losses. Operation in the partial open-cycle mode continued until December 23, 1983.

2.1.4 1983-Present: Open Cycle Cooling

The Station commenced the current full open cycle mode of operation via the diffuser pipes on December 23, 1983. The open-cycle agreement was signed on October 11, 1983 and approval from the ILEPA for open-cycle mode of operation was received on December 23, 1983. The Station has been operating in this mode since December 23, 1983.

2.2 Proposed Thermal Standard Conditions

Quad Cities Nuclear Station employs once-through-cooling, which entails a discharge of heated effluent to the Mississippi River.[6] This thermal discharge is authorized under the Station's

[6] Located on Navigation Pool 14 of the Mississippi River near Cordova, IL.

NPDES Permit, issued by the ILEPA. Thermal limits in the NPDES Permit are based on Illinois environmental regulations, and studies and Demonstrations related to the thermal plume, performed under Section 316(a) of the Federal Clean Water Act.

The NPDES Permit defines the mixing zone boundary as a straight line across the Mississippi River, 500 feet downstream of the diffuser pipes, and compliance with the temperature standards in the NPDES Permit is measured at the end of this mixing zone boundary. The NPDES Permit (and Illinois regulations) requires that the discharge meets the following standards:

1. Fixed standard limiting the <u>change</u> in water temperature - Natural river water temperatures shall not be increased by more than 5°F at the downstream end of the mixing zone.

2. Variable standard defining the maximum monthly temperature <u>limit</u> – the monthly limits are set forth in Table 1.

3. Variable standard limiting the <u>duration</u> of elevated water temperatures – An exceedance of the monthly temperature thresholds (3°F less than the maximum limit) triggers the tracking of the time period elevated water temperatures occur (commonly referred to "excursion hours"). The plant is allowed to exceed the monthly temperature thresholds for up to 1% of the hours in a twelve month period ending with any month (e.g., in August, excursion hours occur when the water temperatures exceed 86°F [from Table 1]. The temperatures must still remain below the noted maximum limit (e.g., 89°F during August).

Exelon is proposing the following modification to these thermal standards:

1. Changing the method for tracking and regaining excursion hours from a rolling 12-month basis to a calendar year basis (January through December);

2. Increasing the number of excursion hours available per year from 1% (87.6 hours) to 2.5% (219 hours). .

3. Increasing the maximum excursion hour temperature limit to 5°F above the Table 1 Excursion Threshold Temperature (ETT) for up to 60% of the allotted excursion hours in July, August and September. During the balance of the allotted excursion hours, the maximum excursion hour temperature limit would remain at 3°F above the ETT.

4. Allowing a Zone of Passage of at least 66% of the cross-sectional area or volume of the river.

3.0 VARIANCE FOR THERMAL DISCHARGES UNDER CLEAN WATER ACT SECTION 316(a)

3.1 Legal standards governing issuance and effect of a variance under Section 316(a)

Congress determined that heat should be treated differently than other pollutants. Therefore, with respect to thermal discharges, Section 316(a) of the Clean Water Act establishes a flexible, case-by-case alternative to the uniform application of standards based on either a prescribed technology or water quality criteria.[7] Section 316(a) expressly provides that:

> "With respect to any point source otherwise subject to the provisions of section 301 of this title or section 306 of this title, whenever the owner or operator of any such source, after opportunity for public hearing, can demonstrate to the satisfaction of the Administrator (or, if appropriate, the State) that any effluent limitation proposed for the control of the thermal component of any discharge from such source will require effluent limitations more stringent than necessary to assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the body of water into which the discharge is to be made, the Administrator (or, if appropriate, the State) may impose an effluent limitation under such sections for such plant, with respect to the thermal component of such discharge (taking into account the interaction of such thermal component with other pollutants), that will assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on that body of water." (Emphasis supplied.)

During the 37 years since its enactment, EPA has consistently interpreted Section 316(a) to mean that a permittee will be granted a variance from otherwise applicable federal or state limits on its thermal discharge if the permittee provides "reasonable assurance" that would satisfy a "reasonable person" that a proposed alternative thermal limit will be consistent with the

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[7] *See* A Legislative History of the Water Pollution Control Act Amendments of 1972, *reprinted by* Congressional Research Service ("Legislative History") at 263 (1973) (Statement of Rep. Clausen); *id.* at p. 227 (Statement of Rep. Harsha) (Section 316 is "[i]ntended to provide modifications of effluent limitations or standards of performance under these other Sections [301, 302 and 306] because heat should be treated in a different manner than other pollutants").

protection and propagation of a balanced indigenous community ("BIC")[8] of biota in or on the receiving waterbody. This Demonstration makes the requisite showing, thereby entitling Exelon to a Section 316(a) variance for Quad Cities Nuclear Station.

3.1.1 Prospective and retrospective aspects of the 316(a) Demonstration.

In addition to showing that proposed alternate standards are protective of the BIC, the regulations implementing Section 316(a), allow an existing discharger to support a 316(a) variance based on the absence of prior appreciable harm. Specifically, such a demonstration must show:

> (i) That no appreciable harm has resulted from the ... discharge (taking into account the interaction of such thermal component with other pollutants) ... to the [BIC]; or
>
> (ii) That despite the occurrence of such previous harm, the desired alternative effluent limitations (or appropriate modifications therefore) will nevertheless assure the protection and propagation of a [BIC]....

40 C.F.R. § 125.73(c)(1).

Because the proposed alternate standards are only incrementally different from those that have been in place since December 23, 1983, and because past station operations (conducted pursuant to grants of temporary emergency relief) are similar to those that will be allowed under the proposed alternate standards, the retrospective Demonstration examines whether historical operations have caused any appreciable harm to the BIC.

Since early 1972, there have been numerous, comprehensive studies concerning the effects of Quad Cities Nuclear Station operations on the BIC. (See Appendices A, B, C and E.) These studies clearly show that the Station's historical impacts on the fish and freshwater mussel populations are negligible, particularly in relation to other stresses to these populations, including fishing pressure and zebra mussel infestations.

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[8] The statute uses the term "population"; the EPA regulations use the term "community." *See* 40 C.F.R. § 125.71. Recognizing that the biological term "community" consists of populations, EPA uses the terms "population" and "community" interchangeably. This Demonstration will use the EPA term "community."

In addition to the retrospective analysis, this Demonstration also includes a prospective analysis of the future effects of the Quad Cities Nuclear Station's thermal discharge under the proposed alternate thermal standards. The prospective analysis establishes that, going forward, Station operations under of the proposed alternate thermal standards will adequately protect the BIC.

As shown in this Demonstration, Illinois' standards are more stringent than necessary to protect the BIC and should be superseded by a variance authorizing Quad Cities Nuclear Station to discharge pursuant to the proposed alternate thermal standards. As will be demonstrated below and in the attached Appendices, operation of Quad Cities Nuclear Station pursuant to the proposed thermal standards will be protective of the BIC.

3.2 Results of the Prospective Assessment - Protection of balanced indigenous community

Section 316(a) of the CWA requires an applicant for a variance to demonstrate that the proposed permit limit on its thermal plume will "assure the protection and propagation of a balanced, indigenous population [community] of shellfish, fish, and wildlife in and on the body of water." For the prospective assessment, HDR conducted comprehensive literature surveys, analyzed field data collected by HDR and LMS,[9] used state-of-the-science hydrothermal models generated by Iowa Institute of Hydraulic Research and followed EPA and TAC protocols for assessing the impacts of heat on Representative Important Species (RIS) of fish. RIS species selected for this demonstration include largemouth bass, channel catfish, spotfin shiner, and walleye. River and plant operating conditions evaluated in this study were selected so that they would provide the basis for a stringent (i.e., conservative) assessment of potential plant-related biological effects. Because excursion hours occur during warm periods of the year, the biothermal assessment focused on the months of June, July, August, and September. The results indicate that the proposed thermal standard change will have a negligible impact on largemouth bass, channel catfish, and spotfin shiner. Spotfin shiner growth days may even be increased by the change. Walleye chronic mortality could be increased by 8.5% immediately downstream of the mixing

[9] The methodology, analysis, and results are explained in detail in Appendix B and summarized here. LMS was acquired by HDR in 2005.

zone, if one assumes no avoidance behavior (which is not realistic). Placed in the areal context of Pool 14, this would be less than a 1% effect on the walleye population in the Pool.[10]

Conservative values were selected for each of the major model input parameters to assure that the resultant thermal plume temperatures used in the analysis are representative of reasonable worst-case conditions. HDR reviewed Lock and Dam 13 temperature data provided by the Army Corps of Engineers for the October 1996 through April 2006 time period. The June through September 2006 time frame included periods of low river flow and warm summer temperatures. Actual river water temperatures recorded at Lock and Dam 13 (located about 12 miles upriver of the Station) during June through September 2006 were adjusted and used for ambient river temperature values. The Lock and Dam 13 temperatures were adjusted by increasing the temperatures exponentially with river flow to simulate conditions under the proposed alternate standards, i.e. exceeding 86°F at the end of mixing zone for 3.0% of annual hours and exceeding 89°F 1.5%[11] of the annual hours without exceeding 91°F. In this variable flow analysis, river flows recorded at Lock and Dam 13 during 2006 were used and the plant was assumed to operate at full capacity. A similar analysis was performed with fixed river flows ranging from the 7Q10 rate (13,800 cfs) to more typical summertime flows (30,000 cfs). While the variable flow scenario represents the worst case thermal condition under the proposed standard, the fixed flow scenarios provide results over a range of excursion hours that may be typical of less extreme conditions.

The scenario utilizing actual daily river flows (i.e., variable flows) provides the assessment of biological effects that would result under the most extreme conditions that would be allowed if proposed alternate thermal standards were granted, i.e., excursion hours of 3.0% and 1.5% for 86°F and 89°F, respectively. One additional analysis was also performed to quantify the thermal effects (if any) from ambient temperature alone (i.e., with no thermal discharge). This analysis provides the basis for determining what portion of the predicted thermal effects should be assigned to plant operations, versus those caused by the natural variation in ambient river temperatures.

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[10] The Prospective Assessment presented in Appendix B, and summarized here, evaluated increasing the number of excursion hours available to QCNS on an annual basis from 1% (87.6 hours) to 3% (262.8 hours). However, as explained in more detail in Section 1.2.1, Exelon is limiting its request to 2.5% excursion hours (219 hours). It follows that a 2.5% standard, being more stringent than the 3% standard evaluated in the Prospective Assessment would have would have even smaller effects on the RIS than those summarized here.

[11] Although the target percentage for exceedance of the 89°F EOMZ limit was 1.5%, the percentage is computed on a daily basis and exceedance of 5 days yields a 1.4% value ([5/365] * 100) while 6 days yields a 1.6% value ([6/365] * 100).

Results of the IIHR hydrothermal model at various levels of river flow were used in conjunction with the adjusted Lock and Dam 13 temperatures to predict temperatures in Pool 14 downstream of the discharge. These results were then compared to the individual temperature tolerances for each species analyzed. This analysis took into account both acclimation and exposure temperatures for each species in order to evaluate effects on three key biological functions: growth, avoidance, and chronic thermal mortality. See Appendix B.

To determine whether the Station's heat discharge under the proposed alternate thermal standard would cause any appreciable harm to any RIS, the analysis determined when and where in Pool 14 each species was located for each critical life function. Some species only spend a few months of the year in Pool 14; others move around in the Pool depending on whether they are spawning or growing.

Importantly, continued Station operation under the proposed alternative thermal standard will not impair the successful completion of life cycles of indigenous species, thus assuring the protection and propagation of a balanced, indigenous community as required under Section 316(a). Findings from the assessment are summarized below.

3.2.1 Temperature during critical growth seasons

Little change in growth for largemouth bass (less than 4%) and channel catfish (less than 1%) was predicted for all of the realizable scenarios evaluated. For spotfin shiner, it appears that the plume's higher temperatures expand the volume of water that falls within the normal temperature range for growth, and thus as the Station's thermal influence increased (i.e., at lower river flows and higher percent excursion hours), so did the predicted number of growth days. For walleye, a modest shift out of its normal temperature tolerance range is predicted, so an increase in the Station's allotted excursion hours from 1.0% to 3.0% of annual hours above 86°F and 1.4% above 89°F would increase the predicted number of lost growth days from 9.6 to 12.2 days; an increase of 2.6 days or 2.1% of total growth days for the 122 day period of study.

3.2.2 Thermal avoidance and habitat loss

The predicted overall average percentage of habitat avoided from June 1 to September 30 for all scenarios was relatively small (<2.0%) for channel catfish, largemouth bass and spotfin shiner. On the basis of this information, it was concluded that the proposed increase in percent excursion hours would not result in a material change in available habitat for these three species. Although sufficient acclimation/avoidance temperature data sets were not available to perform the same analysis for walleye, this "data gap" is addressed in Attachment 3 to Appendix B, which provides a supplemental analysis using data from the HDR Summertime Electro-fishing Program. Based on these observations, it is predicted that any displacement of walleye for either low flow or thermal reasons will be transitory and will not cause appreciable harm to the walleye population which inhabits Pool 14 or adjacent pools.

3.2.3 Predicted Chronic Mortality

The predicted chronic mortality for largemouth bass, channel catfish, and spotfin shiner is negligible. Increasing the percent of excursion hours over 86°F from 1.0% to 3.0% increased the predicted chronic mortality of walleye from 1.1% to 3.4% under the constant flow scenarios. This incremental increase of 2.3% under reasonable worst-case conditions is not expected to cause appreciable harm.

For the variable flow scenario, which simulates the most extreme excursion hour case under the proposed alternative standard, the predicted increase in chronic mortality over the current 1% standard is 8.5% (9.6-1.1%) and the predicted increase over the ambient condition is 9.5%. This assumes laboratory controlled conditions, i.e. no avoidance occurs. In the real world (e.g., Pool 14) walleye will, if possible, avoid stressful temperatures before they reach lethal levels. Given the fact that the Quad Cities Nuclear Station plume encompasses only a small portion of Pool 14 downstream of the diffuser, there should be ample opportunity for walleye to avoid lethal temperatures by moving into cooler waters. While some chronic mortality may occur with temperature working in concert with other stresses, e.g. disease or low dissolved oxygen levels, the increase over the current standard is expected to be substantially less than 8.5%. Daily inspections conducted both upstream and downstream of the diffusers during the excursion hour periods in 2006 and 2007 revealed very few dead or moribund walleye

3.2.4 Conclusions of Prospective Analysis

The proposed alternate thermal standard will not cause appreciable harm to the RIS evaluated. Furthermore, the low level of impacts predicted in this assessment for the RIS suggests that a 3% increase in excursion would be adequately protective of the overall fish community and that the requested 2.5% increase would be even more protective.. It is important to remember that the affected area represents only a small fraction of the total area of Pool 14 (approximately 8.5%). Thus the small predicted biothermal effects on the study area's fish populations are even more negligible when viewed within the context of the entirety of Pool 14 and the river wide populations of these species.

3.3 Results of Retrospective Demonstration – No Prior Appreciable Harm

3.3.1 Identification of the Relevant Communities

Over the years that 316(a) studies have been conducted, it has become evident that certain biological communities require more detailed study and evaluation than do others. For example, as a rule the fish community always requires detailed evaluation due to recreational and/or commercial fisheries. Depending on the nature of the receiving waters, certain of the lower trophic level communities, e.g. phytoplankton and zooplankton, may not require detailed investigation due to heterogeneity of distribution, short regeneration times, and seasonality. In addition, these communities function as a source of food for various life stages of fish populations. Thus, any permanent adverse effects on these lower trophic level communities would be reflected in an adverse shift (imbalance) in the fish community.

It is generally agreed by the resource agencies that within the Station's discharge area, freshwater unionid mussel communities require a high priority of protection and warrant detailed evaluation under 316(a). For these reasons, the primary emphasis for this demonstration has been on the freshwater unionid mussel and fish communities.

3.3.1.1 Lower Trophic Levels

Although no studies were conducted to monitor the lower trophic levels (phytoplankton, zooplankton, and non-mussel benthic macroinvertebrates) between the early 1970s and the present, it is possible to reach conclusions about their status in Pool 14, both retrospectively and prospectively. Two communities that rely on these lower trophic levels as a basis for their food supply, either directly or indirectly are freshwater mussels and finfish. Both of these communities are discussed in depth retrospectively in this demonstration and the same conclusion is reached for both, i.e., operation of the Station since late 1983 has not caused appreciable harm to these balanced, indigenous communities. This demonstrates that an adequate food supply (plankton and invertebrates) has been available.

In addition, during the operating history of the Quad Cities Nuclear Station, there have been periods during which thermal conditions in the receiving waters have been similar to conditions that could result from operations under the proposed alternate thermal standards, particularly during the Summer of 2006. If the thermal conditions of 2006 had had adverse effects on the lower trophic levels, the fish and mussel communities should have manifested the effect of reduced food supply. However, no such effects were observed. The constant supply of planktonic organisms drifting downriver and their ability to quickly reproduce ensures that an adequate food supply is continually available and that any losses are quickly replaced. Taken together, these observations suggest no appreciable harm has occurred to the lower trophic levels under the current thermal standard and none will result from the small increment in added heat that could result if the proposed standard is implemented.

3.3.1.2 Freshwater Mussels

In 2007, a study was undertaken by Environmental Specialists, Inc. to define the balanced indigenous community within Pool 14 of the Mississippi River, MRM 515 to 495 (ESI, 2009). Preliminary sampling was conducted in June 2007 to identify unionid beds upstream and downstream of the thermal diffuser located at approximately MRM 506.4. A total of 15 beds was sampled with certain beds selected for more intense sampling and evaluation. Habitat and water quality information was collected for all intensively sampled beds, and substrate temperature and fish communities were sampled in the Upstream (UP), Steamboat Slough (SS), and Cordova Beds. The SS unionid bed, located on the Iowa bank at MRM 505.6, is the most proximate downstream bed to the Station's thermal diffuser. The Cordova Bed, which is listed as an Essential Habitat Area for *Lampsilis higginsii* by USFWS, is further downstream, about one mile from the diffuser. The federally endangered *Lampsilis higginsii* was most abundant in the Albany (upstream) and Cordova beds, but was found in seven of the 15 beds sampled.

In summary, unionid beds were found throughout the study area in a variety of habitats and both upstream and downstream of the QCNS. One unionid bed, the SS Bed, occurs in the immediate vicinity of the QCNS thermal diffuser. Density within this bed is similar to beds both upstream and further downstream of the diffuser with similar habitat characteristics. Unionid and fish communities within the SS Bed reflect habitat conditions, as similar communities were found in similar habitats both upstream and downstream of the diffuser. Based on the results of this study, if QCNS had not operated, the unionid community within the SS Bed would likely be similar to the community that presently exists in the bed. Likewise, the community characteristics of the other unionid beds located downstream of the plant are very similar to those observed in upstream beds that have comparable habitats. Mussel monitoring in 2004 thru 2008 indicated that some mortality occurred in 2006; however, mortality was higher in the bed upstream of the diffusers (UP bed) than in the bed located downstream of and nearest the diffusers (SS bed)

(Heidi Dunn, personal communication, 2011). In sum, based on the results of ESI's investigation and studies, QCNS operations have not harmed the unionid community in Pool 14. In addition, the unionid community in the area of the QCNS discharge, and in Pool 14, can generally be described as healthy, balanced, and composed of the indigenous species of unionids one would expect to find at this location. This finding, combined with the fact that thermal exposures experienced by the unionid community during the 2006 high ambient temperature/low river flow episode are comparable to thermal exposures that would be permitted under the proposed alternate thermal standards, supports the conclusion that the proposed thermal standards will adequately protect the balanced indigenous unionid community in the QCNS receiving waters.

3.3.1.3 Fish

3.3.1.3.1 Ichthyoplankton

Ichthyoplankton include the eggs and larvae of fish. Based on data collected during river fish larval monitoring (LMS 1985 and LMS 1986), peak larval drift tends to occur at ambient river temperatures in the range of 21 to 23°C (69.8 to 73.4° F) and when river flows are relatively high, which suggests that they are not exposed to temperatures high enough or for sufficient duration to cause thermally-induced mortality at the end of the mixing zone where temperatures would range from 74.8 to 78.4°F.

During the period of ichthyoplankton sampling (1978 through 1985), the majority of the eggs and larvae drifting by the Station were those of freshwater drum. The highest concentrations of these were found near the Illinois shoreline, an area in which the diffuser pipe ports are closed to approximately 840 feet offshore. Also, 95% of the freshwater drum egg drift occurs before July 2, with the peak occurring before June 5 (LMS, 1985). The peak freshwater drum larval drift occurs before June 15 (LMS, 1985). An increase in excursion hours or thermal limits (which are not being requested for June) will have a negligible effect on eggs and larvae of this species. Another species that contributes substantially to the larval drift is gizzard shad, which tend to drift closer to the Iowa shoreline where they are exposed to the thermal plume. However, based on the numbers of gizzard shad captured in the monitoring program for the past 28 years and observations of those that die natural deaths during the winters, the gizzard shad population in Pool 14 and adjacent pools has not been harmed by the thermal addition and it is not expected to be harmed by the small increment in added heat that could result if the proposed thermal standard is implemented.

