NRR-PMDAPEm Resource

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Cc: Grange, Briana; Logan, Dennis
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Hi Rick –
This is the first of two email messages containing Exelon's responses to the NRC Staff's questions about special status species that were discussed during a conference call on 6/19/2015.
Please let me know if there are followup questions, or issues with the attached files.

Nancy

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NRC Questions for Exelon on Braidwood DSEIS from State & Federal Agencies

EPA Comment on Bald Eagles

Have bald eagles been observed nesting on any of the cooling ponds islands during the 2014 nesting season or in 2015 to date?

Exelon response -*No.*

If bald eagles were observed nesting on the site, would Exelon coordinate with FWS regarding its adherence to the 2007 National Bald Eagle Management Guidelines?

Exelon response -*Most of the islands in the Braidwood Station cooling pond are located in areas managed by the IDNR under provisions of the Mazonia - Braidwood Lease, which requires that IDNRassure compliance in the leased area with all Environmental Laws, including laws that protect wildlife. The term of the Lease extends through the currently licensed term of Braidwood Station Unit 1, which includes a portion of the anticipated license renewal terms for both units. Accordingly, as long as the Lease remains effective, if Exelon Generation personnel become aware of nesting Bald Eagles in the leased area, Exelon Generation will inform IDNR of the observation, and request that IDNR undertake its responsibilities in accordance with the Lease. If Exelon Generation personnel become aware of nesting Bald Eagles in the restricted access areas of the cooling pond (i.e., areas not managed by IDNR), Exelon Generation personnel will notify and coordinate with USFWS regarding adherence to the 2007 National Bald Eagle Management Guidelines.*

IDNR Comments on State-Listed Species

Has Exelon engaged with IDNR at any time (past or present) regarding the potential for State-listed species to be impinged or entrained during Braidwood operations?

Exelon response – *During the time of initial Braidwood Station licensing (i.e., 1975 to 1986), the IDNR (then, the Illinois Department of Conservation) was an active participant in interagency negotiations that led to restrictions on the Station's rate of water withdrawal from the Kankakee River. Before permits allowing construction of the Braidwood intake structure were issued in 1977 by the Illinois Department of Transportation Division of Water Resources and the U.S. Army Corps of Engineers, Exelon Generation (then, Commonwealth Edison Company) agreed at the behest of the Illinois Department of Conservation (now IDNR) to limits onBraidwood's water withdrawal rate from the Kankakee River during low flow periods as a measure to protect aquatic species in the river. In addition, IDNR's concerns were considered by Illinois EPA during negotiations from 1979 through 1990 about conditions in the Braidwood Station NPDES permit, including a condition to reduce intake impacts, which remains and reads as follows in the current NPDES permit, Special Condition 8:*

> *Intake impacts will be reduced by limiting pumping from the river during the peak entrainment period. For a four-week period (last three weeks in May and first week in June), pumping will be allowed only during the day (between one hour after sunrise and one hour before sunset). In addition, during the four-week period, pumping will be minimized during the day. Pumping will occur when needed to fill the freshwater holding pond and to maintain efficient operation of the cooling pond. In an extreme emergency,*

and upon immediate notification of the Agency, pumping could occur at night. Such pumping would cease as soon as the emergency was over. Records of all pumping during the four-week period will be maintained. Such records will include dates, number of pumps operating and start and end times.

The purpose of Special Condition 8 is to reduce impingement and entrainment impacts, especially with respect to pallid shiners and river redhorse, which are State-listed fish species.

Does Exelon intend to pursue an Incidental Take Authorization under the Illinois Endangered Species Protection Act for the State-listed species mentioned in IDNR's letter? (pallid shiner, river redhorse, western sand darter, American eel, sheepnose, black sandshell, spike, purple wartyback)

Exelon response –*The Braidwood Station NPDES Permit expires July 31, 2019. In the next renewal application, which must be submitted on or before January 31, 2019, Exelon Generation intends to submit information to the permitting agency (i.e., Illinois EPA) characterizing impingement mortality and entrainment, in accordance with 40 CFR §122.21(r)(1)(ii), USEPA's recently finalized rule governing NPDES permitting requirements for intake structures at existing facilities. During a recent conversation between Exelon Generation and IDNR (Nathan Grider), IDNR agreed that concerns aboutpossible impingement and entrainment of State-listed species at Braidwood Station as well as the question of whether a need exists for the Station to pursue an Incidental Take Authorization under the Illinois Endangered Species Protection Act could appropriately be addressed in the context of the Braidwood Station's next NPDES Permit renewal proceedings rather than the NRC license renewal proceedings.*

The NRC did not find the State-threatened American eel or the State-threatened mudpuppy to be present in any of the preoperational or operational monitoring or in any impingement and entrainment studies associated with Braidwood. Does Exelon have any information that would suggest that either of these species are present in the vicinity of the site or that either species is at risk of impingement or entrainment?

Exelon response -*No.*

Exelon Comment on Pallid Shiner

Please provide copies of the two studies by EA Engineering, Science, and Technology, Inc. that show, as stated by Exelon, that pallid shiner is increasing in abundance in the Kankakee River.

Exelon response – *Exelon is providingPDF files containing the requested documents with this response.*

FWS and EPA Comments on Northern Long-Eared Bat

Please describe the type and amount of tree clearing activities that Exelon expects to perform over the license renewal period (from now until the expiration of the renewed license, if granted). Has Exelon developed a tree-clearing management plan or guidance that would

protect any northern long-eared bat habitat on site. Because Exelon, FWS, and NRC are in Endangered Species Act Section 7 informal consultation regarding northern long-eared bat, please provide copies of any past and future correspondences with other agencies regarding that species.

Exelon response – *Tree clearing has not been a recurring activity at Braidwood Station in the past, and it is not expected to be a recurring activity in the future. However, NRC Regulatory Guide (RG) 1.23, "Meteorological Monitoring Programs for Nuclear Power Plants," recommends that wind measurements should be made at locations and heights that avoid airflow modifications by obstructions such as large structures, trees, and nearby terrain. As part of its routine meteorological monitoring program, Braidwood Station retains a contractor to operate and maintain the Station's meteorological tower. During an annual site inspection on May 21, 2015, the contractor identified several individual trees and groups of trees in the vicinity of the meteorological tower that, considering the guidance in RG 1.23, it suggested for removal based on distance from the meteorological tower, height, and compass direction. Accordingly, Exelon Generation plans to remove the trees, as suggested in the contractor's report. When issued, the work order will include guidance to minimize effects on northern long-eared bats, such as restricting tree removal activities to months when bats would not be present.*

No past correspondence with agencies other than NRC has occurred regarding the northern long-eared bat at Braidwood Station.

<u>**FWS and EPA Comments on Endangered Sheepnose Mussel**</u>

Please send a copy of the proposal for mussel survey work to be conducted by ESI this summer. Because Exelon, FWS, and NRC are in Endangered Species Act Section 7 informal consultation regarding the endangered sheepnose, please provide copies of any past and future correspondences with other agencies regarding that species.

Exelon response – *Exelon is providingPDF files containing the following documents with this response.*

- *2015.05.26_ Email to USFWS_RE_US DOI Letter to NRC Regarding Draft Braidwood License Renewal SEIS*
- *2015.05.26_Email from USFWS_Re_US DOI Letter to NRC Regarding Draft Braidwood License Renewal SEIS*
- *2015.05.27_Email to USFWS_RE_ US DOI Letter to NRC Regarding Draft Braidwood License Renewal SEIS*
- *2015.05.29_Email to USFWS_Exelon Generation -- Braidwood Station Mussel Survey*
- *2015.06.02_Email from-to USFWS_RE_ Exelon Generation -- Braidwood Station Mussel Survey*
- *2015.06.05_Email to NRC_RE_U.S. Dept of Interior and IDNR Comments to NRC regarding Braidwood Station Lic Renewal Supplemental EIS - T&E Species*
- *2015.06.12_Emails to-from USFWS_RE_ Exelon Generation -- Braidwood Station Mussel Survey*
- *2015.06.18_Email to USFWS_RE_Telephone Call on Friday, 6_18_2015*
- *2015.06.18_Email_from_USFWS_Re_ Exelon Generation -- Braidwood Station Mussel Survey*
- *P14-055 Proposal - 2015_mussel_survey (without costs)*

While theinformal consultation process regarding potential effects near the Braidwood Station intake and discharge structureson the endangered sheepnose mussel continues, Exelon Generation will provide USFWS and NRC with copies of any correspondence with other agencies regarding that species.

APPENDIX B

Information Supporting Representative Important Species Rationale: Biothermal Assessment – Predictive Demonstration

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1.0 ANALYTICAL METHODOLOGY – COMPARISON WITH PRIOR 316(A) ASSESSMENT

Commonwealth Edison (Edison) filed a §316(a) Demonstration (Edison 1980) with the Illinois Pollution Control Board to support its request for alternative thermal limits (ATLs) for the DNS. That Demonstration used a retrospective analysis of aquatic community monitoring data collected during DNS operations in indirect open-cycle mode, between 15 June and 30 September. These biological data were used to demonstrate that the existing thermal limitation requiring closed cycle cooling year-round was "more stringent than necessary to assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife." The Demonstration showed no prior appreciable harm to the aquatic community resulted from indirect open cycle operations (between 15 June and 30 September) that took place between September 1971 and October 1974. The DNS Simulation Model provided a qualitative analysis of thermal conditions in the Dresden Pool under two operating scenarios (closed cycle year round and indirect open cycle 15 June through 30 September).

The present Demonstration, conducted to consider whether the existing ATLs continue to satisfy the §316(a) criteria, utilizes two technical approaches to evaluate the effects of Station operations on water temperature, aquatic habitat utilization, and the condition of the aquatic community. The first approach (Appendix C), similar to the 1980 Demonstration, presents a retrospective analysis of the balanced indigenous community (BIC) to demonstrate the absence of prior appreciable harm to this community, relying on an expanded database of nearly 20 years of additional monitoring of the aquatic community collected subsequent to the 1980 Demonstration. This extensive database, collected under operating conditions similar to the proposed ATLs, provides a rigorous test for demonstrating the absence of prior appreciable harm. The second approach, not included in the 1980 Demonstration, uses quantitative hydrothermal modeling to predict thermal conditions under various operating and ambient flow conditions, integrated with metrics of thermal requirements and tolerance limits identified in scientific literature for selected aquatic species representative of the BIC. This prospective analysis is used to predict the response of the aquatic community to the effects of the DNS thermal discharge plume on the biological community and receiving water body. For this Demonstration, a three-dimensional mathematical model (MIKE 3) that was used to estimate ambient temperatures under various river flow conditions and DNS thermal plume conditions under 3 representative flow and temperature scenarios (Appendix D), including conditions representative of the proposed ATLs. The model was calibrated and validated using a recent bathymetric survey and three field surveys of water temperature and velocity conducted under various river flow and weather conditions during 2013-2014. The calibrated model was used to estimate water temperature within each model cell under various ambient flow and station operating scenarios to estimate dilution and dispersion of elevated thermal plume temperatures. Model estimated cross section and bottom water temperatures are compared to biothermal metrics to estimate the extent of otherwise available aquatic habitat that would be excluded or would be at less than optimum conditions for selected life history functions (e.g., spawning, growth, survival) of representative important species (RIS) due to water temperature.

2.0 ENVIRONMENTAL CONDITIONS STUDIED AND HYDRODYNAMIC MODEL INPUTS

2.1 Hydrodynamic Model

Thermal modeling utilized DHI's MIKE3 model (DHI, 2012), which provides a state-of-art, three-dimensional modeling framework. The model domain included portions of both the Des Plaines and Kankakee Rivers upstream of their confluence and extended downstream to the Dresden Island Lock and Dam. Bathymetric mapping, three-dimensional field surveys of water temperature and flow, and meteorological conditions were used as inputs to calibrate and validate the MIKE3 model used to predict the configuration and temperature distribution of the DNS thermal plume under selected operating, river flow, and weather conditions. The model grid (Appendix D, Figure D-12) is composed of 1,530 rectangular or triangular cells divided into 12 vertical layers. The upper three layers were confined to a maximum 1.0 m depth. Below 1.0 m, layer thickness increased from 0.5 m to 1.0 m in the deepest layer. These additional layers were adjusted as necessary to extend to the river bottom. The shape and horizontal dimensions of the cells vary depending on complexity of mixing conditions in that portion of the model grid; the finest model grid was constructed in the vicinity of the thermal plume to increase the model resolution in the primary area of interest for the biothermal analysis.

2.2 Station Operating and Environmental Conditions Evaluated

This analysis examines three scenarios of flow and water temperature in conjunction with operation of DNS at full load using indirect open cycle cooling between 15 June and 30 September. These scenarios include:

1. Typical flow (50th percentile) and water temperature (60th percentile);
2. Typical high temperature conditions (5th percentile flow and 95th percentile water temperature); and
3. Extreme meteorologic/high temperature conditions similar to those that occurred during the exceptional heat wave in early July 2012.

More detailed discussion of flow and ambient river temperature conditions for these scenarios is presented in Section 2.5.1.

2.3 Biothermal Metrics Evaluated

The prospective analysis of potential thermal effects on aquatic biota integrates sophisticated hydrothermal modeling (Appendix D) of the dynamics of the thermal plume under selected DNS operations and river flow conditions with critical thermal response metrics for the selected RIS (Appendix B, Section 3). Data from scientific literature are used to characterize the thermal sensitivity of each of the RIS and critical life stages that could potentially utilize the area influenced by the DNS thermal discharge plume. The potential effects of the DNS thermal discharge on RIS were evaluated for five categories of thermal effects as recommended in the Draft *Interagency Technical Guidance Manual* (USEPA and NRC 1977) (Interagency Guidance Manual):

1. Temperature requirements for survival of juveniles and adults.

2. Avoidance temperature.

3. Temperature requirements for early development.

4. Optimum temperature for performance and growth.

5. Thermal shock tolerance.

This information was then compared to the spatial and temporal characteristics of, and thermal gradients in the thermal plume to predict the potential effects of the plume on the RIS under each assessment scenario. The primary biothermal metrics used in this analysis were:

- Spawning temperature range
- Optimum temperature for growth
- Temperature avoidance
- Chronic thermal mortality (prolonged exposure).

2.3.1 Spawning

For many aquatic species the maturation of gonadal tissue, the onset of spawning migration and spawning, and completion of spawning are closely tied to water temperature (among other environmental and physiological triggers). Most records of spawning temperatures are based on field observation of spawning runs and physiological condition of gonads at various locations within the geographic range of the species. When adequate thermal range data have been documented, a polygon was plotted on the thermal effects figure that indicates the reported temperature range for spawning based on the seasonal period during which spawning typically occurs in the vicinity of DNS.

2.3.2 Growth

Water temperature plays a significant role in the growth of aquatic species, affecting metabolic rates and the energy expended seeking and capturing food material. The optimum temperature range for growth occurs when there is a balance between the energy expended capturing food, energy for maintenance, and for growth. Most freshwater fish species exhibit seasonal patterns in growth; for most temperate species growth is minimal during the winter and peaks between spring and fall, while boreal species often exhibit minimal growth during peak summer temperatures or move to deeper, cooler waters. Much available data for temperature and growth is for smaller species or early life stages that are more readily reared under laboratory or hatchery conditions. The relationship between temperature and growth varies. During some periods of the year, portions of the thermal plume may provide optimal temperatures for growth that are not present with available ambient temperatures (e.g., spring and fall for many species). Outside of the optimum temperature range, growth can continue to occur at a lower rate. Aquatic organisms typically prefer water temperatures that are within the optimum range for growth; preferred temperatures can be used as a surrogate for the optimum range of growth and performance.

2.3.3 Temperature Avoidance

Many species of fish and invertebrates actively avoid potentially stressful temperatures, both high and low, depending on their acclimation conditions. Although this ability minimizes the potential exposure of organisms to temperatures that could result in mortality, avoidance of elevated temperatures may preclude access to critical habitat located within a thermal discharge plume. When avoided temperatures exist over a large enough cross-section of the receiving water body, passage of organisms upstream or downstream of the discharge location may be inhibited. As with many other thermal effects parameters, the water temperatures avoided by an organism are typically dependent on an organism's acclimation history.

2.3.4 Thermal Mortality

Mortality associated with temperature has been measured using several metrics (e.g., Upper Incipient Lethal temperature [UILT], Critical Thermal Maximum [CTM], TL50, TL95, LD 50, and LD100). These data can also be qualified by rate of temperature increase and by the exposure duration ranging from seconds (thermal shock, typical of rapid entrainment into higher temperature portion of the thermal mixing zone) to days (typical of the experience of organisms exposed to temperatures in the more diluted portion of the plume).

Exposure to rapid short-term changes in water temperature can cause mortality to organisms passing through, or resident within, portions of the thermal discharge plume. Thermal shock can occur in conjunction with a rapid decrease in water temperature, cold shock, or a rapid increase in water temperature associated with plume entrainment. The attraction of some species to thermal discharge plumes during winter and early spring when ambient temperatures are low has been well documented. During a station shutdown when the heat source is suddenly discontinued, organisms acclimated to warm plume temperatures can be stressed to the point of mortality when they are suddenly returned to colder ambient temperatures, depending on the rate and magnitude of the temperature decrease. In contrast, planktonic organisms entrained into the

thermal plume near the discharge point with ambient dilution water can experience rapid short-term increases in temperature that may be capable of causing mortality. Similar to general thermal mortality discussed above, thermal shock has been measured using various metrics including the TL95, TL50, and LD50 from high temperature, short exposure tests, and CTM.

CTM is estimated with tests where organisms are subjected to a controlled rate of temperature increase over time (e.g., 0.5 °C/min [0.9°F/min]) until loss of equilibrium; resulting CTM metrics can be difficult to compare to real-world conditions due to the variation in test methods (e.g., temperature step, rate of increase, observed test end point). The tolerance limit for 95 percent of test organisms (TL95) measures the temperature at which 95 percent of the organisms survive for the exposure period; that is, negligible mortality associated with temperature. In contrast, lethal dose to 50 percent of the test organisms (LD50) measures the temperature causing mortality to 50 percent of the test organisms. Thus a TL50 and LD50 would be equivalent and the TL95 would be comparable to an LD5.

Information for metrics in each of these categories was identified through review of scientific literature including peer-reviewed literature, compilation reviews, and utility industry project reports for studies conducted to support various §316(a) Demonstrations. Other measures of organism response to temperature (including preference, thermal shock, cold shock) were also reviewed as the relative relationship of these various metrics provides a level of quality assurance for evaluating the reliability of individual values reported in the scientific literature and project laboratory or field study reports.

As water temperature increases, organisms progressively exhibit a range of integrated physiological and behavioral responses including avoidance, impaired growth and reduced feeding, impaired swimming ability, loss of equilibrium, and finally mortality. Genetics and acclimation history affect the physiological response of species and individual organisms to abiotic factors, such as temperature, in their environment. Laboratory studies are able to control a range of variables that can affect an organism's physiology in order to isolate and assess the specific influence of temperature under those specific conditions. In contrast, organism in their natural environment rarely experiences constant abiotic conditions, but are adapted to considerable variability. Because most of these physiological and behavioral responses are affected by acclimation temperature, it is important that the results from laboratory studies of thermal effects are evaluated relative to acclimation history. It is also important to understand, that while potentially lethal temperatures may exist in a waterbody or near a thermal discharge, it is unusual to observe mortality related to elevated water temperatures because of the ability of many organisms to avoid potentially lethal temperatures.

2.4 Representative Important Species (RIS) Evaluated

2.4.1 Selection of RIS

Candidate RIS were selected from a checklist of native fish species collected during surveys of Dresden Pool near DNS and downstream of the Dresden Island Lock and Dam. Surveys of the Dresden Pool were conducted during 17 years between 1994 and 2014 and surveys downstream of Dresden Island Lock and Dam were conducted during 15 years between 1994 and 2014

(Appendix G). Electrofishing and seining between 1994 and 2014 documented the presence of 96 fish species in the vicinity of DNS (Table B-1). The catch included 20 species that dominated the abundance or biomass of the fish community over much of this period (Tables B-2 and B-3). These 20 species were collected in all four river survey segments (Des Plaines River, Kankakee River, and Illinois River upstream and downstream of the Dresden Island Lock and Dam) and during 18 of 19 survey years in at least one segment between 1991 and 2013 (Table B-2). Seventy-one species were collected in at least three of the survey river segments while 19 species were collected in only one river survey segment. Twenty-six species were collected during only one or two annual surveys (Table B-2).

To adequately assess the potential effects of DNS's thermal discharge plume and operating conditions on all of these species would be extremely difficult and, in the case of many species with minimal available data on their thermal requirements, nearly impossible. Recognizing this, the Interagency Guidance Manual proposes an approach for predictive demonstrations (Type II[1]) that relies on selection and assessment of effects on a subset of RIS. The rationale for this approach is that the species selected for detailed analysis of potential thermal effects are representative of key species or groups of species that comprise the dynamic, complex aquatic community affected by the thermal discharge, that is, a BIC. Some species are selected because they fill critical roles seasonally or during occasional years. Interagency Guidance Manual list six categories of fish that may be considered RIS:

1. Commercially or recreationally important species;
2. Threatened or endangered species;
3. Species critical to ecosystem structure and function of the receiving water body;
4. Species potentially capable of becoming a localized nuisance;
5. Species necessary in the food chain; and
6. Species representative of critical thermal requirements, but which themselves may not be important.

Factors considered in the selection of RIS for the DNS prospective biothermal analysis include:

- Numerical dominance or prominence in the BIC (see Appendix C);
- Their role in energy transfer through the aquatic food chain as important forage or predator species;

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[1] The Interagency Guidance Manual also discusses two other predictive demonstrations Type 111 Low Potential Impact and Type 111 Regular (Biological, Engineering, and Other Data) and a Non-Predictive Demonstrations - Type I (Absence of Prior Appreciable Harm). RIS discussions are not required in the Type 1 or in the Regular Type 111 and TYPE 111 Low Potential Impact unless a particular biotic category has a high potential impact

- Important links between primary producers, primary consumers, and secondary consumers;
- Similarity of their food, habitat, and life history requirements to groups of other species utilizing aquatic habitat in the vicinity of the DNS thermal plume;
- Support of important commercial or recreational fisheries;
- Thermally sensitive species;
- Species of special interest or concern (e.g., rare, threatened, or endangered species);
- Non-native and potential nuisance species; and
- Species with unique or critical habitat or life history stages in the vicinity of the thermal discharge.

Only fish species were selected as RIS for the DNS thermal evaluation because fish represent the top of the food chain, are important to the public because of their recreational and/or commercial value, and because their overall wellbeing shows that the lower trophic levels are supporting the trophic levels occupied by the RIS. Lower trophic levels (e.g., phytoplankton, zooplankton, periphyton, and benthic macroinvertebrates) were not selected as RIS because of a general lack of thermal endpoint data and historical §316(a) studies have shown only localized thermal effects on lower trophic levels that have not resulted in adverse harm (Duke/Fluor Daniel 1992). The potential effects of thermal discharges from DNS on these lower trophic levels are addressed as part of the retrospective assessment (Appendix C of this Demonstration) demonstrating no prior appreciable harm to the BIC.

Twelve fish species were selected as RIS (Table B-4) for the DNS thermal evaluation. Each of these species represents one or more of the categories listed above from the Interagency Guidance Manual. In order to be a candidate, species had to have published thermal tolerance endpoints in order to conduct the required thermal evaluation. Based on these criteria, the following 12 species were selected as RIS:

- Gizzard shad
- Common carp
- Golden redhorse
- White sucker
- Channel catfish
- Emerald shiner
- Largemouth bass
- Smallmouth bass
- Bluegill
- Black crappie
- Logperch
- Freshwater drum

Except for common carp, hybrids and exotic species were excluded. Forty-two species considered incidental (I) and occasional (O) constituents of the community were excluded from the RIS list; these species were collected in only 1 study reach and/or during less than 5 sampling years (shaded in Table B-4). When several congeneric species were common in the vicinity of DNS, generally only one was selected as an RIS. For example, of the abundant minnows collected near DNS (emerald shiner, spotfin shiner, bluntnose minnow, and bullhead minnow), only emerald shiner was chosen as it has slightly lower thermal endpoints than the other three species. One exception, both congeneric smallmouth bass and largemouth bass were selected because both are the target in recreational fisheries.

Federally threatened and endangered (T&E) fish species have not been collected in Dresden Pool or adjacent study areas in the upstream Des Plaines and Kankakee Rivers, or downstream of Dresden Island Lock and Dam. Five state-listed fish species were collected. The state-listed threatened river redhorse (*Moxostoma carinatum*) and endangered greater redhorse (*M. valenciennesi*) were collected infrequently and in low numbers upstream and downstream of the Dresden Island Lock and Dam. The pallid shiner (*Hybopsis amnis*), also state-endangered in Illinois, was first collected from the DNS study area in 2001 and has been collected each year since. It was also collected upstream and downstream of the Dam but primarily upstream in the Kankakee River. The state-endangered western sand darter (*Ammocrypta clara*) was collected infrequently in low numbers and downstream of the Dresden Island Lock and Dam. The state-threatened banded killifish (*Fundulus diaphanus*) was first collected as part of the DNS monitoring program in 2013 and were collected again in 2014.

The selected RIS include species that feed primarily on one or several of the following: detritus, phytoplankton, zooplankton, crustaceans, mollusks, insect larvae, other invertebrates and benthos, and fish. They include pelagic and demersal species that utilize habitats in channel, pool, run, riffle, or backwater areas. Individual RIS have preferences for a variety of substrate, including hard or soft bottom with mud, muck, and silt, sand, gravel, cobble, and rock; some RIS prefer dense vegetation or structure (e.g., roots, woody debris, and boulders). The selected RIS include species representative of various levels of the food chain including primary consumers, omnivores, forage species, and top predators, and species that are common targets for recreational or commercial fisheries.

In general, species that occur infrequently or in low abundance (I or O in Table B-4) in the vicinity of DNS were excluded from consideration as RIS, except for state or federally listed sensitive species (e.g., pallid shiner, river redhorse, greater redhorse) where thermal data are available or species considered to be thermally sensitive (e.g., white sucker, black crappie). The area in the vicinity of DNS does not provide unusual, unique, or critical habitat that would be necessary to complete important life history functions (Table B-4) for any of the incidental or occasional species that were excluded (Table B-4, shading).

Other dominant and common species not selected as RIS have habitat, feeding, and life history requirements very similar to the selected RIS, which is the rationale for use of RIS to evaluate the effects of the discharge on aquatic biota. The trophic relationships within the aquatic community in the vicinity of DNS for which each of the selected RIS are representative are

summarized below and in Table B-4:

- Gizzard shad – the most common and abundant pelagic species in the vicinity of DNS feeding primarily on invertebrates in mud substrate as well as zooplankton and phytoplankton. Juvenile gizzard shad are an important component of the forage base.

- Common carp – omnivore and scavenger; non-native species that is considered a nuisance species where it occurs in high abundance.

- Golden redhorse – representative of a diversity of 15 species in the sucker family (Catostomidae) collected in the area of DNS including other redhorse species, buffalo, sucker, and carpsucker. Golden redhorse is a surrogate for the state-listed river redhorse and greater redhorse.

- White sucker – considered a thermally sensitive member of the sucker family, although rarely collected in the study area.

- Channel catfish – representative of a variety of catfish species collected in the vicinity of DNS and can be an important recreational target species.

- Emerald shiner – one of the most abundant forage species in the area and is representative of the diversity of shiners and minnows in the aquatic community. Emerald shiner is a surrogate for the state-listed pallid shiner.

- Largemouth bass and smallmouth bass – representative of an array of piscivorous top predators in the vicinity of DNS and important targets of recreational anglers.

- Bluegill – representative of a variety of sunfish species (Centrarchidae) collected near DNS and is an important target for recreational anglers.

- Black crappie – considered a thermally sensitive recreational species also in the Centrarchid family, but relatively uncommon in the vicinity of DNS.

- Logperch – representative of a variety of darter species collected occasionally in the vicinity of DNS.

- Freshwater drum – an important demersal species feeding extensively on mollusks and crawfish that support commercial and recreational fisheries. The species is also an important host species for glochidia, the larval life stage of several freshwater mussel species.

More detailed life history information and thermal requirements relevant to their interaction with the DNS thermal discharge are summarized for each RIS in the following subsections. Sources of the life history information summarized below include Scot and Crossman (1973), Smith (1979), Trautman (1981), Etnier and Starnes (1993), Pflieger (1997), and Page and Burr (2011).

2.4.2 Gizzard shad (*Dorosoma cepedianum*)

Gizzard shad is an important forage species in the aquatic ecosystem near DNS. It is a prolific warmwater species that produces abundant juvenile year classes used as forage by top predators such as largemouth bass. Gizzard shad is typically one of the most abundant species captured during electrofishing and seining surveys of the Des Plaines, Kankakee, and Illinois Rivers. It occurs throughout the state and the Illinois River drainage. This schooling species is most common in large rivers and reservoirs and is often seen in large schools in the upper water column. Gizzard shad is in the simple breeding guild (i.e., broadcast spawning without parental care) producing adhesive eggs that adhere to vegetation and substrate. In the Illinois River and its tributaries, spawning occurs in open water from about late April through June. No gizzard shad eggs were collected during the 2005-2006 ichthyoplankton surveys at DNS.

Ambient water temperatures when the first yolk-sac larvae were observed in the vicinity of DNS during 2005-2006 were between 10°C (50°F) and 15°C (59°F) (EA 2007). Peak densities of yolk-sac larvae occurred from mid-May to mid-June in 2005 and late-May to early July in 2006; water temperatures during these periods were 14°C (57.2°) to 27°C (80.6°F). Post yolk-sac larvae were most abundant during June in 2005 and mid-June to mid-July 2006 at a temperature range of 18°C (64.4°F) to 28°C (82.4°F).

Annual electrofishing catches from 1991 through 2014 near DNS averaged 1,075 gizzard shad (range = 422 to 2,019). It was the most or second most abundant species collected during 19 of the 20 years surveyed (Table B-3). Gizzard shad were among the 10 most abundant species in beach seine sampling during the same period. Annual mean electrofishing catch rates were generally higher in the Kankakee and Illinois Rivers upstream of the Dresden Island Lock and Dam than in the Des Plaines River or downstream of the Dresden Island Lock and Dam. Its average biomass since 2000 has ranked second highest accounting for 15 percent of the mean biomass. Abundance of gizzard shad increased from a seasonal low in spring (prior to 15 June), through summer, and into fall (after 30 September).

2.4.3 Common carp (*Cyprinus carpio*)

Common carp, a non-native, warmwater species introduced to Lake Michigan in the 1800s (Fuller et. al 1999), was collected during all fish survey years in the vicinity of DNS. When abundant, common carp are considered a nuisance species; particularly during spawning season common carp can be responsible for high turbidity levels as they thrash about in shallow weed beds and over silty substrates. Since 2000 common carp has not ranked higher than 12th (average rank, 15) in abundance and except in 2001, fewer than 100 common carp have been collected in all gear annually since 1994 (Table B-3). They are in the Illinois River up and downstream of Dresden Island Lock and Dam and in the Kankakee River carp have generally declined in abundance over the last decade compared to the early 1990s. Although they were not numerically abundant (Table B-3), common carp comprised at least 16 percent of the annual biomass (Appendix C). The disparity between the numerical rank and biomass rank reflects the large average size of common carp routinely collected.

Common carp spawn in shallow weedy areas during spring and early summer; eggs are broadcast over debris and vegetation. Eggs were collected on one sampling date in mid-May 2006 during ichthyoplankton sampling in the vicinity of DNS; no eggs were collected in 2005 (EA 2007). Yolk-sac and post yolk-sac larvae were collected in the Kankakee River and at the DNS cooling water intake and discharge between mid-May and the first week of July during 2005. During 2006 larvae were collected intermittently between early May and late August. During the week prior to collection of the first carp yolk-sac larvae, water temperatures in the Kankakee River upstream of DNS were between 10°C (50°F) and 15°C (59°F). Common carp eggs and larvae accounted for less than one percent of the ichthyoplankton collected in the vicinity of DNS during 2005 and 2006.

2.4.4 Emerald shiner (*Notropis atherinoides*)

Emerald shiner is a native forage species that utilizes nearshore habitats in shallow water. It is most common in open water near the surface and avoids dense vegetation (Trautman1981). Emerald shiner is in the simple breeding guild (i.e., broadcast spawning without parental care). Spawning occurs in open water from about May through June when water temperatures are 22°C (71.6°F) to 24°C (75.2°F) (ESE 1992). Few emerald shiner larvae and early juveniles were identified in samples collected during the 2005-2006 ichthyoplankton survey in the vicinity of DNS (EA 2007). Yolk-sac larvae, post yolk-sac larvae, and early juveniles of the Cyprinid family were collected between mid-May and late August. Water temperatures during the week prior to the first observation of cyprinid yolk-sac larvae were between 15°C (59°F) and 20°C (68°F). Peak larval abundance occurred between early June and early July in both years (EA 2007). Early juveniles were most abundant in early August during 2005 and from early July through mid-August during 2006 (EA 2007).

Mature and immature shiner were collected during all except one year and was the most abundant minnow species collected near DNS (Table B-3). It was generally the first or second most common species collected by beach seine and electrofishing between 1991 and 2014.

2.4.5 Golden redhorse (*Moxostoma erythrurum*)

Golden redhorse is a native riverine species in the sucker family, widely distributed in Illinois that prefers clear rivers and medium-sized streams with gravelly riffles, permanent pools, and moderate currents. Habitat preference, spawning habits, and food preference is similar to many other redhorse sucker species including the state-listed river redhorse. Adults grub in the bottom substrate in riffles and adjacent pools, selectively feeding on insect larvae and other benthic invertebrates. Juveniles feed in backwater areas on algae and micro-crustaceans. Redhorse are a popular sport fish for hook and line anglers.

Golden redhorse typically spawn in riffle habitat during April and May; eggs are dispersed over sand and gravel substrate with no parental care. In larger rivers, adults move into tributaries to spawn as water temperatures increase in the spring. During the 2005-2006 ichthyoplankton survey at DNS, early life stages of golden redhorse were not specifically identified in collections taken in the vicinity of DNS (EA 2007). *Moxostoma* spp. yolk-sac larvae and post yolk-sac larvae were collected in the Kankakee River between mid-May and late June with peak densities

(120-140 organisms per million gallons) in early June. Water temperatures during the week prior to the first observation of *Moxostoma* yolk-sac larvae were between 15°C (59°F) and 20°C (68°F). Early juveniles were collected in June during the 2006 survey. *Moxostoma* spp. was not collected in the vicinity of the Dresden cooling water intake or discharge (EA 2007).

Mature and immature golden redhorse were collected each sampling year from 1991-2014; it was the ninth most abundant species collect by electrofishing and fifteenth collected by beach seine over this period (Table B-3). It is the most abundant of five redhorse species collected near DNS. Its average biomass ranked seventh highest since 2000 accounting for 4 percent of the ten-year mean biomass. Golden redhorse accounted for two to four percent of the annual numerical electrofishing catch between 1991 and 2014 (Table B-3). The beach seine catch per haul for golden redhorse increased steadily between 2000 and 2007 in the Kankakee and Des Plaines Rivers, followed by a sharp decline between 2008 and 2014. Abundance in the Illinois River upstream and downstream of the Dresden Island Lock and Dam remained low in beach seines and demonstrated no trend over this period. The catch per hour for electrofishing was also relatively high, particularly in the Kankakee and Des Plaines Rivers from 2002 to 2008 and declined after 2008.

2.4.6 White sucker (*Catostomus commersonii*)

White sucker is a native, demersal warmwater species, widely distributed in Lake Michigan and throughout Illinois. It prefers sand and coarse substrates in clear creeks and small rivers (Smith 1979), but can be found in habitat with silt and fine sediment. White sucker is not common in the vicinity of DNS, but is included in this thermal assessment because it is considered to be relatively sensitive to increases in summer water temperatures above ambient. Spawning occurs during April and May over gravel substrate in riffles and pools; eggs are broadcast with no parental care and typically hatch in approximately three weeks depending on water temperature. During 2005 ichthyoplankton surveys (EA 2007), white sucker post yolk-sac larvae were collected in the Kankakee River during the second week of June. Yolk-sac and post yolk-sac larvae were collected in the Kankakee River during 2006 between the last week of May and late June. Water temperatures during the week prior to the first observation of white sucker yolk-sac larvae were between 17°C (62.6°F) and 23°C (73.4°F). Post yolk-sac larvae were collected near the DNS cooling water intake once in mid-July 2006; no early life stages of white sucker were collected in the vicinity of the DNS cooling water discharge in either year.

White sucker comprise less than one percent of the overall catch in surveys between 1994 and 2014 and have been collected in four or fewer years over that period in the study reaches of the Illinois, Des Plaines, and Kankakee Rivers (Table B-3). They were only collected in the Kankakee River upstream of DNS in one annual survey. White sucker was not collected between 1993 and 2004 by electrofishing or between 1993 and 2006 by beach seine.

2.4.7 Channel catfish (*Ictalurus punctatus*)

Channel catfish is a common native sport and food fish widely distributed in Illinois. It is usually found in greatest abundance in fast-flowing, medium to large rivers with sand and gravel-substrates, but can tolerate a wide range of habitats that exist near DNS. Adults typically

inhabit deep water in large pools near submerged logs, debris, and other cover. Juvenile catfish feed primarily on small insects; adults are omnivores and scavengers, feeding on fish, crayfish, mollusks, insects, plant material, and other organic material. Channel catfish is in the complex breeding guild. They use natural cavities and undercut banks to lay their eggs. The male builds the nest and remains over the nests to fan the fertilized eggs and guard hatched larvae. As a result of this behavior, eggs and larvae are uncommon in ichthyoplankton surveys. Spawning typically occurs in June and July. A few yolk-sac larvae were collected in the Kankakee River and at DNS cooling water intake and discharge during July in 2005; no post yolk-sac larvae were collected (EA 2007). Water temperatures during the week prior to the first observation of channel catfish ichthyoplankton were between 21°C (69.8°) and 24°C (75.2°F) during 2005. No channel catfish larvae were collected during the 2006 surveys. Early juveniles leave the nest and become more vulnerable to the sampling gear. Juveniles were collected in the Kankakee River and in the vicinity of the DNS cooling water intake and discharge from late June through mid-August during the 2005 and 2006 surveys (EA 2007).

Channel catfish have been collected each year upstream and downstream of Dresden Island Lock and Dam and was the most abundant of six catfish species collected near DNS accounting for 88 percent of the catfish in the Dresden Pool electrofishing catch since 2000 (Table B-3). Its average biomass ranked third highest since 2000 accounting for 12 percent of the 10-year mean biomass. Since 2000, channel catfish have generally been more abundant in the Illinois River downstream of Dresden Island Lock and Dam than upstream or in the Des Plaines or Kankakee Rivers.

2.4.8 Smallmouth bass (*Micropterus dolomieu*)

Smallmouth bass is a popular recreational species widely distributed in much of northern Illinois. It prefers clear streams and rivers with gravel and rocky substrate, moderate to fast currents, and relatively cooler summer conditions than do largemouth bass. They utilize cover and structure in large pools, but will forage for minnows and other fish in shallow water near the shoreline. They are relatively intolerant of turbidity and siltation. Insect larvae and micro-crustaceans are the primary food for young bass; adults feed primarily on crayfish and fish, but also opportunistically consume insects. Spawning occurs in May and June. Males excavate nests in gravel and guard the developing eggs, larvae, and young fry. Nests are typically constructed in sheltered areas near shore with negligible flow. No larvae or early fry were collected in the 2005-2006 ichthyoplankton surveys, a reflection of nesting habitat, nest building and parental protection that minimizes their vulnerability to ichthyoplankton sampling gear.

Numerically smallmouth bass ranged from 3rd to 13th in annual electrofishing surveys between 1994 and 2014, averaging 7th overall. Annual abundance was variable among the study reaches, but was considerably higher in the Des Plaines River between 2003 and 2008 than the other study reaches. Abundance of smallmouth bass was highest in the spring/early summer sampling periods and generally declined through the summer and fall sampling periods. This may reflect the use of deeper, cooler areas as seasonal water temperatures increase through the summer that are deeper than the effective depth of the electroshocking equipment.

2.4.9 Largemouth bass (*Micropterus salmoides*)

Largemouth bass is closely related to smallmouth bass and are also a popular recreational species. It is widely stocked in ponds and lakes to support recreational fishing. It utilizes a wide range of habitat from small streams to large rivers and lakes and is common throughout Illinois. It prefers shallow weedy lakes and river backwaters, the type of habitat preferred by bluegill. Adults feed predominantly on crustaceans and fish and may feed more actively in shallow areas in the evening. Adults prefer deeper habitat with structure such as boulders snags and root wads during daylight hours. They are relatively intolerant of turbidity and siltation. Spawning typically occurs in May and June with nest construction in sand gravel and around vegetation with the male guarding the nest and early life stages similar to smallmouth bass. Largemouth bass larvae or early fry were not collected in the 2005-2006 ichthyoplankton surveys (EA 2007), a reflection of spawning habitat, nest building, and parental protection by this species which minimizes their vulnerability to ichthyoplankton sampling gear.

Largemouth bass were more abundant than smallmouth bass in the DNS study reaches (Table B-3). Between 1994 and 2014 largemouth bass numerically ranked from 2nd to 8th annually and averaged 6th over this period in electrofishing surveys. Abundance in beach seines was relatively low as beach seines are relatively ineffective in habitat frequented by largemouth bass except during spawning. The species exhibited a general trend of increasing abundance in the vicinity of DNS since 2000, particularly in the Des Plaines River and Illinois River upstream of Dresden Island Lock and Dam (Table B-3).

2.4.10 Bluegill (*Lepomis macrochirus*)

Bluegill is a widely distributed native species that is usually most abundant in clear lakes with aquatic vegetation, but can tolerate a wide range of habitats as exists near DNS. Bluegill is widely distributed target for recreational fishing. They are gregarious and occur in small schools. Bluegill feed primarily on aquatic insects, small crustaceans, and small fish; peak feeding activity typically occurs around dawn and dusk. They prefer gravel substrates to build nests, but will utilize most substrates. Nests are constructed in relatively high density in shallow water. Spawning begins in late May and often continues into August. Male bluegill guards eggs and larvae on the nest, but do not guard the young fry as do smallmouth and largemouth bass. Bluegill were not specifically identified in the 2005-2006 ichthyoplankton samples; however, *Lepomis* spp. yolk-sac and post yolk-sac larvae were collected from early June through late August both years (EA 2007). Water temperatures during the week prior to the first observation of *Lepomis* yolk-sac larvae were between 23°C (73.4°F) and 27°C (80.6°F). Early juveniles were also collected from early July through the end of sampling in August (EA 2007).

Bluegill was the most abundant of six sunfish species collected by electrofishing near DNS, accounting for over 50 percent of the sunfish collected between 2000 and 2014 (Table B-3). It ranked 1st to 7th annually in abundance in electrofishing surveys from 1994 -2014 and averaged 2nd overall. It was the 4th in abundance in beach seine collections between 2000 and 2014. Bluegill abundance has generally trended higher since 2000 (Table B-3). Its average biomass ranked ninth since 2000 accounting for 3 percent of the mean biomass over that period.

2.4.11 Black crappie (*Pomoxis nigromaculatus*)

Black crappie is a popular sportfish widely distributed in Illinois. It is relatively intolerant of turbidity and silt, avoids areas with strong currents, and is common in well-vegetated habitat. Black crappie do not school, but can be found in loose aggregations around cover, such as root wads, woody debris, boulders and aquatic vegetation. Aquatic insects, crustaceans, and small fish are primary food for crappie. Spawning begins when water temperatures rise above 13°C (55.4°F); males fan fine sediment and debris from a nest, but nest building is minimal compared to the activities of bluegill and bass. Nests are often created in close proximity to each other and near underwater structure and cover. Males guard the nest until fry leave the nest. Black crappie was not identified to species during the 2005-2006 ichthyoplankton surveys; however, *Pomoxis* spp. was collected in relatively low abundance in the Kankakee River. Yolk-sac larvae were collected between late April and late June in 2005 and between mid-May and early June in 2006 (EA 2007). Water temperatures during the week prior to the first observation of *Pomoxis* yolk-sac larvae were between 15°C (59°) and 20°C (68°F) during both years. Post yolk-sac larvae occurred from early May through mid-June in 2005 and late May to late June in 2006. *Pomoxis* larvae were not collected at the DNS cooling water intake or discharge during 2006 (EA 2007). A few larvae were collected at the intake on one sampling date in 2005.

Black crappie was never abundant in the DNS study area, but was collected in low numbers during electrofishing surveys during most years in all four study reaches (Tables B-2 and B-3). It ranked 51st in relative abundance in all sampling gear between 1991 and 2014 and 45th in electrofishing collections.

2.4.12 Logperch (*Percina caprodes*)

Logperch is a widely distributed darter species that occurs throughout Illinois where streams are large and stable enough to provide habitat. It is particularly common in the sluggishly flowing and sand-bottomed Illinois River and associated pools. It is a demersal species that prefers mixed sand and gravel substrates. In riffle habitat, it often takes cover in brush and woody debris and commonly buries itself in sandy substrates. Its primary food consists of immature stages of aquatic insects. Logperch spawn over gravel in strong riffles during April. Logperch early life stages were not identified to the species level during the 2005-2006 ichthyoplankton surveys. Nine species of darter have been identified during fish surveys in the vicinity of DNS between 1991 and 2014 (Table B-3); most have been occasional or incidental occurrences. Logperch was the only darter among the common dominant taxa collected; most of the darter early life stages collected during the 2005-2006 ichthyoplankton surveys are likely to have been logperch. Darter yolk-sac larvae were collected between the beginning of sampling in early April through late June in 2005-2006; during the 2006 ichthyoplankton survey a few yolk-sac larvae were collected again on one date in mid-July and again in late August (EA 2007). Water temperatures at the time of the first observation of darter yolk-sac larvae were between 10° (50°) and 15°C (59°F). Post yolk-sac darter larvae were collected from mid-April to mid-July in 2005 and early May to mid- August in 2006. Early juveniles were only collected during 2005, between mid-June and mid-July.

Logperch was collected every sampling year between 1991 and 2014 in at least one sampling gear; it was collected in every year in the Kankakee River and all but one year in the Illinois

River upstream and downstream of the Dresden Island Lock and Dam (Table B-3). Their presence in the Des Plaines River was more sporadic; logperch was not collected in 6 of 19 sampling years. It was the most abundant of nine darter species collected near DNS accounting for 77 percent of the darters collected in the four study reaches since 1991 (Tables B-2 and B-3). The catch of the other eight darter species totaled 237 individuals compared to 795 logperch (Table B-3). Logperch catches were low relative to the other RIS as they contributed less than one percent of the total numerical catch since 2000 and ranked 17th in the electrofishing catch from 1994 through 2014.

2.4.13 Freshwater drum (*Aplodinotus grunniens*)

Freshwater drum is a native species in Illinois that prefers large rivers, but also occurs in large lakes and may ascend smaller rivers. It is the target of both sport and commercial fisheries. In rivers, it is most common in large pools and avoids strong currents. It is a bottom-dwelling species most abundant in turbid water over a bottom of mixed sand and silt. It feeds on mollusks, crayfish, and fish, and generally forages for food organisms in bottom substrates. Information on spawning habits of drum is limited, but it appears that spawning occurs during May and June and may be preceded by migration from lakes and large rivers into smaller tributaries. Eggs are released and float to the surface and hatch quickly. During the 2005-2006 ichthyoplankton surveys, freshwater drum eggs were the most abundant taxa/lifestage by an order of magnitude and were common from mid-May to late June; during 2006 eggs continued to be abundant into early July (EA 2007). When eggs first appeared in ichthyoplankton surveys water temperatures were 18-20°C (64.4-68°F) in the Kankakee River. Yolk-sac larvae occurred in much lower numbers than eggs from early June into early July (EA 2007). A few post yolk-sac larvae were observed in late June and early July.

Freshwater drum was collected in all four study reaches during almost every survey year since 1991 (Table B-2) and probably continuously since the early 1970s. Beach seines were ineffective sampling drum, but it was common in electrofishing samples. Numerically it ranked 13th in abundance in the electrofishing catch between 1994 and 2014 (Table B-3). Abundance is variable from year to year, but freshwater drum has generally been most abundant in the study reach of the Illinois River downstream of Dresden Island Lock and Dam since 2000. Since 2000 average biomass of freshwater drum ranked 4th highest, accounting for 11 percent of the mean biomass of all species collected over this period. It was most abundant in the spring (prior to 15 June); abundance declined slightly through the summer and into the fall (after 15 September).

2.5 Methods Employed and Species-Specific Information Used

The prospective analysis developed for evaluation of the DNS thermal discharge plume combines information on the response (behavioral and physiological) of aquatic organisms to temperatures associated with the predicted hydrodynamic characteristics of the thermal plume under selected ambient flow and station operating conditions. The primary steps in this analysis include:

- Prediction of the spatial and temporal configuration and characteristics of the DNS thermal plume using output of the three-dimensional MIKE 3 model (Appendix D).

Selection of operating and environmental scenarios for model simulation.

- Determination of ambient/acclimation temperature for the MIKE3 model grid using ambient temperatures recorded upstream in the Kankakee and Des Plaines Rivers and at the DNS cooling water intake (Appendix D).

- Identification of thermal endpoints related to growth, avoidance, chronic mortality, and temperature shock for each of the 12 RIS, as available (Appendix D).

- Identification of the period of occurrence of key life stages of the RIS in the vicinity of DNS (Section 2.5.3).

- Comparison of identified thermal endpoints for RIS with the predicted thermal plume temperatures (Section 3).

- Tabulation of cumulative cross section and bottom area affected by water temperatures in excess of selected temperature endpoints (Section 3).

2.5.1 Acclimation-Ambient Temperature Thermal Assessment Scenarios

Acclimation temperature is an important factor in evaluating most of the biothermal metrics selected in order to relate them to the effects of temperature exposure in a thermal plume. Fish are cold blooded organisms, that is, they are unable to control their body temperature, which is consequently determined by the temperature of the surrounding water. The rates of various physiologic and metabolic processes are therefore affected by the water temperature to which the organism is acclimated. Acclimation temperature is the temperature to which an organism has been exposed for a period adequate to achieve physiological equilibrium; it can take a few days to more than a week for an organism to fully acclimate to a new temperature regime. The acclimation condition can affect the response of an organism to a water temperature gradient. As an example, a group of organisms acclimated to winter or early spring water temperatures typically exhibit avoidance or preference for temperatures significantly lower than the same organisms acclimated to warmer summer ambient water temperatures.

The behavioral or physiological response of many aquatic organisms to changes or gradients of water temperature is affected by the temperature and other physical and chemical conditions to which the organism has acclimated over a period of time. Under laboratory test conditions these conditions can be fixed and controlled; under natural conditions in a waterbody, natural ambient water temperature and other factors can vary spatially over short distances (e.g., shallow shore zone versus open water, or surface versus bottom in thermally stratified areas) and on the scale of hours (diel), days, weeks, and seasons. Thus, in the natural environment acclimation temperature represents an integration of an array of conditions to which the organism has been exposed over space and time. Consequently, in the assessment of potential thermal effects from exposure to the DNS thermal plume, laboratory thermal effects data that are tied to a controlled laboratory acclimation temperature need to be considered in the context of the acclimation history of organisms that might be exposed to the DNS thermal plume and conditions in

available proximal habitat (i.e., immediately upstream of the DNS thermal plume).

To predict potential thermal effects of the DNS thermal discharge plume based on results from laboratory studies, seasonal natural ambient temperature of the Illinois River predicted from upstream Des Plaines and Kankakee River temperatures and flows can be used to represent acclimation temperature. The assumption the ambient temperature represents the acclimation condition of the community is conservative because a portion of the community can be acclimated to higher temperatures in the DNS plume which could result in higher thermal tolerance and avoidance temperatures for some organisms. Several sources of water temperature data are available for the vicinity of DNS. Water temperature is continuously monitored at the DNS cooling water intake on the Kankakee River (0.4 miles upstream of the DNS discharge) in compliance with the DNS NPDES permit. As part of the §316(a) Demonstration studies, water temperature was monitored at the following three additional USGS monitoring sites, since September 2012:

- Des Plaines River at Channahon, 4.1 miles upstream of the DNS discharge;
- Kankakee River at Wilmington, 6 miles upstream of the DNS discharge;
- Illinois River at Seneca, 19 miles downstream of the DNS discharge.

Acclimation temperature curves were estimated (Figure B-1) using the 7-day running average ambient temperature for each of these monitoring stations and the cooling water intake; the 7-day average was selected as representative of an organism's acclimation state under variable natural water temperatures. Water temperatures in the Kankakee River are consistently cooler than those in the Des Plaines River; by as much as 8°C (14.4°F) during fall and winter and approximately 2-4°C (3.6-7.2°F) during spring and summer (Figure B-1). Water temperature at the Dresden cooling water intake typically falls between temperatures in the Des Plaines and Kankakee rivers; more similar to the Kankakee River during fall, winter, and spring and closer to the Des Plaines River during summer (Figure B-1). Water temperatures at Seneca also typically fall between those recorded in the Des Plaines and Kankakee rivers. During seasonal low-flow periods (summer-fall), flows in the Des Plaines River are generally higher than in the Kankakee River (Figure B-2); however, during high flow events Kankakee River flows are typically higher than flows in the Des Plaines River. Ambient temperature in the Illinois River downstream of the confluence of the Des Planes and Kankakee Rivers near the DNS discharge was estimated based on flow-weighted mixing of the respective upstream temperatures from the Des Plaines and Kankakee Rivers (Figure B-3). The flow-weighted temperatures in the upper Illinois River and measured temperatures downstream at Seneca are typically warmer than at the DNS cooling water intake which entrains primarily water from the Kankakee River.

For this analysis the following three scenarios of flow and water temperature (Tables B-5 and B-6, Figure B-4) were examined:

1. Typical flow (median, 50^{th} percentile) and water temperature (60^{th} percentile);

2. Typical high temperature conditions (5th percentile flow and 95th percentile water temperature); and

3. Extreme high temperature conditions reflected flow (<5 percentile in the Des Plaines and 15-20 percentile in the Kankakee River) and air and water temperatures (maximum water temperatures in the range of 97-99 percentile) that occurred during an exceptional heat wave in early July 2012 (Table B-6 and Figure B-4).

July flows under the typical high temperature scenario were about 60 percent of flows for the typical scenario and flows during the extreme event of July 2012 were 38-52 percent of flows under the typical conditions scenario. Under the typical high temperature scenario ambient July water temperature did not exceed 31.7°C (89°F) and DNS discharge temperatures did not exceed 33.3°C (92°F).

In order to more adequately evaluate the potential effects of the DNS discharge under the ATLs, the model was used to estimate thermal plume conditions during extremely warm meteorologic conditions that occurred during early July 2012. During July 2012, DNS operated under a provisional variance with significantly higher DNS intake and discharge temperatures than represented by the typical high temperature scenario. During the extremely warm event of July 2012, daily maximum air temperatures increased steadily from 30.0°C (86°F) on 1 July to 37.8°C (100°F) on 7 July, while maximum daily intake water temperatures increased from about 29.4°C to 34.4°C (85°F to 94°F) over the same period (Figure B-4). DNS discharge temperatures increased from about 31.1°C (88°F) to slightly more than 34.4°C (94°F) (Figure B-4). The heat wave broke during the 8-9 July overnight period with night-time low air temperature dropping to 16.7°C (62°F); during this 36-hr period intake and DNS discharge water temperatures decreased from about 34.4°C to 31.1°C (94°F to 88°F) (Figure B-4).