3.3.1.3.2 Adults

Trends evident in the long-term electrofishing fish monitoring database covering the past 41 years include increases in numbers of freshwater drum, channel catfish, largemouth bass, and bluegill and decreases in the numbers of white crappie, black crappie, and sauger, while flathead catfish abundance has been relatively without trend[12]. These long-term sampling trends are apparent at locations both upstream and downstream of the diffuser pipes and most likely are the product of fixed locations that have undergone substantial habitat changes such as backwater siltation and the appearance of beds of rooted aquatic plants that was coincident with a noticeable increase in water clarity. Abundances of two species targeted by commercial fishermen, common carp and river carpsucker, have declined somewhat over the period of record. Changes in fishing regulations (e.g. increases in channel catfish length limits) by one or more of the resource agencies may have also influenced these trends.

Over the past 41 years, a total of 94 taxa have been collected. During most years the number collected has ranged from 50 to 60 taxa and has been reasonably stable over the 28 years of open cycle cooling.

Age analysis indicates that freshwater drum is long-lived in Pool 14, often exceeding age 20 and occasionally age 30. Annual adult survival has averaged between 70 and 75% for the past 29 years. Maximum theoretical growth has steadily increased since 1983. Standing stock estimates of freshwater drum equal to or greater than 150 mm (TL) vary among years because this metric is driven by population estimates and year class strength (HDR, 2011).

Haul seine catches are dominated by large gizzard shad and freshwater drum. Meaningful trends cannot be identified because haul seining is primarily a qualitative sampling operation that is influenced by a large number of variables which cannot be controlled.

2006 Mooneye Mortality Event

During July and early August of 2006 Illinois experienced a period of very hot weather. Upon being advised by the U.S. Army Corps of Engineers on July 31, 2006 that they were going to drop the flow in Pool 14 by 46% from 23,300 cfs to 12,700 cfs. QCNS initiated the derating process. The Station derated up to 50% and did not restore full plant power production until after the Corps restored river flows to pre-event levels (about 23,000 cfs) on August 3, 2006. On August 1, 2006 distressed and dead fish were observed both above and below the plant and Illinois DNR was notified of the event. Exelon personnel documented that during the August 1-3, 2006 period, 215 (73.7%) of the 292 dead fish counted at all upstream and downstream stations

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[12] Trends in walleye are not monitored in this program because this species is stocked annually in Pool 14.

were mooneye. Three species of dead fish (sauger, smallmouth buffalo, bigmouth buffalo) were found only upstream of the plant. Seven of the 15 species of the dead fish collected during August 1-3 were represented by only one specimen. The sampling station (station 13) downstream from the plant where the highest number of dead mooneye was counted is an area of high deposition due to prevailing westerly winds and the morphology of the river. Little or no dead fish were collected at the two other sampling stations (9 and 11) directly below the diffuser. USACE data from rivergages.com indicated that during the August 1-3, 2006 period southwesterly, westerly, and northwesterly winds were gusting at 21-26 mph. Therefore, fish counted in the station 13 area likely originated not only below the Station, but from upriver as well. Steamboat Slough (stations 9 and 11) had higher water temperatures, but far fewer dead fish than did station 13, as the Slough is much less influenced by wind.

The temporal pattern of abundance of mooneye in QCNS impingement samples can aid in determining the spatial distribution of the mooneye mortality. As expected, during the August 1-3, 2006 event, the numbers of mooneye in impingement collections (August 2-3, 2006) showed a marked increase above the background levels observed in the preceding weeks and prior summers. One week after the event (August 9-10, 2006), when river flows had been restored and water temperatures had returned to normal levels, the number of mooneye collected in impingement samples was only 25% less than during the event, i.e., still well above pre-event levels. The numbers of mooneye collected in impingement samples did not return to levels close to those normally observed during the summer until August 16-17, 2006. These observations strongly suggest that dead mooneye continued to float into the QCNS intake area from upstream for over a week after the August 1-3, 2006 die-off and nearly a week after flows and temperatures had returned to normal. This means the die-off occurred not only in the vicinity of the plant but also well-upstream of the discharge. Apparently, as a result of the low river flows during the first few days of August, ambient water temperatures outside the influence of the plant's discharge, i.e., well upstream, reached levels that caused increased mortality of mooneye. As a result, it is difficult to determine to what extent the plant's discharge contributed to the mooneye die-off.

Average annual mortality is a term used to account for the many causes from which fish die naturally each year (e.g. parasites, bacterial, fungal and viral diseases, predation, old age, low flow, high ambient temperatures). Estimates of the annual mortality rate of mooneye are not readily available, however, a very conservative (i.e., biased low) estimate is the 30% average mortality rate for freshwater drum derived from the longterm monitoring of fish abundance in Pool 14 (HDR, 2011). The mooneye mortality rate is likely much lower because they are much shorter lived than drum which live 3-4 times as long.

The standing stock of mooneye in terms of biomass in Pool 14 can be estimated from the haul seine program conducted in the Pool each year. The seine program catches indicate average mooneye abundance of 1.15 lb/acre in the side channel habitat. Slough habitat sampling suggests higher abundance per acre so a conservative estimate of mooneye abundance can be derived by applying the side channel number over the entire 10,412 acres in the pool. Applying the 30% annual mortality rate to this number gives an estimate of mooneye mortality, in the absence of extreme events like that in 2006, of 0.34 lb/acre or 3,540 lbs.

An estimate of mooneye mortality possibly influenced by station operations during the August 1-3, 2006 event can be derived from the biomass of dead mooneye collected at all stations below the plant and the area sampled (93.64 acres). Dividing the 41.1 pounds of dead mooneye collected, by the 93.64 acres sampled, gives 0.44 lb/acre. The study area over which the thermal effects of the plume might be detected has been defined as covering 885 acres downstream of the plant. Making the very conservative assumption that mooneye might be affected over this entire area results in an estimate of mooneye mortality of 389 lbs. (0.44lb/acre*885 acres) within the study area. These 389 lbs represent only 10.9% of the 3,540 lbs of average annual mooneye mortality in Pool 14, calculated as described above. Furthermore, this 10.9% figure is likely a considerable overestimate because the 30% average annual mortality rate used in its calculation is probably a considerable underestimate of actual mooneye natural mortality rate.

It should be noted that the mooneye standing stock estimate for the fall of 2006, i.e., immediately after the August event, was 1.1 lb/acre, very close to the 1.15 average for the period 1986-2009. In the fall of 2007 the estimate of mooneye standing stock was 3.3 lb/acre. These data further support the conclusion that the August 2006 mooneye mortality event was of no biological consequence to the mooneye population in Pool 14.

The above information suggests that the thermal additions that have occurred since the return to open cycle cooling (1983) have caused no appreciable harm to the finfish in Pool 14 and that the requested modifications to the thermal standards will assure the protection and propagation of a balanced indigenous community of finfish in the Pool.

Monitoring During 2012 Excursion Hours

During July 2012 Illinois experienced a period of very hot weather that resulted in the use of 219 excursion hours. On any date that provisional variance hours are used, Exelon crews make three visual inspections of the Station's intake and discharge areas and document the number and general category of dead or stressed fish/aquatic life. If, during any observation, it appears a "fish kill" is occurring (numbers of individuals exhibiting difficulty in swimming or breathing), Exelon dispatches a team to determine the magnitude of the event and species affected.

As required, surveys were conducted during the July 2012 excursion hour episodes. With the exception of July 7, 8, and 9 no dead fish or presence of stress was observed. During July 7-9, when temperatures peaked, very small numbers of dead fish were observed both upstream and downstream of the plant. A total of two dead northern pike and one dead catfish were observed downstream of the diffuser. One catfish that appeared to have been dead a few days was observed at the diffuser. A total of 17 dead northern pike was found upstream of the diffuser. Two carp, two freshwater drum and two walleye were also found dead upstream of the diffuser.

These observations indicate that the thermal plume from QCNS did not cause an apparent increase in thermal stress or mortality during the excursion hour periods in July 2012.

3.3.2 Interaction with Other Pollutants

3.3.2.1 Organic Carbon

There are limited organic carbon data available on the Mississippi River system; however composite bed sediment samples were collected from the lower one-third of the Upper Mississippi River navigation pools prior to and after the summer flood of 1993. Bed sediment contaminant concentrations exhibited a general decrease following the flood. Decreases in pollutant levels were attributed to an increase in the portion of coarser sediment and low inputs or remobilization of contaminated sediments during or immediately following the flood. Bed sediment elevations in the sampling areas were found to increase significantly in the middle (Pools 5-13) and lower (Pools 14-26) reaches, likely a result of an increase in deposition of coarser sediment. System-wide, concentrations of dissolved organic carbon ranged from 3-12 mg/l. For the most part, dissolved carbon is unavailable to aquatic organisms other than bacteria. The reintroduction of organic carbon into the food web through bacteria results in additional energy to higher trophic levels (e.g., fish). The energy contributed by the QCNS thermal plume may increase bacterial growth rates but there is no indication of any harm caused by this potential interaction and there is no reason to expect that the small amount of additional heat that would be permitted to be discharged under the proposed alternative standard would cause a harmful interaction.

3.3.2.2 Total Phosphorous

In general, wastewater treatment plant discharges and urban and agricultural nonpoint source inputs are major sources of phosphorus. Agricultural watersheds contributing high concentrations of sediment are especially important because phosphorus is commonly bound to sediment particles. Nitrogen and phosphorus are abundant in the Mississippi River drainage basin because of the widespread use of commercial and animal-manure fertilizers. There are no nutrients added to the once-through cooling water during passage through the plant.

The most likely result of an interaction between the thermal plume and phosphorous would be an increase in the rate of algal growth during warm periods. However, this would be a localized effect in the less than 10% of the pool occupied by the thermal plume and no difference in algal abundance or growth has been observed in the plume. Given that there has been no evidence of a synergistic effect between total phosphorous and the thermal discharge in the past, there is no reason to expect that the small amount of additional heat that would be permitted to be discharged under the proposed alternative standard would cause any such effect

3.3.2.3 Total Nitrogen

Nitrogen is used in agricultural fertilizers to stimulate the production of crops, especially corn. Runoff from areas with intensive cultivation or large livestock densities are important sources of nitrogen. In addition, certain industrial discharges and municipal wastewater effluents may contain high concentrations of inorganic nitrogen, especially ammonia or nitrate nitrogen. Nitrogen concentrations throughout the river increased to higher levels in the 1990s, compared to concentrations observed during 1985-89. For the upper river, this response may have been partly associated with changes in municipal wastewater treatment technology (nitrification). However, changes in precipitation and river flow are additional factors associated with river-wide increases in nitrogen concentrations. The drought conditions of the late 1980s reduced non-point source runoff and increased utilization of inorganic nitrogen within the riverine pools. Increased non-point source runoff in the 1990s likely favored mobilization of nitrogen from agricultural watersheds that resulted in high nitrogen concentrations in the river during this period. The large amount of agricultural sources of nitrogen in the area suggests that the small amount discharged from the QCNS treatment plant is negligible by comparison. While nitrogen concentrations have increased during the recent decades for the reasons stated above, the Station's thermal discharge and treatment plant effluent have not contributed to this increase.

The most likely result of an interaction between the thermal plume and nitrogen would be an increase in the rate of algal growth during warm periods. However, this would be a localized effect in the less than 10% of the pool occupied by the thermal plume and no difference in algal abundance or growth has been observed in the plume. Given that there has been no evidence of a synergistic effect between total nitrogen and the thermal discharge in the past, there is no reason to expect that the small amount of additional heat that would be permitted to be discharged under the proposed alternative standard would cause any such effect.

3.3.2.4 Biocides

To control biofouling organisms in cooling water systems, power plants generally need to apply some type of biocide. Historically, Quad Cities Nuclear Station has treated its cooling water system with sodium hypochlorite. Sodium hypochlorite is normally used as the sole biocide for treatment of the circulating water system. Sodium bisulfite is used as a neutralizing agent prior to discharge to the river to ensure compliance with the TRC/TRO limit of 0.05 ppm. The detection limit is 0.05 ppm, an order of magnitude lower than the levels that cause fish mortality. Therefore, the Station's discharge of chlorine is well below levels that would cause harm to fish and the Station's use of biocides cannot reasonably be expected to alter or cause harm to fish communities in Pool 14 and adjacent pools, nor does it pose any risk of harm to the BIC. Any potential interaction of the thermal discharge with the biocides is similarly harmless.

3.3.2.5 Heavy Metals

Heavy metals are released to the Mississippi River from numerous sources including municipal wastewater-treatment plants, manufacturing industries, mining, and rural agricultural cultivation and fertilization. Heavy metals are transported as either dissolved species in water or as an integral part of suspended sediments, and may be volatilized to the atmosphere or stored in riverbed sediments.

Whether the loads and concentrations of heavy metals in the Mississippi River have increased or decreased in recent years is difficult to determine. Although most of the heavy metals in the river are associated with sediment, the majority of the previous studies have focused on the dissolved metals. Even for the dissolved metals, comparisons are difficult to draw between earlier and more recent data because analytical laboratory techniques have become markedly more sensitive in the last decade and field sampling techniques have not been adequately standardized. Those heavy metals that are found in the sediments are typically chemically bound to colloidal materials such as clay particles. This chemical bond is controlled by the electrical charge on the surface of the colloid which is controlled by the numbers of hydrogen ions present or the pH. As pH decreases (becomes more acidic), the surficial charge will eventually reverse, allowing the cation exchange phenomenon to occur. This frees the heavy metal to go into solution in the water. However, the pH of the river water ranges from about 7.0 to about 9.0 which is basic rather than acidic, thus inhibiting the process. Because movement of metals from the sediments into the water column is catalyzed principally by pH rather than temperature, the thermal discharge has not caused the release of heavy metals from the sediments and the proposed change in the thermal standard will also not affect this process. Thus, the heavy metals bound in the sediments can be expected to remain there and not interact with the biota. Therefore, there have not been and will not be any interactive impacts between the thermal plume, heavy metals and the biotic community.

3.3.2.6 Potability, Odors and Aesthetics

There is no evidence of an unnatural odor or an unaesthetic appearance in the Mississippi River in the vicinity of the Quad Cities Nuclear Station in general, and none associated with Station operations in particular. Hence, it is anticipated that the proposed alternative thermal standard will not have any effect on potability, odors or aesthetics of Pool 14.

3.3.2.7 Other Thermal Discharges

Several cooling water discharges are located on the Mississippi River from RM 517.5 to RM 513, which is approximately 10.5 km (6.5 miles) upriver from the Quad Cities Nuclear Station intake. Beaver channel is a side channel of the Mississippi River, which houses industrial discharges for Archer Daniels Midland's (ADM) Corn Processing Plant and Interstate Power Companies' M.L. Kapp Plant. The thermal component of the discharges from these plants is diluted and dissipated to ambient conditions by the time it reaches the Station. Thus, they do not interact with the Station's discharge.

3.3.2.8 Conclusions Regarding Interactions

There is no evidence of harmful interactions between the Station's thermal discharge and other pollutants including dissolved organic carbon, total phosphorus, total nitrogen, biocides, heavy metals, and other thermal discharges located upstream and there is no reason to expect that the small amount of additional heat that would be permitted to be discharged under the proposed alternative standard would cause such an effect.

3.3.3 Conclusions of Retrospective Analysis

On the basis of the analyses performed in connection with the Retrospective Assessment, it is clear that while there may have been changes in the upper trophic levels (i.e., finfish) in Pool 14 since the Station began operating, those changes are not attributable to the thermal input from QCNS. In addition, the overall stability and health of upper trophic levels suggests that lower trophic levels (i.e., zooplankton, phytoplankton) have remained stable and abundant, providing an adequate food supply to allow and sustain growth of the finfish and mussel populations. It is also clear that neither nuisance species nor heat tolerant species of fish have come to predominate in Pool 14 due to Station operations. In sum, QCNS's operations have not caused appreciable harm to the BIC.

3.4 Protection of Threatened and Endangered Species

3.4.1 Freshwater Mussels

In addition to demonstrating that historical operations have not harmed the BIC and that the proposed alternate standards will protect the BIC, the Demonstration has addressed the question of whether operations under the alternate standards could affect endangered species. There is one federally endangered species of mussel, the Higgins' Eye pearly mussel, in Pool 14 and adjacent pools along with a candidate species, the Sheepnose mussel. The more prevalent is the Higgins' Eye mussel, which can be found in several beds in Pool 14 and adjacent pools. Directly below the diffuser area is the Cordova bed, which is one of several essential habitats outlined in the Higgins' Eye Recovery Program. The Cordova bed is an essential area for the species because it is used as a source of brood stock for mitigation activities involving Higgins' Eye mussels throughout the Mississippi River system.

Quad Cities Nuclear Station initiated a consultation with USFWL in 2008 regarding endangered species concerns. With USFWL's guidance, the Station prepared a Habitat Conservation Plan (HCP). The HCP was approved and the Incidental Take Permit (ITP) was issued by USFWS in

August 2010. The Incidental Take Permit authorizes possible impacts to individual mussels (the nature of which, is not expected to be acute, but rather, at most, would be non-lethal, temporary stress), provided the Station complies with and implements the HCP.

The objective of a Habitat Conservation Plan is to avoid, minimize and/or mitigate for the proposed action (i.e. the proposed alternate thermal standard) with regard to federally endangered or threatened species. Adaptive management guidelines within the HCP allow it to be modified to include any additional data that may become evident within the life of the incidental take permit. In addition to requiring implementation of a thorough and comprehensive mussel sampling and monitoring program, the HCP provides for innovative measures designed to propagate the endangered mussels.

Through the HCP/Incidental Take Permit process, the Station satisfies the requirements of the Endangered Species Act and will enhance the likelihood that the endangered mussel species will survive.

3.4.2 Fish

There have been no federal endangered or threatened fish species collected in Pool 14 and the adjacent pools during the past 38 years of sampling.

4.0 CONCLUSIONS

In a 316(a) Demonstration, the ultimate standard used in the assessment of the thermal component of power plant discharges is whether a balanced indigenous community of shellfish, fish, and wildlife has been and will be maintained in or on the receiving water body despite the thermal discharge. Based on guidance documents and the criteria that have evolved based on our work on other 316(a) demonstrations, we believe that standard --protection of the BIC-- is demonstrated when the following criteria are met:

- No substantial increase in abundance or distribution of any nuisance species or heat-tolerant community
- No substantial decreases of formerly abundant indigenous species or community structure to resemble a simpler successional stage than is natural for the locality and season, other than nuisance species
- No unaesthetic appearance, odor, or taste of the water

- No elimination of an established or potential economic or recreational use of the waters
- No reduction in the successful completion of life cycles of indigenous species, including those of migratory species
- No substantial reduction of community heterogeneity or trophic structure
- No adverse impact on threatened or endangered species
- No destruction of unique or rare habitat, without a detailed and convincing justification of why the destruction should not constitute a basis of denial
- No detrimental interaction with other pollutants, discharges, or water-use activities.

Because this demonstration is focused on a request for a change in the thermal standard, the demonstration must show that these conditions will be satisfied in the future if the proposed standard is adopted.

Taken together, the retrospective and prospective evaluations of the QCNS thermal discharge demonstrate that the above criteria will be satisfied if the 316(a) variance is granted for the Station.

✓ **No substantial increases in abundance or distribution of any nuisance species or heat-tolerant community**

To date no apparent substantial changes in abundance of nuisance species have been observed. Our retrospective analysis suggests that there have been changes in the non-thermal components of water quality (e.g., water clarity and subsequent non-nuisance macrophytic growth along the main channel), but the Station's thermal discharge was not a contributing factor. Based on these observations, the relatively small amount of additional heat that will be discharged if the proposed standard is implemented is not expected to cause changes in abundance or distribution of nuisance species.

✓ **No substantial decreases of formerly abundant indigenous species other than nuisance species**

Based on results reported by the monitoring programs and special studies described in Appendix A, most indigenous species in Pool 14 have either maintained or increased in abundance during the period of open cycle cooling, with the exception of the fish species white crappie, black crappie, and sauger. Decline of white and black crappie, however, seems to be common throughout this reach of the river and not isolated to Pool 14. Much of the decline has been attributed to filling in of the backwater areas by sedimentation. As habitat changes, the fish also move out of fixed station sampling areas, which may help explain decreases in numbers collected in the long-term monitoring program. Overall, our retrospective analysis indicates that any trends in abundance are apparent at locations both upstream and downstream of the diffuser pipes, suggesting that the thermal discharge is not a significant contributing factor. The prospective analysis concludes that the proposed alternative thermal standard will not cause any appreciable harm to the indigenous fish species.

Special mussel studies conducted between 2004 and 2008 indicate that unionid mussels are similar in species composition and abundance in beds located both upstream and downstream of the diffuser pipes that have similar habitat. This suggests that the thermal discharge has not caused any appreciable harm to the unionid mussel community in Pool 14. This finding, combined with the fact that thermal exposures experienced by the unionid community during the 2006 high ambient temperature/low river flow episode are comparable to thermal exposures that would be allowed under the proposed alternate thermal standards, supports the conclusion that the proposed thermal standards will adequately protect the balanced indigenous unionid community in the QCNS receiving waters.

The demonstration of no retrospective effects on fish and shellfish supports the conclusion that the lower trophic levels on which they are dependent for food have been similarly unaffected and that no appreciable harm will result from the small increment in added heat that may be released if the proposed standard is implemented.

✓ **No unaesthetic appearance, odor, or taste of the water**

There is no evidence of an unnatural odor or an unaesthetic appearance in general, none associated with Station operations in particular, and none expected if the proposed thermal standard is adopted.

✓ **No elimination of an established or potential economic or recreational use of the waters**

No economic or recreational uses of the Mississippi River have been eliminated or minimized as a result of the Station's thermal discharge. Recreational fisheries have not been adversely impacted and Pool 14 continues to be a popular fishing destination. During the past 25 years, the number of fishing tournaments on Pool 14 has increased substantially. In fact, four national championship fishing tournaments for walleye and black bass have occurred in Pool 14 within the last 10 years. The Quad Cities Convention & Visitors Bureau and Quad Cities Sports Commission have estimated $500,000 - $1,000,000 of economic impact for the Quad Cities area from each of these individual tournaments (Quad Cities Convention & Visitors Bureau, Personal Communication, 2011). The prospective demonstration for finfish indicates the small increment in added heat that may be released if the proposed standard is implemented will not affect these conditions.

- ✓ **No reductions in the successful completion of life cycles of indigenous species, including those of migratory species**

Retrospective analyses of the long-term monitoring program and the historical biological analyses suggest that thermal effects have not compromised the overall success of indigenous species in completing their life cycles. Freshwater drum population dynamics have been studied in detail annually to detect any adverse effects attributable to operation of Quad Cities Nuclear Station. No measurable effects have been observed over the 28-year study period. Further, as demonstrated in Appendix C (Section 2.9 – Zone of Passage), past operations of QCNS, resulting in a ZOP of less than 75%, have not caused appreciable harm to the BIC. These observations combined with the prospective demonstration for finfish indicate that the small increment in added heat that could be released if the proposed standard is implemented will not cause any change in these conditions.

- ✓ **No substantial reductions of community heterogeneity or trophic structure**

Data collected during the long-term monitoring program conducted at the Station since 1984 suggest that the number of species collected has remained reasonably constant (50-60 species) across years. Any long-term changes in the fish community can be attributed to the change in water quality, clarity, and subsequent vegetation increases, in particular to the main channel border and side channel areas. These changes are seen system wide in the Upper Mississippi River Valley and there is no evidence that the Station's thermal discharge has contributed to these changes. Similarly, the proposed, relatively small, change in the thermal standard is not expected to contribute to any such changes.

- ✓ **No adverse impacts on threatened or endangered species**

The retrospective analysis identifies only one Federal endangered species of mussel in Pool 14 and adjacent pools and one Federal candidate species for the endangered list, the Higgins Eye pearly mussel and the sheepnose mussel, respectively. The analysis indicates that these two species have not been impacted by the Station's thermal discharge and are not expected to be if the proposed thermal standard is implemented. If, during the life of the operating permit, evidence of impact is found or provided, a habitat conservation plan is in place to mitigate these impacts.

- ✓ **No destruction of unique or rare habitat, without a detailed and convincing justification of why the destruction should not constitute a basis of denial**

The unique, but not rare, habitat that could potentially be affected by the thermal discharge is the Cordova Mussel Bed which has been designated as essential habitat for Higgins Eye pearly mussel. This bed is located approximately one mile downstream from the diffuser pipes and has been exposed to the thermal plume over the past 25 years, including the extreme case year of 2006 when water temperatures were unusually high and flows abnormally low. ESI began studying this bed and others in Pool 14 in 2004 continuing through 2008. The data collected indicate that the mussels in this bed were not harmed by the 2006 thermal conditions which are comparable to those that would be permitted under the proposed standard. U.S Fish and Wildlife Service has required Exelon to prepare a habitat conservation plan for Higgins Eye pearly mussel to protect this federally endangered species.

- ✓ **No detrimental interactions with other pollutants, discharges, or water-use activities.**

Operation of QCNS has not had a detrimental effect on recreational (e.g. boating and fishing) or commercial (e.g. shipping and fishing) water-use activities in Pool 14 or on potable water use by communities downstream of QCNS. No cumulative effect with thermal additions discharged by industries upstream has occurred because that heat load is dissipated by the time it reaches the QCNS diffuser pipes. Most heavy metals are bound to the sediments and the chemical reactions that would release these metals are driven by lowering the pH of the water to acidic conditions. Typical pH values in Pool 14 are in the range of 7 to 9 pH units which is basic rather than acidic. Thus, thermal discharges play an insignificant role in these chemical reactions and have not interacted with the sediments to release heavy metals. As discussed above, no harmful interactions with other pollutants such as organic carbon, phosphorus, and nitrogen are expected if the proposed standard is adopted.

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APPENDIX A

Description of the Mississippi River in the Vicinity of Pool 14: Hydrology, Geology, Water Quality, Biology, and Anthropogenic Influences

TABLE OF CONTENTS

1.0 HYDRODYNAMICS AND HYDROLOGY

1.1 Hydrographic Data

The Upper Mississippi River drains approximately 714,000 square miles of watershed and extends from Lake Itasca near Hastings, Minnesota to the mouth of the Ohio River near Cairo, Illinois (Interagency Floodplain Management Review Committee, 1994). This portion of the Mississippi River traverses 1,366 miles and comprises an integral part of one of the largest and most productive aquatic ecosystems in the world. The Upper Mississippi River is divided longitudinally into a series of navigation pools by 29 lock-and-dam structures. Pools are numerically identified as the river flows downstream, except for the two uppermost pools (Upper St. Anthony Falls and Lower St. Anthony Falls).

Pool 14 is approximately 29 miles in length and encompasses the reach of the Mississippi River between Lock and Dam 14 at river mile 493.3 and Lock and Dam 13 at river mile 522.4 at approximately the midpoint of the impounded portion of the river. The Mississippi River at Lock and Dam 14 has a drainage area of approximately 85,600 sq. miles. Tributary streams in Pool 14 add another 2,900 square miles and 1,350 cfs to the mean daily flow. The flow characteristics in the river are distinctly seasonal. Annual high flows typically occur between April and June and the annual low flows occur between December and February. The maximum daily flow was recorded on April 28, 1965 (approximately 307,000 cfs). The minimum daily flow was recorded in 1934 (6,200 cfs), five years before Lock and Dam 14 was placed in operation (USACE, 1974). According to data recorded at USGS gauging station 05420500 located in Clinton, Iowa, the mean annual flow at Lock and Dam 14 is approximately 54,114 cfs for the most recent 40 year period (1968-2008) (USGS, 2009).

1.2 Groundwater

Quad Cities Nuclear Station (QCNS) is located in the Meredosia Channel, an ancient channel of the Mississippi River. The Meredosia Channel has been filled over many thousands of years with unconsolidated sediments ranging in depth from approximately 50 to 300 feet (Blume, 1966). Water for industrial and home use in the region comes from both wells and the Mississippi River.

Groundwater sources in the area are developed from three separate aquifer systems. These aquifer systems are: (1) unconsolidated alluvial and outwash sand and gravel deposits, (2) shallow Silurian dolomitic formations, and (3) artesian sandstone aquifers of the Cambrian-Ordovician age (Commonwealth Edison, 1966).

Some wells within a few miles of the Station pump at rates up to 2000 gallons per minute (gpm). These are in the upper alluvial aquifer at depths of 20 to 100 feet below ground surface (AEC 1972). Groundwater in the area is encountered at depths from approximately 17 to 21 feet (Exelon, 2004).

The Silurian dolomitic rocks, the Niagaran and Alexandrian formations, yield moderate to high quantities of water. The highest yielding wells from the dolomite rock formations are found in areas where unconsolidated sediments consisting of sand and gravel are present (Commonwealth Edison, 1966). Wells extending into the Cambrian-Ordovician sandstones penetrate artesian aquifers that produce large quantities of water (Commonwealth Edison, 1966).

The exploration borings and the logs of wells drilled in the area of the site indicate that the ground water level is approximately 17 to 21 feet below the existing ground surface or, at approximately elevation 573 to 577. Normal pool elevation of the Mississippi River in the vicinity of the site is approximately elevation 572. The ground water gradients in the vicinity of the site are relatively flat and slope generally toward the Mississippi River (Commonwealth Edison, 1966).

There are currently eight operating wells providing water to various systems on Quad Cities Station property. The two primary wells for station operations are Wells 1 and 5. These wells provide water for the domestic drinking water system, make-up demineralizer system and gland seal condenser. The largest single use of groundwater is to maintain the former spray canal for raising fish. Water for this purpose is drawn from Wells 6, 7, 10, and 11. The final two wells, Wells 8 and 9, provide water for fire fighter training exercises and dry cask operations. Wells 2, 3 and 4 have been sealed and abandoned.

Groundwater use from all wells has averaged approximate 500 gpm over the last 10 years.

1.3 Anthropogenic Freshwater Sources

1.3.1 Wastewater Treatment Plant Discharges

QCNS has an operable sewage treatment plant that provides primary and secondary treatment before it is discharged into the Mississippi River. The maximum amount of effluent is 15,000 gallons per day. This is chlorinated to less than 3 ppm; in addition the small amount of total effluent (0.023 cfs compound to a blowdown of about 2200 cfs) is unlikely to be a source of adverse effects. The sewage treatment plant is licensed by the State of Illinois and is under the supervision of a licensed sewage-treatment operator (U.S. Atomic Energy Commission, 1972).

1.3.2 Combined Sewer Overflows

There are no combined sewer overflows from the Quad Cities Nuclear Station. The Quad Cities Generating Station NPDES permit (IL0005037) Special Condition 15 states "The Agency has determined that the effluent limitations in this permit constitute BAT/BCT for storm water which is treated in the existing treatment facilities for purposes of this permit reissuance, and no pollution prevention plan will be required for such storm water. In addition to the chemical specific monitoring required elsewhere in this permit, the permittee shall conduct an annual inspection of the facility site to identify areas contributing to a storm water discharge associated with industrial activity, and determine whether any facility modifications have occurred which result in previously-treated storm water discharges no longer receiving treatment. If any such discharges are identified the permittee shall request a modification of this permit within 30 days after the inspection. Records of the annual inspection shall be retained by the permittee for the term of this permit and be made available to the Agency on request." (IEPA, 2008).

2.0 GEOLOGY

2.1 Bedrock Geology of Northwestern Illinois and Northeastern Iowa

The geologic structure of the region is not complex. The region is situated structurally on the extreme northwest flank of the Illinois Basin. The upper bedrock consists of Paleozoic sedimentary strata which dip gently, on the order of 15 to 20 feet per mile, to the southeast towards the center of the basin. The major structure to the North is the Plum River Fault Zone which trends in the east-west direction through Carroll County and is located approximately 30 miles north of the plant site.

There is no evidence of major faulting in the area. Major tectonic deformation has not occurred in the area since the end of the Mesozoic era, some 60 million years ago. The bedrock is generally covered by unconsolidated deposits of glacial till, outwash, and lacustrine sediments that have been deposited as a result of different glaciations occurring during the Pleistocene Epoch. The upland areas are generally covered with morainal deposits left by the retreating glaciers or with wide-deposited sands or loess. Sediment-laden waters escaping from the melting glaciers and flowing down the bedrock valleys have deposited great thicknesses of sand and gravel in these valleys.

The Paleozoic sedimentary rocks underlying the region are of Silurian age or older. The bedrock units that underlie surficial deposits or that outcrop at the surface are the Niagaran and Alexandrian formations which are dolomitic rocks of Silurian age. Some deep wells in the region have penetrated the entire thickness of the Paleozoic sedimentary rocks. The thickness of the sedimentary rocks is on the order of 3,000 feet and these rocks are underlain by Pre-Cambrian crystalline rocks (Commonwealth Edison, 1966).

2.2 Pre-Glacial History

The site is situated in the Meredosia Channel which is an ancient channel of the Mississippi River. The Meredosia Channel has been filled with unconsolidated sediments ranging in depth from approximately 50 to 300 feet. The exploration test borings drilled at the site and on-site observation of the bluffs along the Mississippi River revealed that the site is underlain by predominantly granular soil (unconsolidated sediments) consisting of fine sand to coarse gravels containing some cobbles and boulders. The unconsolidated sediments were deposited by either the receding glaciers of the last glacial period, or stream action in recent times.

The pre-glacial course of the Mississippi River was immediately north and east of the site. However, the present course of the Mississippi River, over the rapids south of the site, was formed when the Meredosia Channel was blocked, in ancient times, by ice of the last glacial age. A lake was formed in the Meredosia Channel which breached a rocky upland south of the city of Cordova and eroded the present channel (Commonwealth Edison, 1966).

2.3 Glacial History

The bedrock surface in the immediate vicinity of the site has been eroded by the passage of the Mississippi River and the Wapsipinicon River in their ancient channels. The confluence of these ancient channels is believed to be located southeast of the site. The site appears to be located on the southern extremity of a rock hill that was left as an erosional remnant between these channels.

2.4 Erosion and Sedimentation

Erosion rates are measured by estimating soil loss in upland areas and measuring stream bank and stream bed erosion along drainage ways. These measurements are generally not very accurate and thus are estimated indirectly, most often through evaluation of sediment transport rates based on in-stream sediment measurements and empirical equations. Similarly, measurement of sedimentation rates in stream channels is very difficult and expensive.

Sedimentation is the process by which eroded soil is deposited in stream channels, lakes, wetlands and floodplains. In natural systems that have achieved dynamic equilibrium, the rates of erosion and sedimentation are in balance over a long period of time. This results in a stable system, at least until disrupted by extreme events. However, in ecosystems where there are significant human activities such as farming, construction, and hydraulic modifications, the dynamic equilibrium is disturbed, resulting in increased rates of erosion in some areas and a corresponding increased rate of sedimentation in other areas.

The Upper Mississippi River Conservation Committee (UMRCC) state and federal biologists are now addressing sedimentation on several fronts. One of these is through the Environmental Management Program (EMP). The EMP is a cooperative effort between the U.S. Fish and Wildlife Service, the Army Corps of Engineers, and the five UMR states. One of its objectives is to collect sedimentation data and to investigate management alternatives for restoring backwaters impacted by sedimentation. Solving this problem will be an extraordinary task because it will involve taking actions throughout the 100+ million acres of the UMR watershed. Reducing sediment input will require remedial actions from the river's mainstem (reducing stream bank erosion) to the heads of tributaries (farm land or "sheet" erosion) hundreds of miles upstream (UMRCC, 2009).

3.0 METEOROLOGY

The climate of the Mississippi River Basin is sub-humid continental with cold dry winters and warm moist summers. Average annual precipitation varies from about 22 inches in the western part of the basin to 34 inches or more in the east. About 75 percent of the total annual precipitation falls between April and September. Basin-wide, the average monthly temperature ranges from about 11°F in January to 74°F in July. Most of the river within the Upper Mississippi River National Wildlife and Fish Refuge, which covers 261 miles of Mississippi River floodplain from Wabasha, Minnesota to Rock Island, Illinois, usually freezes solid each winter. The global warming trend documented nationally and globally in recent years has affected precipitation patterns in the Midwest, resulting in unusual flooding intensity and duration.

Unusually high floods of long duration have occurred on the Upper Mississippi River over the past decade. Professor James Knox at the University of Wisconsin-Madison has found that "model results and instrument records both support the concept that global warming magnifies hydrologic variability and enhances the hydrologic cycle of the Upper Mississippi River basin (Knox, 2002)." He continues, "analyses of sediment properties [in Wisconsin] indicate that large floods on the Upper Mississippi River have commonly accompanied the beginning of warm and dry climate episodes in the region, but long-term persistence of warming and drought eventually results in smaller floods of high short-term variability. "Short-term occurrences of large floods were common about 4700, 2500-2200, 1800-1500, 1280, 1000-750, and 550-400 calendar years B.P. [before present], all times that approximate rapid warming and drought in the upper Midwest identified by others. The recent high frequency of large floods on the Upper Mississippi River since the early 1990s may be a modern analogue because these floods have accompanied major hemispheric warming during the same period." The research by Knox and others indicates that climate is less stable and predictable than people previously thought, and this means that resilience must be a primary consideration in making management decisions. Resilience requires a largely preventive or precautionary approach that leaves an adequate margin for error. The floodplain marshes and forested islands or bluffs of the Upper Mississippi River corridor could have important future roles to play in excess nutrient processing and carbon sequestration, as a means of mitigating effects of climate change (USF&W, 2006).

3.1 Air Temperature

The QCNS site is located approximately 20 miles north-northeast of the Quad Cities Airport at Moline, Illinois. This area has a temperate continental climate, with a wide temperature range throughout the year. There are some intensely hot, usually humid, periods in summer and severely cold periods in winter. Maxima of 90 degrees or more have occurred in summer as frequently as 55 days and zero or lower readings have occurred every winter. Freezing temperatures have occurred as late in spring as late May and as early in autumn as late September (National Climate Data Center, 2008).

The (5-1/2 foot) surface temperature data for Moline reflects the continental mid-latitude type climate that prevails at the Quad Cities site. In winter temperature has dropped to a low of –28°F. In summer it has climbed to 106°F. There is an average of 23.6 days per year with temperatures reaching 90°F, or higher. There are 15.2 days a year on the average when temperatures reach 0°F or lower. The average annual temperature is 50.2°F; with an average daily maximum of 59.9°F and an average daily minimum of 39.9°F (National Climate Data Center, 2008).

3.2 Precipitation

The average precipitation is about 39 inches per year. Of this total, about 29 inches falls during the growing season (March through September). There is an average of approximately 51 thunderstorms per year in the area, with about 50% of the thunderstorms occurring in July and August (Exelon, 2004).

Snowfall data from Moline is generally representative of the Quad Cities site. Moline receives an average of 35.0 inches of snowfall per year. In 2008, the Moline area received a total of 57.1 inches of snow (National Climate Data Center, 2008).

3.3 Relative Humidity

Relative humidity measured at 1200 hours averages approximately 60% over the course of the year, while at 1800 hours it averages about 63%. During the summer, humidity varies more as a diurnal range than on a monthly average (National Climatic Data Center, 2008).

3.4 Wind

Data gathered from on-site meteorological towers and from the Summary of Hourly Surface Observation at Moline, Illinois, by the U.S. Weather Bureau show a rather uniform distribution of wind direction which is typical of mid-continent locations. The most frequent wind directions are from the southwest and northwest sectors. (A sector is defined as 22-1/2 degrees.) The highest velocity of wind officially reported at various locations around the site is 87 mph at Chicago and 75 mph at Peoria. Higher gusts are reported unofficially, up to 109 mph, during heavy thunderstorms and scattered tornadic activity. Severe winds in the form of tornadoes have also been reported in the Quad Cities region with at least one damaging the plant site (Commonwealth Edison, 1971).

4.0 WATER QUALITY

Quad Cities Station operates with approximately 970,000 gpm discharged to the river with two units running at full power. The combined cooling and service water, heated 28°F above the intake temperature, is discharged through two 16-foot diameter diffuser pipes with nozzles that jet the water into the deepest part of the river channel. Biocides, chlorine, and bromine, are used at the condenser inlets to minimize aquatic growth and bacteria in the condenser tubes. Quad Cities injects a chemical to neutralize the biocide in the discharge bay so that river organisms are not affected by the biocide. A silt dispersant and scale inhibitor are also injected at the river intake. Additionally, biocide, silt dispersant, and a corrosion inhibitor are injected into the service water system. Sanitary waste from the Quad Cities site is sent to the wastewater treatment system and discharged to the Mississippi River.

In addition to serving the cooling needs of Units 1 and 2 at QCNS, the Upper Mississippi River provides water of sufficiently high quality to serve a variety of other uses, including propagation of fish and wildlife and contact recreation. However, river reach IL-M02 (Basin 9), which includes a portion of Pool 14, is identified in the Illinois State 2008 Section 303(d) list of impaired water due to the presence of mercury, polychlorinated biphenyls (PCBs) and manganese. Iowa identifies the portion of Pool 14 from Lock and Dam 13 to the mouth of the Wapsipinicon River as impaired due to aluminum and nutrient loads (2008 Iowa Impaired Waters 303(b) list). The mouth of the Wapsipinicon River is directly across from the station intake.