2.5.2 Thermal Assessment Diagrams for RIS

Thermal diagrams (Figures B-5 to B-16) were constructed for each RIS to graphically present the relationship of acclimation temperature and the selected biothermal response metrics (as discussed in Section 2.3) to help interpret the potential effects of thermal loading from the Dresden cooling water discharge on the RIS and the aquatic community that they represent. The diagrams illustrate the relative relationship and progression of the selected biothermal response metrics and the inherent variability among individual responses for each species. Figures B-5 to B-16 are used in Section 3 (Results of Biothermal Assessment), in conjunction with thermal plume modeling and habitat mapping (Section 2.5.4), to predict potential effects of the DNS thermal plume on the aquatic community represented by the RIS.

With regard to the data presented in Figures B-5 to B-16, for each metric, the individual test results reported in the scientific literature are graphed along with the associated linear regression line for these data when appropriate. For clarity in reading the diagrams, the markers and trend lines for each specific metric are plotted in the same color with different data sources represented by distinct marker styles, as listed in the legend. Acclimation temperature (X axis) and response

temperature (Y axis) are plotted at the same scale on the diagrams for all 12 RIS to facilitate comparison of relative thermal sensitivity among species. Although thermal water quality criteria are written in terms of °F, the majority of thermal data are reported in °C. To facilitate analysis of the thermal data and development of the Master Rationale (Section 3, Dresden 316(b) Demonstration Summary), thermal endpoints are plotted in °C against the left-hand vertical axis; for reference the equivalent °F scale is presented on the right-hand vertical axis. Also for reference and to facilitate interpretation, horizontal lines are plotted on each figure at key regulatory temperatures, 32.2°C, 33.9°C, and 35°C (90°F, 93°F, and 95°F, respectively).

2.5.2.1 Acute thermal mortality under short exposure duration (dark red line and markers)

This metric depicts the lethal response of organisms to dynamic temperature increases over a relatively short period. This response is measured by the CTM which is not necessarily an indication of final mortality, but frequently uses the loss of equilibrium as the test endpoint.

2.5.2.2 Chronic thermal mortality under prolonged exposure (light green line and markers)

This line depicts the species' mean tolerance limit; that is, the acclimation/exposure-temperature combinations at which 50 percent mortality would occur due to elevated temperatures for a prolonged exposure of more than 24 hours (typically 24 to 96 hours). Based on Coutant (1972), the temperature at which the species' chronic thermal mortality approaches zero is about 2°C (3.6°F) lower than the mean tolerance line (TL5024 to 96 hrs) shown in the thermal diagram. By extension, assuming a normal distribution, chronic thermal mortality would effectively be 100 percent at 2°C (3.6°F) higher than the TL50. This 2°C (3.6°F) range around the mean is an expression of the variable response of individuals within a population to a prolonged exposure to elevated temperatures. Chronic mortality is very conservative measure of potential thermal effects because it assumes that fish are unable to avoid potentially lethal elevated temperatures by moving to cooler temperatures along a temperature gradient, and thus could potentially succumb to elevated temperatures during a prolonged exposure.

2.5.2.3 Avoidance (dark blue line and markers)

A thermal avoidance response occurs when mobile species evade stressful high temperatures by moving to water with lower, more acceptable temperatures (Meldrim et al. 1974, Mathur et al. 1983). While the avoidance response can minimize the potential for thermal mortality associated with elevated water temperatures in portions of a thermal plume, it can also deter organisms from occupying otherwise useful or critical habitat that may occur in the vicinity of a thermal plume. The plotted avoidance data (acclimation/response temperature) and line represent the expected mean avoidance response of a population.

2.5.2.4 Thermal preference zone (orange line and markers)

The zone of thermal preference is defined by a range of laboratory acclimation/preferred

temperature response data reported for some RIS. The ideal temperature range for growth cannot be accurately characterized under controlled laboratory conditions for those species for which captive rearing methods have not been developed. The thermal preference polygon provides a surrogate to delineate the acclimation and exposure temperature combinations for which optimal growth (i.e., preferred temperatures) would be predicted (McCullough 1999). Optimal temperatures for growth are defined as the preferred temperature of fish in a thermal gradient; for "cold-blooded" organisms (ectotherms), such as fish, this is an adaptive mechanism that allows organisms to selectively utilize habitat within a waterbody where temperatures are such that they can maintain optimal physiological performance (Coutant 1977; Hutchison and Maness 1979).

The occurrence and distribution of both optimal and non-optimal water temperatures will naturally vary on a spatial, diel, and seasonal basis; the presence and configuration of the thermal plume overlays this natural variability. Maximum weekly average temperature for growth (MWAT) is a metric that attempts to account for this variability, using a 7-day running average of ambient water temperature to capture this variability and characterize the acclimation conditions of the organisms that affect growth. The RIS selected for DNS exhibit a period of zero growth between late fall and early spring when water temperatures are less than their threshold for growth. Peak summer ambient water temperatures in portions of the ecosystem and portions of the thermal plume can exceed the upper zero growth (bright red line on thermal diagram) temperature for some species. Thus, growth occurs to a greater or lesser extent over a range of temperatures and a thriving population can be maintained even when temperatures non-optimal during certain periods or in a segment of a waterbody. In the presence of a thermal plume, growth can begin earlier in the spring or continue later in the fall in some segments of the waterbody and fish have the ability to move from areas with non-optimal temperatures to areas with more optimal water temperatures. For this reason it is difficult to quantify the effect of the thermal plume on growth of individuals within a population utilizing habitat in the vicinity of the DNS thermal plume. Instead, this analysis looks at the relative amount and frequency of habitat affected by the thermal plume where water temperatures are outside of the optimum range for growth.

2.5.2.5 Thermal tolerance zone (purple line)

The thermal tolerance zone extends beyond the preference zone. It delineates the temperature regime over which each species can survive and continue to grow, but at less than optimum rates. Optimum temperatures for maximum growth do not consistently occur spatially or temporally in nature and delineation of a tolerance "zone" makes clear the fact that non-optimal temperatures are not necessarily adverse. Areas outside the polygon of the tolerance zone and below the onset of predicted chronic mortality (within the 2°C [3.6°F] range of variability below the chronic thermal mortality line discussed above), delineate the temperature regime over which a species can survive, but in which they may be stressed and experience near-zero or negative growth, that is, weight loss (Bevelhimer and Bennett 2000; Beitinger and Bennett 2000).

2.5.2.6 Thermal range for spawning (bright green line)

When adequate thermal range data have been documented, a polygon on the thermal effects figure indicates the reported temperature range for spawning based on the seasonal period during which spawning typically occurs in the vicinity of DNS. This range is typically based on field observations of natural spawning activity.

2.5.2.7 Lower lethal temperatures (teal line and markers)

Lower incipient lethal temperatures (chronic exposure) and cold shock (acute rapid exposure) measure mortality caused when organisms acclimated to warm temperatures in the thermal plume are exposed to significantly colder ambient water temperatures. This typically occurs when fish attracted to plume during the winter are exposed to cold ambient water temperatures in conjunction with a station outage. Similar to the upper chronic thermal mortality graphic the lower thermal threshold has a range of variation of ±2°C (3.6°F) and falls about 2°C (3.6°F) below the lower boundary of the tolerance zone polygon. When a station has multiple operating units, the potential for this source of mortality is mitigated in that all units are typically not taken offline and therefore organisms acclimated to the thermal plume do not experience a full decrease to ambient temperatures. Given that the focus of this Demonstration is the period of indirect once-through cooling (15 June through 30 September) lower incipient lethal temperatures and cold shock are presented for completeness but are not a significant issue for this analysis.

2.5.3 Periods of Occurrence

The temporal focus of this biothermal assessment is the period 15 June through 30 September when DNS operates in indirect once-through cooling mode. With the exception of cyprinids (e.g., emerald shiner) and freshwater drum, most of the RIS spawn prior to 15 June. Ichthyoplankton sampling during 2005-2006 collected few or no eggs of most of the RIS; most of the RIS have eggs that are demersal, adhesive, or deposited in nests in shallow areas protected by the adults and thus have limited vulnerability to the sampling gear, but also have minimal exposure to the DNS thermal plume. Freshwater drum was the only species for which eggs were collected in abundance during the 2005-2006 surveys. Their eggs are buoyant and pelagic and were collected between early May and mid-July with peak abundance between early June and early July.

During the 2005-2006 sampling program in the Kankakee River in the vicinity of the DNS cooling water intake, 85-88 percent of the ichthyoplankton drift occurred prior to 15 June, before DNS switches from closed cycle to indirect open cycle cooling (EA 2007, Figures 3-13 and 3-14). With the exception of emerald shiner and freshwater drum, peak abundance for yolk-sac larvae of most of the RIS also occurs before mid-June. Abundance of post yolk-sac larvae and early juvenile life stages of all RIS typically peaks during the period when DNS operates in indirect once-through cooling mode.

Young of the year and adults of the RIS occur throughout the summer when DNS operates in

indirect open cycle cooling mode and at which time the proposed ATLs would apply. The abundance of young of the year through adult life stages of the most common RIS (gizzard shad, emerald shiner, and bluegill) during the 2005-2006 surveys increased gradually from spring (before 15 June), through summer into fall (after 30 September). Smallmouth bass and channel catfish, in much lower abundance, exhibited the reverse trend, decreasing in numbers from spring through fall. All other RIS occurred in relatively low and variable abundance with no apparent seasonal trend. Thus, during the summer period of interest, when ambient temperatures are at maximum and river flows are typically at annual lows, the abundance of RIS fish in the vicinity of DNS is generally at an intermediate level, compared to spring and fall.

2.5.4 Species Habitats

Habitat in the area encompassed by the thermal model (approximately 544 acres), from Dresden Island Lock and Dam upstream to the lower reaches of the Des Plaines and Kankakee Rivers above their confluence, is dominated by relatively deep channel (greater than 2.5 meters) accounting for approximately 53 percent of the study area (Figure B-17). The channel area in the modeled reach of the Kankakee River is dominated by sand substrates, whereas substrates in the channels of the Des Plaines River and Illinois River is a variable mix of silt, sand, gravel, hardpan, and debris.

Between the DNS discharge and Dresden Island Lock and Dam, habitat less than 2.5 m accounts for about 15 percent of available aquatic habitat. Within the larger boundaries of the hydrothermal model and bathymetric survey, depths less than 2.5 meters account for about 47 percent of the area. Several large depositional areas, primarily located upstream of the DNS discharge, significantly increase the diversity and available shallow habitat of the reach including: upstream of the discharge along the left bank at the inside bend of the Illinois River between the DNS intake and discharge (hard bottom compact sand and silt with limited lotus beds close to shore); and the point and backwater areas between the channels of the Des Plaines and Kankakee Rivers at their confluence (submerged macrophytes and lotus beds with sand or detritus/mud over gravel and cobble). A small area along the right bank immediately upstream from Dresden Island Lock and Dam (lotus beds with detritus/mud substrate) provides limited shallow water habitat downstream of the DNS discharge. The shallow shore zone habitat throughout much of the rest of the study reach extends only a short distance from the shoreline with submerged and limited emergent vegetation generally over rocky, sand, or silt substrate. These habitat types are delineated on Figure B-17 including a summary of the areas encompassed by each habitat type.

These shallows typically have substrates comprised of silt and detritus overlaying sand, gravel, or cobble. These areas could provide spawning habitat for the four centrarchid RIS (largemouth and smallmouth bass, bluegill, and black crappie). Large woody debris provides cover in the shallow right bank embayment immediately upstream of the dam and is typical of channel catfish spawning habitat. Scattered submerged aquatic vegetation (SAV) occurs along the inside bend of the Illinois River upstream of the Dresden discharge. Lotus beds are common in the shallow and backwater habitat between the Des Plaines and Kankakee Rivers. Habitat with SAV and other floating vegetation beds (approximately 153 acres or 23 percent of the area within the

reach) could provide spawning habitat for common carp and other cyprinids (e.g., emerald shiner). Aquatic vegetation in these shallow areas can also provide cover and foraging habitat for top predator species such as smallmouth and largemouth bass.

Riffles, typically used by logperch, golden redhorse, and to some extent by white sucker as spawning habitat, do not occur within the geographic boundaries of the hydrothermal model. The closest riffle/run habitat occurs downstream below the Dresden Island Lock and Dam and in tributary habitat in Aux Sable Creek about 3 miles below the dam. Upstream of the DNS discharge, the closest riffle habitat is about 5 miles in the Kankakee River, near the I-55 bridge. Additional riffle habitat is also found in Grant Creek, a tributary to the Des Plaines River about 3 miles upstream of the DNS discharge.

3.0 RESULTS OF THE BIOTHERMAL ASSESSMENT

3.1 Thermal Plume Assessment Scenarios

3.1.1 Typical river conditions

The typical condition assessment scenario used median monthly flows in the upper Illinois River (combined flows from the Des Plaines and Kankakee Rivers) that ranged from 9,720 cfs in June to 5,366 cfs in September (Table B-5). The associated typical ambient Illinois River temperatures (60 percentile flow-weighted for the Des Plaines and Kankakee Rivers) ranged from about 25°C (77°F) in June and September to 27.6°C (81.7°F) in August. The median DNS discharge temperatures ranged from 29.8°C (85.7°F) in June to 30.8°C (87.4°F) in July, and 28.6°C (83.5°F) in September (Table B-5).

The cross-sectional and bottom areas affected by the DNS thermal plume are used to assess the potential effects of the plume on aquatic habitat and RIS populations in the vicinity of the DNS discharge. The hydrothermal model was used to estimate the percent of the cross-sectional area at fixed transects below specified water temperatures for each of the four months evaluated (Table B-7 to B-10) and percent of the bottom area upstream and downstream of the DNS discharge below specified water temperatures (Table B-11). The area encompassed by selected temperatures was compared to the biothermal metrics for each of the RIS, and presented in Sections 3.2 to 3.7, below. Zone of passage (ZOP) was evaluated against a 75% benchmark to determine if temperatures in at least 75 percent of the plume cross section are less than the avoidance temperature for an RIS.

Under the typical condition scenario, river flows and temperatures and DNS discharge temperatures are most constraining during July and August. At the upstream transect, in July the Kankakee River (KP-1800) ranged from 24.1°C to 24.5°C (75.4°F to 76.1°F), while water temperatures in the Des Plaines ((DP-1700) were 6-7°F higher (Table B-8). At a median DNS discharge temperature of 30.8°C (87.4°F) in July (Table B-5), temperatures immediately downstream of the discharge (IL125) ranged from 27.6°C to 30.3°C (81.7°F to 86.6°F); temperatures in 75 percent of the cross-section were less than 29.0°C (84.2°F) (Table B-8). Moving downstream to the Dresden Island Lock and Dam, in July the range of cross-section

(IL1000) temperatures narrowed (28.5°C to 28.9°C [83.3°F to 84°F]) with mixing and dilution. Predicted water temperatures near the bottom upstream of the DNS discharge are 24.1-28.2°C (75.4-82.8°F) and 27.1-30.8°C (80.8-87.4°F) downstream of the discharge in July (Table B-11). Water temperatures in 75 percent of bottom habitat upstream of the DNS discharge are less than 27.9°C (82.3°F), and downstream of the discharge are less than 28.7°C (83.7°F) (Table B-11). Water temperatures in bottom habitat upstream of the DNS discharge are about 2.2-2.8°C (4-5°F) lower than downstream.

During August, the median DNS discharge temperature is about 0.3°C (0.5°F) lower than July, but temperatures at the upstream Des Plaines and Kankakee Rivers transects are about 1.7°C (3°F) higher than in July (Table B-9); combined flow from the Des Plaines and Kankakee Rivers is about 900 cfs lower (15 percent) than in July. During typical August conditions, the highest temperature immediately downstream of the DNS discharge (transect IL125) is predicted to be 0.1°C (0.2°F) lower than in July, but the coolest temperatures in the transect are 0.4°C (0.8°F) higher than in July. Water temperatures at transect IL125 are less than 29.2°C (84.5°F) in 75 percent of the cross-section. Downstream near Dresden Island Lock and Dam (IL1000), water temperatures are about 0.3-0.4°F higher than in July, and 75 percent of the cross-section is predicted to be below 29.0°C (84.2°F) (Table B-9), with a maximum temperature of 29.1°C (84.3°F). Predicted water temperatures near the bottom upstream of the DNS discharge are 24.8-28.3°C (76.7-83.0°F) and 28.0-30.6°C (82.4-87.0°F) downstream of the discharge in August (Table B-11). Water temperatures in 75 percent of bottom habitat upstream of the DNS discharge are less than 28.1°C (82.5°F) and downstream of the discharge are less than 28.9°C (84.1°F) (Table B-11). Water temperatures in bottom habitat upstream of the DNS discharge are about 2.2-2.8°C (4-5.5°F) lower than downstream.

3.1.2 Typical high temperature conditions

The typical high temperature condition assessment scenario used 5 percentile monthly flows in the upper Illinois River (combined flows from the Des Plaines and Kankakee Rivers) that ranged from 4,134 cfs in June to 3,032 cfs in September (Table B-5). These flows are 42-56 percent of those used for the typical condition scenario (Section 2.3.1.1). The associated typical ambient Illinois River temperatures (95 percentile flow-weighted for the Des Plaines and Kankakee Rivers) ranged from about 27.2°C (81°F) in June to 31.1°C (88°F) in July and 28.3°C (83°F) in September. The 95 percentile DNS discharge temperatures ranged from 31.8°C (89.2°F) in June to 33.2°C (91.8°F) in July and 31.6°C (88.8°F) in September (Table B-5).

Under the typical high temperature scenario, river flows and temperatures and DNS discharge temperatures are most constraining during July and August. At the upstream transect, in July the Kankakee River (KP-1800) ranged from 29.4°C to 30.9°C (84.9°F to 87.6°F), while water temperatures in the Des Plaines ((DP-1700) were 31.3-31.4°C (88.3-88.5°F) (Table B-8). At a 95 percentile, DNS discharge temperature of 33.2°C (91.8°F) in July (Table B-5), the temperatures immediately downstream of the discharge (IL125) ranged from 31.9 to 32.9°C (89.5°F to 91.3°F); temperatures in 75 percent of the cross-section were less than 32.7°C (90.9°F) (Table B-8). Moving downstream to the Dresden Island Lock and Dam, in July the range of cross-section (IL1000) temperatures narrowed (32.5°C to 32.6°C [90.5°F to 90.6°F])

with mixing and dilution. Predicted typical high temperature condition water temperatures near the bottom upstream of the DNS discharge are 29.4-32.0°C (84.9-89.6°F) and 31.0-33.2°C (87.8-91.8°F) downstream of the discharge in July (Table B-11). Water temperatures in 75 percent of bottom habitat upstream of the DNS discharge are less than 31.4°C (88.5°F) and downstream of the discharge are less than 32.6°C (90.6°F) (Table B-11). Water temperatures in bottom habitat upstream of the DNS discharge are about 1.1-1.7°C (2-3°F) lower than downstream.

During August, the 95 percentile DNS discharge temperature is about 0.6°C (1°F) lower than July, but temperatures at the upstream Des Plaines and Kankakee river transects are about 1.1°C (2°F) and 2.5°C (4.5°F) lower, respectively, than in July (Table B-9); combined flow from the Des Plaines and Kankakee rivers in August are about the same as in July. During typical high temperature conditions in August, the highest temperature immediately downstream of the DNS discharge (IL125) is predicted to be 0.7°C (1.3°F) lower than in July, and the coolest temperatures in the transect are 0.6°C (1°F) lower than in July. Water temperatures at transect IL125 are less than 31.9°C (89.5°F in 75 percent of the cross-section, about 0.8°C (1.5°F) less than July. Downstream, near Dresden Island Lock and Dam (IL1000), water temperatures are about 0.8°C (1.5°F) lower than in July and 75 percent of the cross-section is predicted to be below 31.7°C (89°F), with a maximum temperature of 31.7°C (89.1°F) (Table B-9). Predicted high temperature scenario water temperatures near the bottom upstream of the DNS discharge are 26.8-31.0°C (80.3-87.8°F) and 29.1-32.6°C (84.3-90.7°F) downstream of the discharge in August (Table B-11). Water temperatures in 75 percent of bottom habitat upstream of the DNS discharge are less than 30.2°C (86.4°F) and downstream of the discharge are less than 31.7°C (89.0°F) (Table B-11). Water temperatures in bottom habitat upstream of the DNS discharge are about 1.7-2.2°C (3-4°F) lower than downstream.

3.1.3 Extreme high temperature conditions

Typical high temperature scenario conditions can occur about 5 percent of the time; under these conditions DNS discharge temperature approaches 33.3°C (92°F) only during July and does not exceed 32.8°C (91°F) in August or 32.2°C (90°F) in June. Consequently, to evaluate the potential effects of the proposed ATLs on the RIS, the extreme high temperature conditions that occurred during July 2012, that were similar to the temperatures that could be experienced under the proposed ATLs, were evaluated.

During these extreme temperature and river flow events, intake temperatures increase rapidly, due to upstream intrusion of more buoyant (i.e., warmer) water from the Des Plaines River over the less buoyant (i.e., cooler) water from the Kankakee. Temperatures typically moderate downstream of the confluence, upstream of the DNS discharge where the Des Plaines and Kankakee Rivers mix. To evaluate thermal plume characteristics under infrequent, more extreme meteorological conditions, the hydrothermal model was used to assess unusual conditions of high air temperatures and low flow that occurred during July 2012.

During early July 2012, maximum daily air temperatures steadily increased from about 30°C (86°F) on 1 July to 37.8°C (100°F) on 7 July (Figure B-4); overnight temperatures were in the low to high 70s°F and also increased during this period. The heat wave broke the evening of 7-8

July and DNS intake and discharge temperatures responded relatively quickly, decreasing by about 3.1°C (5.5°F) over the next 36 hours. Maximum daily intake temperatures during 6-8 July 2012 were in the upper 3 percent of the period of record (2003-2014) (Table B-6); the maximum recorded intake water during this 3-day period was 34.4°C (93.9°F) which occurred at about 1500 hours, the afternoon of 7 July 2012. DNS cooling water intake temperatures were above 33.9°C (93°F) for about 9 hours between 1100 and 2000 hours on 7 July (Figure B-18). The DNS discharge temperature peaked a few hours later at about 34.9°C (94.9°F); the discharge temperature exceeded 34.4°C (94°F) for about 3 hours and exceeded 33.9°C (93°F) for about 11 hours. Night-time low water temperatures were in the upper 4-5 percent of the record. The diurnal cycle of air temperature and its effect on intake temperature and DNS discharge temperature is apparent in Figure B-4. The combined flow from the Des Plaines and Kankakee Rivers during this period ranged from slightly below to slightly above the 7Q10 (2456 cfs) calculated from the upstream USGS gages (Appendix D) scaled to the confluence of the two rivers.

Under the proposed ATLs, the plant's discharge could exceed 93°F (up to 95°F) for up to 24 hours when intake temperatures exceed 90°F (32.2°C). Using the July 2012 extreme heat event, modeled mixed ambient water temperatures at surface, middle, and bottom depths upstream of the DNS discharge (transect IL-200) peaked above the 90°F (32.2°C) threshold at 33.3°C (92°F) for 1-4 hours on 7 July (Figure B-18). The duration that ambient water temperatures were above 32.8°C (91°F) increased with depth (Figure B-18) as cooling of surface waters was enhanced by overnight cooling of water over the large shallow habitat (Figure B-17) in the immediate vicinity of transect IL-200 upstream of the DNS discharge. Downstream of the DNS discharge (transect IL475), modeled water temperatures at surface, middle and bottom depths exceeded 33.3°C (92°F) on 6 July for about 15 hours, declining below 33.3°C (92°F) for about three hours near dawn on 7 July, then increasing again to the peak for the 3-day period on the afternoon of 7 July. Temperatures at this transect exceeded 33.9°C (93°F) for approximately 6 hours on 7 July (Figure B-19). Temperatures at all depths were below 32.8°C (91°F) by 0300 on 8 July. Temperatures at this transect again exceeded 32.8°C (91°F) briefly on the afternoons of 17, 18, and 19 July (Figure B-20); temperatures upstream of DNS discharge did not exceed 32.5°C (90.5°F) on these three dates and bottom temperatures remained below 90°F (Figure B-21). Temperatures for the remainder of July and August were typically below 31.1°C (88°F) upstream at transect IL-200 and below 31.7°C (89°F) downstream at transect IL475.

3.2 Potential for Thermal Mortality at Elevated Temperatures

Acute and chronic thermal mortality data are known for the following RIS:

Species	Acute	Chronic
Gizzard shad		x
Emerald shiner	x	x
Common carp	x	x
Golden redhorse	x	
White sucker	x	x
Channel catfish	x	x
Largemouth bass	x	x
Smallmouth bass	x	
Bluegill	x	x
Black crappie	x	x
Logperch	x	
Freshwater drum	x	

Acute mortality data represent effects of short term (minutes to hours) exposure to high temperatures, while chronic mortality data are the result of longer exposures (48-96 hours) to elevated temperatures. Acute data are shown as dark red lines and markers at top of Figures B-5 to B-16 and chronic data are shown as light green lines and markers several °F below the acute data on Figures B-5 to B-16. At ambient/acclimation temperatures above 29.4°C (85°F), acute mortality is not predicted for the RIS until temperatures in the thermal plume exceed 35-37.2°C (95-99°F), which is well above temperatures predicted under the three scenarios evaluated in this assessment.

Based on these data (Figures B-5 to B-16), no acute or chronic mortality is predicted for any of the RIS under the typical conditions scenario. For this scenario, upstream ambient temperatures are below 28.3°C (83°F) and DNS discharge temperatures are below 31.1°C (88°F) (Tables B-7 to B-9) during July and throughout the indirect open cycle period from June through September. At this acclimation temperature, chronic mortality is typically not observed for most of the RIS until exposure temperatures exceed 32.2°C (90°F (Figures B-5 to B-16), 1.7°C (3°F) higher than the highest discharge temperatures under this scenario.

Under the typical high temperature scenario, upstream ambient temperature (95 percentile) near the DNS discharge is 31.1°C (88°F) in July and less than 30°C (86°F) the remainder of the indirect open cycle period. Discharge temperatures (95 percentile) are 32.6°C (90.7°F) in June and 33.2°C (91.8°F) in July. Chronic mortality data indicate that white sucker is the most thermally sensitive of the RIS selected for this analysis; at an acclimation temperature of 31.1°C (88°F) the predicted threshold for chronic thermal mortality is about 32.2°C (90°F). Because fish may be acclimated to temperatures higher than the upstream ambient, if they reside in portions of the plume, the assumption that ambient is representative of acclimation temperatures is conservative and could predict higher potential for thermal mortality than would actually be observed in the DNS thermal plume. It should also be noted, that although white sucker have been included as an RIS due to their thermal sensitivity, it occurs incidentally in the vicinity of DNS and has only been collected during three of the past 20 sampling years.

During July, the typical high temperature scenario with a DNS discharge temperature of 33.2°C (91.8°F), the Illinois River between the DNS discharge and Dresden Island Lock and Dam becomes relatively well mixed with temperatures at each of the modeled transects generally between 32.2°C (90°F) and 32.8°C (91°F) (Tables B-8 and B-11). Although temperatures in this range could create stressful conditions for white sucker under an extended period of exposure (e.g., 48-96 hour typical thermal mortality test durations), the exposure conditions in the DNS thermal plume are unlikely to result in any thermal mortality due to several mitigating factors. As discussed previously, DNS intake and discharge temperatures vary diurnally in response to daily cycles in air temperature (Figure B-4). Consequently, aquatic organisms are not exposed to constant elevated temperatures, but experience thermal reductions each evening as air temperatures decline. In addition, under various thermal mortality test protocols, the test organisms are exposed in a test chamber with well mixed and constant temperature, whereas, in natural riverine habitat, a range of temperatures are often available and organisms are capable of avoiding stressful temperatures (Section 3.3). Although the thermal model predicts that much of the area between the DNS discharge and the Dresden Island Lock and Dam is well mixed at 32.2-32.7°C (90-91°F), the majority of aquatic habitat immediately upstream of the DNS discharge is predicted to be less than 31.7°C (89°F) during July under the typical high temperature scenario (Tables B-8 and B-11). The majority of aquatic habitat downstream of the DNS discharge consists of deeper channel which is also abundant upstream (Figure B-17); other shallow water habitat found downstream is significantly more abundant upstream of the DNS discharge for temporary utilization by organisms potentially displaced for brief periods by elevated thermal plume temperatures.