Pursuant to the Federal Water Pollution Control Act of 1972, also known as the Clean Water Act (CWA), the water quality of the plant effluents is regulated through the National Pollutant Discharge Elimination System (NPDES). The Illinois Environmental Protection Agency (IEPA) is authorized to issue NPDES permits. The current permit (IL0005037) was issued August 26, 2010 and in accordance with the 5-year renewal cycle is due to expire August 31, 2015 (IEPA, 2000b). This permit specifies effluent limits for pH, total residual chlorine, oil, grease, biological oxygen demand, fecal coliform, total suspended solids, boron, temperature and flow. Any new regulations promulgated by the U.S. Environmental Protection Agency (USEPA) or the State of Illinois would be reflected in future permits. The Iowa Department of Natural Resources (IA DNR) is also a signatory on the original Illinois NPDES permit, as the effluents discharge to the waters of both states (U.S. Nuclear Regulatory Commission, 2004).

Nonpoint source inputs from tributary streams, major point source discharges, and river flows are the dominant factors influencing the observed longitudinal water quality patterns. This was especially apparent in Pool 2, where the river flow is relatively low and nonpoint source pollution from the Minnesota River and wastewater discharges from the Twin Cities Metropolitan Area have a strong influence on the river's quality. Large changes in the river's quality are also observed in the lower portion of the UMR, where nonpoint source pollution from large agricultural watersheds, including the Missouri River, contributes to high nutrient and suspended solids concentrations. Point source pollutant abatement activities implemented in the 1980s have resulted in noticeable reductions in total and un-ionized ammonia nitrogen concentrations and increases in dissolved oxygen (DO) concentrations below the Twin Cities Metropolitan Area. Widespread infestations of zebra mussels in the river reach extending from Pool 9 (RM 648) to Pool 14 (RM 494) in the late 1990s are believed to have had some influence on water quality during some summers, and may partly explain the lower DO concentrations reported during late 1990s.

4.1 Water Temperature

The NPDES permit for the Quad Cities Nuclear Station defines a mixing zone as an area of the river where plant releases mix with river water. The plant is required not to exceed the temperature criteria specified in the NPDES permit outside the mixing zone. To ensure compliance with State of Illinois water quality standards, the NPDES permit for Quad Cities contains monthly maximum temperature limits for "representative locations in the main river" at the edge of the designated mixing zone, a maximum temperature increase of 5 °F above ambient at the edge of the mixing zone, and restrictions on the size of the thermal mixing zone (IEPA 2000b).

An investigation was undertaken to develop strategies and associated diffuser pipe modifications to enable Quad Cities Nuclear Station to operate at full load during periods of low flow. The investigation was conducted in three major phases: development of an optimum configuration of the diffuser pipe systems by analyzing the QCNS thermal-plume data; evaluation of the cooling potential of the cooling canal; and trend analysis of the river-water discharge and temperature data. The summary and conclusions of this investigation are as follows:

- A one-dimensional analytical model and field data from eight surveys during the summer of 1988 and 1989, when the river discharges were unusually low, were used to evaluate the performance of, and to optimize, the existing QCNS diffuser pipe system. The results of the analytical model were in agreement with the field data. The overall mixing of the condenser water discharge with the ambient flow in surveys with discharge ratios less than the critical discharge ratio, was almost uniform, except for local "hot spots" and "cold spots" which occurred, respectively, due to relative deficiency and excess dilution water. A modified temperature monitoring curve, TMC-1, based on the field data and a simple procedure for monitoring the thermal plume were developed.

- Reducing the condenser water discharge near the Iowa shore and increasing it in the deeper portion of the river section could improve the performance of the diffuser system. Another modified temperature monitoring curve, TMC-2, based on the modified distribution of the condenser water discharge was developed. For TMC-2, the minimum river discharge to comply with the thermal standards at full load is about 11,000 cfs.

- The cooling potential of the cooling canal was evaluated by using a one-dimensional plug-flow model. The cooling canal could be used to cool only about 0.9 to 2.2 percent of the maximum condenser water discharge. The cooling canal would be a beneficial adjunct to the optimum diffuser configuration and could be used for river flows less than 11,000 cfs; such flows only occur about .016% of the time. The additional electric power generated by the use of the cooling canal is about 8 to 19 MW-day per year.

- A nonparametric trend test was used to analyze trends in the discharge and temperature data for the Mississippi River at Clinton, Iowa. Neither long-term nor short-term trends were detected in the data.

The NPDES permit for Quad Cities Nuclear Station also contains specific requirements for daily monitoring of plant circulating water flows, daily continuous monitoring of discharge temperatures, weekly determination of river flow rate, daily monitoring of the ambient temperature of the river, daily determination of plant load (percent power), and, as warranted, daily determination of the temperature at a river cross-section 500 feet downstream from the plant's diffuser system. This monitoring allows the operators of QCNS to respond to changing conditions in the river and to adjust power levels to ensure compliance with NPDES temperature limits (IEPA 2000b).

Based on a study of the diffuser system, Exelon concluded that Quad Cities Nuclear Station Units 1 and 2 could operate at full load without violating discharge permit limits under most river flow conditions (ComEd, 1981). To demonstrate compliance at low river flows, Exelon developed a temperature monitoring curve that allowed calculation of permissible plant load as a function of river flow. With these data and the lack of biological effects in the river, as demonstrated by ongoing monitoring, the parties agreed in 1983 to allow open-cycle operation (Open-Cycle Agreement 1983). The temperature monitoring curve was last modified in 2001 to more accurately represent current conditions. The curve may continue to be modified over the license renewal period, under agreement with affected parties (U.S. Nuclear Regulatory Commission, 2004).

4.2 Dissolved Oxygen

Dissolved oxygen (DO) is a critical water quality parameter, and its presence or absence has a dramatic impact on the distribution and abundance of fish and aquatic life in the UMR. All of the states bordering the Upper Mississippi River have established a water quality criterion of 5 mg/L to protect and support aquatic life use, including fisheries. This criterion provides a useful reference for spatial and temporal comparisons. Summer DO concentrations during four time periods generally ranged from about 5 to 12 mg/L in the Upper Mississippi River. DO levels below 5 mg/L have been reported and were most apparent below the Twin Cities Metropolitan Area in the 1980s. In the 1990s, DO concentrations in this reach improved noticeably, primarily as a result of advanced wastewater treatment technology (Johnson and Aasen, 1989; USEPA, 2000).

During the 1995 to 1999 period, DO levels below 5 mg/L were observed in a 150-mile segment of the river extending from Pool 9 to Pool 14 (RM 648 to RM 500). It is suspected that the marked growth and expansion of zebra mussel populations in this reach in 1997 may have contributed to low DO levels, due to zebra mussel respiratory demands and excretory products (Sullivan and Endris, 1998). Additional factors contributing to reduced DO levels in this reach during the 1995 to 1999 period may include increased biochemical oxygen demand and reduced algal and aquatic plant photosynthesis caused by polluted runoff and turbid inflows following major rainfall events. DO concentrations exceeding 15 mg/L were apparent in Pool 8 during the 1990 to1994 period and likely reflect periods of high photosynthetic activity. DO concentrations in the open river reach were generally lower and less variable. This may indicate higher water temperatures (lower DO saturation), increased biochemical oxygen demand and decreased photosynthetic activity (UMRCC, 2002).

4.3 Nutrients

4.3.1 Organic Carbon

There is limited organic carbon data available on the Mississippi River system. However, composite bed sediment samples were collected from the lower one-third of the Upper Mississippi River navigation pools prior to and after the summer flood of 1993. These samples were analyzed for particle size, total organic carbon, nitrogen, trace metals and organic compounds. Bed sediment contaminant concentrations exhibited a general decrease following the flood of 1993. Decreases in pollutant levels were attributed to an increase in the portion of coarser sediment and low inputs or remobilization of contaminated sediments during or immediately following the flood. Bed sediment elevations in the sampling areas were found to increase significantly in the middle (Pools 5-13) and lower (Pools 14-26) reaches and were likely a result of an increase deposition of coarser sediment (Moody et al., 1999).

4.3.2 Total Phosphorus

Phosphorus is an essential plant nutrient and is normally the major element affecting eutrophication in freshwater systems. Like nitrogen, phosphorus can be measured in several forms, but total phosphorus, representing the sum of all those forms, is most commonly measured and reported in water quality surveys. The U.S. EPA has previously suggested a total phosphorus concentration of 0.1 mg/L as a general guidance for protection of flowing waters from eutrophication (Mackenthun, 1973). National and state efforts are currently underway to develop more formal nutrient criteria for lakes and streams (USEPA, 1998). Total phosphorus concentrations were very high throughout the entire UMR, with values greater that 0.5 mg/L at many sites. In general, wastewater treatment plant discharges and urban and agricultural nonpoint source inputs are major sources of phosphorus. In particular, agricultural watersheds contributing high concentrations of sediment are especially important because phosphorus is commonly bound to sediment particles. Maximum phosphorus concentrations exceeded 1 mg/L at many sites during the most recent time period (1995 to 1999) as compared to the previous monitoring periods. Some of these high phosphorus concentrations are likely associated with high total suspended solids concentrations (> 200 mg/L), especially in the lower half of the Upper Mississippi River (UMR). This relationship does not appear to explain the high phosphorus values observed in the upper portion of the UMR, where lower suspended solids concentrations were observed. However, the Minnesota River is a major contributor of suspended solids and phosphorus to the upper portion of the UMR (UMRCC, 2002).

4.3.3 Total Nitrogen

Like phosphorus, nitrogen is also an essential plant nutrient. Nitrogen in surface water may be present in various organic and inorganic forms. As a result, the estimation of total nitrogen content may be based on direct analytical determination, or the combined sum of individual forms such as organic nitrogen, ammonia, nitrite, and nitrate. Nitrogen is an important plant nutrient and has been used in agricultural fertilizers to stimulate the production of agricultural crops, especially corn. Runoff from areas with intensive cultivation or large livestock densities is an important source of nitrogen. In addition, certain industrial discharges and municipal wastewater effluents may contain high concentrations of inorganic nitrogen, especially ammonia or nitrate nitrogen. In oxygenated surface waters, including the Mississippi River, the dominant form of nitrogen is normally nitrate. As a result, total nitrogen concentrations closely follow the patterns and trends exhibited by nitrate nitrogen. On a national scale, excessive nitrogen input from the Mississippi River to the Gulf of Mexico has been implicated in nutrient enrichment and hypoxic conditions in the Gulf (CENR, 2000). Total nitrogen concentrations in the Upper Mississippi River increase markedly in Pool 2 (RM 847.5 to RM 815) as a result of agricultural inputs from the Minnesota River Basin and point source contributions from the Twin Cities Metropolitan Area. Concentrations decrease downstream due to dilution from tributaries with lower nitrogen levels, nutrient assimilation by aquatic plants, denitrification, and sedimentation of particulate organic nitrogen. Nitrogen concentrations increase again below Le Claire, IA (Pool 15, RM 497), likely due to increased nitrogen loading from Iowa and Illinois tributaries.

Based on Pool 2 data collected over the 20-year period, total nitrogen levels were higher in the 1990s than in the 1980s. A similar temporal comparison for the lower reach of the UMR was not possible due to the unavailability of data for the early time periods (UMRCC, 2002).

Nitrite+nitrate nitrogen concentrations throughout the river increased to higher levels in the 1990s, compared to concentrations observed during 1985-89. For the upper river, this response may have been partly associated with changes in municipal wastewater treatment technology (nitrification). However, changes in precipitation and river flow are additional factors associated with river-wide increases in nitrite+nitrate nitrogen concentrations. The drought conditions of the late 1980s reduced nonpoint source runoff and increased utilization of inorganic nitrogen within the riverine pools. Increased nonpoint source runoff in the 1990s likely favored mobilization of nitrite+nitrate nitrogen from agricultural watersheds, resulting in high nitrogen concentrations in the river during this period.

4.4 pH

Measurements of pH provide an index of the acidity or alkalinity of water. Most UMR states have adopted a standard that incorporates a pH range from 6 to 9 units to protect and support aquatic life use, including fisheries. Monitoring agencies have typically used different methods to measure pH. Most summer pH values in the UMR range from 7 to 9 units, thus normally supporting full fish and aquatic life standards. At a number of locations during several time periods, summer pH values have exceeded 9. These elevated pH values were likely the result of high levels of photosynthetic activity (UMRCC, 2002).

The relatively high pH values recorded in the Upper Mississippi River can be traced to the underlying dolomitic bedrock which has high concentrations of calcium and magnesium carbonates, both of which contribute to higher pH values upon dissolution.

4.5 Water Transparency

Total suspended solids (TSS) represent the amount of filterable particulate material in water, expressed as mg/L. In general, the concentration of TSS increases with increasing river flow. Higher flows may result in increased sediment suspension or may reflect periods of runoff, both of which contribute to higher TSS concentrations. In particular, runoff from watersheds with a predominance of cultivated lands is an important source of suspended matter in the river. In addition, stream bank erosion in many tributaries contributes large loading of TSS to the river during high flow events. Once TSS has reached the river, the particulate material may contribute to sedimentation problems in backwaters, negatively influence submersed aquatic plant growth due to decreased light penetration, smother benthic invertebrates, and lead to other impairments. The states have not adopted TSS standards for the river. Highest TSS concentrations (> 500 mg/L) are found in the lower portion of the Upper Mississippi River (below RM 200) and are attributed to turbid inflows from the Illinois and Missouri Rivers. The Minnesota River is the major source of TSS in the upper portion of the river and contributes to elevated concentrations from its confluence with the UMR (RM 844) to the St. Croix River (RM 811.5) where levels decrease due to dilution. Lowest TSS concentrations in the UMR are normally found at the mouth of Lake Pepin (RM 764.5), a 25-mile long natural riverine lake, which acts as an effective sediment trap (Engstrom and Almendinger, 1998).

5.0 HUMAN USE

5.1 Surrounding Land Use

The Quad Cities Nuclear Station site is located in the Upper Mississippi River Basin, on the east bank of Pool 14 of the Mississippi River, about 16 miles below Dam 13 and 13 miles from Dam 14. The station is approximately 506.5 miles upstream from its confluence with the Ohio River (i.e., river mile [RM] 506.5). The site is on moderately high ground that rises abruptly from the surface of the river to form bluffs between 20 feet and 40 feet high. It is situated in the Meredosia Channel, an ancient channel of the Mississippi River. The topography of the site is flat, with an elevation of 23 feet above normal pool level and a grade level approximately 9 feet above the maximum recorded flood stage over a 102-year period. The river flow of the adjacent Pool 14 (an approximately 25 mile section), between Lock and Dam 13 and Lock and Dam 14 is controlled below flood stage (U.S. Nuclear Regulatory Commission, 2004).

The QCNS site consists of 920 acres. In addition to the two nuclear reactors and their turbine buildings, intake and discharge canals, and ancillary buildings, the site includes switchyards and a retired spray canal now utilized to raise fish. The retired spray canal is approximately 3 miles long and 250 feet wide and it surrounds the plant and occupies approximately 90 acres. A publicly available, paved bicycle trail passes along the eastern edge of the site property, adjacent to Route 84. The Rock Island County Land Use Plan designates the site as industrial use (U.S. Nuclear Regulatory Commission, 2004).

The Quad Cities metropolitan area, consisting of the Cities of Davenport and Bettendorf, Iowa and Rock Island, Moline, and East Moline, Illinois is located 20 miles southwest of QCNS. QCNS is about four miles north of Cordova, Illinois, and ten miles southwest of Clinton, Iowa.

The region within six miles of the site includes portions of Rock Island and Whiteside Counties in Illinois and Scott and Clinton Counties in Iowa. The area surrounding QCNS is predominantly rural, consisting of farmland and woods; however, there is an industrial park approximately one mile north of the Station and a gas-fired power plant approximately one mile southeast of QCNS. The lower segment of the Upper Mississippi River National Wildlife Refuge is across the river from QCNS, providing habitat for numerous plant and animal species. The predominant land cover in this section of the refuge is woody terrestrial with a small portion characterized by wetland emergents (Exelon, 2004).

5.2 Recreational Uses

Boating is an important recreational activity throughout the Upper Mississippi River and its tributaries. Houseboats, powerboats and fishing boats of all types are used during the warmer months of the year. Indiscriminate boat mooring along the shore is a problem influenced by the ownership of waterfront property. There are evidently limited amounts of public frontage available to boat owners. Gas and oil spills, as well as litter and human wastes discharged from these boats affect the water quality.

Sand bars, especially fresh ones, are prime river recreational areas. Boaters, swimmers, picnickers, and others seem to pick fresh sand bars over all other habitats for their recreational site. These sand bars are created at the upper ends of pools from spoil materials dredged from the river bed. The open sandy dredge bank remains a breach for a period of 5 to 6 years before sand willows become established. Sand bar formation and the associated recreational demand is probably lower at the Quad Cities site which is located some distance from both Dam 13 and Dam 14, the major areas of sand-bar formation in the Quad Cities region.

Fishing is one of the more intensely pursued recreational activities in Pool 14. Many local and non-local fishermen fish this area for many species including walleye, sauger, largemouth bass, bluegill, channel catfish, black and white crappie, and hybrid striped bass throughout the year as fishing regulations permit. Many local bass fishing tournaments are held annually on Pool 14 and several national walleye and bass tournaments have fished this Pool.

5.3 Transportation

5.3.1 Shipping

U.S. Army Corps of Engineers maintains the commercial shipping channel and operates the Lock and Dam system on the Upper Mississippi River. Clinton maintains a municipal dock directly accessible from the Mississippi Navigation Channel. Beaver Slough, a secondary channel of the river, provides an additional connection between Clinton and the navigation channel. Other towns along the shore of Pool 14 that have direct access to the Channel are Fulton, Comanche, Princeton and Le Claire (U.S. Army Corps of Engineers, 1974).

5.3.2 Airports

The Quad Cities Airport, which is located about 20 miles southwest of QCNS in Moline, IL, is the major commercial airport serving the region. Several major airlines maintain daily flight schedules to other cities in the Midwest including St. Louis and Chicago.

The Clinton Airport is located 3 miles southwest of Clinton, IA and is owned and operated by the City of Clinton. It currently serves the private sector, primarily. All municipalities along Pool 14 have access to both the Clinton Airport and the Whiteside County Airport near Rock Falls, Illinois.

5.3.3 Highways

Illinois State Route 84, a two lane paved road, follows the east bank of the river for the entire length of Pool 14, intersects Interstate 80 south of Rapids City and joins Illinois Highway 92, continuing its parallel course with the river. On the Iowa bank of the river, U.S. Highway 67 follows the entire length of the pool.

Three highway bridges cross the river within the Pool 14 area. The Fulton Bridge is a two-lane span that carries the traffic of U.S. 30A and State Road 136; the Clinton Bridge is also a two-lane span that carries U.S. 30 traffic. The Interstate 80 Bridge, south of Rapids City and Le Claire, carries two-lane traffic in each direction (U.S. Army Corps of Engineers, 1974).

5.4 Municipal, Commercial, and Industrial Use

QCNS is located on Mississippi River Pool 14, an impoundment that was established by the U.S. Army Corps of Engineers and continues to be maintained by the Corps.

Approximately one mile north of QCNS is an industrial park with several plants, the largest of which is operated by Minnesota Mining and Manufacturing Company (3M). This plant manufactures hydrofluorethers. Many of the facilities in this complex discharge to the air and to the Mississippi River. The town of Clinton, Iowa, about 10 miles upriver, also contains several large industrial facilities that influence the environmental quality of Pool 14. One such plant is the M.L.Kapp Station, a 235-megawatt coal-fired electrical generating station owned by Alliant Energy. Another is the ADM corn processing plant.

In addition to the existing, long-term industrial base near QCNS, there is a recently completed gas-fired generating plant located less than one mile southeast of QCNS. The Station is owned by MidAmerican Energy who completed the 500-megawatt Cordova Energy Center in June 2001. It withdraws makeup water for condenser cooling from groundwater, but discharges its blowdown to Pool 14 at ambient temperatures (Exelon, 2004).

5.5 Contaminants

Land use practices, floods, other natural events, spills, and other human caused incidents within the watershed affect contaminant levels in river water and sediments. These, in turn, affect quality and quantity of fish and wildlife habitat. Dissolved oxygen (DO) is crucial to fish and invertebrate survival and DO levels are good indicators of pollution (Soballe and Wiener, 1999). Water quality of the Upper Mississippi River has improved in recent decades in the area of gross sewage pollution, but the river still receives a wide array of agricultural, industrial, and urban contaminants. The risks and threats of certain herbicides, such as atrazine, on the aquatic biota are largely unknown. Excessive nutrients cause excessive plant growth, which upon decomposition, can impact benthic organisms such as fingernail clams. Polychlorinated biphenyls (PCBs) have been linked to a contaminated Upper Mississippi River food web affecting fish, mink, and burrowing mayflies (Soballe and Wiener, 1999).

The Lost Mound Unit of the Upper Mississippi River National Wildlife and Fish Refuge was formerly the Savanna Army Depot, which was placed on the National Priorities List for Superfund Cleanup in 1989. The Savanna Army Depot officially closed on March 18, 2000, as part of the Base Realignment and Closure Act. The former Depot included a total of 13,062 acres that have been transferred to four agencies: the U.S. Fish and Wildlife Service; the Local Redevelopment Authority; the U.S. Army Corps of Engineers; and the Illinois Department of Natural Resources.