The heat wave that occurred July 2012 provides extremely unusual natural thermal conditions to evaluate potential effects of the DNS thermal plume on aquatic resources in the area of the upper Illinois River. During these extreme temperature conditions, intake temperatures exceeded 32.2°C (90°F) for 3 days from the afternoon of 5 July to the evening of 8 July with a peak of 34.4°C (93.9°F). DNS discharge temperatures exceeded 32.2°C (90°F) intermittently from 2 July to 8 July. Discharge temperatures were above 33.9°C (93°F) for about 6 hours on the evening of 5 July and about 11 hours during the day on 7 July with a maximum of 34.6°C (94.3°F) (Table B-6; Figures B-4 and B-19). Between 1200 and 1600 on 7 July the percent of the cross-sectional area downstream of the DNS discharge in excess of 33.9°C (93°F) (yellow shaded cells in Table B-12) increased from less than 5 percent at the transect 125 m (IL125) downstream to greater than 95 percent 475 m downstream. During this same period upstream transects in the Des Plaines and Kankakee Rivers had ambient temperatures above 33.9°C (93°F) in 75 percent of the cross-sectional area. Between 1800 and 2000 on 7 July discharge temperatures began to decrease and the area with temperatures above 93°F began to contract, cool immediately downstream of the DNS discharge, and shift farther downstream toward Dresden Island Lock and Dam (Table B-12). Although the area influenced by 33.9°C (93°F) temperatures began to decrease downstream of DNS during this period, the area with ambient temperatures above 33.9°C (93°F) increased upstream in the Des Plaines and Kankakee Rivers as a result of atmospheric conditions. By 2200, 7 July, water temperatures throughout the reach were below 33.9°C (93°F).

Most RIS for which chronic temperature tolerance data are available are able to tolerate water temperatures above 35°C (95°F) for extended periods of time (48-96 hours) at acclimation temperatures above 29.4°C (85°F), with the exception of white sucker. For white sucker, the upper thermal tolerance limit for chronic exposure for juveniles appears to be about 35°C (93°F) at an acclimation of 32.2°C (90°F); the highest thermal tolerance chronic exposure for adults is 32.5°C (90.5°F) at an acclimation temperature of 26°C (78.8°F). However, under the extreme conditions observed during early July 2012, the maximum exposure duration was approximately 11 hours, considerably less than the exposure durations for the test data. During this period, ambient water temperatures beyond the influence of the DNS thermal plume that are predicted to have been less than 32.5°C (90.5°F) were available in 10-25 percent of the habitat upstream of the DNS discharge to allow white sucker the opportunity to avoid habitat with warmer temperatures downstream.

Although under extreme conditions, temperatures exist within the DNS thermal plume with the potential to cause mortality under extended chronic exposure, these conditions are rare and of relatively short duration. Refuge for fish avoiding these high water temperatures is available in extensive habitat upstream of the DNS discharge. Consequently, temperatures in the plume, even under extreme meteorological condition, are unlikely to result in any significant mortality. In fact, during the 2012 July heat event no fish kills were observed in the vicinity of the DNS and the Dresden Island Lock and Dam. While white sucker may be relatively more sensitive than the other RIS to elevated water temperatures in the DNS thermal plume during extreme conditions, the species occurs only incidentally in the Des Plaines, Kankakee, and upper Illinois Rivers in the vicinity of DNS.

3.3 Thermal Avoidance and Habitat Loss

As discussed in the previous section, except in unusual circumstances, mortality of fish as a result of exposure to high water temperatures is rare because many species have demonstrated the ability to sense and avoid stressful elevated temperatures when areas with cooler temperatures are available. Even in the event of the extreme heat event of July 2012, substantial channel and shallow water habitat is available upstream of the DNS discharge with cooler water temperatures for fish that may avoid portions of the thermal plume. While the ability to avoid stressful water temperatures minimizes the potential for fish mortality, it could result in avoidance of important habitat areas that may be affected by portions of the thermal plume.

Avoidance data were identified and reviewed for gizzard shad, channel catfish, largemouth bass, smallmouth bass, and bluegill; these data are plotted in dark blue in Figures B-6 and B-10 to B-13. As would be expected these avoidance data plot a few degrees below the chronic mortality data on these figures.

Avoidance temperature test data (Table B-13; Figures B-6, B-10, B-11, and B-13) indicate that at ambient/acclimation temperatures (30.6-33.3°C [87-92°F]) representative of the three assessment scenarios (Table B-5 and B-6), gizzard shad, channel catfish, largemouth bass, smallmouth bass, and bluegill would not avoid any portions of the plume under typical, typical warm, and extreme warm conditions. For each of these RIS the temperatures avoided are

typically several degrees higher than the highest plume cross-section (Tables B-8 and B-12) and bottom (Table B-11) temperature estimated for each assessment scenarios. These avoidance temperatures are also typically several degrees below the chronic mortality temperatures.

RIS for which avoidance data were not available generally exhibited acute and/or chronic mortality metrics within a similar range to the five RIS with avoidance information discussed above. For species where avoidance has been documented, fish typically avoid temperatures slightly below the threshold of chronic mortality. Thus, it is likely that the RIS for which avoidance data are not available exhibit a similar pattern of avoidance and would not be expected to avoid significant areas of habitat in the vicinity of the DNS thermal plume. This assessment supports the finding that the DNS thermal plume would not be expected to cause avoidance of aquatic habitat for any of these species, even at very low river flow conditions (1-4 percentile), high air temperatures (37.8°C [100°F]), and high DNS discharge temperatures (34.79°C [4.5°F]) (1-3 percentile).

3.4 Potential for Blockage of Migration

Given that this assessment indicates that the RIS and the aquatic community that they represent are not likely to avoid significant areas of habitat in the vicinity of the DNS thermal plume, it is unlikely that the thermal plume would interfere with the migration and localized movement patterns (e.g., diel and seasonal onshore/offshore, upstream/downstream, or spawning) of the fish community in the upper Illinois River. As discussed in Sections 3.2 and 3.3, more than 75 percent of the cross-section at selected transects within the DNS thermal plume and more than 75 percent of the channel bottom habitat is predicted to have water temperatures below the chronic mortality and avoidance temperatures of most of the RIS under a likely range of station operating, hydrologic, and meteorological conditions to be encountered in the upper Illinois River in the vicinity of DNS.

Reported thermal mortality metrics indicate that white sucker would be the most sensitive of the RIS to elevated plume temperatures, particularly under rare, extreme high temperature conditions such as occurred during July 2012. Although it is likely that white sucker might avoid significant areas of the DNS thermal plume during such extreme conditions, moving to more moderate upstream habitat, the duration that avoided temperatures persist is short, less than 24 hours. Such short durations when white sucker might avoid portions of the DNS thermal plume are unlikely to have any extended effect on habitat utilization by this species which, in any event, has been only an incidental component of the aquatic community over the historical operation of DNS (Appendixes A, C, F, and G).

3.5 Temperature during Critical Reproductive Seasons

Most spawning by the RIS in the vicinity of DNS appears to occur prior to 15 June during the period of closed cycle cooling operation and is, therefore, not affected by indirect open cycle cooling operation that is the subject of this assessment. It should be noted that the reported range of spawning temperatures for a given species is typically based on the observation of spawning across the geographic range of the species and may not be indicative of conditions at a given site. Gizzard shad, white sucker, golden redhorse, black crappie, and logperch typically finish

spawning prior to mid-June and the start of indirect open cycle cooling operation at DNS and would, therefore, not be affected.

Emerald shiner, common carp, smallmouth bass, largemouth bass, and freshwater drum typically spawn during May and June and could, therefore, be affected by indirect open cycle cooling operation of DNS during the final quarter of the spawning season. The reported (Wisconsin 2007) upper range of spawning temperatures for emerald shiner is about 27.2°C (81°F); water temperature exceeds 27.2°C (81°F) in less than 10 percent of the cross-section of the Illinois River for a distance of about 475 m downstream of the DNS discharge under the typical condition scenario in June. Under the typical high temperature scenario, ambient temperatures are predicted to exceed 27.8°C (82°F) in the Illinois and Des Plaines River upstream of DNS discharge in June. Thus, it is likely that emerald shiner spawning would end as a result of rising ambient temperatures during typical and extremely warm years prior to initiation of indirect open cycle cooling at DNS.

The reported (Wismer and Christie 1987) upper range of spawning temperatures for common carp is about 27.8°C (82°F); water temperature rarely exceeds 82°F in any portion of the cross-section of the Illinois River downstream of the DNS discharge under the typical condition scenario in June. Under the typical high temperature scenario, ambient temperatures are predicted to exceed 27.8°C (82°F) in the Illinois and Des Plaines Rivers upstream of DNS discharge in June as well as most of the Illinois River cross-section downstream of the DNS discharge. Thus, it is likely that common carp spawning would end as a result of rising ambient temperatures during typical and extremely warm years prior to initiation of indirect open cycle cooling at DNS.

The reported (Wisconsin 2007) upper range of spawning temperatures for largemouth bass and smallmouth bass is about 22.8°C (73°F). Under the typical and typical high temperature scenarios ambient temperatures are predicted to exceed 24.4°C (76°F) in the Illinois and Des Plaines River upstream of DNS discharge in June; even in the cooler Kankakee River, ambient temperatures are predicted to exceed 23.3°C (74°F) (Table B-7). Thus, it is likely that largemouth bass and smallmouth bass spawning would end as a result of rising ambient temperatures during typical years, prior to initiation of indirect open cycle cooling at DNS. Since smallmouth bass and largemouth bass spawn in shallow weed free habitat which would tend to warm faster, it is likely that bass spawning ends before June in the Illinois River. In addition preferred spawning habitat is considerably more common upstream of the DNS discharge (Figure B-17).

The reported (Small and Bates 2001) upper range of spawning temperatures for freshwater drum is about 28.9°C (84°F). Under the typical temperature scenario, ambient temperatures are not predicted to exceed 28.9°C (84°F) in the Illinois, Des Plaines, and Kankakee Rivers upstream of DNS discharge or in any portion of the DNS thermal plume in June (Table B-7). Under the typical high temperature scenario, water temperatures above 28.9°C (84°F) occupy more than 90 percent of the cross-section of the Illinois River downstream of the DNS discharge. Thus, it is likely that freshwater drum spawning would not occur downstream of the DNS discharge during the latter half of June under typical high temperature conditions, but would continue to spawn

into the end of June upstream of DNS. Open water spawning habitat utilized by freshwater drum is abundant upstream in the Illinois, Des Plaines, and Kankakee Rivers (Figure B-17).

The only RIS likely to spawn after June are channel catfish and bluegill, which may continue to spawn into July or August in some parts of their range. The reported (Wismer and Christie 1987) upper range of spawning temperatures for channel catfish and bluegill is about 28.9-29.4°C (84-85°F). Under the typical temperature scenario, ambient temperatures are not predicted to exceed 28.9-29.4°C (84-85°F) in the Illinois, Des Plaines, and Kankakee Rivers upstream of DNS discharge or in most of the DNS thermal plume in June-August (Tables B-7 through B-9). Under the typical high temperature scenario, water temperatures above 28.9°C (84°F) occupy more than 90 percent of the cross-section of the Illinois River downstream of the DNS discharge during June-August. Thus, it is likely that channel catfish and bluegill spawning would not occur downstream of the DNS discharge later than mid-June under typical or extreme high temperature conditions, but would continue to spawn into the end of June upstream of DNS. Ambient temperatures in the Illinois and Des Plaines Rivers upstream of DNS are generally 86-31.7°C (89°F) during July and August (Tables B-8 and B-9), well above the reported upper spawning temperature. Thus, it is unlikely that channel catfish and bluegill continue to spawn past the end of June in the vicinity of DNS during typical high temperature years.

Ichthyoplankton drift sampling in the Kankakee River in the vicinity of the DNS cooling water intake during 2005-2006 (EA 2007) indicate that 85-88 percent of the annual production of early life stages of fish in the vicinity of DNS occur prior to 15 June. This is consistent with the findings above, that most spawning by RIS and the species they represent occurs prior to initiation of indirect open cycle cooling at DNS on 15 June.

For ichthyoplankton that do occur into late June and July mortality is not predicted based on available thermal tolerance data. Early life stages frequently have higher thermal tolerance than adults. Eggs and larvae of several RIS (common carp, channel catfish, and bluegill) acclimated to temperatures of 10-33°C (50-91.4°F) tolerate acute exposure to temperatures of 31-41°C (87.8-105.8°F) and chronic exposure up to 38.8°C (101.8°F) (Wismer and Christie 1987; Beitenger et al. 2000). These temperatures are considerably higher than those predicted in the vicinity of the DNS thermal plume even under the modeled extreme high temperature scenario.

3.6 Critical Temperatures for Growth

Reported optimum thermal conditions for growth are generally difficult to interpret and are frequently qualitative or anecdotal. The rate of growth is variable and is affected in individuals and populations by a number of factors including water temperature, food availability, habitat availability, physico-chemical conditions, and population density, among others. Because the methods and resources to hold and test adult and larger fish species are limited, quantitative data on growth is frequently limited to early life stages or species that are reared in hatcheries as part of commercial or recreational fisheries management programs. Laboratory results where constant temperatures and food rations can be regulated provide quantifiable results, but are difficult to interpret in the context of variability that occurs in the natural environment and habitat of these species. It is often reported that the range of temperatures preferred by a species

is representative of the temperature range promoting optimum growth. As a result the range of optimum growth reported for many of the RIS can appear to be artificially constrained given the seasonal range of temperatures over which growth occurs.

The RIS all exhibit a seasonal growth pattern typical of temperate zone fishes with zero growth over winter beginning when temperatures decline below some critical temperature in the fall. Growth resumes in the spring as temperatures rise above that critical temperature and peak during the summer. If peak temperatures rise above a critical level, growth may decline or cease for a period during the summer. Between reported upper temperature for optimum growth and upper zero growth temperature, growth continues, but at a slower rate. While elevated temperatures in portions of a thermal plume may inhibit growth during peak summer periods, they may also stimulate growth earlier and later in the year than typically observed without the artificial source of heat in the water body.

The reported upper zero growth temperatures for gizzard shad, emerald shiner, common carp, channel catfish, largemouth bass, and smallmouth bass exceed 33.9°C (93°F) (Table B-14). It is unlikely that temperatures in the DNS thermal plume, even under the extreme conditions of July 2012, would adversely affect growth or cause a cessation of growth for these RIS.

The upper zero growth temperature for bluegill and freshwater drum is about 32.8°C (91°F) (Table B-14). During conditions reflected by the typical high temperature scenario, July temperatures in much of the thermal plume between the DNS discharge and the Dresden Island Lock and Dam are in the range of 32.2-32.8°C (90-91°F) (Table B-8), approaching the zero growth temperature. However, temperatures immediately upstream of DNS are within the optimum range for these two species. Under the extreme high temperatures scenario of July 2012, upstream ambient temperatures as well as DNS thermal plume temperatures (Table B-12) are above the zero growth temperatures for these two species. During the period 6-8 July 2012, it is possible that growth of bluegill and freshwater drum diminished to zero, but would have resumed as ambient and DNS discharge and plume temperatures cooled below 32.8°C (91°F) on 8 July (Figures B-20 and B-21).

Black crappie and white sucker have been included as RIS because they are expected to be more sensitive to high temperatures. These two species have the lowest reported zero growth temperatures of the RIS, 30.5°C and 29.6°C (86.9°F and 85.3°F, respectively). Under the typical scenario, ambient and plume temperatures are below the zero growth temperature throughout the summer for both species. For the typical high temperature scenario during June ambient temperatures and at least 90 percent of the DNS plume are below the zero growth temperature for black crappie (30.5°C [86.9°F], Tables B-7 and B-14).

During July, ambient temperatures in the upstream Illinois River, Des Plaines River, and throughout the DNS thermal plume (Table B-8) exceed the zero growth temperature for black crappie. During August, ambient temperatures in the upstream Illinois and Des Plaines Rivers approach or exceed the zero growth temperature for black crappie (Table B-9); temperatures throughout the DNS thermal plume also exceed the zero growth temperature. In September, under the typical high temperature scenario, upstream ambient temperatures are below the black

crappie upper zero growth temperature, but higher than the upper temperature range for optimum growth except in a portion of the Kankakee River (Table B-10). At least 90 percent of the DNS thermal plume exceeds the black crappie upper zero growth temperature by 0.1-0.6°C (0.2-1.1°F). During the extreme high temperature scenario of July 2012, the entire modeled reach, including ambient temperatures in upstream areas, exceeded the black crappie zero growth temperature by 2.2-3.3°C (4-6°F) (Table B-12).

White sucker occur incidentally within the Des Plaines, Kankakee, and upper Illinois Rivers. During July and August under the typical conditions scenario, ambient temperatures in the Des Plaines and upper Illinois Rivers exceed the upper range for optimum growth of white sucker. During July-September under the typical high temperature scenario, ambient temperatures in the Des Plaines and upper Illinois Rivers exceed 27°C (80.6°F), the upper range of temperatures for optimum growth of white sucker (Tables B-8, B-9, and B-14). During these periods under both typical and typical high temperature scenarios, ambient temperatures in the Kankakee River remain within the range for optimum growth of white sucker. During July and August under the typical high temperature scenario ambient temperatures in much of the upstream area exceed the white sucker zero growth temperature (29.6°C [85.3°F]; Tables B-8 and B-9). During July-September the entire DNS thermal plume and during June about 50 percent of the plume exceed the white sucker zero growth temperature (Tables B-7 to B-11). During the extreme high temperature scenario of July 2012 the entire modeled reach, including ambient temperatures in upstream areas, exceeded the white sucker zero growth temperature by 3.3-4.4°C (6-8°F) (Table B-12).

This analysis indicates that for most of the RIS and the community they represent, temperatures in the DNS thermal plume are not expected to adversely affect normal patterns of growth. For white sucker (which occurs only incidentally in the upper Illinois, Des Plaines, and Kankakee Rivers) and black crappie under typical high temperature and extreme high temperature conditions, even ambient temperatures during July and August can exceed the upper temperature for optimum growth and the zero growth temperature.

3.7 Potential for Cold Shock Mortality

Cold shock can occur when fish are quickly exposed to much lower temperatures than those to which they are acclimated such as when fish attracted and acclimated to a thermal plume during winter are returned to much colder ambient temperatures in the event of a station shutdown. DNS operates using closed cycle between October and mid-June; the risk of cold shock is minimal because the winter thermal plume is relatively small with less differential over ambient temperatures. Although for completeness, cold chock data are presented when available for each of the RIS (Figures B-5 to B-6), the proposed ATLs do not affect the period during cooler ambient temperatures between 1 October and 14 June, when DNS operates in closed cycle cooling mode.

4.0 CONCLUSIONS OF BIOTHERMAL ASSESSMENT

This biothermal assessment has been prepared to support Exelon's request for renewal and revision of the alternative thermal standards in the DNS NPDES Permit. During the period 15 June-30 September, when water temperatures at the DNS intake exceed 90°F, Exelon has requested that the temperatures at the DNS discharge be allowed to exceed 33.9°C (93°F) up to a maximum excursion of 35°C (95°F), for a duration not to exceed 24 hours per episode and for a total of no more than 10 percent of the hours available during this time period - 259 hours. This predictive assessment used the MIKE3 model to characterize and predict hydrothermal conditions in the lower Des Plaines and Kankakee Rivers and the Illinois River from their confluence downstream to the Dresden Island Lock and Dam located approximately 1,000 meters downstream of the DNS discharge (Sections 1.3 through 1.6). The MIKE 3-predicted thermal plume dimensions and distribution in the Illinois River were compared to available biothermal metric data (Section 2.1.4) related to survival, avoidance, spawning, and growth of fish. This assessment evaluated the predicted effects of DNS thermal plume temperatures (Section 2.3) on the aquatic community represented by 12 selected RIS (Section 2.1.5) under 3 scenarios (Section 2.3.1) of river flow and ambient water temperature conditions (Tables B-5 and B-6):

1. Typical Scenario—50th percentile river flow and 60th percentile ambient river temperature;

2. Typical High Temperature Scenario—5th percentile river flow and 95th percentile ambient river temperature; and

3. Extreme High Temperature Scenario—equivalent to the proposed ATLs. Based on modeled conditions for the unusual heat wave event of July 2012 when intake temperatures exceeded 32.2°C (90°F), the 97th or higher percentile for ambient temperature. Flows were in the lower 1-4th percentile for the Des Plaines River and 15-20th percentile for the Kankakee River.

Ambient temperatures did not exceed 32.2°C (90°F), the proposed ATLs' threshold, under either the Typical or Typical High Temperature scenarios. DNS discharge temperatures did not exceed 88°F under the Typical Scenario or 33.3°C (92°F) under the Typical High Temperature Scenario. Thus, both scenarios did not exceed the 33.9°C (93°F) maximum discharge temperature excursion allowed under the existing permit.

The Extreme High Temperature Scenario, based on the July 2012 event, provides a good match for analysis of the proposed ATLs. Under this assessment scenario, intake temperatures upstream of the DNS cooling water discharge reached 34.4°C (93.9°F) and the maximum discharge temperature reached 34.9°C (94.9°F), the approximate maximum excursion temperature requested by Exelon. Conditions similar to those modeled for the July 2012 Extreme High Temperature Scenario are unusual occurrences; during the July 2012 event modeled for scenario 3, ILEPA issued a provisional variance for continued DNS operations. The worst case conditions during this extreme event extended from 6 to 8 July 2012 with peak

temperatures in portions of the DNS thermal plume of 33.9-34.4°C (93-94°F) for a continuous period of about 12 hours on 7 July and in more than 50 percent of the plume for 6-8 hours.

The following findings are drawn from the biothermal assessment developed in Section 3:

1. **Potential for Thermal Mortality**—although under extreme conditions, temperatures exist within the DNS thermal plume that have the potential to cause mortality under extended chronic exposure, these conditions are rare and of relatively short duration. Refuge for Fish have the ability to avoid these high water temperatures and extensive and diverse aquatic habitat is available upstream of the DNS discharge. Most of the aquatic habitat affected by the DNS thermal plume is open deep channel habitat; significant channel habitat is available upstream of the DNS thermal plume. There is little shallow water habitat available downstream of the DNS thermal discharge and is typically limited to a narrow margin near the shoreline; extensive shallow water habitat is available immediately upstream of the DNS discharge. Consequently, temperatures in the plume, even under extreme meteorological conditions, are unlikely to result in any significant mortality. During the 2012 July heat event (the Extreme High Temperature Scenario) no fish kills were observed during monitoring in the vicinity of DNS and the Dresden Island Lock and Dam.

   For white sucker, the upper thermal tolerance limit for chronic exposure for juveniles appears to be about 35°C (93°F) at an acclimation of 32.2°C (90°F); however, the highest thermal tolerance chronic exposure for adults is at an acclimation temperature of 26°C (78.8°F). White sucker is the only RIS for which the potential exists for mortality associated with chronic exposure to temperatures above 32.5°C (90.5°F) in the DNS thermal plume that are predicted to occur during these extreme conditions. These conditions did not persist for more than 24 hours in the thermal plume and throughout this period ambient temperatures in 10-25 percent of the area immediately upstream of the DNS discharge was less than 32.5°C (90.5°F) and would have provided refuge for white sucker avoiding the potentially stressful high thermal plume temperatures. While white sucker may be relatively more sensitive than the other RIS to elevated water temperatures in the DNS thermal plume during extreme conditions, the species occurs only incidentally in the Des Plaines, Kankakee, and Illinois River in the vicinity of DNS.

2. **Temperature Avoidance and Habitat Avoidance**—Except in unusual circumstances, mortality of fish as a result of exposure to high water temperatures in their natural habitat is rare because fishes have a demonstrated ability to sense and avoid stressful elevated temperatures when areas with cooler temperatures are available. While the ability to avoid stressful water temperatures minimizes the potential for fish mortality, it could result in avoidance of important habitat areas that may be affected by portions of the thermal plume. Avoidance data available for gizzard shad, channel catfish, largemouth bass, smallmouth bass, and bluegill indicate that these RIS would not avoid any portions of the plume under extreme ambient and discharge temperature conditions. For each of these RIS, the temperatures avoided are typically several degrees higher than the highest plume cross-section and bottom temperature estimated during extreme conditions. Other

RIS for which avoidance data were not available, generally exhibited acute and/or chronic mortality metrics within a similar range to the five RIS with avoidance information. For species where avoidance has been documented, fish typically avoid temperatures slightly below the threshold of chronic mortality. It is likely that the RIS without upper avoidance temperature data would exhibit a similar pattern of avoidance and would not be expected to avoid significant areas of habitat in the vicinity of the DNS thermal plume. This assessment supports the finding that the DNS thermal plume would not be expected to cause avoidance of aquatic habitat for any of these species, even at very low river flow conditions (1-4 percentile), high air temperatures (37.8°C [100°F]), and high DNS discharge temperatures (34.9°C [94.9°F]) (1-3 percentile). Although it is likely that white sucker might avoid significant areas of the DNS thermal plume during such extreme conditions, moving to more moderate upstream habitat, the duration that avoided temperatures persist is short, less than 12 hours. Such short durations when white sucker would avoid portions of the DNS thermal plume are unlikely to have any extended effect on habitat utilization by this species which has been only an incidental component of the aquatic community. Because avoidance is predicted to be minimal and of short duration the DNS thermal plume is unlikely to inhibit local movement or diel and seasonal migrations of RIS.

3. **Temperatures during Critical Spawning Periods**—Most spawning by the RIS in the vicinity of DNS appears to occur prior to 15 June during the period of closed cycle cooling operation and is, therefore, not affected by indirect open cycle cooling operation that is the subject of this assessment. Gizzard shad, white sucker, golden redhorse, black crappie, and logperch typically finish spawning prior to mid-June and the start of indirect open cycle cooling operation at DNS and would, therefore, not be affected. Over their geographic range emerald shiner, common carp, smallmouth bass, largemouth bass, and freshwater drum typically spawn during May and June; the only RIS reported to spawn after June across their geographic range are channel catfish and bluegill which may continue to spawn into July or August in some regions. However, ambient temperatures in the Des Plaines, Kankakee and Illinois Rivers typically exceed the reported upper temperatures range for spawning by these species before the end of June, particularly during warmer years. Ichthyoplankton drift sampling in the Kankakee River in the vicinity of the DNS cooling water intake indicate that 85-88 percent of the annual production of early life stages of fish in the vicinity of DNS occur prior to 15 June. This is consistent with the findings above, that most spawning by RIS and the species they represent occurs prior to initiation of indirect open cycle cooling at DNS on 15 June and would therefore, not be affected by the proposed ATLs..

4. **Critical Temperatures for Growth**—This analysis indicates that for most of the RIS and the community they represent, temperatures in the DNS thermal plume are not expected to adversely affect normal patterns of growth. The RIS all exhibit a seasonal growth pattern typical of temperate zone fishes with zero growth over winter beginning when temperatures decline below some critical temperature in the fall. Growth resumes in the spring as temperatures rise above that critical temperature and peak during the

summer. If peak temperatures rise above a critical level, growth may decline or cease for a period during the summer. Between the reported upper temperature for optimum growth and the upper zero growth temperature, growth continues, but at a slower rate. While elevated temperatures in portions of a thermal plume may inhibit growth during peak summer periods, they may also stimulate growth earlier and later in the year than typically observed without the artificial source of heat in the water body. The reported upper zero growth temperatures for gizzard shad, emerald shiner, common carp, channel catfish, largemouth bass, and smallmouth bass exceed 33.9°C (93°F). It is unlikely that temperatures in the DNS thermal plume even under the extreme conditions of July 2012 would adversely affect growth or cause a cessation of growth for these RIS. For white sucker (which occurs only incidentally in the upper Illinois, Des Plaines, and Kankakee River) and black crappie under typical high temperature and extreme high temperature conditions, ambient temperatures during July and August can exceed the upper temperature for optimum growth and the zero growth temperature and the DNS Thermal plume would not exacerbate this condition. During rare, but extremely warm years represented by July 2012, the observed high ambient temperatures are predicted to limit growth for a brief period of several days for thermally sensitive species such as white sucker and black crappie. The brief period of extreme ambient temperatures is not predicted to have an extended long-term effect on growth patterns. Both of these species are uncommon in the fish community in the vicinity of DNS.

The findings from this predictive assessment indicate that temperatures in the DNS thermal plume under the proposed ATLs are unlikely to have more than minimal and transitory effects on incidental components of the aquatic community even under rare and extreme meteorological conditions.

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FIGURES

Figure B-1. Seven-day rolling average of water temperatures at four monitoring locations, Sept 2012 - Sept 2014.

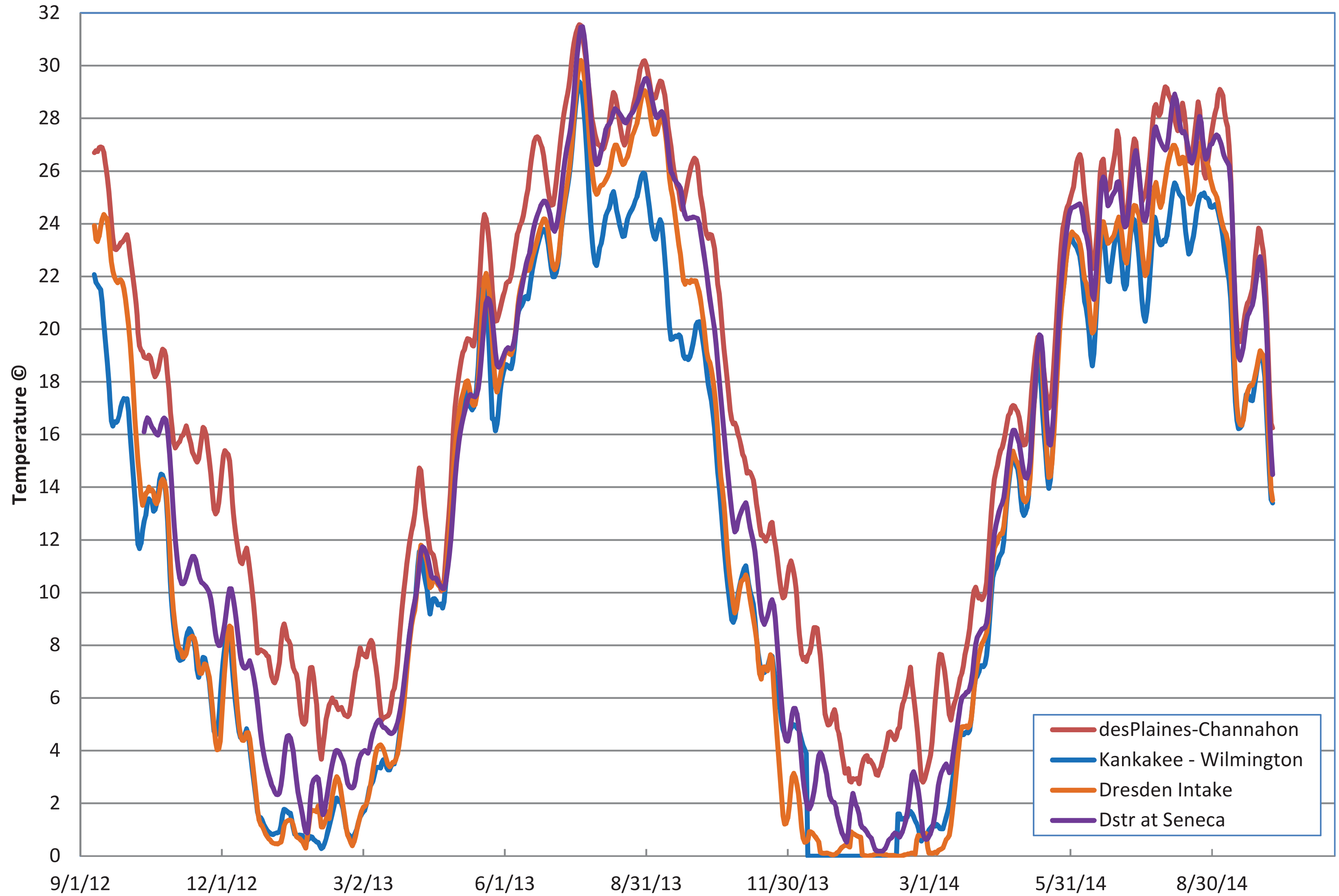


Figure B-2. Measured flows from USGS gages on the Kankakee and Des Plaines rivers, Sept 2012 - Oct 2014.

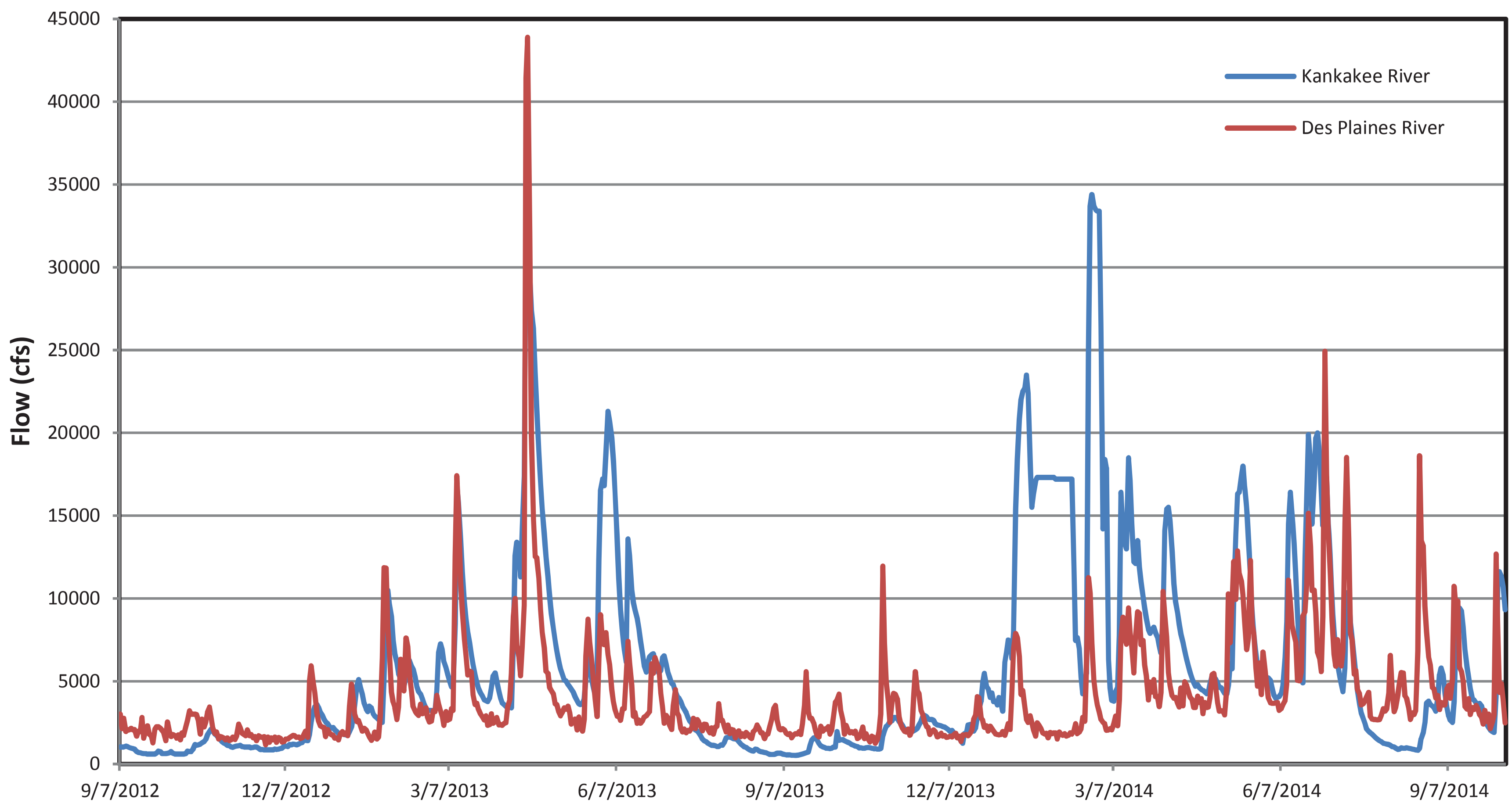


Figure B-3. Seven-day rolling average of estimated flow-weighted ambient water temperatures in the Illinois River downstream of the confluence of the Kankakee and Des Plaines Rivers, Sept 2012 - Sept 2014.

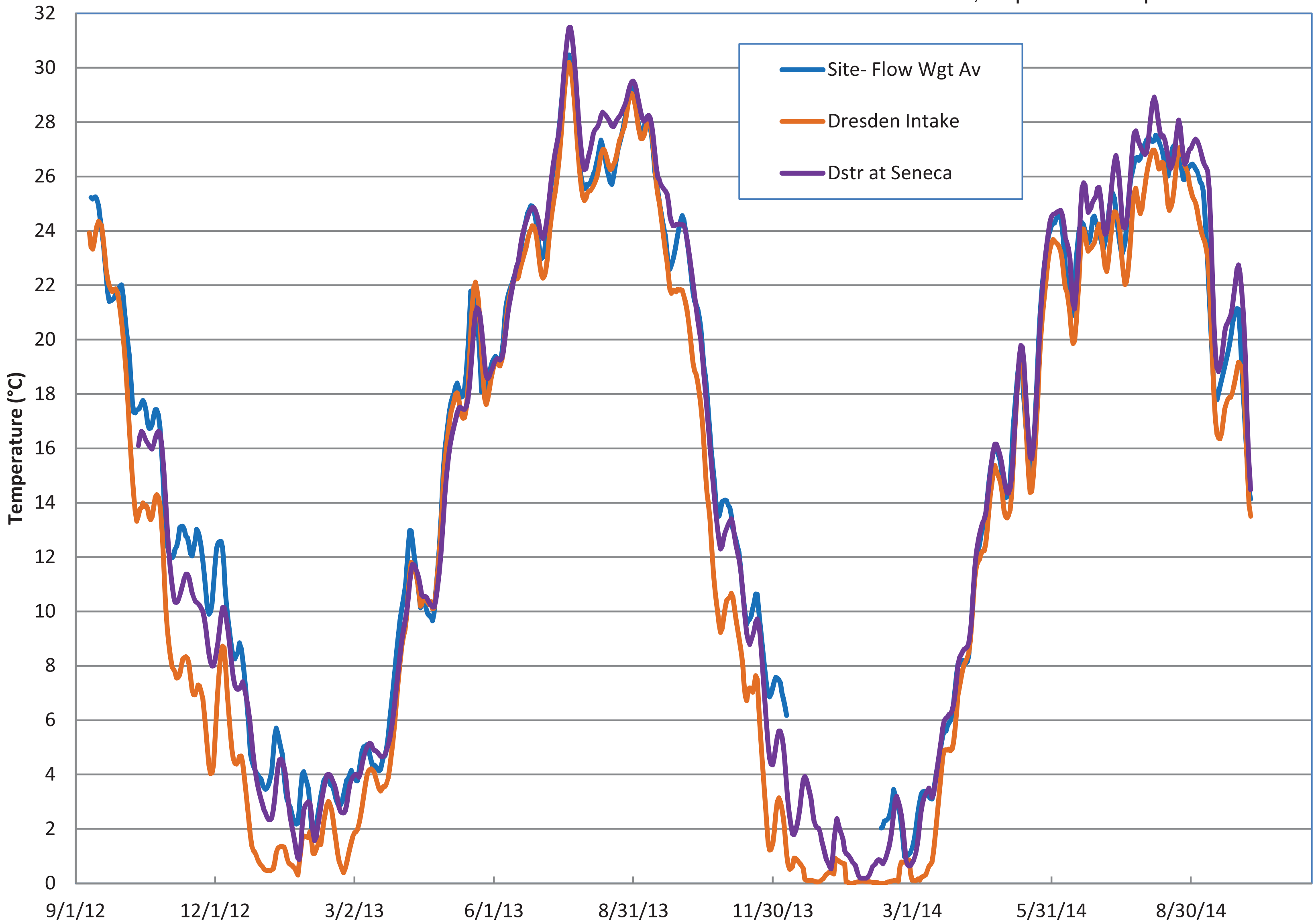


Figure B-4. DNS intake and discharge temperatures and air and wet bulb temperatures, 1-11 July 2012.

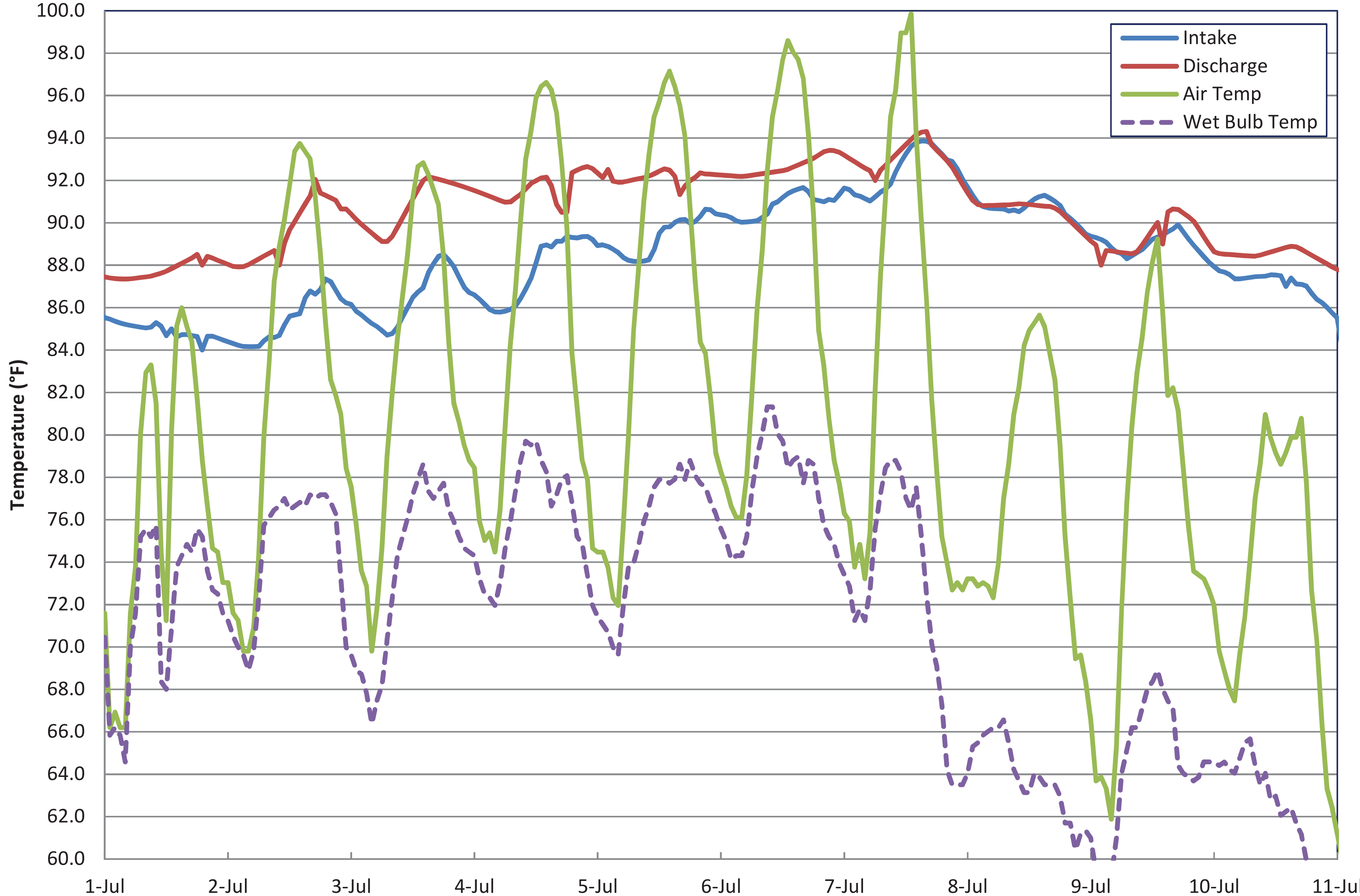


Figure B-5. Diagram of thermal parameter data for gizzard shad.

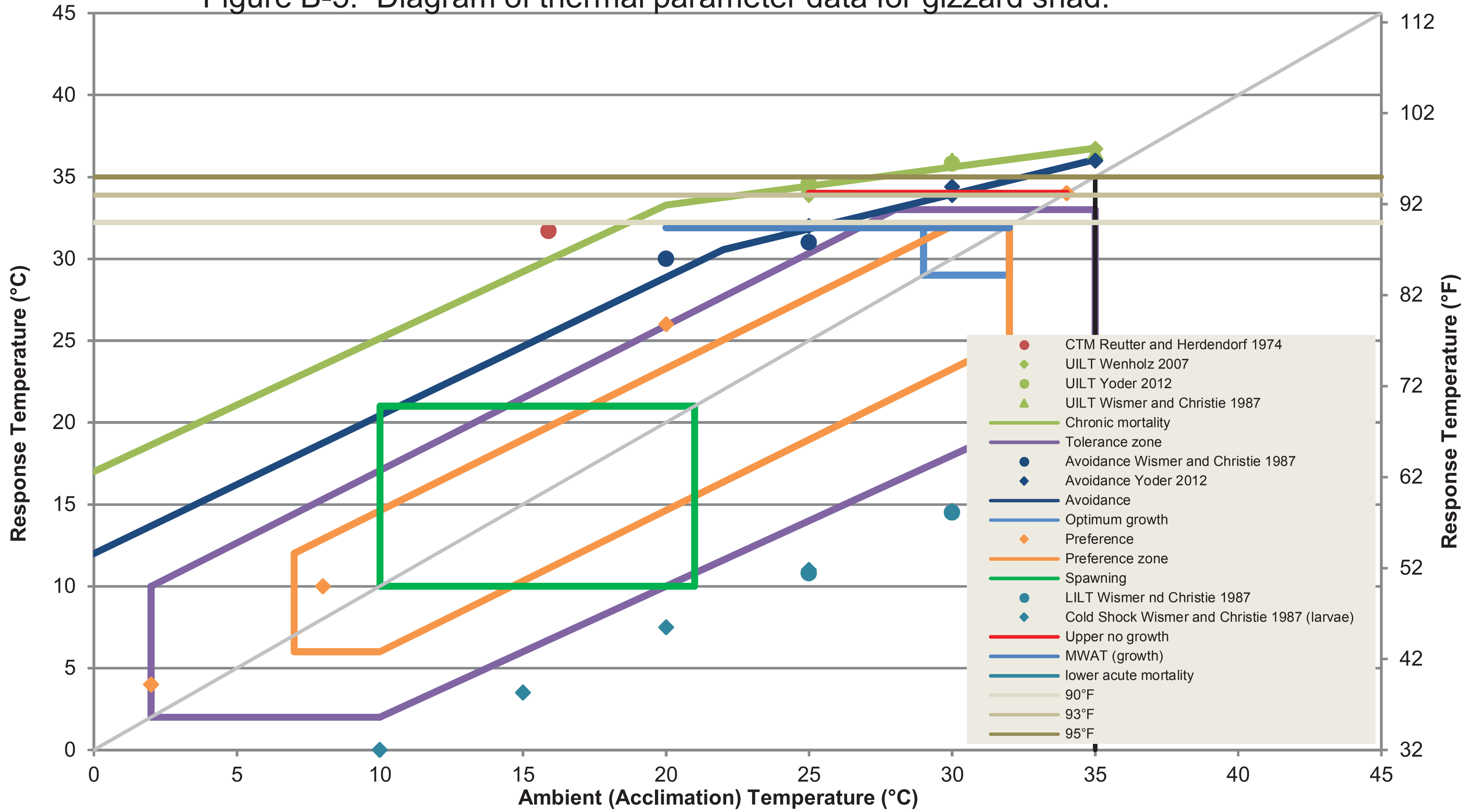


Figure B-6. Diagram of thermal parameter data for emerald shiner.

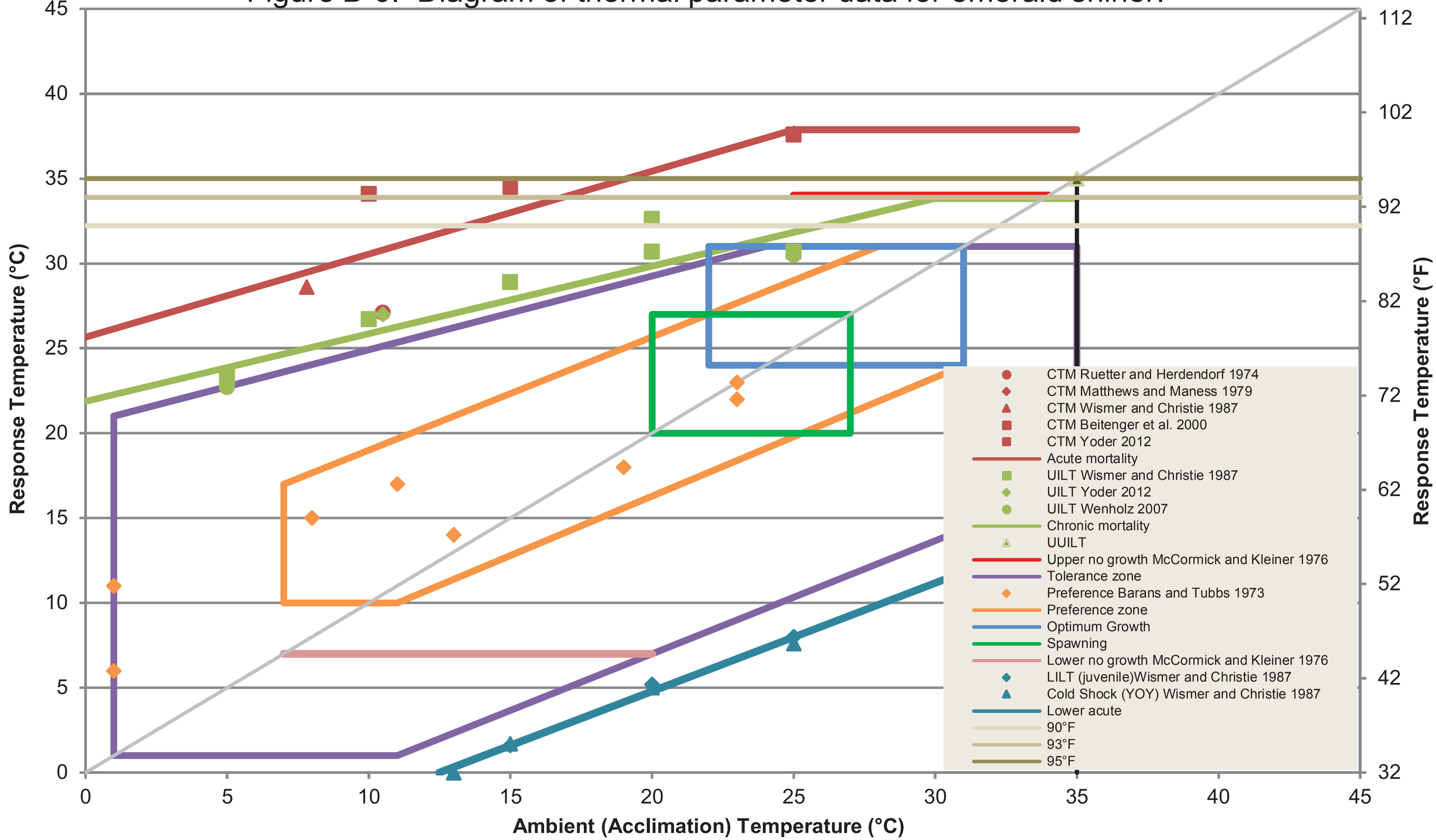


Figure B-7. Diagram of thermal parameter data for common carp.

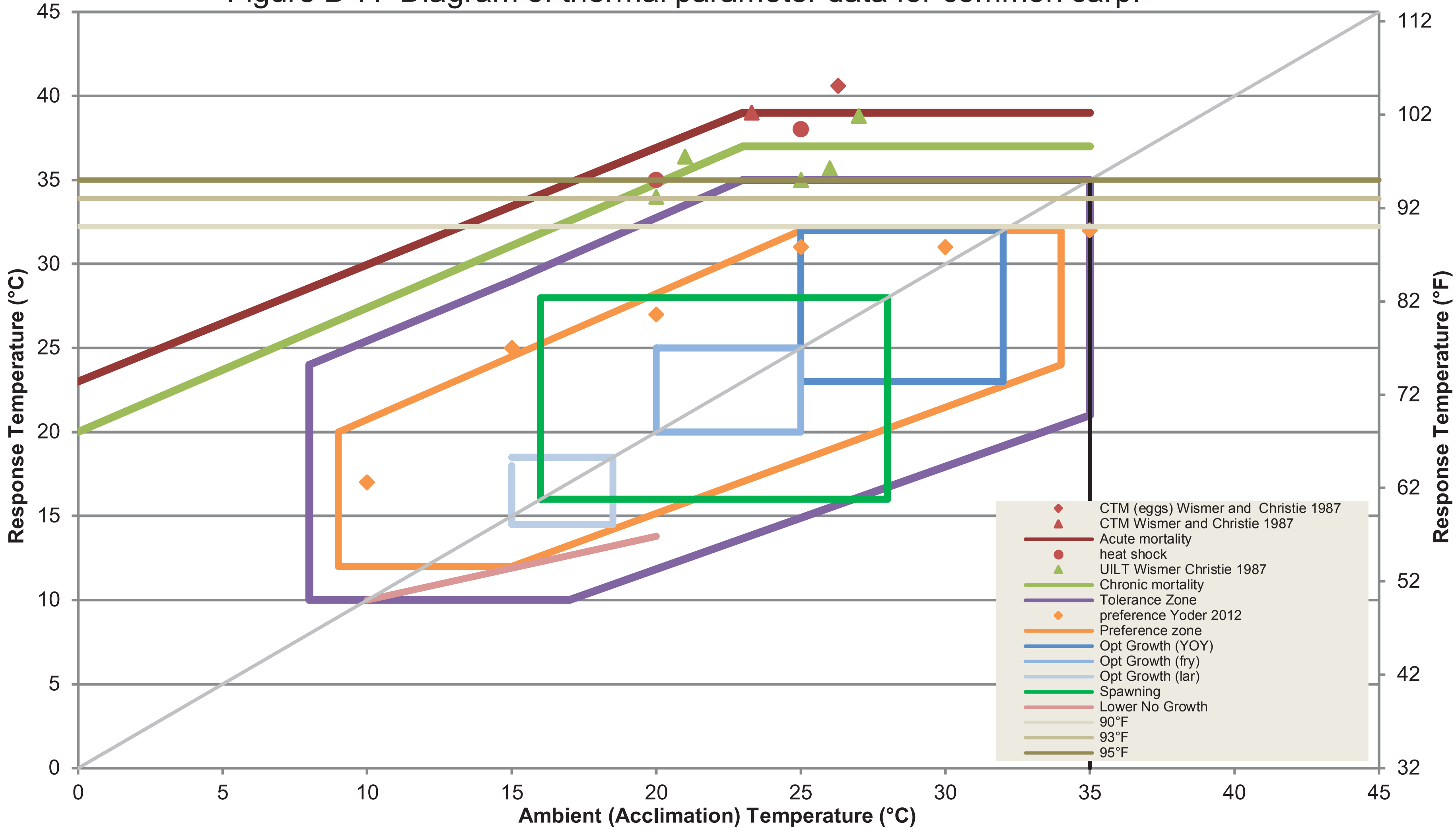


Figure B-8. Diagram of thermal parameter data for golden redhorse.