On September 26, 2003, the Department of Defense agreed to transfer 9,404 acres of land to become the Lost Mound Unit of the Upper Mississippi River National Wildlife and Fish Refuge. A total of 3,022 acres was actually transferred in fee at the time of the signing of the Memorandum of Agreement. The remaining acreage will be transferred in the future as parcels are certified clean from environmental contaminants. In the meantime, the Service will manage wildlife and habitat on all 9,404 acres. The Lost Mound Unit was included in a comprehensive conservation plan (CCP) completed by the Upper Mississippi River National Wildlife and Fish Refuge in 2006. The CCP is intended to outline how the Refuge will fulfill its legal purpose and contribute to the National Wildlife Refuge System's wildlife, habitat and public use goals (USFWS, 2009).

5.6 Organic Contaminants—Types, Sources, and Risks

The Mississippi River receives a variety of organic wastes, some of which are detrimental to human health and aquatic organisms. Urban areas, farms, factories, and individual households all contribute to contamination of the Mississippi River by organic compounds. This contamination is important to consider because about 70 cities rely on the Mississippi River as a source of drinking water. Considerable gains have been made in the last two decades in controlling point-source contamination, but control of nonpoint-source contamination has been more difficult.

Organic contaminants in the Mississippi River were assessed by collecting water and sediment samples between Minneapolis-St. Paul, Minnesota, and New Orleans, Louisiana, during 10 sampling surveys conducted in 1987-92, and analyzing the samples for the organic contaminants and indicator compounds listed in Table A-1.

The most significant factors controlling the concentrations of organic contaminants in rivers are the physical processes of dispersion and dilution. Within this physical framework, the most significant chemical and biological processes controlling the fate of organic contaminants in the Mississippi River are (1) sorption to the sediment and removal by deposition, (2) desorption and diffusion of contaminants from bed sediments back into the water, (3) biological transformation to intermediate compounds, or biodegradation for complete removal, (4) volatilization to the atmosphere, (5) bioconcentration and magnification in the food chain, (6) photolysis, or the breakdown of contaminants under the influence of sunlight, and (7) hydrolysis, or the decomposition of contaminants by taking up the elements of water. Organic compounds of the type called "hydrophobic" (meaning that they prefer being adsorbed onto sediment or organic particles to being dissolved in water) can be adsorbed onto sediments in concentrations that are a thousand to a million times greater than in the associated water. Once they are adsorbed, the contaminants can be deposited and eventually become buried as sediments continue to accumulate. Buried contaminants can be remobilized, however, by resuspension of the sediments. Likewise, the sedimentary organic matter may decompose, reintroducing its adsorbed contaminants to the river by desorption and diffusion of organic colloids. If the contaminants are adsorbed onto the sediments in high concentrations, they can adversely affect bottom-dwelling organisms. The tendency of a contaminant to adsorb onto the sediment is frequently indicative of its capacity to bioconcentrate and become magnified in the food chain.

A summary of the major organic contaminants identified, their range of concentrations, their water-quality criteria, and their environmental fate is presented in Table A-2. Fecal coliform bacteria was the only contaminant that exceeded health limits. Although concentrations of most organic compounds measured in this study were below regulatory limits, their distributions indicate that the entire Mississippi River has been contaminated by point and nonpoint sources. Significant sources of organic contaminants include municipal-wastewater discharge, urban runoff, power-plant cooling-water discharges, pulp-mill effluents, feedlot runoff, commercial and recreational river traffic and refueling, discharges from industrial facilities, and agricultural runoff.

The Mississippi River carries higher concentrations of organic contaminants in the vicinity of major metropolitan areas. Concentrations are typically greatest in the upper river where the stream- dilution factors are lowest. Major tributaries such as the Minnesota, Illinois, Missouri, and Ohio Rivers have significant effects on the organic chemistry of the Mississippi River. Seasonal differences are related to hydrologic, climatic, biological, and geochemical factors. Concentrations are greatest during periods of low flow (fall) and least during periods of high flow (spring). Likewise, concentrations of biologically labile and volatile organic compounds are greatest during the winter when temperatures are lowest.

Although the data presented above provide only a brief glimpse of the water quality of the Mississippi River, comparisons with historical data show trends of improving water quality for several constituents. The improvements can be related to: (1) changes made by the chemical manufacturing industry to address the environmental fate of problematic chemicals, and (2) improved wastewater treatment by municipal and industrial dischargers. Converting primary treatment facilities to secondary treatment has resulted in improved water quality, although chemicals that are not completely removed present a challenge for treatment technology (Meade et al., 1995).

5.7 Heavy Metals Contaminants

Metals in the Mississippi River come from natural as well as artificial sources. Metals that are naturally introduced into the river come primarily from such sources as rock weathering, soil erosion, or the dissolution of water-soluble salts. Naturally occurring metals move through aquatic environments independently of human activities, usually without any detrimental effects. However, as the valleys of the Mississippi River and its tributaries were settled and industrialized, the metals added by human activities have affected the water quality of the Mississippi River and ultimately the Gulf of Mexico. Some of these metals are essential for proper metabolism in all living organisms yet toxic at high concentrations; other metals currently thought of as non-essential are toxic even at relatively low concentrations.

Heavy metals are released to the Mississippi River from numerous artificial sources. Typical sources are municipal wastewater-treatment plants, manufacturing industries, mining, and rural agricultural cultivation and fertilization. Heavy metals are transported as either dissolved species in water or as an integral part of suspended sediments, and may be volatilized to the atmosphere or stored in riverbed sediments. Toxic heavy metals are taken up by organisms with the metals dissolved in water having the greatest potential of causing the most deleterious effects.
The heavy metals are defined as those having densities five times greater than water. Well-known examples of heavy metallic elements are iron, lead, and copper. Many heavy metals can become toxic or aesthetically undesirable when their concentrations are too great. Several heavy metals, like cadmium, lead, and mercury, are highly toxic at relatively low concentrations, can accumulate in body tissues over long periods of time, and are nonessential for biological well-being.

No specific health guidelines for heavy metals associated with suspended or bed sediments have been established by the U.S. Environmental Protection Agency. This lack of national guidelines based on concise scientific criteria causes difficulty when evaluating the environmental effects of heavy metals in sediments.

Two of the largest lead-zinc mining areas in the world are located along the Mississippi River between Prairie du Chien, Wisconsin, and Galena, Illinois; thus providing the opportunity for these metals to enter the river system. Cultivated soils can become enriched with toxic metals associated with the application of fertilizers and pesticides. Although the concentrations may vary between specific formulations, many of these fertilizers contain chromium, copper, iron, manganese, nickel, and zinc. Some pesticides use heavy metals such as mercury as an integral component. During the late spring and early summer, after fertilizers and pesticides have been applied, the runoff from rain flushes these contaminants into the Mississippi River.

The atmosphere is also a source of metal contamination to aquatic environments. Metal-containing particulates that are washed from the atmosphere by rain and snow are deposited in drainage basins and find their way into lakes and rivers. As of 1973, the total nationwide airborne particulate emissions were distributed basically among three sources: 51 percent from industrial processes, 29 percent from fossil-fuel combustion, and 20 percent from miscellaneous burning practices (Magee et al., 1973). Since 1973, vehicle emissions (and perhaps other emissions as well) have decreased. Stone and rock crushing, iron and steel foundries, grain-handling operations, and cement production emit the greatest percentage of the particulates. Coal, used extensively for power generation, often contains significant concentrations of metals such as vanadium, copper, nickel, chromium, zinc, lanthanum, cobalt, molybdenum, gallium, germanium, tin, and mercury (Magee et al., 1973).

The numerous studies of the heavy-metal water quality of the Mississippi River that have been conducted over the last several decades have emphasized mostly the water quality in specific regions of the river. However, the study performed by Garbarino, Hayes, Roth, Antweiler, Brinton and Taylor assesses the heavy-metal contamination through the full length of the Mississippi River from Minneapolis, Minnesota, to the Gulf of Mexico using one set of field scientists and one set of laboratory analysts for the duration of the study. Heavy metals released into the Mississippi River, by both natural processes and human activities, can be either transported with the water and suspended sediment or stored within the riverbed bottom sediments.

The different chemical forms of heavy metals in the river influence their availability and toxicity to organisms. Heavy metals are readily available to aquatic organisms and pose a significant health hazard when they are present as dissolved inorganic or organic species in the water or loosely adsorbed to particulate surfaces. When heavy metals are present as components of particulates, such as inorganic metal-hydroxide coatings or metal-organic compounds, some chemical alterations are required before they can be released and become biologically available. Even stronger chemical reactions (cation exchange) are required to release heavy metals that are integral parts of the minerals composing river sediments. These reactions are driven by pH rather than temperature.

Information on heavy metals in the Mississippi River that are described in this section generally was based on data collected during the summer and autumn of 1991 and the spring of 1992. Data that were collected in the Lower Mississippi River during 1987-90 (Brinton et al., 1995) reinforce the findings presented here. Concentrations of toxic heavy metals dissolved in the water in the 1,800-mile reach of the Mississippi River from Minneapolis, Minnesota, to Belle Chasse, Louisiana, are well below USEPA guidelines for drinking water and water that supports aquatic life. However, heavy metals associated with suspended sediments exceeded the pollution guidelines at many of the main-stem sampling locations. Heavy-metal concentrations in the suspended sediments were generally greater in the small colloidal-sized particles than the larger silt-sized particles. Even though the colloids compose a significantly lower percentage of the total suspended sediment, their heavy-metal concentrations are greater. Sediments stored in pools upstream from every lock and dam of the Upper Mississippi River also have elevated heavy-metal concentrations. The biological accessibility to heavy metals associated with suspended and stored sediment also depends on the chemical form in which the metal exists (Meade, 1995).

Whether the loads and concentrations of heavy metals in the Mississippi River have increased or decreased in recent years is difficult to determine. Although most of the heavy metals in the river are associated with sediment, most of the previous studies have focused on the dissolved metals. Even for the dissolved metals, comparisons are difficult to draw between earlier and more recent data because analytical laboratory techniques have become markedly more sensitive in the last decade and field sampling techniques have not been adequately standardized. Specific conclusions about increases or decreases in heavy metals with time in the Mississippi River are tenuous at best (Meade et al., 1995).

5.8 Other Stressors

In the Upper Mississippi River basin, sedimentation and toxic contaminants have been identified as the major threats to biotic resources (Wiener et al. 1984).

5.8.1 Contaminant Concentrations in Surface Waters

Land use practices, floods, other natural events, spills, and other human caused incidents within the watershed affect contaminant levels in river water and sediments. Agricultural fields, animal feedlots, and urban areas are principle sources for plant nutrients that enter the river (Soballe and Wiener, 1999). Excessive inputs of nitrogen and phosphorus can cause algal blooms, contribute to excessive plant growth and subsequent decomposition that depletes DO (limiting fish and other aquatic life distribution and survival), and cause public health concerns. Plant decomposition in the sediment can also be a source of ammonia that adversely affects burrowing organisms such as fingernail clams and mayflies (USFWS, 2006)

5.8.2 Contaminant Concentrations in Sediments

The Upper Mississippi River transports moderate to high quantities of sediments that enter the river from row crop farming, mining, and urban development. Turbidity levels, a measure of suspended sediments, at the Maquoketa River (Pool 13) in Iowa are more than double all up-river inputs combined. This reflects a substantial increase in inputs from erodible agricultural lands. Sediments fill backwaters and reduce the diversity of water depths. Sediments also absorb and transport containments.

5.8.3 Contaminant Concentrations in Animal Tissue

Polychlorinated biphenyls (PCBs) have been linked to a contaminated Upper Mississippi River food web affecting fish, mink, and burrowing mayflies (Soballe and Wiener, 1999).

In 1993, investigators collected great blue heron eggs from 10 colonies on the Upper Mississippi River (8 on the Refuge) to determine the effect of organochlorines, mercury, and selenium on heron nesting (Custer et al., 1997). The authors concluded that these contaminants do not seem to be a serious threat to nesting great blue herons on the Upper Mississippi River. Organochlorine concentrations (including DDE, the metabolite of the insecticide DDT or dichlordiephenyltrichloroethane) were generally low (mean DDE = 1.3 µg/g; PCB = 3.0 µg/g; TCDD [dioxin] = 11.5 µg/g). Eggshell thickness was negatively correlated with DDE concentrations but eggshell averaged only 2.3 percent thinner than eggs collected during the years prior to the use of DDT. Mercury and selenium concentrations (mean = 0.8 and 3.1 µg/g, respectively) in eggs were within background levels.

Mercury and PCBs are present in fish of the Mississippi River. Sources of mercury are both natural and man-made; PCBs do not occur naturally. Both contaminants build up through the food chain and the highest levels occur in predatory fish (walleyes, bass, and northern pike), scavengers (catfish) and bottom feeders (carp). Fish consumption advisories are issued by the Health Departments of the four states overlapping the Upper Mississippi River National Wildlife & Fish Refuge.

Minnesota, Wisconsin, and Illinois all have advisories directed primarily toward reducing intake of mercury and PCBs by pregnant women and children under the age of 15. Minnesota and Wisconsin have detailed advisories for consumption of fish taken from various pools of the Refuge. However, the extent of consumption and the number of species included on the lists vary between states along the same pool.

6.0 AQUATIC HABITATS

Pool 14 encompasses a variety of aquatic habitats and communities in the vicinity of Quad Cities Station. Although municipal and industrial waste discharges from the Clinton, Iowa area have occasionally resulted in excessive slime growths in the slough areas in the vicinity of the station, Pool 14 is a relatively unpolluted environment. (U.S. Atomic Energy Commission, 1972)

Major Mississippi River habitats near the station are the channel habitat, channel border habitat, side-channel habitat, river lake and pond habitat, slough habitat, and island lake habitat. These habitats are chiefly defined by location, depth, bottom material and vegetation. The main channel in the vicinity of the station is characterized by a scoured sand bottom and the highest current velocity. Directly downstream from the station along the Illinois shore are several small islands with adjacent, relatively quiet, shallow water areas. Further downstream, across the main channel, are extensive areas of side channel and slough habitats. The 16-mile portion of the pool upstream of the station has a large amount of side-channel and slough habitat, five or six times as much as that downstream from the station (U.S. Atomic Energy Commission, 1972).

7.0 AQUATIC LIFE

Biological studies in Pool 14 and other pools in the river have established the existence of relatively diverse and productive planktonic, periphytic and benthic communities which support commercial and sport fisheries.

7.1 Producers

7.1.1 Submerged Aquatic Vegetation

Submerged aquatic vegetation includes plants that grow below the surface of the water and are usually anchored to the bottom by their roots. This group of plants generates dissolved oxygen, filter suspended material, stabilize bottom sediments, and cycle nutrients (Rogers and Theiling, 1999). Submerged aquatics provide crucial fish habitat, provide substrate for invertebrate growth, and are important foods for mammals and migratory birds. They are most often found in backwater areas of low water velocity, adequate light penetration and relatively stable water levels. Beginning in the 1960s and 1970s, river scientists and users noted declines in submerged (and emergent) vegetation cover throughout the Refuge. Factors included wind and wave action, poor light penetration due to highly turbid water conditions, sedimentation and filling of backwaters, major flooding events, and long term inundation with few drying periods. Due to these factors, there is an uneven distribution of submerged plants through the length of the Refuge. Recovery of lost submerged plant beds has occurred naturally or through habitat rehabilitation projects in Pools 4, 5A, 7, 8, 9, and 13. Within the last decade, beds of submerged plants have been naturally re-established throughout Pool 14 (HDR, 2009a; USF&WS, 2006).

7.1.2 Emergent Aquatic Vegetation

Emergent aquatic vegetation (emergents) are plants whose roots are anchored under water with much of the plant extending above the water surface. They include cattail, river bulrush, giant reed grass, burreed, arrowheads and wild rice. They are backwater plants adapted to low water velocities and shallow- to deep-water marsh conditions. The emergent plant community in Pool 14 and throughout this reach of the river is sparse and a concern of resource managers. It is characterized by the abundant river bulrush and reduced numbers of cattail, burreed, and arrowhead. Much of the declines of the last three taxa has occurred since the 1970's (USF&WS, 2006)

7.1.3 Phytoplankton

Biological studies conducted for Commonwealth Edison by Biotest Laboratories Inc. (1970 a, b) documented that the most prevalent phytoplankton were diatoms of genera Cyclotella, Melosira, and Stephanodiscus. Even in summer samples, diatoms were the common organisms and blue-green alga seldom comprised 10% of the population. Species lists of typical phytoplankton species found near Quad Cities Station during the periods March through July 1972 and August 1972 through January 1973 are given in Tables 2 and 3 of the report titled "An Evaluation of the Quad Cities Station of Commonwealth Edison Company for a 316(a) Demonstration" dated January, 1975. This original January, 1975 316(a) Report concludes that organisms present between river mile 501 and 509 in the Mississippi River are characteristic of a somewhat enriched habitat and, although seasonal variations exist, the phytoplankton communities have been relatively stable. Comparisons of total phytoplankton, major algal divisions, and dominant species at locations upstream and downstream from the originally designed side-jet discharge or of the diffuser pipe dissipation system indicated that neither mode of heat discharge had any detectable effect upon phytoplankton numbers or community composition. This evidence led to the eventual discontinuation of phytoplankton studies in the Mississippi River in the area of Quad Cities Station (Commonwealth Edison, 1975).

Phytoplankton studies were conducted in conjunction with and at the same locations as zooplankton studies from August 1972 through August 1973. During full open-cycle cooling, an overall stimulatory effect on phytoplankton was measured in the river downstream of the diffuser pipe, which was not interpreted as a negative influence. Mean values for carbon fixation rates, chlorophyll *a* concentrations and phytoplankton abundances during chlorination and non-chlorination periods were compared at several upstream and downstream locations. No trends of significant differences ($P<0.05$) in phytoplankton productivity and chlorophyll *a* concentrations for the sample period between the sampling locations immediately upstream and downstream of the diffuser pipes were observed. Many of the individually significant differences that were identified during this period between upstream and downstream locations were attributed to non-homogeneity of phytoplankton populations between locations.

7.1.4 Periphyton

Growth of periphyton occurs upon many submerged substrates in the Mississippi River. Biological studies conducted for Commonwealth Edison by Industrial Bio-Test Laboratories, Inc. (1970 a, b) in Pool 14 indicate that periphytic growths are common on logs and rocks in slack-water locations. Cladophora was the principal genus in the periphyton of Pool 14, although a variety of other forms (Oscillatoria, Melosira, Stigeoclonium and Lyngbya) were common. During July, abundant growths of blue-green algae (Aphanizomenon) were collected on substrata at two locations. Also, Microcystis was found to be abundant at one location and Plectonema at one location from this monitoring. A species list of typical periphytic alga found in the vicinity of Quad Cities Station during May-June 1972 monitoring by Industrial Biotest Laboratories Inc. is given in Table 4 of the report titled "An Evaluation of the Quad Cities Station of Commonwealth Edison Company for a 316(a) Demonstration" dated January, 1975. No consistent differences between upstream and downstream periphyton colonizing the artificial substrates were attributable to diffuser pipe operation (Clark, 1974). All changes in periphytic algal communities or chlorophyll a production were related to seasonal fluctuations or other hydrological conditions and were not affected by operation of the Quad Cities Station during the diffuser pipe mode of discharge. This evidence led to the discontinuation of periphyton studies in the Mississippi River in the area of Quad Cities Station (Commonwealth Edison, 1975).

7.2 Consumers

7.2.1 Zooplankton

The nature and distribution of zooplankton populations in the Mississippi River, particularly in Pool 14, has not been well documented with the exception of the work that has been conducted for Commonwealth Edison Company by Industrial Bio-Test Laboratories, Inc. Studies in other river systems in North America, however, have described the nature of these organisms and examined the problem of survival in relationship to a variety of factors. The relationship between species richness and abundance in streams appears to be largely due to changes in flow rate and specific habitats within a specific river system. Studies in Pool 14 substantiate this finding. One of the major factors affecting variations in zooplankton density and community composition at locations with similar habitats are the hydrological conditions in the river. Densities were found to be inversely related to flow conditions while the species richness observed on a particular sampling date was directly related to flow. The dynamic nature of the Mississippi River with its variable flow and water levels, as well as the contribution from its many tributaries, enhances the randomness of zooplankton distribution (Commonwealth Edison, 1975).

The zooplankton community in Pool 14 is dominated by several true planktonic species such as Cyclops vernalis, Cyclops bicuspidatus thomasi, Diaptomus siciloides, and Bosmina longiorstris. Additional dominant taxa are total Rotiferia and tycohoplanter Chydorus spaericus. Other species such as Diaphanosoma spp. and Moina spp. demonstrate seasonal pulses. Remaining species are considered incidental forms which are present as results of hydrologic conditions (Commonwealth Edison, 1975).

Figures 4 and 5 of the original 316(a) report (Commonwealth Edison, 1975) show the seasonal variations of the zooplankton community in the Mississippi River from February 1973 through January 1974. Table 5 of this report is a species list of the typical representative planktonic crustaceans collected during the period August 1973 through January 1974. Comparisons of total zooplankton and the three major groups of zooplankters prior to and during all phases of the station operation at locations upstream and downstream from the Quad Cities Station did not reveal any differences attributable to plant operations. This evidence led to the eventual discontinuation of zooplankton studies in the Mississippi River in the area of Quad Cities Station (Commonwealth Edison, 1975).

7.2.2 Benthic Invertebrates

In the July 1969 – June 1970 study by Industrial Bio-Test Laboratories, Inc. the benthic organisms were found to be composed mainly of "facultative" forms (adaptable to a wide range of conditions). The dominant organisms were insects of the orders Ephemeroptera (mayflies), Trichoptera (caddisflies), and Diptera (family Chironomidae or midge flies). Oligochaete worms were present in some of the organically rich sediments. Samples from the main channel contained few organisms probably because of a combination of two factors: (1) scouring action of the current and (2) the presence of sandy substrates which are regarded as unsuitable habitat for aquatic animals (Hynes, 1970). In areas such as wing dams, sloughs, and shorelines, which are protected from the current and where more suitable substrates occur, a greater abundance and diversity of invertebrates were observed. In July, 1970, two genera, midges (*Chironomus*) and sludge worms (*Limnodrilus*), were the two most abundant groups present, comprising 34.7 and 41.1 percent of the 297 organisms collected. Other groups, such as crustaceans, caddisflies, and leeches comprised 3% or less of the total organisms found during this period. Mollusks were found in very small numbers and generally exhibited no consistent pattern of distribution. A species list of typical benthic invertebrates collected in the Mississippi River near the Quad Cities Station during the periods of February – July 1973 and August 1973 – January 24, 1974 is shown in Tables 6 and 7 of the 316(a) demonstration (1975). Analyses of the data indicated no discernable effects on the benthos relative to the thermal discharge from Quad Cities Station. The benthos data that was compiled over a four year time period indicated that the variation of the major organisms between locations upstream and downstream of Quad Cities Station was due to seasonal fluctuations, substrate differences and changes in river flows. This evidence led to the discontinuation of benthic studies in the Mississippi River in the area of Quad Cities Nuclear Station.

Studies of aquatic macroinvertebrates were conducted during 1972 in Pool 14 (U.S. Army Corps of Engineers, 1974). During this study, 33 families representing 40-53 genera were found to be present. The Chironomidae (midges) consistently contributed the major portion of genera (13 to 28) and represented 28 to 50 percent of the total genera identified in the samples. The mussels (Unionidae) most often contributed the second highest number of genera, with four to six, or nine to 13 percent of the genera present. The highly productive mayflies (Ephemeridae) contributed three or four genera (seven to nine percent) to most samples. Other invertebrate families were usually represented by only one genus although one family of the caddisflies (Hydropsychidae) was often represented by three genera.

The caddisflies (Trichoptera) generally contributed the greatest numbers of individuals at two stations sampled along the navigation channel between miles 504.5 and 506; however, midges (primarily Chrironomidae) nearly equaled the caddisflies in numbers of individuals collected. Mayflies, sideswimmers (amphipoda), and aquatic worms (Oligochaeta) occupied the next three positions in number of individuals collected in most samples.

Caddisfly larvae, snails (Gastropoda), stonefly nymphs (Plecoptera), and mussels (Unionidae) live on course substrates. Caddisflies and sideswimmers live on a variety of substrates, including the silty bottoms of Pool 14. Midges, mayflies, and aquatic earthworms are confined mostly to silty bottoms.

7.2.3 Drifting Invertebrates

Sampling for drifting macroinvertebrates was conducted in 1971 in Pool 14. The dominant forms comprising typical drift organisms during the period April through December 1971 are shown in Table 8 of the 316(a) demonstration (Commonwealth Edison, 1975). Subsequent to that time sampling for drifting macroinvertebrates was conducted near the area of the diffuser pipe discharge from May-November 1972. The amphipod Hyalella azteca was the most abundant drifting invertebrate collected. Mayfly nymphs, Hexagenia spp., were the second most abundant taxa in the collections, and the two-winged fly Chaoborus punctipennis was the third most abundant taxon collected.. Other important organisms reaching high seasonal peaks were: caddisfies (Cheumatopsyche sp., Potamyia flava, and Hydropsyche orris); mayflies (Caenis spp., Brachycerus spp., Tricorytnodes spp., Baetis spp., Baetisca spp., and Isonychia spp.); water mites (Acari sp), and a diverse population of midges. No consistent effects on the drifting macroinvertebrate populations were attributable to operation of the diffuser-pipe mode of heat dissipation. This evidence led to the discontinuation of drifting benthic macroinvertebrate studies in the Mississippi River in the area of Quad Cities Station.

7.2.4 Mussels

The Upper Mississippi River contains a rich assemblage of freshwater mussels. Historically, as many as 50 species of mussels were documented from the Upper Mississippi River, but only 30 species have been reported in recent surveys. Two of these are listed as federally endangered; and many of the others are rare (i.e., listed as endangered, threatened, rare, or of special concern by one or more states (USGS, 1999). The freshwater mussels have been adversely impacted by activities such as the pearl button and cultered pearl industries, siltation (associated with agriculture, poor land management, and impoundments), pollution from agricultural and industrial chemicals, establishment and maintenance of the navigation channel, and competition from exotic species, particularly the zebra mussel (*Dreissena polymorpha*) (Exelon 2003; USGS, 1999). A high mussel die-off occurred in Pools 14 and 15 in the 1980s, but the cause was not identified (USGS, 1999).

Mussels are often found in dense aggregations called mussel beds. While these beds may be miles apart, an individual bed can be up to several miles long (USGS, 1999). Thirty-one species of unionid have been collected from Pool 14. The most abundant species include threeridge (*Amblema p. plicata*; 37.9 percent), pimpleback (*Quadrula p. pustulosa*; 16.4 percent), plain pocketbook (*Lampsilis cardium*; 10.1 percent), Wabash pigtoe (*Fusconaia flava*; 6.2 percent), threehorn wartyback (*Obliquaria reflexa*; 5.8 percent), mapleleaf (*Quadrula quadrula*; 4.8 percent), and giant floater (*Pyganodon grandis*; 4.5 percent) (Exelon 2003a). These species are widespread and relatively common throughout the Mississippi River and its tributaries (Cummings and Mayer, 1992). Populations of fingernail clams (Sphaeriidae) have declined in certain reaches of the Upper Mississippi River during recent decades. The declines have occurred chiefly during low-flow periods associated with droughts (Fremling and Drazkowski, 2000).

The zebra mussel became established in the upper Mississippi River by 1992 and has continued to spread throughout the river system. Their increase causes a decline among many native mussels, as it can out-compete native species for oxygen and food and is so prolific that it can smother native mussels (USFWS 2001c). The zebra mussel has also increasingly displaced other macroinvertebrates, such as hydropsychid caddisflies that live on submerged hard surfaces (Fremling and Drazkowski, 2000).

The Higgins' eye pearlymussel (*Lampsilis higginsi*) was listed as a federally endangered species on June 14, 1976 (41 FR 24064) (USFWS 1976). It is only found in the Mississippi River, St. Croix River in Wisconsin, the Wisconsin River, and the Rock River in Illinois. It was never abundant, historically comprising only about 0.5 percent of the mussel population. At the time the original recovery plan was written in 1983, the Higgins' eye pearlymussel had undergone a 53 percent decrease in its known range (USFWS undated). It is generally found in mussel beds with at least 15 other species present (USFWS 2003b).

No critical habitat has been designated for the Higgins' eye pearlymussel. However, fourteen Essential Habitat Areas for this species occur within the Upper Mississippi River watershed. Essential Habitat Areas are locations known to contain reproducing populations in association with a healthy and diverse unionid community (e.g., mussel beds) (USFWS, 1998). An Essential Habitat Area begins approximately 1.0 mile downstream of Quad Cities, Units 1 and 2 at River Mile (RM) 505.5 and continues to RM 503.0 at Cordova, Illinois (USFWS, 2003b). A second essential habitat (designated in 2008) begins at RM 509.1 and continues to RM 510.1. This area is known as Hanson's Slough.

The only other Essential Habitat Area located downstream of the Quad Cities site occurs in Pool 15 in the Sylvan Slough at RMs 485.5 through 486.0, and pool 16 near Buffalo, Iowa at RM 470-471 The other Essential Habitat Areas are upstream of Pool 14 in Pools 9, 10, and 11 of the Mississippi River, St. Croix River, and the Wisconsin River (USFWS, 2003b; USFWS, 2008). Nearly all the remaining habitat for the Higgins' eye pearlymussel within the Mississippi River occurs within the navigation channel. In a 2000 Biological Opinion, the USFWS concluded that the continued operation and maintenance of the navigation channel would jeopardize the continued existence of the Higgins' eye pearlymussel (USFWS, 2000a).

Several mussel species have been designated as threatened or endangered by the State of Illinois and the State of Iowa. The spectaclecase (*Cumberlandia monodonta*), which is listed as endangered in both Illinois and Iowa, inhabits large rivers with swiftly flowing waters among boulders in patches of sand, cobble, or gravel in areas where current is reduced (Cummings and Mayer, 1992). Within Illinois, it is currently restricted to the Mississippi River (Herkert, 1992).

The butterfly (*Ellipsaria lineolata*), which is listed as threatened in both Illinois and Iowa, usually inhabits medium to large rivers. It inhabits areas of strong current on coarse sand or gravel bottoms and at water depths from a few inches to four feet (Parmalee, 1967). The black sandshell (*Ligumia recta*), which is listed as threatened in Illinois, is a medium to large river species that occurs in riffles or raceways on firm sand or gravel bottoms at depths of four-to-six feet or more. It is less tolerant of siltation and pollution than many other mussel species (Cummins and Mayer, 1992; Herkert, 1998; Parmalee, 1967). The sheepnose (*Plethobasus cyphyus*), which is listed as endangered in both Iowa and Illinois, inhabits currents of medium to large rivers in gravel or mixed sand and gravel substrates at depths of up to 6.6 feet (Cummings and Mayer, 1992; Parmalee, 1967). Reasons for the decline of these mussel species are similar to those discussed above for the Higgins' eye pearlymussel; dredging, sand and gravel mining, siltation, pollution, and/or zebra mussels (Herkert, 1992, 1998).

In 2004, Exelon established a monitoring program for freshwater unionids near the QCNS thermal discharge diffuser. The purpose of the monitoring program is to provide data and information regarding the unionid community, to evaluate the effects QCNS discharge has had on the community, and to establish the baseline unionid community characteristics for comparison with community characteristics observed following the issuance of alternate thermal standards.

Three unionid beds occur within 3500 m (approximately two river miles) of the QCNS thermal diffuser: The Steamboat Slough (SS) Bed, located approximately 675 to 1125 meters (m) downstream of the QCNS mixing zone; the Upstream (UP) Bed, located approximately 730 to 1130 m upstream of the QCNS diffuser; and the Cordova Bed, located about 3300 to 3700 m downstream of QCNS (Figure 1-1). Ecological Specialists, Inc. (ESI) monitored each of these unionid beds in 2004, 2005, 2006, 2007, and 2008. In 2007, the monitoring program added 400 m sections of three additional beds to further evaluate unionid community characteristics among and within unionid beds. The three additions were: The Albany Bed, located approximately 14,000 to 14,400 m upstream of the diffuser, Hansons Slough (HS) Bed, located approximately 5000 to 5400 m upstream of the diffuser, and Woodwards Grove (WG) Bed located approximately 10,500 to 10,900 m downstream of the diffuser.

Upstream Bed

The Upstream Bed habitat has remained consistent among monitoring events (July 2004, July and October 2005, August and September 2006, October 2007, August 2008). The UP Bed is located near the mouth of the Wapsipinicon River and upstream of the QCNS diffuser discharge. Substrate in the Upstream bed is a mixture of sand, silt, and clay, with sand being the major constituent. However, substrate constituents varied considerably among sample points. Substrate in the shallower areas at the upstream end of the bed contained more clay, and sand was more abundant along the edges of the bed (ESI, 2009).

Steamboat Slough Bed

The Steamboat Slough Bed is located approximately 750 m downstream of the QCNS mixing zone. In previous years, the northern portion of the sampling area was downstream and riverward of a small island. This island was absent in 2007 and 2008. Substrate in the SS Bed was primarily sand in 2004 and 2005, but in 2006 silt increased from <10% to >20%, forming a layer over the sand. Substrate in 2007 was nearly equal parts sand and silt, with silt forming a layer over the sand. Substrate again changed in 2008; with an average of 55% sand and 39% silt. However, substrate in the upstream part of the bed contained more silt, and substrate in the downstream portion of the bed consisted of sand mounds with silt valleys. Unionids were more abundant in the silt valleys. This change in substrate with flow conditions (low flow years more silt, higher flow in Spring/Summer 2008 resulting in sand and silt waves) was not as apparent in other unionid beds (ESI, 2009).

Cordova Bed

The Cordova Bed is one of the Essential Habitat Areas designated in the *L. higginsii* recovery plan (USFWS, 2004). The portion of the Cordova Bed sampled in this study is approximately 3300 m downstream of QCNS mixing zone, on the Illinois bank of the river. The Cordova Bed differs from the Upstream and Steamboat Slough beds in that it occurs along a slight outside bend in the river and its substrate is coarser (higher percentages of gravel, cobble, and shell). Zebra mussel shells contributed 44% to substrate constituents in 2007, but only 13% in 2008 perhaps due to high spring flows. In some areas, a 1 to 1.5 ft layer of dead zebra mussel shells covered the substrate in 2007, whereas dead zebra shells were mixed in the substrate in 2008, although live zebra mussels covered the substrate in some parts of the bed (ESI, 2009).

Albany Bed

Albany Bed was the upstream-most bed sampled. The bed extends upstream from Albany, IL (near RM 513) to Cattail Slough (near RM 516). Although very long, the bed is narrow, extending an average of only about 40 m from the bank into the river. The widest portion of the bed (about 70 m wide) was within the town of Albany, IL, near RM 513 and was selected for sampling. Land use along the riverbank is residential, and the bank is lined with rip-rap. The Albany Bed was most similar to the Cordova Bed in habitat characteristics. Substrate was primarily zebra mussel shells mixed with cobble, gravel, and sand. Substrate was silty near the bank, a heterogeneous mixture within 40 m of the bank, and well sorted sand or zebra mussel shells riverward of 40 m in 2008 (ESI, 2009).

Hansons Slough Bed

The Hansons Slough Bed (HS Bed) is upstream of the QCNS diffuser, approximately 4600 to 6400 m. The bed appears to extend from approximately RM 509.1 to 510.1. This bed was recently (USFWS, 2008) designated as an Essential Habitat Area (EHA) based on the criteria for designation listed in the Higgins' Eye recovery plan (USFWS, 2004). These criteria include *L. higginsii* comprise at least 0.25% of the community (0.4% in 2008 HS Bed), density >10/m^2 (HS Bed density 11.1/m^2 in 2007), and contain at least 15 other unionid species with density >0.01/m^2 (19 other species in HS Bed >0.01/m^2). The bed is within the upstream portion of Hansons Slough and within a dike field, similar to the SS Bed. However, the HS Bed was shallower (0.3 to 2.7 m) and substrate was sandier and less silty (primarily fine sand similar to UP Bed) than within the SS Bed (ESI, 2009).

Woodwards Grove Bed

The Woodwards Grove mussel bed is downstream of the QCNS diffuser, approximately 8300 to 10,900 m. The bed appears to extend from approximately RM 499.5 to 500.8 along the Iowa bank within a slight outside bend. The bed extends from the bank at least 150 m riverward. Other than zebra mussels, substrate was primarily silt and clay closer to the bank, turning to finer sand riverward. A deeper, sandy channel occurred in the center of the bed in 2008, perhaps a result of high spring flow in 2008 (ESI, 2009).

The high ambient water temperature and low river flows over almost a month in July/August 2006 resulted in the use of 222.75 excursion hours in 2006. Although July and August water temperatures in 2007 were high, they never reached 2006 levels and only 74.00 excursion hours were used in 2007. Unusually high discharges occurred in mid-August 2007 that reduced water temperatures. Substrate temperature was similar to water temperature in 2007, and the buffering effect noted in 2006 was not observed in 2007. High flows (>200,000 cfs) occurred within Pool 14 in early 2008. Water temperature and substrate temperature within the monitored mussel beds remained fairly low throughout the summer. The high spring flow did affect substrate characteristics at least in the SS Bed, where sand peaks and silt valleys were observed in the downstream portions of the sampled area, and perhaps in the WG Bed, where a sandy, deep channel bisected the bed in 2008. Flow was fairly low during the August sampling (27,000 to 33,500 cfs), but did not fall to the levels observed in August of 2006 and 2007 (<20,000cfs). No excursion hours were used in 2008, and some current velocity was present at sample points in all beds except the Cordova Bed. The area within 10 to 20m of the Cordova Bed was covered with a heavy algae mat, which was not observed in other monitoring years (ESI, 2009).

Changes to unionid community characteristics were observed in all three beds in 2006 compared to prior years. However, these changes seemed to be temporary or simply due to stochastic factors. Community characteristics in October 2007 and August 2008 in the UP, SS, and Cordova beds were similar to previous monitoring events. In 2007 and 2008, recruitment (% young individuals) was high and mortality was low. Total density of live unionids fluctuated among monitoring events, but no increasing or decreasing trends were apparent (see Figure 4-1 of ESI, 2009). Increased mortality was observed in the UP and Cordova beds in 2006, but declined to pre-2006 levels in 2007 and 2008 (see Figure 4-1 of ESI, 2009). Density of both live Ambleminae and Lampsilinae has similarly fluctuated over time (Figure 4-2 of ESI, 2009). Most of the increase in 2006 mortality, particularly in the UP Bed, was due to mortality of Lampsilinae (Figure 4-3 of ESI, 2009), which was most apparent upstream of the QCNS (ESI, 2009).

The monitoring program added three beds in October 2007: Albany Bed, HS Bed, and WG Bed. The Albany Bed shared many of the same habitat and unionid community characteristics with the Cordova Bed in both 2007 and 2008. Both of these beds appear to have been heavily affected by zebra mussel infestation, species composition was similar, and species richness higher than in other beds. *Ligumia recta* and *L. higginsii* were fairly common in both beds. The HS Bed shares some habitat and community characteristics with both the SS and UP beds. The bed is within a slough and dike field similar to the SS Bed, but substrate consisted more of fine sand similar to the UP Bed. Zebra mussel infestation was also apparent within this bed in 2007, but shells were not a major substrate constituent. However, zebra mussel infestation in the HS and SS beds was much lower than within other beds in 2008. Similar to the SS Bed, Ambleminae dominated the community, and the percentage of young Ambleminae was high and Lampsilinae low in the HS Bed, but *Q. p. pustulosa* rather than *A. plicata* was the dominant species. Similar to the UP Bed, density was high in the HS Bed and *L. higginsii* were present. The WG Bed, downstream of QCNS, differed in substrate (mostly silt and clay) but shared some community characteristics with the other beds. Adding these beds to the 2007 and 2008 study expanded the knowledge base for comparisons of mussel bed and community characteristics upstream and downstream of the QCNS diffuser, and strengthened the conclusions that can be drawn from such comparisons in evaluating the impacts, if any, on the mussel beds and communities associated with the plant's discharges.

The 2007 and 2008 studies show that community characteristics within unionid beds sampled in this study do not seem to be significantly affected by the QCNS thermal effluent, including the increased river temperatures experienced during the Summer of 2006, at least in the short-term. Unionid beds downstream of the QCNS exhibited similarities and differences in habitat and unionid community characteristics with unionid beds upstream of the QCNS. Increased mortality noted in some beds in 2006 was not observed in 2007 or 2008 and did not appear to affect unionid density either upstream or downstream of the QCNS (ESI, 2009).

7.2.5 Fish

Adult and Juvenile Fish

Despite the modifications and multiple competing uses of the Upper Mississippi River, the overall fish biodiversity has been persistent and resilient (USGS, 1999). The river's main channel, navigation and wing dams, side channels, sloughs, chutes, backwater lakes and ponds, marsh areas, flooded bottomland forests, and tributaries create diverse habitats for at least 118 species of fish (USFWS 1991a). However, over-wintering habitats for fish have declined due to water depth reductions caused by sedimentation. Also, recent die-offs of aquatic vegetation have reduced the suitability of many areas as nursery habitats for fishes (Fremling and Drazkowski, 2000). Within the last decade, this trend has been reversed in Pool 14 (HDR, 2009a).