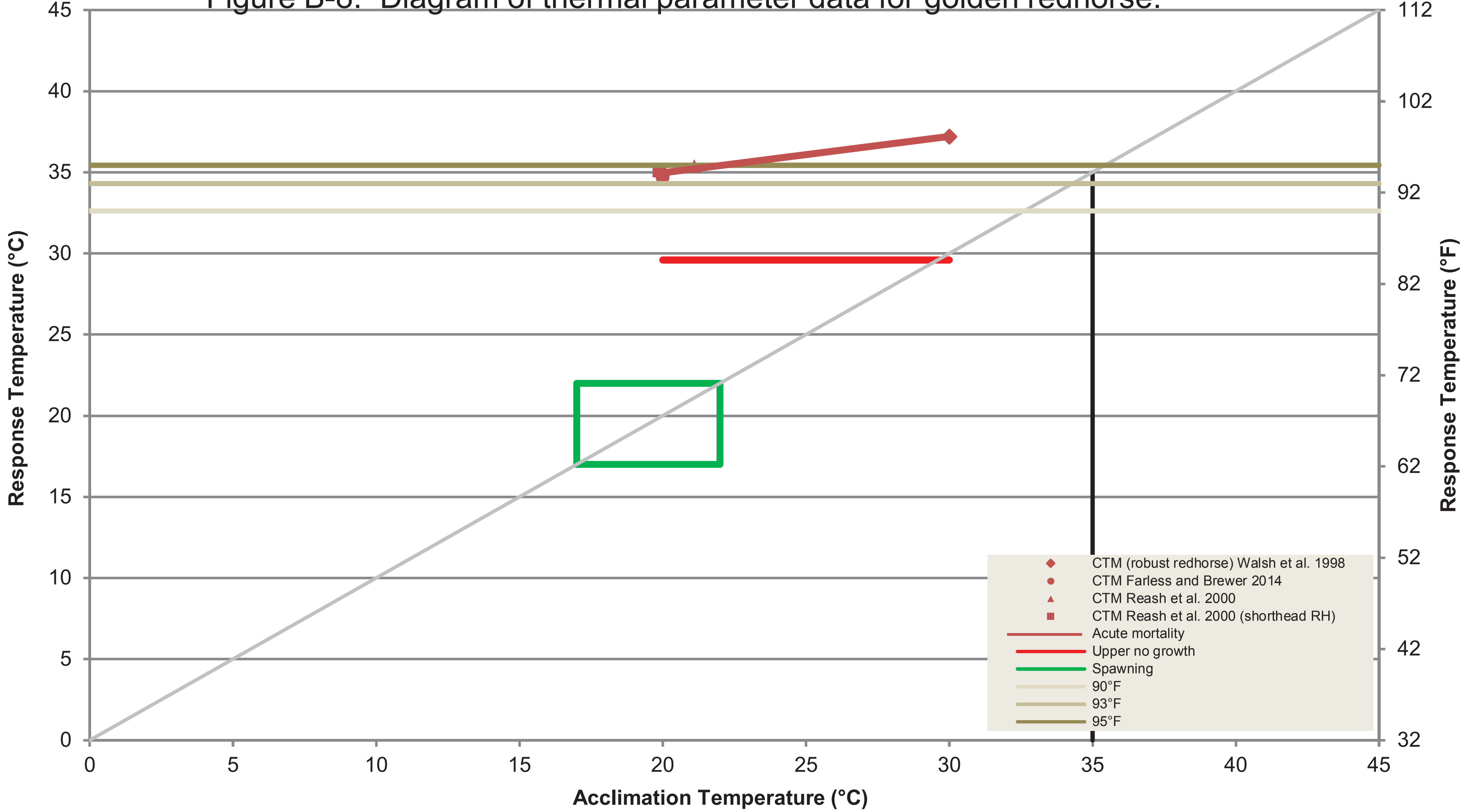


Figure B-9. Diagram of thermal parameter data for white sucker.

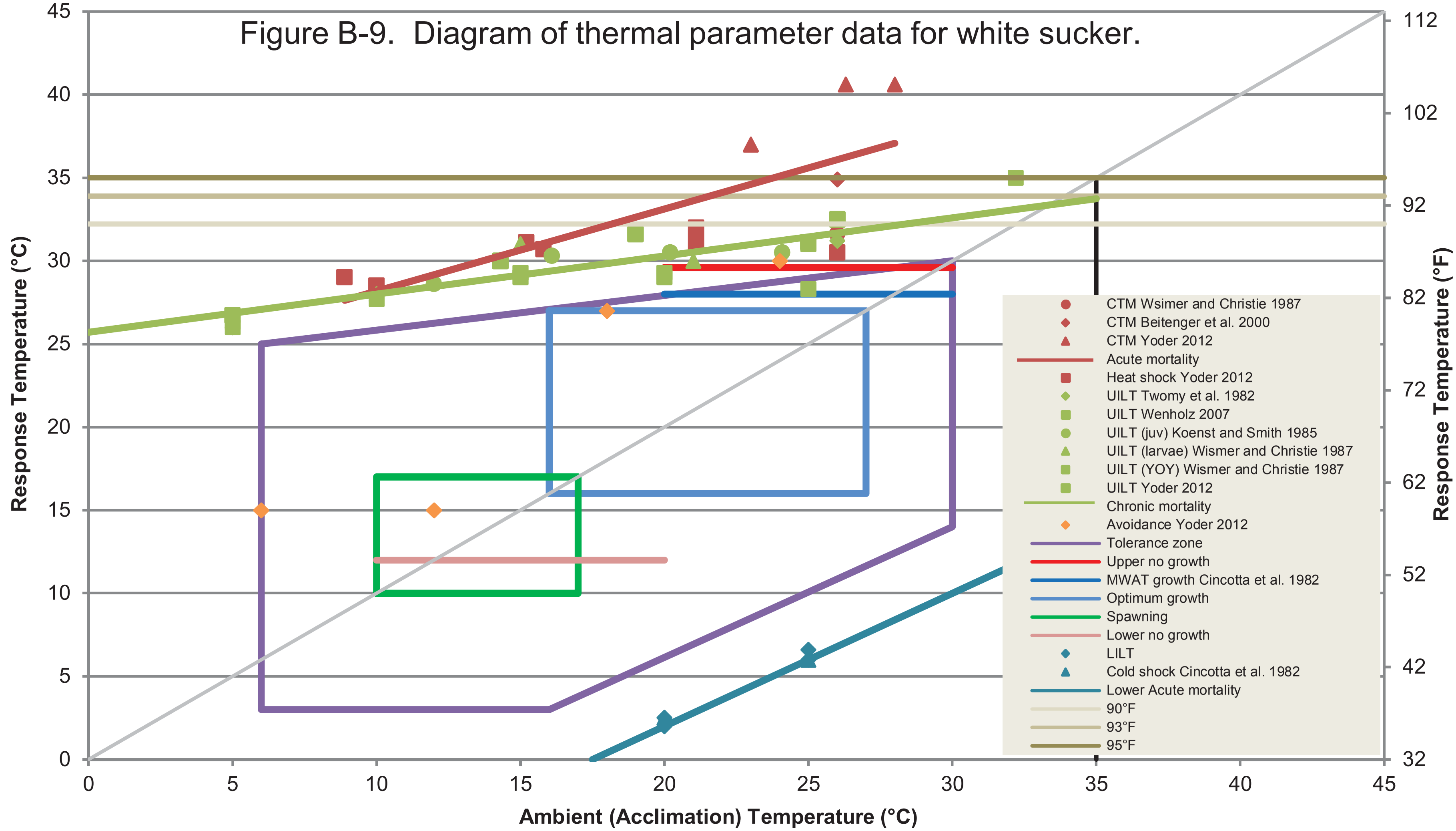


Figure B-10. Diagram of thermal parameter data for channel catfish.

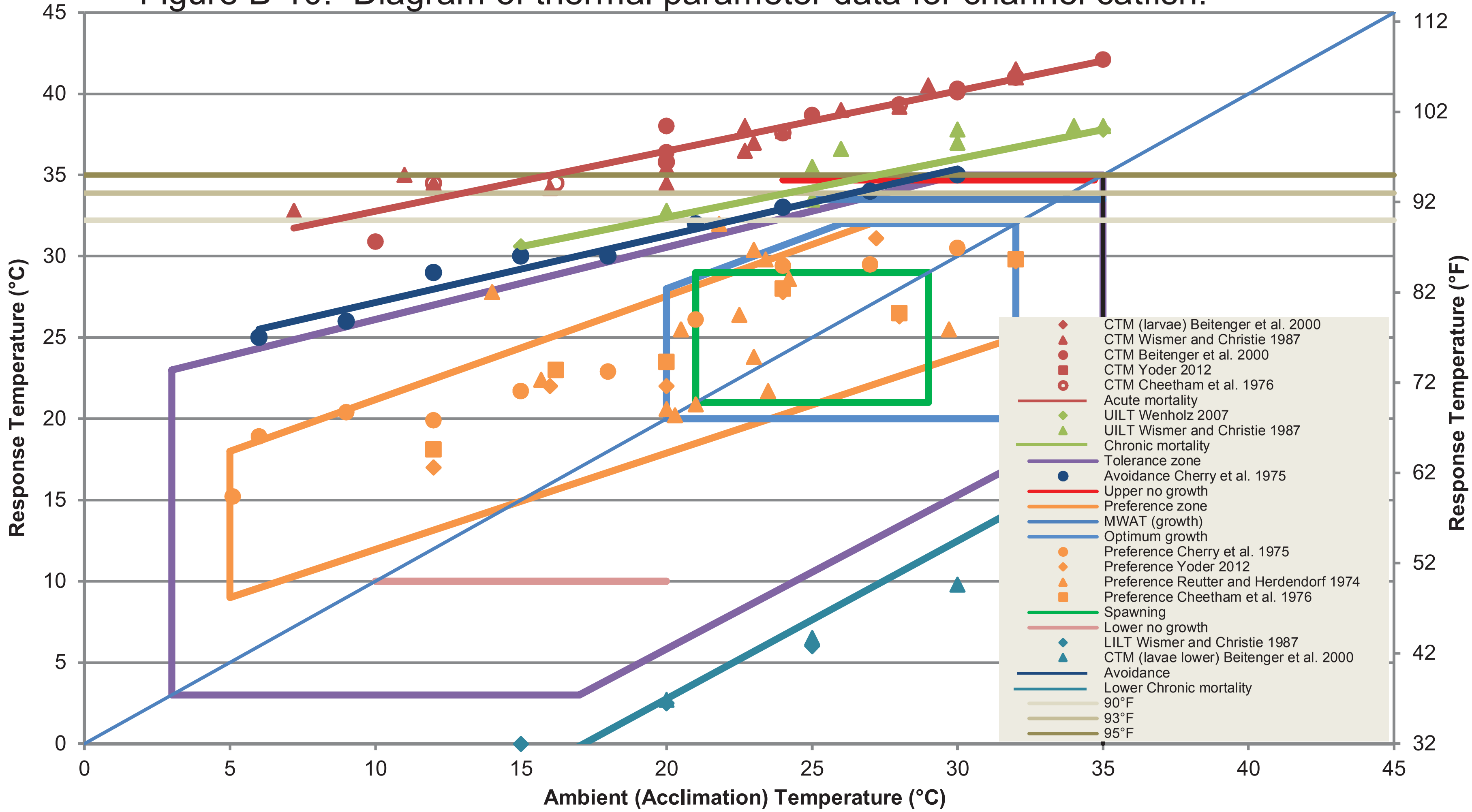


Figure B-11. Diagram of thermal parameter data for largemouth bass.

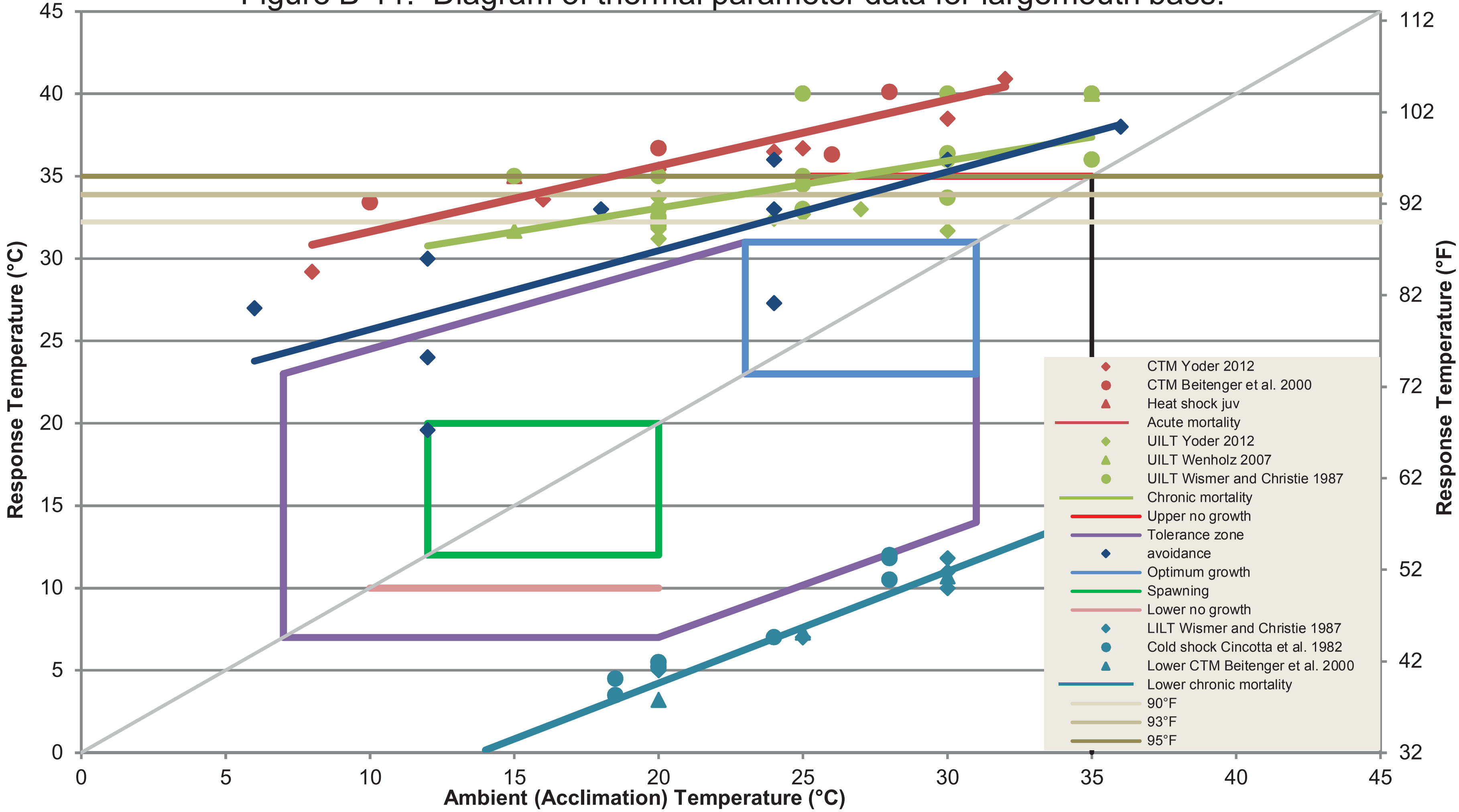


Figure B-12. Diagram of thermal parameter data for smallmouth bass.

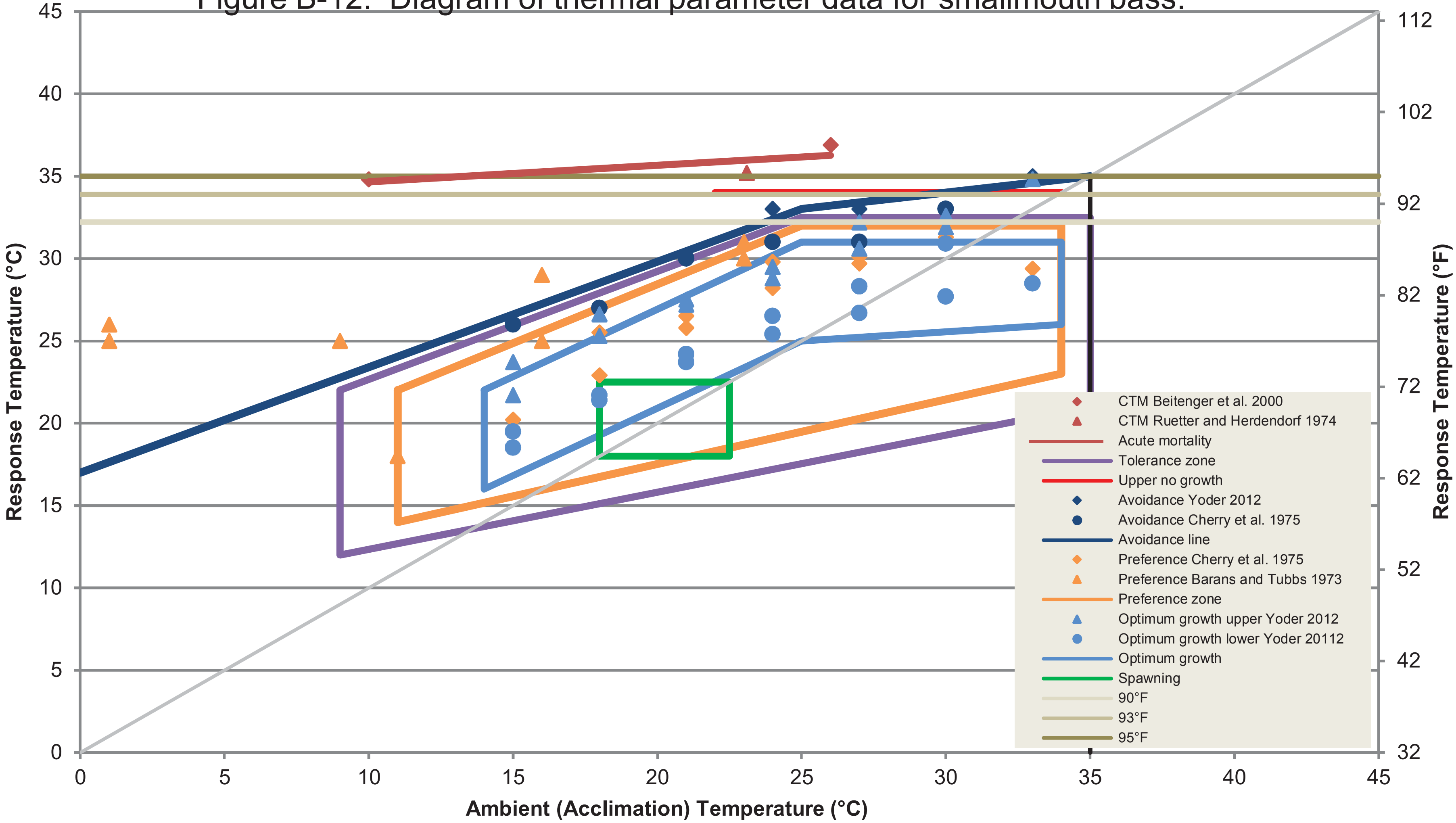


Figure B-13. Diagram of thermal parameter data for bluegill.

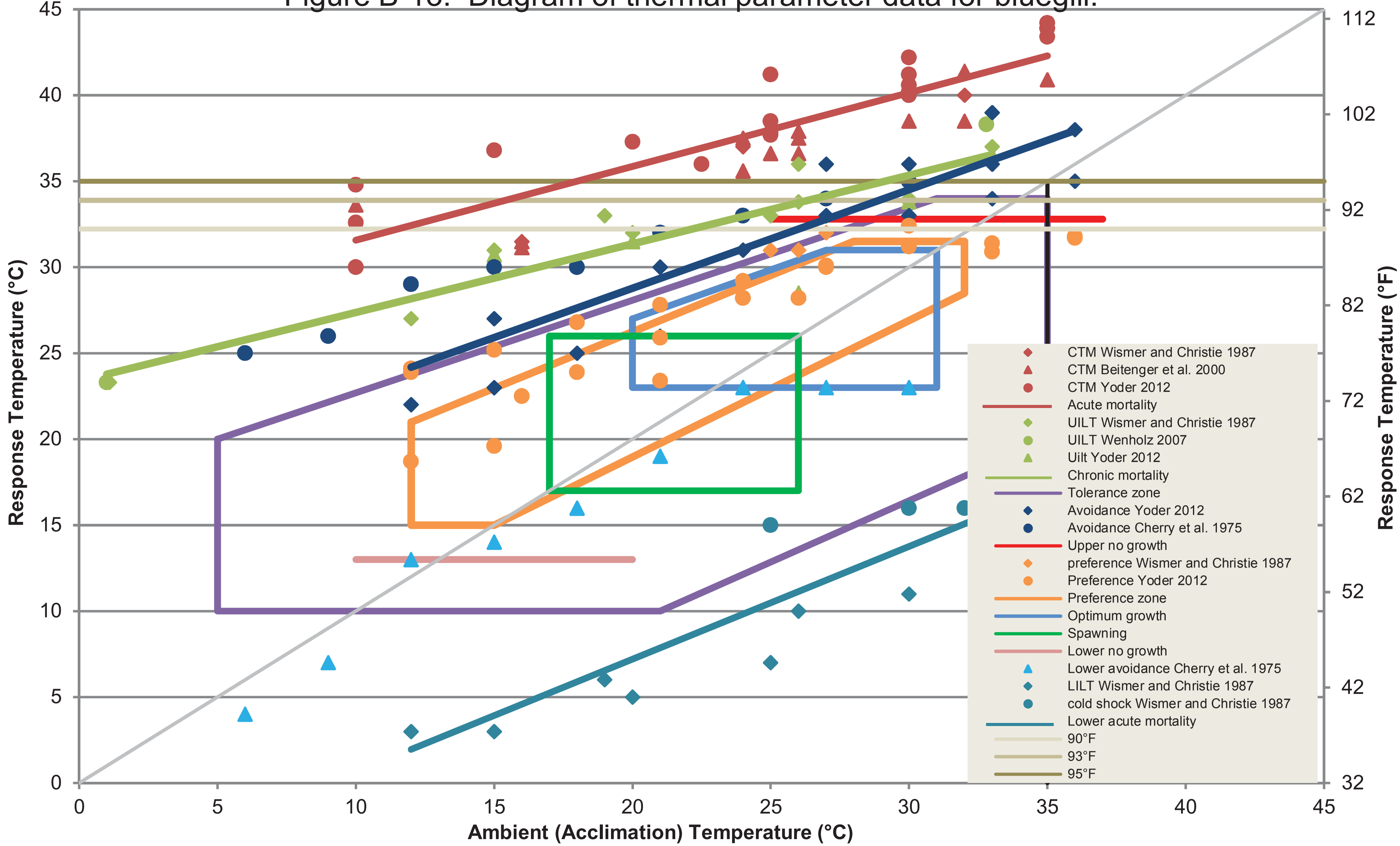


Figure B-14. Diagram of thermal parameter data for black crappie.

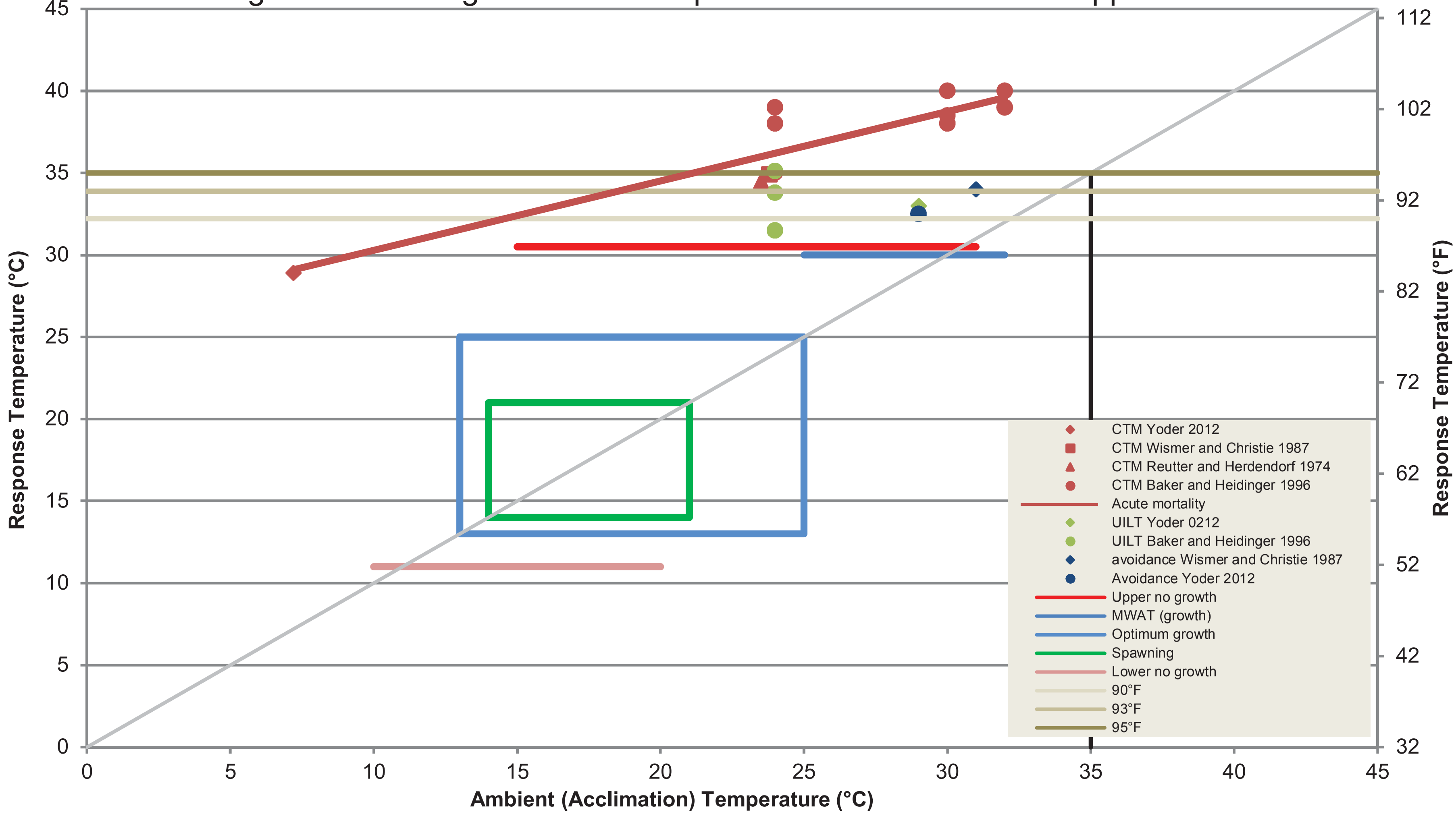


Figure B-15. Diagram of thermal parameter data for logperch.