Ninety-four (94) fish species representing 22 families have been collected in Pool 14 during the 41-year monitoring program at QCNS (Table A-3). Hybrid striped bass, hybrid sunfish and one carp X goldfish hybrid have also been collected. Steuck et al. (2010) list 163 species that have been collected in the Upper Mississippi River, 100 of them in Pool 14. Seven species on Steuck's list for Pool 14 have not been collected by the QCNS program, but one species that was not listed by Steuck et al., crystal darter (*Crystallaria asprella*), has been identified. The crystal darter that was collected in 2009 (HDR, 2010) was thought to have been extirpated from this reach of the Mississippi River since the early 1900's. This species has not been reported as collected from any of the pools (Pools 1-26) listed by Steuck et al. (2010), but a few individuals have been collected in Iowa waters in recent years near the confluence of the Turkey River and the Mississippi River (RM 608) in Clayton County, Iowa (Pool 11), and two specimans were collected from the Mississippi River near Cotton Island (RM 77) downstream of Grand Tower (Jackson County, Illinois) in 1998 and at Picayune Chute (RM 55, Alexander County, Illinois) in 2004(Stewart, et al., 2005). Prior to that, the crystal darter had not been collected in Illinois since 1901.

Three cyprinid species (bigmouth shiner, southern redbelly dace, and pearl dace) were captured exclusively by minnow seining that was conducted during the early years (prior to 1976) of the QCNS long-term monitoring program (Bowzer and Lippincott, 1995). Six of the species collected are presently listed as endangered (weed shiner, pearl dace, lake sturgeon) or threatened (grass pickerel, western sand darter, chestnut lamprey) by the Iowa DNR (2009).

Five of the species collected are listed as endangered (lake sturgeon, pallid shiner, weed shiner, western sand darter) or threatened (longnose sucker) by the Illinois Endangered Species Board (2011). The crystal darter is not currently protected in either Iowa or Illinois as it was assumed to have been extirpated from the waters of both states.

Review of historical data failed to document the collection of the starhead topminnow as was first reported in 1983. Several species have been represented by only one or two specimens during the 41-year monitoring program. Most were collected by minnow seine or impingement during the early years of the monitoring program. These species include the lake trout, grass carp, central stoneroller, weed shiner, common shiner, mimic shiner, southern redbelly dace, pearl dace, blacknose dace, longnose sucker, and pallid shiner.

Fish species considered abundant within the Upper Mississippi River include gizzard shad (*Dorosoma cepedianum*), common carp (*Cyprinus carpio*), emerald shiner (*Notropis atherinoides*), river shiner (*N. blennius*), bullhead minnow (*Pimephales vigilax*), and bluegill (*Lepomis macrichirus*). Common species include longnose and shortnose gar (*Lepisosteus osseus* and *L. platostomus*), bowfin (*Amia calva*), mooneye (*Hiodon tergisus*), spottail shiner (*N. hudsonius*), river carpsucker (*Carpiodes carpio*), quillback (*C. cyprinus*), bigmouth buffalo (*Ictiobus cyprinellus*), shorthead redhorse (*Moxostoma macrolepidotum*), channel catfish (*Ictalurus punctatus*), white and hybrid striped bass (*Morone chrysops* and *M. chrysops x M. saxatilis*), rock bass (*Ambloplites rupestris*), green sunfish (*Lepomis cyanellus*), and river darter (*Percina shumardi*) (Bowzer and Lippincott, 2000; USFWS 1991a). Favorite sport fish species include walleye, sauger (*Stizostedion canadense*), largemouth bass (*Micropterus salmoides*), smallmouth bass (*M.dolomieu*), white bass, bluegill, black and white crappie (*Pomoxis nigromaculatus* and *P. annularis*), pumpkinseed (*L. gibbosus*), and channel catfish (USFWS 1991a). Commercial fisheries also exist for some species, such as the bigmouth buffalo, common carp, catfish and bullheads, and freshwater drum (*Aplodinotus grunniens*) (USFWS 1991a). The carp is the most important non-native fish species in the Mississippi River, comprising most of the commercial harvest; it is the dominant species in the Upper Mississippi River (USGS, 1999).

The abundance of walleye and hybrid striped bass has increased in the vicinity of the Quad Cities site since 1985 due to stocking of these fish (Bowzer and Lippincott, 2000; LaJeone and Monzingo, 2000). The walleyes are reared in the Quad Cities Units 1 and 2 inactive spray canal, while hybrid striped bass are maintained in the fish laboratory at the Quad Cities site (Exelon, 2003a). Conservatively, the adult walleye population in Pool 14 is comprised of approximately 30 percent stocked fish, with lesser, yet measurable contributions to downstream pools (LaJeone and Monzingo, 2000). Results indicate that the contribution of stocked walleye to the population of

Age 0 walleye in the Pool is within the range of 15-40% most years (HDR, 2009b). Riverine species, such as the freshwater drum, channel catfish, flathead catfish (*Pylodictis olivaris*), and white bass have generally increased in Pool 14; while backwater species, such as white and black crappies have generally decreased due to degradation of the backwater areas and sloughs from sedimentation associated with operation of the 9-foot navigation channel (Bowzer and Lippincott, 2000).

Population estimates for freshwater drum are considered to be relative among years rather than absolute estimates because very few marked fish are recaptured in any year. Age analysis indicates that freshwater drum are long lived in Pool 14, often exceeding age 20 and occasionally age 30. Survival has averaged between 70 and 75% for the past 29 years. Maximum theoretical growth has steadily increased since 1983. Standing crops vary amongst years because this metric is driven by population estimates and year class strength (HDR, 2009a).

Trends in the long term data base include increases in numbers of freshwater drum, channel catfish, largemouth bass, bluegill and decreases in the numbers of white crappie, black crappie, and sauger. These trends are apparent at locations both upstream and downstream of the diffuser pipes and most likely are the product of long term sampling at fixed locations that have undergone substantial habitat changes such as backwater siltation and the appearance of beds of rooted aquatic plants (HDR, 2009b).

The trend in haul seine catches is that they are dominated by large gizzard shad and freshwater drum. Gizzard shad, freshwater drum, bluegill, white bass and channel catfish have consistently dominated impingement. Gizzard shad and freshwater drum together typically account for more than 80% of fish impinged by number and weight each year. Impinged fish are predominately small, juvenile specimens, regardless of species (HDR, 2009b).

Impingement increases in the fall and remains high throughout the spring under any operational mode. Peak impingement occurs during the winter months with very few fish being impinged during the May-August period. Since the return to open-cycle operation in 1984, annual projections of fish impinged have been highly variable. In any year, the level of fish impingement is influenced by several environmental variables such as river flow, winter conditions, and standing crop of individual species. Station operation influences impingement depending on the number of units operating; however, Station operation is relatively constant compared to the high variability of environmental factors affecting the River's fishery (HDR, 2009b). Despite the ineffectiveness of barrier nets in reducing impingement under open-cycle operation, the ecological impact of such losses appears to be minimal. Evaluation of the condition of fish trapped on the intake barrier net indicates that greater than 90% of the fish impinged during the winter months are drifting passively with the river flow and are either dead or moribund when they arrive at the intake (LMS, 1989). Gizzard shad and freshwater drum are particularly sensitive to near freezing water temperatures, which result in greatly reduced swimming stamina and high mortality (Lewis and Bodensteiner, 1986; Lippincott, 2006). The high rate of fish impingement occurring during the winter is not a result of Station operation, but a reflection of natural high winter mortality for species such as gizzard shad and freshwater drum.

An estimated total of 9,194,604 fish (uncorrected for dead and moribund fish) representing 75 taxa, 72 species, and 20 families were collected in 538 impingement collections that were conducted from January 1996 through December 2005 (HDR/LMS, 2007). The 538 impingement samples represent 12,728 hours of sampling effort. The total number of taxa collected during each year of the 10-year period ranged from 52 (1998) to 61 (2002). Total estimated annual impingement for the 10-year period ranged from 173,046 fish in 1998 (due to an extended two unit outage) to 1,600,676 fish (2001), with a 10-year estimated mean of 919,460 fish/year.

The 10-year data set and the data from each individual year shows that fluctuations in the fish community in Pool 14 do not result from impingement effects but that they are driven by changes in natural conditions. It has become evident over the Long Term Aquatic Monitoring Program that fluctuations in impingement are reflecting the natural dynamic equilibrium of populations that occur in the pool and are not driving those changes.

Ichthyoplankton

During sampling in 1978 and 1979, freshwater drum eggs and larvae were abundant at all locations, demonstrating that all of Pool 14 above the Station serves as a spawning and nursing area (LMS, 1986). Results also showed sizable contribution of freshwater drum eggs and larvae to Pool 14 and Pool 13. The intensive 1978 study concluded that there was little difference between average day and night abundance; however, more ichthyoplankton was caught during the day than at night. The difference, less than 10%, was statistically significant due to the large of number of samples included in the hypothesis testing. There were also no substantial differences in vertical distribution of all larval stages combined. A few statistically significant differences in vertical distribution were found, (yolk-sac larvae, which exhibited much higher abundances in the bottom samples at night) which was to be expected given the large number of tests conducted. There were, however, horizontal differences in abundances, with the Illinois side of the river exhibiting greater larval abundances than the Iowa side. These conclusions were based on all larval stages combined (LMS, 1986). Sampling at these locations was discontinued after 1979 because the objectives of the 1978 and 1979 programs were met.

From 1980 through 1983 only one location was sampled upstream of the intake (LMS, 1986). In previous years a minimum of three upstream locations were sampled. This adequately documented the diel, vertical, and horizontal differences in ichthyoplankton abundance. The return to an open-cycle operation in 1984 necessitated a more intensive ichthyoplankton sampling that included entrainment monitoring. Ichthyoplankton samples were collected near the surface and bottom on the Illinois side, in midchannel, and on the Iowa side in Pool 14 of the Mississippi River in the vicinity of the Quad Cities Station and only at the surface in the discharge canal in 1984 and 1985. These samples and results are the most indicative of current operations (LMS, 1986).

Ichthyoplankton (fish egg and larvae) typically begins to drift by QCNS in late April or early May and continues to be present into August with the peak numbers (driven by freshwater drum) passing the Station during the first half of June. Based on information derived from river ichthyoplankton monitoring studies (LMS, 1985 and LMS, 1986), 65 to 96% of the total larvae and 94 to 99% of freshwater drum larvae cumulative passage occurs by the end of June. Peak larval drift tends to occur at ambient river temperatures in the range of 21 to 23°C.

The results of this program showed that eggs were present in the river from April 30 to July 30. Freshwater drum eggs made up 84.0% of the catch and emerald shiner eggs constituted another 11.7%. Cyprinid, carp, and unidentifiable eggs constituted the remaining 4.3%. Approximately 84% of the freshwater drum eggs drift occurred between 7 and 28 May; 95% of the drift occurred during a nine-week period ending July 2. This drift period was similar to that of previous years with the exception of 1983, which was unusually short. A two-way ANOVA was preformed on freshwater drum and emerald shiner eggs. Freshwater drum egg concentrations were significantly higher on the Illinois side than on the Iowa side of the river. No other differences were found.

Larvae of 23 taxa were collected during these studies. Freshwater drum, emerald shiner, and cyprinids were the most abundant taxa collected. Collectively, these three taxa constituted 90.4% of the total catch. The remaining 20 taxa constituted 9.6% of the catch. ANOVAs were preformed on densities of the seven most abundant species using location and depth. During most years of sampling, freshwater drum larval concentrations were greatest near the Illinois shoreline with concentrations being significantly lower in the mid-river and near the Iowa shoreline (LMS, 1986). Mid-river is defined as being approximately 1100 ft from the Illinois

Bank. The nearest open port to the Illinois bank is about 840 ft from the shoreline or approximately 80% of the distance to mid-river. Consequently, most of the freshwater drum larvae drifting through this portion of the river will not pass over the open ports. Therefore, it is expected that the majority of these larvae will not be exposed to the maximum discharge temperatures which would result in thermal mortality.

The analysis also showed that gizzard shad densities were significantly different by location, with higher densities occurring on the Iowa side of the river. No other species exhibited significant location difference. Emerald shiner, cyprinid, and gizzard shad densities were significantly greater near the surface. Freshwater drum densities were significantly greater near the bottom. All other results indicated no significant differences in densities in 1985.

The effect of potentially being exposed to an instantaneous increase of 15.2°C as larvae pass the diffusers was evaluated (LMS, 2000b). Several conditions of this potential exposure are described below.

- The nearest open port to the Illinois shoreline is approximately 840 ft from the shore.
- The nearest open port to the Iowa shoreline is approximately 200 ft from the Iowa bank.
- The river width at the diffuser placement is approximately 2200 ft.
- Ports are spaced 19-20 ft apart in the deeper portions of the river and 39-40 ft apart in the shallow zones.
- Ports are angled 20° from the bottom.
- This analysis was a worst-case approximation because it assumed that all organisms were exposed to the maximum temperature. This most likely is not true either vertically or horizontally.
- Duration of exposure to maximum temperature is not known; but several assumptions regarding incipient lethal temperatures (ILT), which are threshold temperatures for mortality, and incorporation of flow information permitted modeling that predicts mortality.
- Data were developed for total larvae, freshwater drum, and gizzard shad. These species are the two most abundant species taken in impingement collections at the Station (LMS, 2000b) and freshwater drum was selected as the indicator species for the Station's fish monitoring program beginning in 1980.
- Estimates of mortality were calculated for a variety of ambient river temperatures to determine the thresholds at which mortality begins to occur.

Based on data collected during river fish larvae monitoring (LMS, 1985 and LMS, 1986), peak larval drift tends to occur at ambient river temperatures in the range of 21 to 23°C. Estimates of mortality at these temperatures indicate that there will be no mortality. By contrast, species that spawn during the June through August period may lose some percentage of their larvae at the maximum temperature increase of 15.2°C, depending upon river flow and ambient river temperatures.

Data indicate that mortality for freshwater drum larvae will begin to occur at an ambient river temperature of about 22°C and river flows of approximately 30,000 cfs. Mortality is expected to remain below 1% until ambient river temperatures reach approximately 23.5°C at this flow. These data suggest that this thermal addition has little effect on freshwater drum through their period of peak drift. The small percentage of freshwater drum larvae that are spawned later in the summer may experience high mortality as they drift over the diffusers. A similar comparison of data calculated for gizzard shad indicates that mortality will first occur at ambient river temperatures of approximately 25°C for ILT's of 28 and 29°C when flows are about 30,000 cfs. As the flows increase, these threshold ambient river temperatures for mortality increase. It is expected that, at flows in the range of 60,000 cfs, threshold ambient river temperatures for mortality would exceed 25°C. Only those gizzard shad spawned later in the season when flows are lower may suffer some mortality.

8.0 BIRDS

The Upper Mississippi River National Wildlife & Fish Refuge is a 261-mile refuge, which is the longest river refuge in the continental U.S. The refuge begins at the confluence of the Chippewa River near Wabasha, Minnesota, and ends near Rock Island, Illinois. The refuge lies within four states: Minnesota, Wisconsin, Iowa, and Illinois. The refuge provides migratory habitat for a large percentage of the migratory birds in the Mississippi Flyway, through which an estimated 40 percent of the continent's waterfowl migrate. It is a critical migration corridor (Reid et al., 1989) for 10 species including tundra swans, ring-necked duck and hooded merganser. The other seven species are also on the U.S. Fish & Wildlife Service's Region 3 Resource Conservation Priority List and include: lesser snow geese, Canada geese, wood duck, mallard, blue-winged teal, canvasback, and lesser scaup.

Songbirds include a wide array of land birds such as hummingbirds and woodpeckers, as well as the large order of birds called passerines or "perching" birds. Passerines comprise more than half the world's species of birds. The refuge still provides a vital migration corridor for songbirds, many of which fly thousands of miles each year between Central and South America and the

United States and Canada. It is estimated that millions of birds migrate through the area each year.

Colonial nesting birds on the refuge include species that nest on floating mats of aquatic vegetation, such as the black tern, and tree-nesting species, including great blue herons, double-crested cormorants, great egrets, and green herons. Colonies are often on islands and/or located in the upper third of the pools where forests are more extensive. Secretive marsh birds include bitterns and rails that utilize wet meadow and emergent wetland habitats, both of which are declining on the refuge.

Raptors are birds of prey that include vultures, hawks, and eagles. Several species nest on the Refuge and more migrate along the Mississippi River Corridor. The refuge supports approximately 160 nesting pairs of bald eagles. The bald eagle, northern goshawk, red-shouldered hawk, and peregrine falcon occur on the refuge and are on the Regional Resource Conservation Priority list. In recent years, large numbers of bald eagles spend the winters along the shoreline of Pool 14 (USFWS, 2006).

9.0 THREATENED AND ENDANGERED SPECIES

This section addresses one federally listed threatened and endangered species and three candidate threatened and endangered species that occur on or very near the refuge. State listed threatened and endangered species are not described in this section but will be addressed in the Comprehensive Conservation Plan and appropriate step-down plans. The state listed species that occur on refuge include: six mammals, 40 birds, 18 fish, seven reptiles, three amphibians, and 20 mussels (USFWS, 2006).

9.1 Higgins Eye Pearlymussel

The Higgins eye pearlymussel *(Lampsilis higginsii)* was listed as endangered in 1976 due to declines in abundance and distribution. Higgins eye pearlymussel recovery teams have identified Essential Habitat Areas that are believed to contain viable reproducing *L. higginsii* populations. These teams indicate that recovery of the species could not be accomplished without maintaining the Essential Habitat Area populations. One of the 14 identified Essential Habitat Areas, Cordova, Illinois, Pool 14 (River Mile 503.0 - 505.5) is located immediately downstream of the diffuser pipes (USFWS, 2008).

9. 2 Candidate Threatened and Endangered Species

The eastern massasauga rattlesnake *(Sistrurus catenatus catenatus)* has declined throughout its range, an area that extends from New York and southern Ontario westward to Iowa and Missouri. Small populations of massasaugas are scattered along the length of the lower Wapsipincon River in Scott and Clinton Counties, Iowa, which are adjacent to Pool 14 (VanDeWalle and Christiansen, 2002). The most recent records of live specimens found in that area were near Long Grove and Calamus, 13 and 30 miles west of the Upper Mississippi River floodplain, respectively. Searches in 2001 and 2002 found no live specimens in these counties (USFWS, 2006).

The unionid mussel sheepnose *(Plethobasus cyphyus)* has been eliminated from two-thirds of the total number of streams from which it was historically known (26 streams versus 77, historically). It was uncommon in what are now Mississippi River Pools 13-23. In the upper Mississippi River, the sheepnose is an example of a rare species becoming more so (Upper Mississippi River Refuge Final Environmental Impact Statement/Comprehensive Conservation Plan, July, 2006).

The spectaclecase *(Cumberlandia monodonta)* mussel was declared a candidate species May 4, 2004 (USFWS, 2002b). As reported in the Federal Register, the spectaclecase is apparently more of a habitat specialist than are most mussel species. Primarily a large-river species, it can occur on outside river bends below bluff lines. The only live specimens found recently on the Upper Mississippi River were in Pool 15 and further down river; none on the Refuge portion of the Upper Mississippi River, Pools 4-14 (USFWS, 2006).

10.0 COMMUNITY ECOLOGY

10.1 Upper Mississippi River Fish Communities

The Upper Mississippi River National Wildlife & Fish Refuge supports at least 119 species of fish, including sport fish, commercial fish, forage fish, ancient fish (paddlefish and sturgeon), and many other unique species that make the river's fishery so diverse (Gutreuter and Theiling, 1999). Populations of at least 41 fish species are so low that they are listed as threatened or of concern by state or federal agencies along the Upper Mississippi River. Loss of habitat, the navigation system, over-exploitation, and impacts of exotic species (see discussion below) are the main causes (USFWS, 2006).

Favorite sport fish in Pool 14, as well as the rest of the refuge, include walleye, sauger, white bass, largemouth bass, smallmouth bass, channel catfish, northern pike, bluegill, and crappies. Bluegills are the number one harvested fish species of the Upper Mississippi River backwaters. Presently, smallmouth bass populations in Pools 1-14 are increasing and are a significant component of the fishery. Fishing tournaments are ever-increasing and may put extra pressure on local fish populations (USFWS, 2006).

10.1.1 Other Fish

The paddlefish is one of the ancient fish of the Upper Mississippi River and is distinguished from all other fish by its broad, flat bill-like snout. People consume paddlefish meat and roe (caviar). The worldwide protection of sturgeon species in 1998 is expected to have a dramatic impact on commercial paddlefish harvest by creating a greater demand for paddlefish caviar as a surrogate to sturgeon roe. It has declined throughout its range due to habitat loss and over-harvest. Competition from invasive species such as silver and big head carp, plankton eaters, is a potential serious threat to paddlefish if these species move up the Upper Mississippi River (UMRCC, 2004a).

10.1.2 Sturgeon

Included in the list of "ancient species" three kinds of sturgeon inhabit the Upper Mississippi River: The lake, pallid and shovelnose. The pallid sturgeon is endangered and occurs in waters well south of the Refuge. Lake and shovelnose are rare or uncommon in most Refuge waters, but the shovelnose is found in modest numbers in Pool 14. A decline in shovelnose numbers is attributed to overharvest, habitat degradation and fragmentation by dams, water pollution, and flow alteration (USFWS, 2006).

10.1.3 Invasive Fish Species

Invasive and exotic species are the "greatest threat to ecosystem integrity within the refuge system" (USFWS 2004a). The refuge and Upper Mississippi River System are inundated with invasive fish, plants, and invertebrates. Asian carp threaten native paddlefish via competition for plankton. These carp also can potentially eliminate vegetation beds, snail and mussel populations, and deplete the commercial fishing industry on the Upper Mississippi River System (USFWS, 2006).

The common carp, a native of Europe and Asia, was first found in the Upper Mississippi River in 1883 and presently comprises most of the commercial harvest of fish in the Upper Mississippi

River. It has increased in abundance in Pools 4, 8, 13, and 26 of the Upper Mississippi River from 1990-94 (Gutrueter and Theiling, 1999). As the common carp increased, the native buffalo fish, the ecological equivalent, has declined in the harvest by about 50 percent.

Findings of a recent feasibility study funded by Minnesota Department of Natural Resources noted "that an acoustic deterrent such as a Sound Projector Array based acoustic bubble curtain downstream of a lock location perhaps in conjunction with attractants (i.e. pheromones, plankton, lights, etc.), and an integrated management/harvest plan may provide the most feasible opportunity to limit or slow the upstream invasion of Asian Carp" (FishPro, 2004).

10.2 Navigation Pool 14 Fish Communities

Exelon Generation and its contractors have monitored the fish populations of Pool 14 (the reach of the Mississippi River between Lock and Dam 13 and Lock and Dam 14) since 1971. A number of common species (gizzard shad, freshwater drum, emerald shiner, river shiner, bullhead minnow, carp and bluegill) have consistently dominated fish collections. A number of other species, including mooneye, river carpsucker, smallmouth buffalo, shorthead and golden redhorse, channel and flathead catfish, white bass, largemouth bass, black crappie, sauger, and walleye have also been regularly collected.

The long-term monitoring program has not identified any measurable impacts on the fishery of Pool 14 attributable to station operation (LMS, 1995; LMS, 2000b; HDR, 2009b). Monitoring has demonstrated that the physical characteristics of the river (i.e., flow, temperature and silt loads) are highly variable and subject to relatively rapid changes that do affect the Pool 14 fish community. As a consequence, individual fish species in Pool 14 have shown both short term and long term fluctuations in abundance, but community composition has remained relatively stable (LMS, 1995).

Two significant changes in the Pool 14 fishery (neither of which is associated with QCNS operations) have been observed since the early 1970's. First, the abundances of two popular game fish, walleye and hybrid striped bass, have increased in the vicinity of the Station since 1985 as a result of a stocking program carried out by Southern Illinois University and QCNS. The adult walleye population of Pool 14 is presently comprised of approximately 30 percent stocked fish (LaJeone and Monzingo, 2000); increasing numbers of these canal-reared walleye are also appearing in downstream pools.

Second, the abundance of riverine fish species (e.g., freshwater drum, channel catfish, flathead catfish, and white bass) has generally increased in Pool 14, while the abundance of backwater fish species (e.g., white and black crappie) has generally decreased as sedimentation associated with operation of the navigation channel has degraded backwater areas and sloughs (LMS, 2000b). Increases in channel catfish numbers are also believed to be related to changes in commercial fishing regulations that allow more fish to survive to adulthood and spawn (LaJeone and Monzingo, 2000).

11.0 ENERGY FLOW AND TROPHODYNAMICS

11.1 Energy Flow and the Riverine Food Web (Odum, 1971)

The transfer of food energy from the source in plants through a series of organisms with repeated eating and being eaten is referred to as the food chain. At each transfer a large portion, 80 to 90 percent, of the potential energy is lost as heat. Therefore, the number of steps or "links" is a sequence is limited, usually to four or five. The shorter the food chain is (or the nearer the organism to the beginning of the chain), the greater the available energy.

Food chains are of two basic types: the grazing food chain, which, starting from a green plant base, goes to grazing herbivores (i.e., organisms eating living plants) on to carnivores (i.e., animal eaters); and the detritus food chain, which goes from dead organic matter into micro-organisms and then to detritus-feeding organisms (detritivores) and their predators. Food chains are not isolated sequences but are interconnected with one another. The interlocking pattern is often spoken of as the food web. In complex natural communities, organisms whose food is obtained from plants by the same number of steps are said to belong to the same trophic level. Thus, green plants (the producer level) occupy the first trophic level, plant-eaters the second level (the primary consumer level), carnivores, which eat the herbivores, the third level (the secondary consumer level), and the secondary carnivores the fourth level (the tertiary consumer level).

Figure A-1 shows very simplified food web for a river system. With the exception of certain species that are mentioned, such as trout and grass carp, this food web is indicative of the food web in the Mississippi River.

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13.0 TABLES AND FIGURES

Table A-1. Organic compounds measured to evaluate wastewater contamination of the Mississippi River, 1987-1992

Contaminant	Abbreviation	Compounds and sources
Dissolved organic carbon	DOC	All natural and synthetic organic compounds; regional-scale natural sources.
Fecal coliform bacteria	None	Bacteria derived predominantly from human and livestock fecal wastes; from unchlorinated sewage effluents and feedlot and agricultural runoff.
Methylene-blue-active substances	MBAS	Composite measure of synthetic and natural anionic surfactants; predominantly from municipal sewage-wastewater discharges.
Linear alkylbenzenesulfonate	LAS	Complex mixture of specific anionic surfactant compounds used in soap and detergent products; primary source is domestic sewage effluent.
Nonionic surfactants	NP, PEG	Complex mixture of compounds derived from nonionic surfactants that includes nonylphenol (NP) and polyethylene glycol (PEG) residues; from sewage and industrial sources.
Adsorbable organic halogen	AOX	Adsorbable halogen-containing organic compounds, including by-products from chlorination of DOC and synthetic organic compounds, solvents and pesticides; from multiple natural and anthropogenic sources.
Fecal sterols	None	Natural biochemical compounds found predominantly in human and livestock wastes; primary source is domestic sewage and feedlot runoff.
Polynuclear aromatic hydrocarbons	PNA	Complex mixture of compounds, many of which are priority pollutants; from multiple sources associated with combustion of fuels.
Caffeine	None	Specific component of beverages, food products, and medications specifically for human consumption; most significant source is domestic sewage effluent.
Ethylenediaminetetraacetic acid	EDTA	Widely used synthetic chemical for complexing metals; from a variety of domestic, industrial, and agricultural sources.
Volatile organic compounds	VOC	A variety of chlorinated solvents and aromatic hydrocarbons; predominantly from industrial and fuel sources.
Semivolatile organic compounds	TTT, THAP	Wide variety of synthetic organic chemicals including priority pollutants and compounds such as trimethyltriazinetrione (TTT) and trihaloalkylphosphates (THAP); predominantly from industrial sources.

Table A-2. Summary assessment of organic contaminants in the Mississippi River and its major tributaries. Compound abbreviations are listed in Table A-1.

[mg/L, milligram per liter; CFU/100 mL, colony-forming units per 100 milliliters; µg/L, microgram per liter; mg/kg, milligram per kilogram; nd, not determined; Sorp, sorption; Bio, biodegradation; Vol, volatilization; >, greater than]

Compound	Concentration		Drinking water standard	Aquatic[1] toxicity	Environmental fate affected by		
	River water	Bed sediment			Sorp	Bio	Vol
DOC	3–12 mg/L	nd	4 mg/L[2]	Unknown	Yes	Yes	No
Fecal coliform	2–700,000 CFU/100 mL	nd	[3]0	200 CFU/100 mL[6]	Yes	Yes	No
MBAS	20–100 µg/L	nd	500 µg/L[3]	250 µg/L[7]	Yes	Yes	No
LAS	0.1–10 µg/L	0.1–1 mg/kg[14]	None	25 µg/L[8]	Yes	Yes	No
NP	0.1–10 µg/L	nd	None	130 µg/L[9]	Yes	No	Yes
PEG	5–150 µg/L	nd	None	1,000 mg/L[10]	Yes	Yes	No
AOX	10–120 µg/L	nd	60 µg/L[4]	Unknown	Yes	Yes	Yes
Coprostanol	nd	0.1–1 mg/kg[14]	None	Unknown	Yes	Yes	No
Total PNAs	nd	0.1–16 mg/kg	0.1–0.4 µg/L[5]	4 mg/kg[11]	Yes	Yes	Yes
Caffeine	0.01–0.1 µg/L	nd	None	Unknown	Yes	Yes	No
EDTA	1–30 µg/L	nd	None	>1,000 µg/L[12]	No	No	No
Total VOC	0.2–3.1 µg/L	nd	5–1,000 µg/L[5]	>1,000 µg/L[13]	Yes	Yes	Yes
TTT	0.01–0.5 µg/L	nd	None	Unknown	No	No	No
THAP	0.01–1.4 µg/L	nd	None	Unknown	No	No	No

[1]Aquatic toxicity of organic compounds is a complex issue that involves many factors including the characteristics of the particular chemical, concentration of the chemical, overall water composition, and the aquatic species under consideration. The scientific literature is rich in specific studies of aquatic toxicity for a wide range of compounds, species, and conditions. The data presented in this table, although limited, are representative of the range of concentrations shown to exhibit toxic effects for sensitive aquatic species.

[2]Pontius, 1993. Drinking water sources with more than 4 mg/L DOC may require pretreatment to minimize formation of disinfection by-product (see the following chapter by R.E. Rathbun).

[3]U.S. Environmental Protection Agency, 1994.

[4]Pontius, 1993. Although no MCLs have been established for AOX, anticipated MCLs for the total of five trihaloacetic acids that are measured as a component of the AOX have been proposed.

[5]Range of MCL values for individual compounds detected in this study. U.S. Environmental Protection Agency, 1994.

[6]Fecal coliform bacteria are not toxic to aquatic species, but rather are indicators of bacterial water quality. This standard is for human primary contact recreation (Dufour, 1984).

[7]MBAS is a nonspecific measure of LAS and related compounds. This value was established based on the assumption that 10 percent of the MBAS response comes from LAS (Kimerle, 1989).

[8]Kimerle, 1989.

[9]McLeese and others, 1981.

[10]Patoczka and Pulliam, 1990. Based on toxicity of linear alcohol ethoxylates that are parent compounds for PEG. PEG will have significantly lower toxicity than the parent compound.

[11]Persaud and others, 1993. Value listed is for sediment toxicity: PNAs are primarily sorbed to bed sediments.

[12]Curtis and Ward, 1981. At concentrations less than 500 µg/L, however, EDTA can reduce the toxicity of heavy metals by forming complexes that lower the concentrations of free metal ions.

[13]Verhaar and others, 1992.

[14]Range of values reported in the table and in figure 55 refers only to bed-sediment samples collected in the main-stem navigation pools. Values of 20 mg/kg of LAS and 7.5 mg/kg of coprostanol were measured in bed sediment in Pigs Eye Slough, which receives effluent from a wastewater-treatment facility in St. Paul, Minn.

TABLE A-3. Master taxa list for selecting the Representative Important Species in Pool 14 of the Upper Mississippi River near Quad Cities Station.

TAXON	SPECIES STATUS[a]	OCCURRENCE[b]
Chestnut lamprey (*Ichthyomyzon castaneus*)[c]	U	X
Silver lamprey (*Ichthyomyzon unicuspis*)	O	X
Lake sturgeon (*Acipenser fulvescens*)[c]	R	X
Shovelnose sturgeon (*Scaphirhynchus platorynchus*)	O	X
Paddlefish (*Polyodon spathula*)	O	X
Longnose gar (*Lepisosteus osseus*)	C	X
Shortnose gar (*Lepisosteus platostomus*)	C	X
Bowfin (*Amia calva*)	C	X
American eel (*Anguilla rostrata*)	U	X
Skipjack herring (*Alosa chrysochloris*)	R	X
Gizzard shad (*Dorosoma cepedianum*)	A	X
Goldeye (*Hiodon alosoides*)	R	X
Mooneye (*Hiodon tergisus*)	C	X
Rainbow trout (*Onchorhynchus mykiss*)	X	X
Brown trout (*Salmo trutta*)	X	X
Lake trout (*Salvelinus namaycush*)	X	X
Central mudminnow (*Umbra limi*)	R	X
Grass pickerel (*Esox americanus*)[c]	R	X
Northern pike (*Esox lucius*)	O	X
Central stoneroller (*Campostoma anomalum*)	-	X
Common carp (*Cyprinus carpio*)	A	X
Grass carp (*Ctenopharyngodon idella*)	U	X
Silvery minnow (*Hybognathus nuchalis*)	U	X
Speckled chub (*Macrhybopsis aestivalis*)	C	X
Silver chub (*Macrhybopsis storeriana*)	C	X
Golden shiner (*Notemigonus crysoleucas*)	O	X
Pallid shiner (*Notropis amnis*)[c]	R	X
Emerald shiner (*Notropis atherinoides*)	A	X
River shiner (*Notropis blennius*)	A	X
Ghost shiner (*Notropis buchanani*)	H	X
Common shiner (*Luxilus cornutus*)	R	X
Bigmouth shiner (*Notropis dorsalis*)[u]	R	X
Pugnose minnow (*Opsopoeodus emiliae*)	R	X
Spottail shiner (*Notropis hudsonius*)	C	X
Red shiner (*Cyprinella lutrensis*)	R	X
Spotfin shiner (*Cyprinella spiloptera*)	C	X
Sand shiner (*Notropis stramineus*)	C	X
Weed shiner (*Notropis texanus*)[c]	-	X
Mimic shiner (*Notropis volucellus*)	R	X
Suckermouth minnow (*Phenacobius mirabilis*)	R	X
Southern redbelly dace (*Phoxinus erythrogaster*)[u]	X	X
Bluntnose minnow (*Pimephales notatus*)	O	X
Fathead minnow (*Pimephales promelas*)	U	X
Bullhead minnow (*Pimephales vigilax*)	C	X
Creek chub (*Semotilus atromaculatus*)	X	X
Pearl dace (*Margariscus margarita*)[c,u]	X	X
Blacknose dace (*Rhinichthys atratulus*)[u]	X	X
River carpsucker (*Carpiodes carpio*)	C	X
Quillback (*Carpiodes cyprinus*)	C	X
Highfin carpsucker (*Carpiodes velifer*)	O	X
White sucker (*Catostomus commersoni*)	X	X
Longnose sucker (*Catostomus catostomus*)[c]	X	X
Blue sucker (*Cycleptus elongatus*)	U	X
Smallmouth buffalo (*Ictiobus bubalus*)	C	X
Bigmouth buffalo (*Ictiobus cyprinellus*)	C	X
Black buffalo (*Ictiobus niger*)	U	X
Spotted sucker (*Minytrema melanops*)	O	X
Silver redhorse (*Moxostoma anisurum*)	U	X
Golden redhorse (*Moxostoma erythrurum*)	O	X
Shorthead redhorse (*Moxostoma macrolepidotum*)	C	X

TABLE A-3. (Continued)

TAXON	SPECIES STATUS[a]	OCCURRENCE[b]
Black bullhead (*Ameiurus melas*)	O	X
Yellow bullhead (*Ameiurus natalis*)	O	X
Channel catfish (*Ictalurus punctatus*)	C	X
Stonecat (*Noturus flavus*)	U	X
Tadpole madtom (*Noturus gyrinus*)	U	X
Flathead catfish (*Pylodictis olivaris*)	C	X
Blackstripe topminnow (*Fundulus notatus*)	-	X
Trout-perch (*Percopsis omiscomaycus*)	-	X
Mosquitofish (*Gambusia affinis*)	R	X
Brook silverside (*Labidesthes sicculus*)	O	X
White bass (*Morone chrysops*)	C	X
Yellow bass (*Morone mississippiensis*)	U	X
Rock bass (*Ambloplites rupestris*)	U	X
Green sunfish (*Lepomis cyanellus*)	O	X
Pumpkinseed (*Lepomis gibbosus*)	C	X
Warmouth (*Lepomis gulosus*)	U	X
Orangespotted sunfish (*Lepomis humilis*)	C	X
Bluegill (*Lepomis macrochirus*)	A	X
Smallmouth bass (*Micropterus dolomieu*)	O	X
Largemouth bass (*Micropterus salmoides*)	C	X
White crappie (*Pomoxis annularis*)	C	X
Black crappie (*Pomoxis nigromaculatus*)	C	X
Western sand darter (*Ammocrypta clarum*)[c]	U	X
Mud darter (*Etheostoma asprigene*)	U	X
Rainbow darter (*Etheostoma caeruleum*)	X	X
Johnny darter (*Etheostoma nigrum*)	U	X
Yellow perch (*Perca flavescens*)	U	X
Logperch (*Percina caprodes*)	O	X
Slenderhead darter (*Percina phoxocephala*)	R	X
River darter (*Percina shumardi*)	U	X
Sauger (*Sander canadense*)	C	X
Walleye (*Sander vitreum*)	C	X
Freshwater drum (*Aplodinotus grunniens*)	A	X

[a]Species listed as collected in Pool 14 by Pitlo et al., (1995) and their status.
[b]"X" indicates the species was collected during the 38-year monitoring period.
[c]Listed as protected by Iowa Department of Natural Resources (2009) or Illinois Endangered Species Protection Board (2011).
[d]Collected by minnow seine only.

X - Probably occurs only as a stray from a tributary or inland stocking.
H - Records of occurrence are available, but no collections have been documented in the last 10 years.
R - Considered rare. Some species in this category may be on the verge of extinction.
U - Uncommon; does not usually appear in sample collections.
O - Occasionally collected; not generally distributed, but local concentrations may occur.
C - Commonly taken in most sample collections; can make up a large portion of some samples.
A - Abundant; taken in all river surveys.

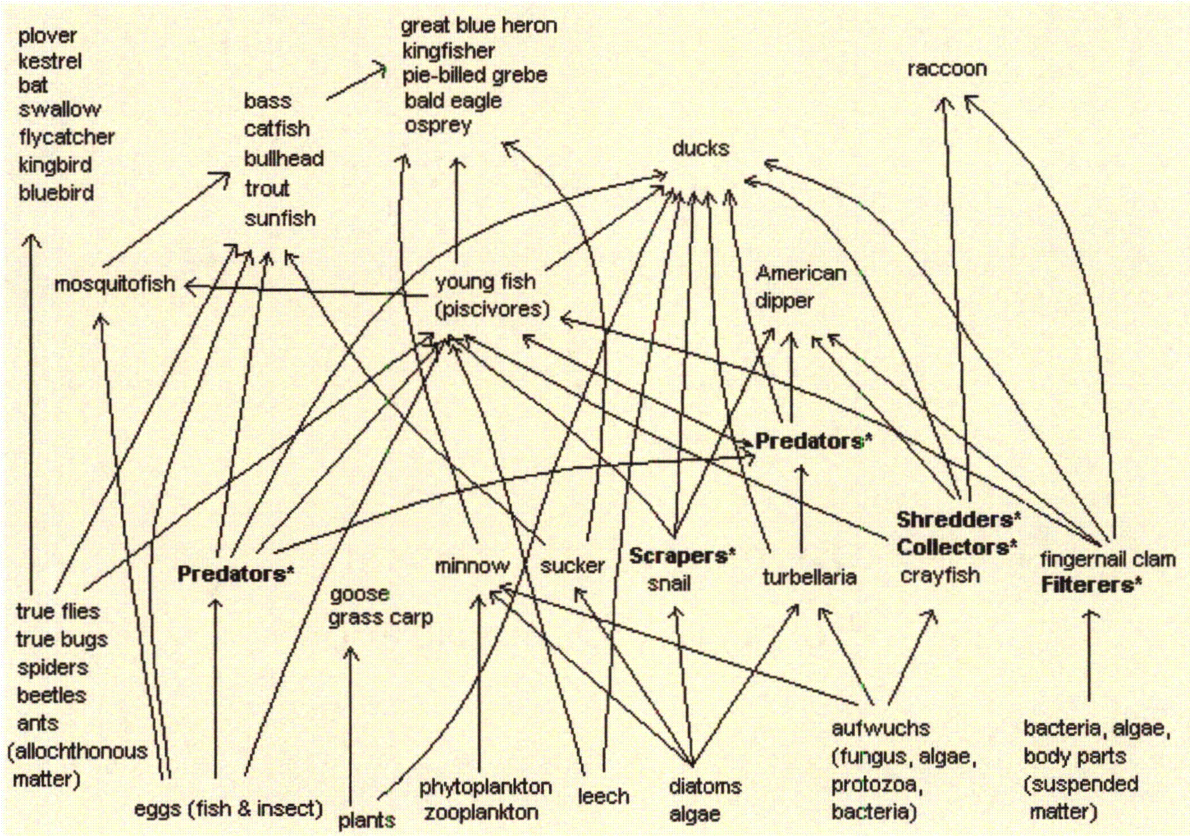

Figure A-1. Simplified food web for a typical river system