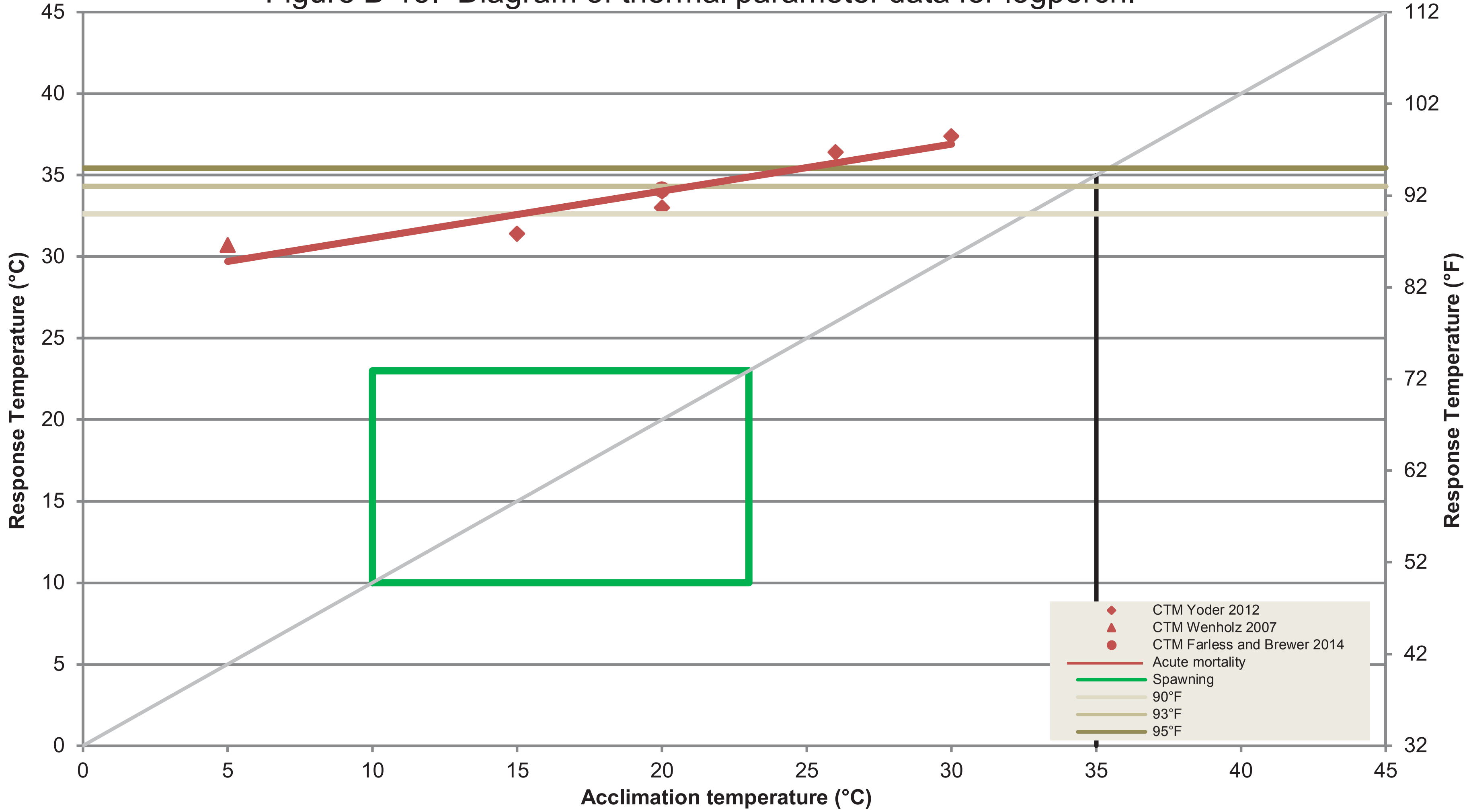
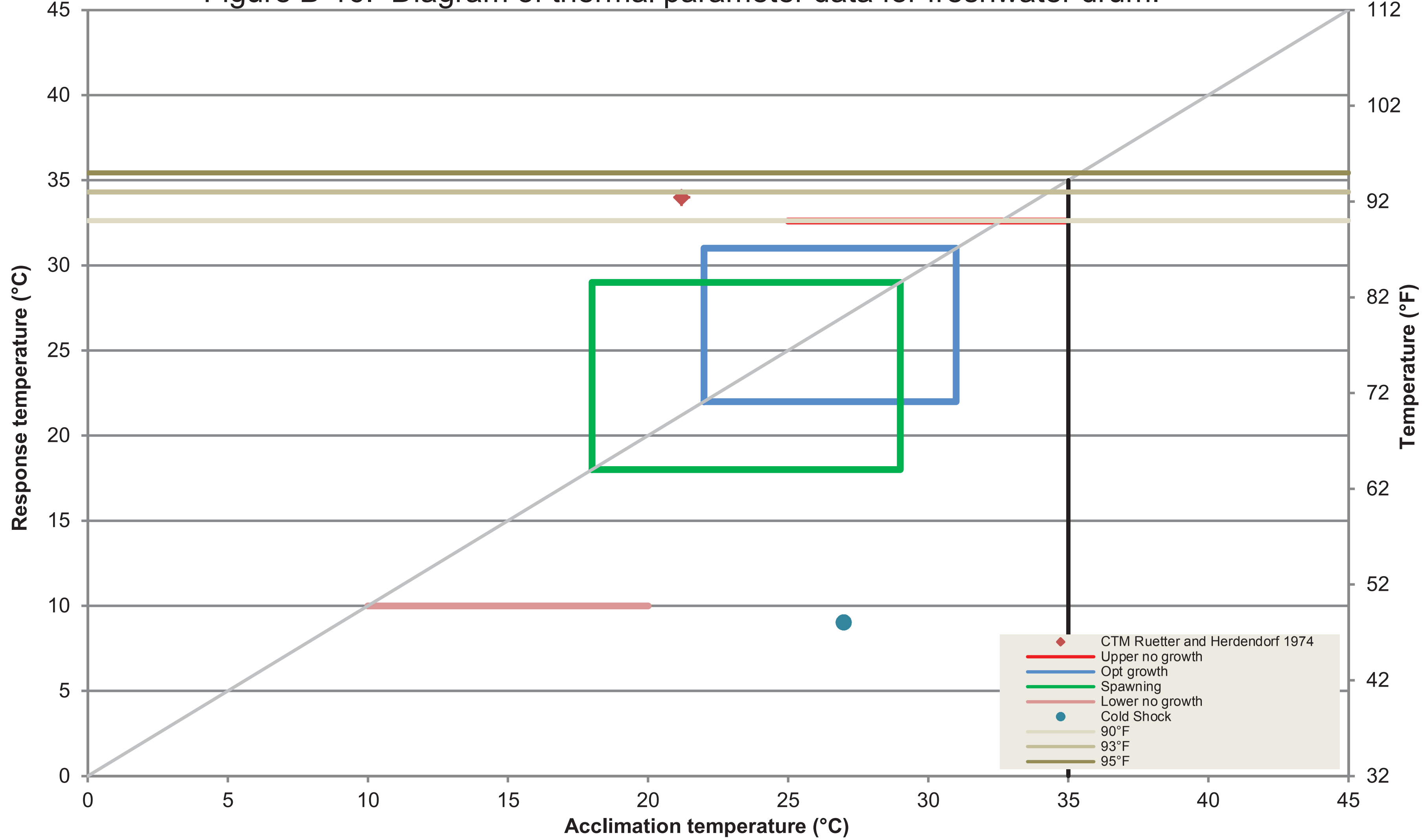
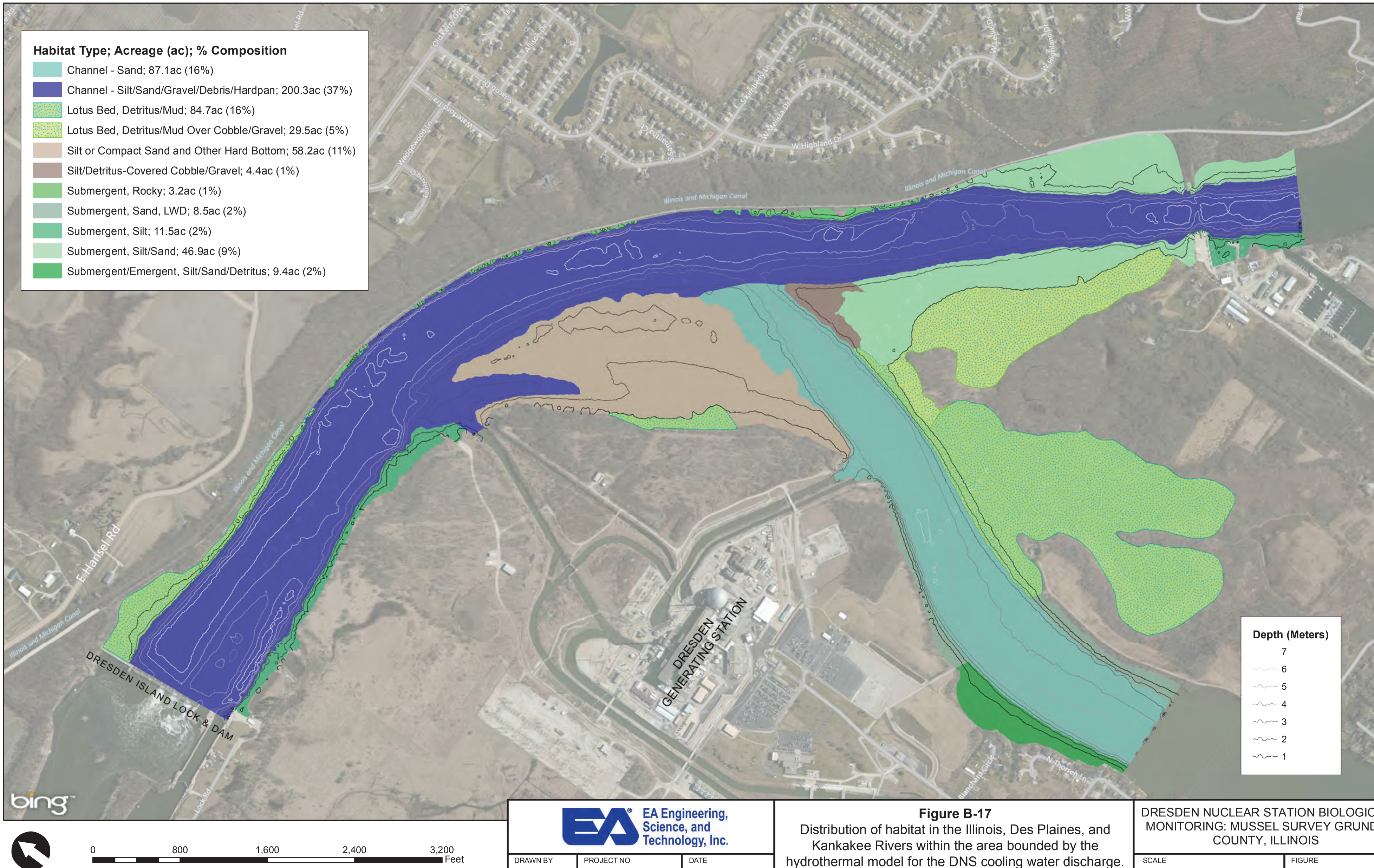


Figure B-16. Diagram of thermal parameter data for freshwater drum.



SOURCE: Bing Maps Hybrid ©2010 Microsoft Corporation and its data suppliers



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BJO	1500404	12/5/2014

Figure B-17
Distribution of habitat in the Illinois, Des Plaines, and Kankakee Rivers within the area bounded by the hydrothermal model for the DNS cooling water discharge.

DRESDEN NUCLEAR STATION BIOLOGICAL MONITORING: MUSSEL SURVEY GRUNDY COUNTY, ILLINOIS

SCALE	FIGURE
1 inch = 800 feet	1

2014.12.05 C:\Users\bonell\Desktop\Exelon\Dresden_Biological.mxd EA-Deerfield bonell

Figure B-18. DNS Intake and Discharge Temperatures and Modeled Surface, Mid, and Bottom Temperatures at IL-200 , 6-8 July 2012

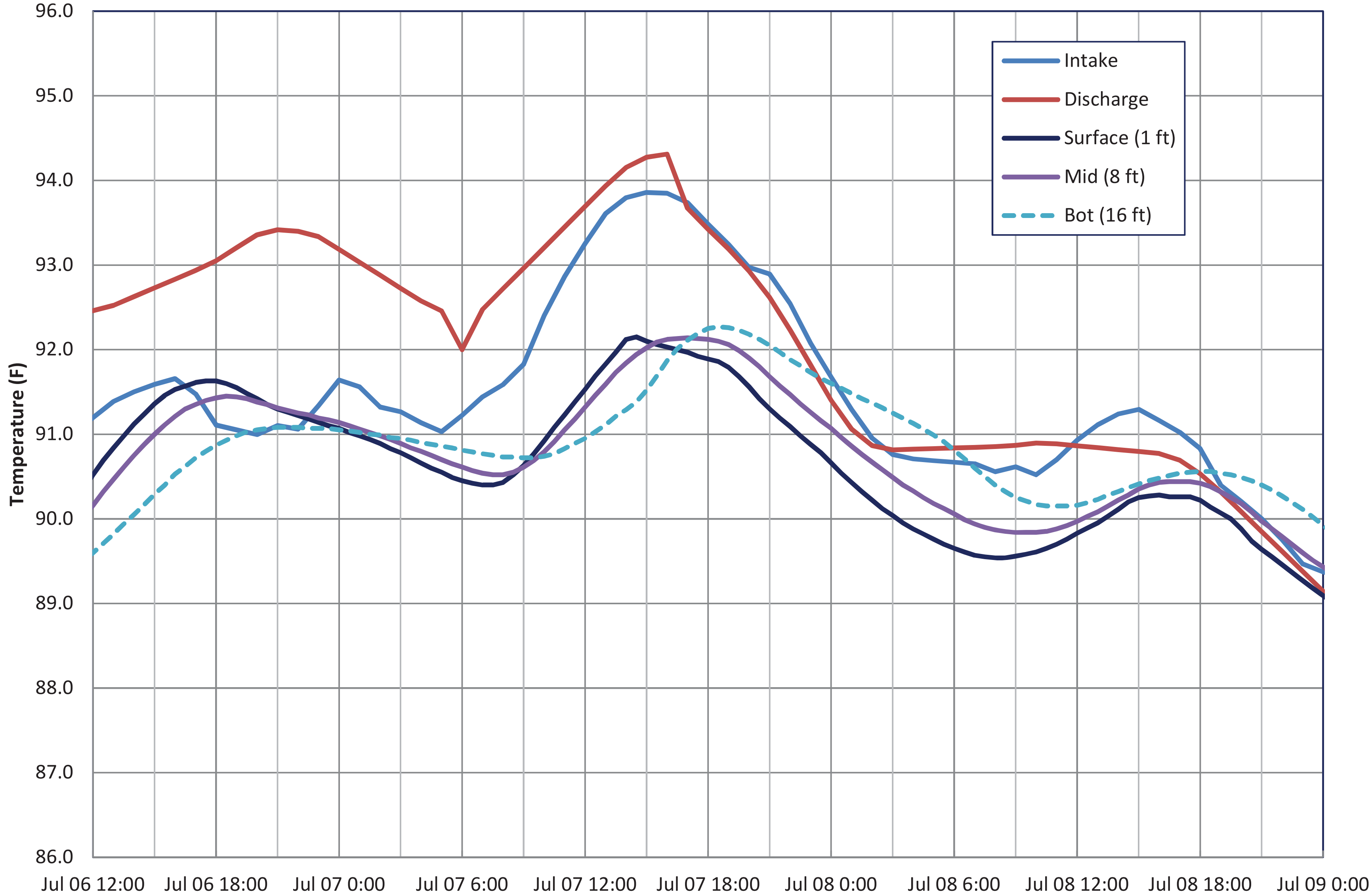


Figure B-19. DNS Intake and Discharge Temperatures and Modeled Surface, Mid, and Bottom Temperatures at IL475 , 6-8 July 2012

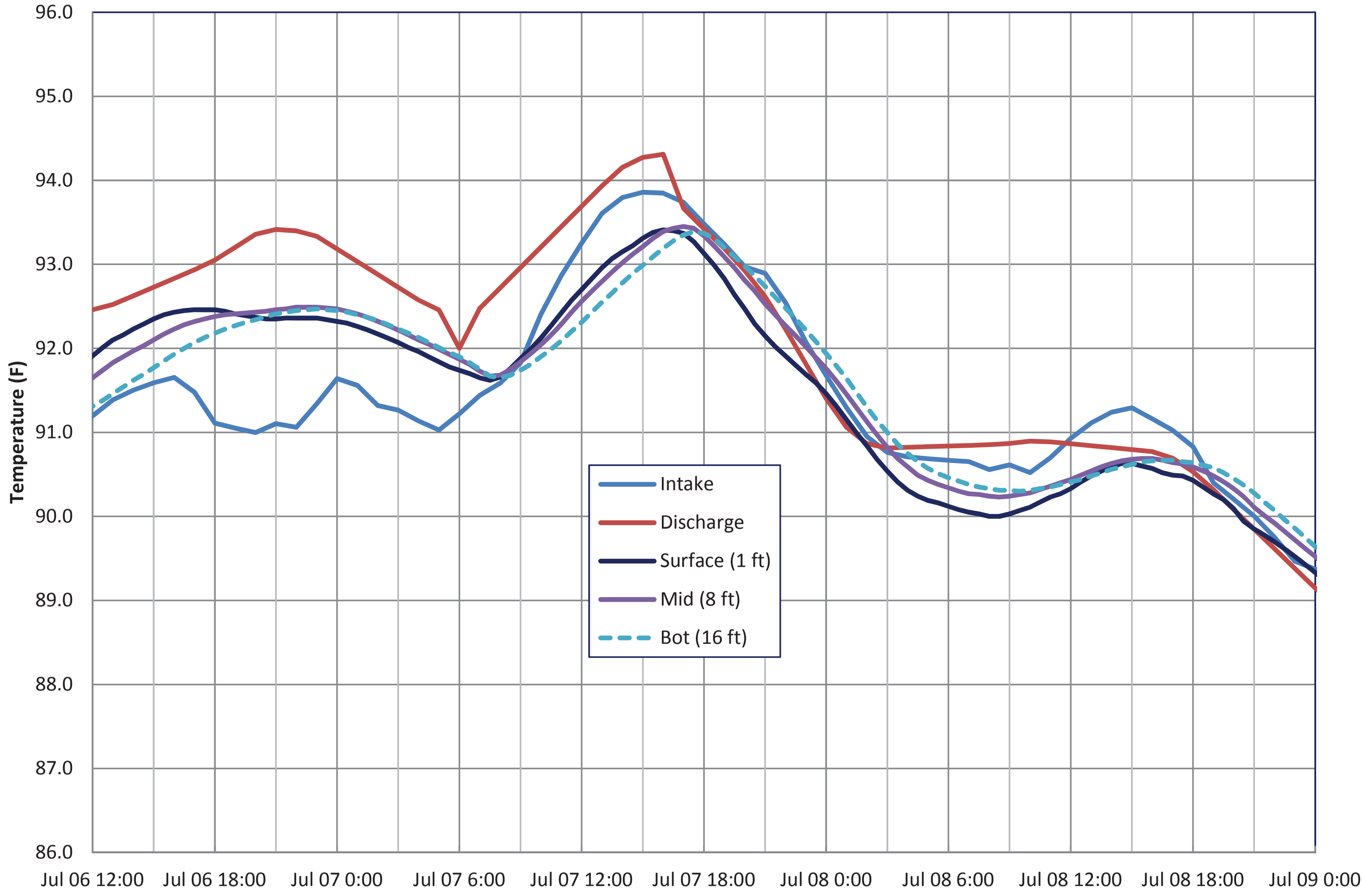


Figure B-20. DNS Intake and Discharge Temperatures and Modeled Surface, Mid, and Bottom Temperatures at IL475 , 1-20 July 2012

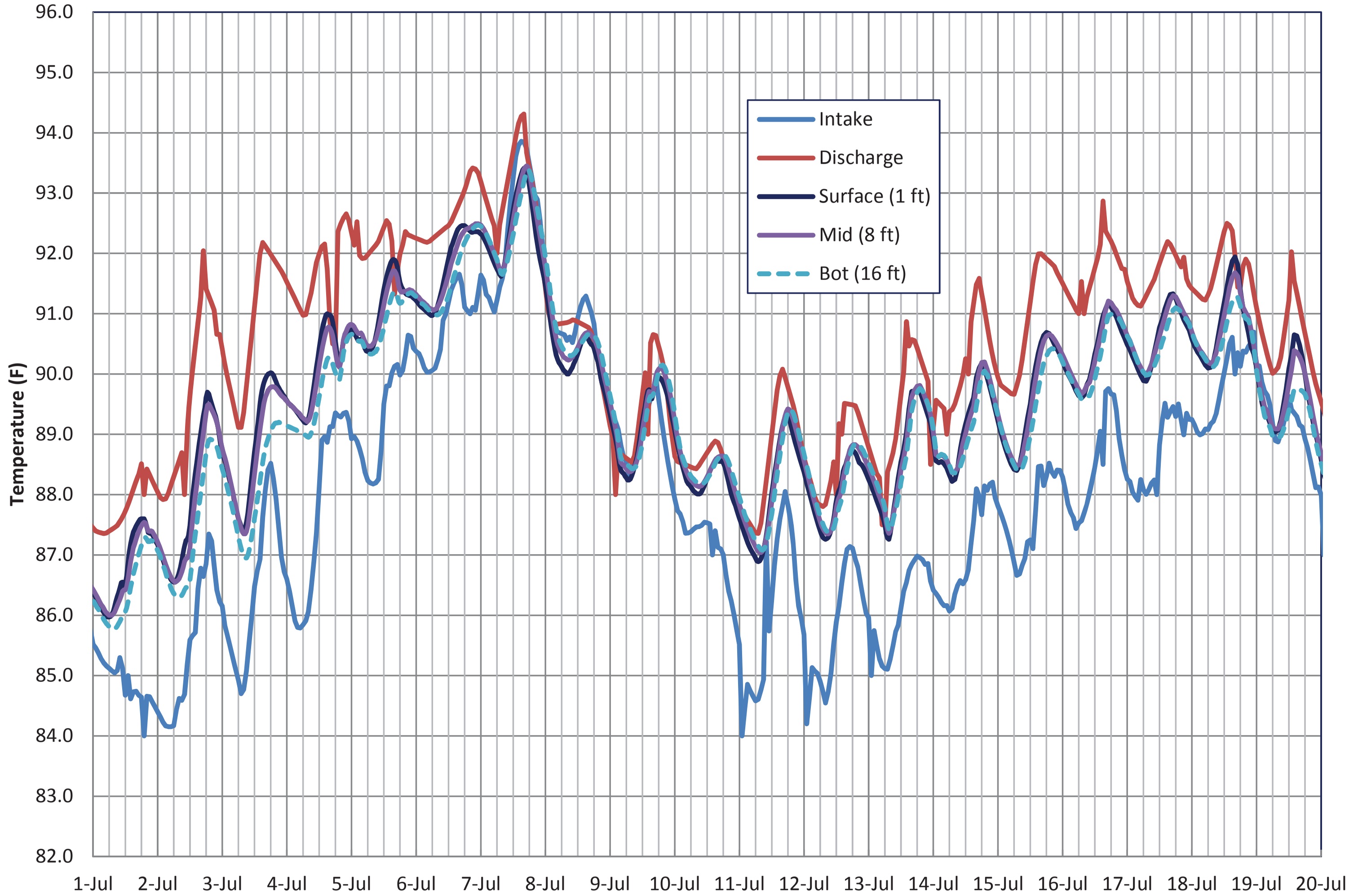
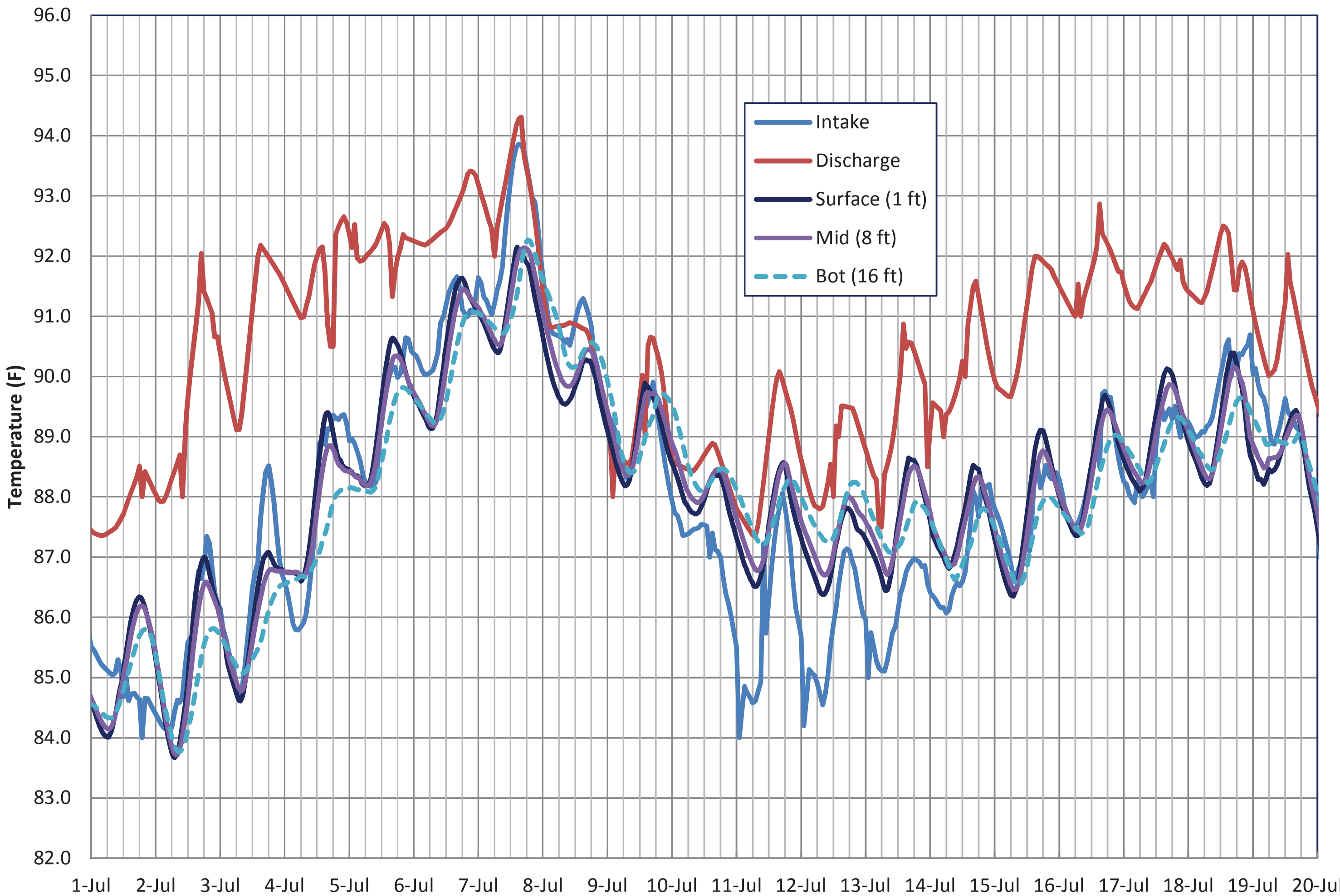


Figure B-21. DNS Intake and Discharge Temperatures and Modeled Surface, Mid, and Bottom Temperatures at IL-200 , 1-20 July 2012



TABLES

Table B-1. Taxa Collected by Various Techniques in the Vicinity of Dresden Station, 1991-2014.

Common Name	Scientific Name	Electrofishing	Seine	Gillnet
SPOTTED GAR	*Lepisosteus oculatus*	X	--	--
LONGNOSE GAR	*Lepisosteus osseus*	X	X	X
SHORTNOSE GAR	*Lepisosteus platostomus*	X	--	X
SKIPJACK HERRING	*Alosa chrysochloris*	X	X	X
GIZZARD SHAD	*Dorosoma cepedianum*	X	X	X
THREADFIN SHAD	*Dorosoma petenense*	X	X	X
GOLDEYE	*Hiodon alosoides*	X	--	X
MOONEYE	*Hiodon tergisus*	--	--	X
CHINOOK SALMON	*Oncorhynchus tshawytscha*	--	--	X
RAINBOW SMELT	*Osmerus mordax*	--	X	--
GRASS PICKEREL	*Esox americanus vermiculatus*	X	--	--
NORTHERN PIKE	*Esox lucius*	X	X	X
CENTRAL STONEROLLER	*Campostoma anomalum*	X	X	--
GOLDFISH	*Carassius auratus*	X	X	X
GRASS CARP	*Ctenopharyngodon idella*	X	--	--
COMMON CARP	*Cyprinus carpio*	X	X	X
SILVER CARP	*Hypophthalmichthys molitrix*	X	--	--
SILVERJAW MINNOW	*Notropis buccatus*	X	X	--
SHOAL CHUB	*Macrhybopsis hyostoma*	X	X	--
SILVER CHUB	*Macrhybopsis storeriana*	--	--	X
HORNYHEAD CHUB	*Nocomis biguttatus*	X	X	--
GOLDEN SHINER	*Notemigonus crysoleucas*	X	X	--
PALLID SHINER	*Hybopsis amnis*	X	X	--
EMERALD SHINER	*Notropis atherinoides*	X	X	X
GHOST SHINER	*Notropis buchanani*	X	X	--
STRIPED SHINER	*Luxilus chrysocephalus*	X	X	X
PUGNOSE MINNOW	*Opsopoeodus emiliae*	X	--	--
SPOTTAIL SHINER	*Notropis hudsonius*	X	X	X
RED SHINER	*Cyprinella lutrensis*	X	X	--
ROSYFACE SHINER	*Notropis rubellus*	X	X	--
SPOTFIN SHINER	*Cyprinella spiloptera*	X	X	X
SAND SHINER	*Notropis stramineus*	X	X	--
REDFIN SHINER	*Lythrurus umbratilis*	X	X	--
MIMIC SHINER	*Notropis volucellus*	X	X	--
CHANNEL SHINER	*Notropis wickliffi*	X	--	--
SUCKERMOUTH MINNOW	*Phenacobius mirabilis*	X	X	--
BLUNTNOSE MINNOW	*Pimephales notatus*	X	X	--
FATHEAD MINNOW	*Pimephales promelas*	X	X	--
BULLHEAD MINNOW	*Pimephales vigilax*	X	X	--
CREEK CHUB	*Semotilus atromaculatus*	X	X	--
RIVER CARPSUCKER	*Carpiodes carpio*	X	X	X
QUILLBACK	*Carpiodes cyprinus*	X	X	X
HIGHFIN CARPSUCKER	*Carpiodes velifer*	X	--	--
WHITE SUCKER	*Catostomus commersonii*	X	X	X

Table B-1 (Continued)

Common Name	Scientific Name	Electrofishing	Seine	Gillnet
NORTHERN HOG SUCKER	*Hypentelium nigricans*	X	X	--
SMALLMOUTH BUFFALO	*Ictiobus bubalus*	X	X	X
BIGMOUTH BUFFALO	*Ictiobus cyprinellus*	X	--	X
BLACK BUFFALO	*Ictiobus niger*	X	X	X
SPOTTED SUCKER	*Minytrema melanops*	X	--	X
SILVER REDHORSE	*Moxostoma anisurum*	X	X	X
RIVER REDHORSE	*Moxostoma carinatum*	X	X	X
BLACK REDHORSE	*Moxostoma duquesnei*	X	--	--
GOLDEN REDHORSE	*Moxostoma erythrurum*	X	X	X
SHORTHEAD REDHORSE	*Moxostoma macrolepidotum*	X	X	X
GREATER REDHORSE	*Moxostoma valenciennesi*	X	--	--
BLACK BULLHEAD	*Ameiurus melas*	X	--	X
YELLOW BULLHEAD	*Ameiurus natalis*	X	X	X
CHANNEL CATFISH	*Ictalurus punctatus*	X	X	X
STONECAT	*Noturus flavus*	--	X	--
TADPOLE MADTOM	*Noturus gyrinus*	X	X	--
FLATHEAD CATFISH	*Pylodictis olivaris*	X	--	X
TROUT-PERCH	*Percopsis omiscomaycus*	X	X	X
BANDED KILLIFISH	*Fundulus diaphanus*	--	X	--
BLACKSTRIPE TOPMINNOW	*Fundulus notatus*	X	X	--
WESTERN MOSQUITOFISH	*Gambusia affinis*	X	X	--
BROOK SILVERSIDE	*Labidesthes sicculus*	X	X	--
WHITE PERCH	*Morone americana*	X	X	X
WHITE BASS	*Morone chrysops*	X	X	X
YELLOW BASS	*Morone mississippiensis*	X	X	X
STRIPED BASS	*Morone saxatilis*	X	--	X
ROCK BASS	*Ambloplites rupestris*	X	X	X
GREEN SUNFISH	*Lepomis cyanellus*	X	X	X
PUMPKINSEED	*Lepomis gibbosus*	X	X	--
WARMOUTH	*Lepomis gulosus*	X	--	--
ORANGESPOTTED SUNFISH	*Lepomis humilis*	X	X	X
BLUEGILL	*Lepomis macrochirus*	X	X	X
REDEAR SUNFISH	*Lepomis microlophus*	X	--	--
NORTHERN SUNFISH	*Lepomis peltastes*	X	X	--
SMALLMOUTH BASS	*Micropterus dolomieu*	X	X	X
LARGEMOUTH BASS	*Micropterus salmoides*	X	X	X
WHITE CRAPPIE	*Pomoxis annularis*	X	X	X
BLACK CRAPPIE	*Pomoxis nigromaculatus*	X	X	X
WESTERN SAND DARTER	*Ammocrypta clara*	--	X	--
RAINBOW DARTER	*Etheostoma caeruleum*	--	X	--
BLUNTNOSE DARTER	*Etheostoma chlorosoma*	--	X	--
JOHNNY DARTER	*Etheostoma nigrum*	X	X	--
BANDED DARTER	*Etheostoma zonale*	X	X	--
YELLOW PERCH	*Perca flavescens*	X	X	--
LOGPERCH	*Percina caprodes*	X	X	--
BLACKSIDE DARTER	*Percina maculata*	X	X	--

Table B-1 (Continued)

Common Name	Scientific Name	Electrofishing	Seine	Gillnet
SLENDERHEAD DARTER	*Percina phoxocephala*	X	X	--
RIVER DARTER	*Percina shumardi*	X	--	--
SAUGER	*Sander canadensis*	X	--	--
WALLEYE	*Sander vitreus*	X	X	X
FRESHWATER DRUM	*Aplodinotus grunniens*	X	X	X
ROUND GOBY	*Neogobius melanostomus*	X	X	--
	Total Number of Species	87	73	46

Table B-2. Number of Years Collected for All Taxa in All Gear During the 19 Survey Years: 1991-1995, 1997-2008, 2011, and 2013

Species	Des Plaines River	Kankakee River	Illinois River Upstream L&D	Illinois River Downstream L&D
GIZZARD SHAD	19	19	19	17
COMMON CARP	19	19	19	17
BLUNTNOSE MINNOW	19	19	19	17
GOLDEN REDHORSE	19	19	19	17
CHANNEL CATFISH	19	19	19	17
GREEN SUNFISH	19	19	19	17
BLUEGILL	19	19	19	17
SMALLMOUTH BASS	19	19	19	17
EMERALD SHINER	18	19	19	17
SPOTFIN SHINER	18	19	19	17
LARGEMOUTH BASS	19	18	19	17
FRESHWATER DRUM	18	19	18	17
BULLHEAD MINNOW	16	19	19	17
SPOTTAIL SHINER	17	18	19	16
SMALLMOUTH BUFFALO	19	14	19	17
SHORTHEAD REDHORSE	13	19	18	17
LOGPERCH	13	19	18	17
ORANGESPOTTED SUNFISH	12	19	17	15
BROOK SILVERSIDE	10	18	18	16
NORTHERN SUNFISH	12	18	17	14
STRIPED SHINER	12	15	19	11
QUILLBACK	8	16	17	16
RIVER CARPSUCKER	17	7	15	16
SILVER REDHORSE	7	16	16	16
FLATHEAD CATFISH	8	17	16	9
SAND SHINER	5	13	14	17
LONGNOSE GAR	5	12	13	16
ROCK BASS	9	16	13	6
BLACK CRAPPIE	10	8	12	14
SKIPJACK HERRING	11	7	12	13
THREADFIN SHAD	6	11	12	12
BLACKSTRIPE TOPMINNOW	12	9	10	10
MIMIC SHINER	--	9	7	14
SLENDERHEAD DARTER	--	13	5	10
GHOST SHINER	5	10	9	13
WHITE BASS	2	11	8	14
GOLDEN SHINER	7	10	10	5
JOHNNY DARTER	2	15	8	7
WHITE CRAPPIE	--	7	3	10
ROUND GOBY	7	6	8	5
PALLID SHINER	5	10	5	4

Table B-2 (Continued)

Species	Des Plaines River	Kankakee River	Illinois River Upstream L&D	Illinois River Downstream L&D
TROUT-PERCH	2	11	6	5
REDFIN SHINER	8	3	6	6
Moxostoma sp.	3	6	8	5
WALLEYE	3	8	4	6
CENTRAL STONEROLLER	2	4	10	4
BLACK BUFFALO	7	1	7	5
REDEAR SUNFISH	--	5	--	--
RED SHINER	1	5	5	8
WHITE PERCH	--	2	3	9
GOLDEYE	--	3	5	5
YELLOW BASS	--	2	3	8
HORNYHEAD CHUB	3	2	8	3
WESTERN MOSQUITOFISH	4	1	1	10
SAUGER	--	--	--	4
PUMPKINSEED	1	5	6	3
BLACKSIDE DARTER	4	4	4	3
YELLOW BULLHEAD	6	--	4	1
WARMOUTH	--	4	3	--
SUCKERMOUTH MINNOW	--	3	3	4
NORTHERN HOG SUCKER	1	2	3	7
GOLDFISH	2	--	4	3
ROSYFACE SHINER	1	--	3	5
HIGHFIN CARPSUCKER	2	--	--	4
RIVER REDHORSE	1	1	5	5
WHITE SUCKER	3	1	3	4
FATHEAD MINNOW	--	2	2	4
SPOTTED SUCKER	3	4	1	--
BANDED DARTER	--	2	3	2
SHORTNOSE GAR	1	--	1	4
GRASS PICKEREL	1	--	3	2
NORTHERN PIKE	1	2	2	3
GRASS CARP	--	--	--	2
SHOAL CHUB	--	--	--	2
SILVER CHUB	--	--	--	2
GREATER REDHORSE	1	--	--	3
WESTERN SAND DARTER	--	--	--	2
RAINBOW DARTER	--	--	2	--
BIGMOUTH BUFFALO	3	2	1	1
BLACK REDHORSE	--	1	1	3
TADPOLE MADTOM	2	--	2	1
STRIPED BASS	--	1	--	2
YELLOW PERCH	--	--	2	1
SPOTTED GAR	--	--	--	1
MOONEYE	--	--	--	1

Table B-2 (Continued)

Species	Des Plaines River	Kankakee River	Illinois River Upstream L&D	Illinois River Downstream L&D
CHINOOK SALMON	--	--	1	--
RAINBOW SMELT	--	--	--	1
SILVER CARP	--	--	--	1
SILVERJAW MINNOW	--	--	1	--
PUGNOSE MINNOW	--	1	--	--
CHANNEL SHINER	--	--	1	--
CREEK CHUB	--	--	1	1
BLACK BULLHEAD	1	--	--	1
STONECAT	--	1	--	--
BANDED KILLIFISH	1	--	--	--
BLUNTNOSE DARTER	1	--	--	--
RIVER DARTER	--	--	--	1
Number Taxa in Segment	66	70	78	86

Table B-3. Total Abundance of Fish Taxa Collected in all Gear and River Segments, 1991-2014.

Common Name	1991	1992	1993	1994	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2011	2013	2014	AVG
EMERALD SHINER	1503	2430	976	655	2198	604	900	915	402	1262	3382	2376	972	2263	4023	2530	1670	172	73	923	1511
GIZZARD SHAD	2086	1465	809	729	565	441	634	1146	635	1582	1343	1189	636	1937	1561	2141	1918	518	426	2000	1188
BLUEGILL	244	1433	209	33	128	154	237	655	957	893	1829	2261	913	3038	1818	1189	1285	663	520	494	948
BLUNTNOSE MINNOW	236	879	409	163	186	70	183	177	378	543	1105	1846	700	2809	1161	1470	818	274	323	947	734
SPOTFIN SHINER	373	891	435	208	669	53	40	195	266	794	390	849	784	1492	1706	673	721	462	921	2274	710
BULLHEAD MINNOW	785	438	499	142	206	295	153	458	298	475	114	916	967	1049	319	333	305	142	192	887	449
GREEN SUNFISH	266	986	212	64	47	96	184	583	483	328	520	931	458	454	300	348	267	112	92	159	345
THREADFIN SHAD	1942	--	--	--	--	--	--	36	61	129	86	32	17	3	29	1	123	38	9	858	240
LARGEMOUTH BASS	116	166	72	35	55	51	62	138	89	227	305	325	203	441	355	415	259	188	126	596	211
SPOTTAIL SHINER	88	384	89	134	99	44	8	16	33	279	106	78	32	526	72	172	183	16	13	558	147
GOLDEN REDHORSE	160	76	166	41	101	44	53	71	78	76	272	369	138	189	284	321	279	45	26	100	144
SMALLMOUTH BASS	113	305	170	55	55	63	67	73	92	147	191	343	169	122	119	159	202	42	59	303	142
BROOK SILVERSIDE	27	111	17	29	10	1	11	10	46	51	72	380	121	331	321	190	241	128	226	357	134
COMMON CARP	293	254	184	97	84	29	29	82	54	100	71	53	45	94	56	58	67	37	19	88	90
FRESHWATER DRUM	176	264	118	65	34	47	16	11	61	97	142	138	79	90	96	103	100	14	14	99	88
PALLID SHINER	--	--	--	--	--	--	--	--	--	12	15	77	150	126	37	165	151	10	34	128	82
GHOST SHINER	--	15	324	10	193	32	--	--	2	9	4	61	16	83	32	386	123	--	1	12	81
CHANNEL CATFISH	159	118	46	65	42	37	15	23	63	61	126	139	101	100	132	78	98	37	25	129	80
NORTHERN SUNFISH	8	6	16	1	--	18	8	13	4	45	45	111	31	34	75	77	149	72	107	331	61
SAND SHINER	20	30	19	7	40	3	1	2	6	145	90	107	66	156	92	45	62	36	45	201	59
LOGPERCH	36	31	60	8	9	23	34	25	33	37	34	36	22	111	56	144	42	15	39	180	49
STRIPED SHINER	45	35	44	2	4	9	5	1	20	27	101	43	62	103	83	67	187	27	15	7	44
BLACKSTRIPE TOPMINNOW	--	--	--	--	--	--	1	--	4	9	6	35	39	51	63	76	45	54	130	62	44
SHORTHEAD REDHORSE	77	62	74	31	56	6	17	13	7	40	31	38	24	47	28	38	52	20	36	142	42
ORANGESPOTTED SUNFISH	19	72	19	5	11	14	8	2	7	56	56	264	25	41	29	42	56	11	6	59	40
SMALLMOUTH BUFFALO	61	51	42	31	12	9	11	31	50	79	69	42	39	28	40	42	51	12	7	61	38
MIMIC SHINER	3	7	41	4	5	15	--	--	1	1	10	49	1	46	38	23	10	1	16	345	34
QUILLBACK	195	46	36	26	56	3	5	4	5	13	6	5	10	91	16	8	12	1	6	10	28
ROUND GOBY	--	--	--	--	--	--	--	--	--	--	--	5	29	20	11	35	77	11	3	46	26
RIVER CARPSUCKER	78	88	40	56	21	3	6	7	6	15	16	6	16	14	5	11	9	1	3	13	21
SILVER REDHORSE	29	27	22	18	53	7	4	4	3	9	4	1	25	11	12	18	14	--	5	92	19
TROUT-PERCH	1	24	136	--	4	23	3	1	--	32	13	22	8	--	--	2	2	1	--	1	18
SKIPJACK HERRING	151	45	10	8	4	2	5	4	1	17	16	4	1	3	10	--	8	--	2	3	16
WESTERN MOSQUITOFISH	--	--	--	--	--	--	--	--	3	5	--	7	14	12	8	6	4	3	84	1	13
WHITE BASS	17	23	10	13	30	1	--	--	4	9	17	21	15	8	6	3	8	--	--	21	13
GOLDEYE	12	3	8	54	7	--	--	--	1	1	--	--	--	--	--	--	--	--	--	--	12
ROCK BASS	6	2	5	1	1	3	2	3	2	6	15	7	8	13	24	15	54	5	14	33	11
LONGNOSE GAR	28	18	15	12	12	1	--	3	6	11	6	11	3	8	9	6	23	4	1	25	11
REDFIN SHINER	--	1	26	2	8	--	--	--	--	--	--	23	--	16	14	4	6	3	10	9	10

Table B-3 (Continued)

Common Name	1991	1992	1993	1994	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2011	2013	2014	AVG
GOLDEN SHINER	25	8	3	--	3	1	2	--	1	9	--	--	7	60	7	6	9	12	2	5	10
JOHNNY DARTER	1	--	12	4	1	1	--	--	1	3	1	24	16	28	13	12	3	6	4	25	9
GOLDFISH	14	3	--	1	--	--	--	--	--	--	--	--	--	--	--	7	2	--	--	27	9
ROSYFACE SHINER	--	--	--	--	--	--	--	--	--	--	--	4	4	1	--	--	--	3	17	24	9
SUCKERMOUTH MINNOW	9	32	--	--	--	--	--	--	--	7	8	1	--	--	--	--	1	--	--	1	8
FLATHEAD CATFISH	8	3	7	--	--	4	1	3	6	9	16	18	8	7	9	14	7	8	8	12	8
NORTHERN HOG SUCKER	--	10	--	--	5	--	--	--	--	--	2	--	--	18	--	3	3	1	--	19	8
SHOAL CHUB	--	--	--	--	--	--	--	--	--	--	--	--	--	8	4	--	--	--	--	--	6
BANDED KILLIFISH	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	10	6
CENTRAL STONEROLLER	4	2	1	--	--	--	--	--	3	14	1	3	4	2	1	19	5	--	4	6	5
PUMPKINSEED	3	--	2	--	--	--	--	--	2	--	--	--	--	--	10	1	1	2	9	13	5
BLACK CRAPPIE	9	5	5	1	1	1	1	2	5	2	6	8	6	9	1	4	4	6	1	16	5
WALLEYE	3	3	5	--	2	1	--	--	--	3	5	4	3	--	3	1	3	--	--	23	5
SLENDERHEAD DARTER	2	1	13	3	--	1	4	1	1	1	1	15	3	--	7	5	9	2	1	--	4
FATHEAD MINNOW	2	--	--	--	--	--	--	--	--	--	16	1	3	1	--	--	3	--	--	2	4
RED SHINER	2	12	--	--	6	2	1	3	2	1	4	5	--	--	--	--	--	--	--	4	4
REDEAR SUNFISH	--	--	--	--	--	--	--	--	--	--	--	1	--	1	9	5	1	--	--	--	3
SILVERJAW MINNOW	--	--	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3
WHITE PERCH	2	4	1	--	--	--	--	--	--	3	4	3	1	1	--	1	2	--	--	11	3
WHITE CRAPPIE	5	4	5	--	--	--	--	--	1	2	4	1	2	2	--	1	5	2	--	3	3
BLACK BUFFALO	4	5	2	--	1	1	--	--	1	2	1	11	--	--	--	--	--	2	--	1	3
RIVER REDHORSE	8	--	3	1	2	--	3	--	2	--	2	--	--	--	--	--	--	--	--	1	3
YELLOW PERCH	1	2	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	6	3
BLACKSIDE DARTER	--	--	2	--	1	--	--	--	--	--	--	7	--	4	1	4	1	1	1	1	2
YELLOW BASS	5	1	2	1	--	--	--	4	1	--	2	--	--	1	--	1	3	--	--	1	2
MOONEYE	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2
BLACK REDHORSE	--	--	--	--	--	--	--	--	1	--	1	4	--	--	--	--	--	--	--	--	2
STRIPED BASS	1	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2
YELLOW BULLHEAD	--	1	--	--	--	--	--	--	--	1	2	3	1	--	--	1	--	4	--	3	2
HIGHFIN CARPSUCKER	1	4	1	--	1	--	--	--	--	--	--	1	--	--	--	--	--	--	--	4	2
BANDED DARTER	--	1	--	1	--	--	--	--	1	--	--	--	2	--	1	--	3	--	--	4	2
HORNYHEAD CHUB	1	1	1	--	--	--	--	--	--	--	--	2	1	4	1	1	4	1	2	--	2
NORTHERN PIKE	--	1	--	4	--	--	--	--	--	1	--	--	--	--	--	--	2	1	1	--	2
WHITE SUCKER	2	5	1	1	--	--	--	--	--	--	--	1	--	--	--	1	1	--	--	1	2
TADPOLE MADTOM	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--	--	2	1	1	2
SILVER CHUB	--	--	1	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2
GRASS PICKEREL	1	--	1	1	--	1	--	--	--	--	--	--	1	--	--	--	--	--	--	4	2
SILVER CARP	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	2	2
BIGMOUTH BUFFALO	1	--	--	1	--	--	--	--	1	2	--	--	--	--	--	--	--	--	--	2	1
GRASS CARP	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	1	--	--	--	2	1

Table B-3 (Continued)

Common Name	1991	1992	1993	1994	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2011	2013	2014	AVG
WESTERN SAND DARTER	--	--	--	--	--	--	--	--	--	--	--	1	--	--	1	--	--	--	--	2	1
WARMOUTH	--	--	1	--	--	--	1	--	--	--	1	1	1	2	2	--	--	--	--	--	1
SHORTNOSE GAR	1	2	--	--	--	--	--	--	--	--	1	1	--	--	--	--	--	--	--	1	1
SPOTTED SUCKER	--	1	1	--	--	--	--	--	1	2	--	1	1	--	--	--	--	--	1	1	1
SPOTTED GAR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	1
CHINOOK SALMON	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1
RAINBOW SMELT	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1
PUGNOSE MINNOW	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	1
CHANNEL SHINER	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	1
CREEK CHUB	--	--	1	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	1
GREATER REDHORSE	1	1	1	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	1
BLACK BULLHEAD	1	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	1
STONECAT	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	1
RAINBOW DARTER	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	1	--	--	--	1
BLUNTNOSE DARTER	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	1
RIVER DARTER	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	1
SAUGER	--	--	--	--	--	--	--	--	--	--	--	--	1	--	1	1	1	--	--	--	1

Table B-4. Summary of Life History and Habitat Information for Species Collected During Monitoring Studies Conducted in the Vicinity of Dresden Nuclear Station, 1979-2014.

Species	Frequency[a]	Non-Native	Feeding Habits[b,c]	Habitat[c,d]	Ecosystem Role[c,e]	State-Listed	RIS
GIZZARD SHAD	D		Z, A, PH,I	P, M	F		X
COMMON CARP	D	X	O, S	P, M, V	F, R,C, N		X
BLUNTNOSE MINNOW	D		D, V, IV	P, H	F		
GOLDEN REDHORSE	D		B, I	Rn, H	--		X
CHANNEL CATFISH	D		O	P, Rn, S, St	R		X
GREEN SUNFISH	D		O	B, M	F		
BLUEGILL	D		O	P, B, V	R		X
SMALLMOUTH BASS	D		P, C, I	P, S, St	TP, R		X
EMERALD SHINER	D		I, C, A	Pg, S	F		X
SPOTFIN SHINER	D		I, V, P	Rn, S	F		
LARGEMOUTH BASS	D		P, C, I	B, P, H, St	TP, R		X
FRESHWATER DRUM	D		M, P, I, C	D, S, M	R, C		X
BULLHEAD MINNOW	D		O	Rn, B, M, S	F		
SPOTTAIL SHINER	D		I, A, V	Pg, H, S	F		
SMALLMOUTH BUFFALO	D		B	C, D, H	C		
SHORTHEAD REDHORSE	D		B, I	R, D, H, S	R, C		
LOGPERCH	D		I, C	R, S, V, St	F		X
ORANGESPOTTED SUNFISH	D		C, I, P	P, M	F		
BROOK SILVERSIDE	D		I, Z	B, P, S	F		
NORTHERN SUNFISH	D		I, IV, P	P, S	R		
STRIPED SHINER	C		O	Rn, H, S	F		
QUILLBACK	C		B, O	P, D, H, S	F, C		
RIVER CARPSUCKER	C		B, O	D, P, M, S	F		
SILVER REDHORSE	C		I	P, D, H, St	R, C		
FLATHEAD CATFISH	C		P, C	P, S, St, R	R		
SAND SHINER	C		O	Rn, S	F		
LONGNOSE GAR	C		P	P, V	TP		
ROCK BASS	C		I, C, P	P, S, V, St	R		
BLACK CRAPPIE	C		P, I, C	B, V	R		X
SKIPJACK HERRING	C		C, P	Pg, S	--		
THREADFIN SHAD	C	X	Z, I	P, M, S	F		
BLACKSTRIPE TOPMINNOW	C		I, C, A	P, V, St	F		
MIMIC SHINER	C		I, IV, C	Pg,	F		
SLENDERHEAD DARTER	O		I, C	R, Rn, S	F		
GHOST SHINER	O		I, C, A	Pg, P, M, S	F		
WHITE BASS	O		P	P, H, Pg	TP, R		
GOLDEN SHINER	O		O	P, V, M	F		
JOHNNY DARTER	O		I, C	P, S	F		
WHITE CRAPPIE	O		P, I, C	P, St	R		
ROUND GOBY	O	X	--	--	N		
PALLID SHINER	O			P, V	F	X	
TROUT-PERCH	O		B, I	P, B, M, S	F		
REDFIN SHINER	O		I	P, M	F		
WALLEYE	O		P, Z	V, St	TP, R		

Table B-4 (Continued)

Species	Frequency[a]	Non-Native	Feeding Habits[b,c]	Habitat[c,d]	Ecosystem Role[c,e]	State-Listed	RIS
CENTRAL STONEROLLER	O		A, D	R, S	F		
BLACK BUFFALO	O		B	C, D, H	--		
RED SHINER	O		I, IV	S	F		
WHITE PERCH	O		O	C, B, P,Pg	R		
GOLDEYE	O		I, P	Rn, S	--		
YELLOW BASS	O		P, I	P, H, Pg	TP, R		
HORNYHEAD CHUB	O		O	R, S	F		
WESTERN MOSQUITOFISH	O		I	B, P, V	F		
REDEAR SUNFISH	I		M, C, I, P	P, V	R		
SAUGER	I		P, C, I	B, V, St	TP, R		
PUMPKINSEED	I		I, M	P, V	R		
BLACKSIDE DARTER	I		I, C	P, H, R	F		
YELLOW BULLHEAD	I		B, O	D, B, P, V	R		
WARMOUTH	I		P,O	P, M, V, St	R		
SUCKERMOUTH MINNOW	I		B, I	R, S	F		
NORTHERN HOG SUCKER	I		B, I	D, R, P, S	--		
GOLDFISH	I	X	O, S	P, V	N		
ROSYFACE SHINER	I		IV, D, V	Pg, Rn, S	F		
HIGHFIN CARPSUCKER	I		B, O	R, P, H, S	--		
RIVER REDHORSE	I		M, I, B	D, R, H, S	--	X	
WHITE SUCKER	I		B, I, O	D, S, H	R, C		X
FATHEAD MINNOW	I		D, A, V	B, M	F		
SPOTTED SUCKER	I		M, I	D, H	--		
BANDED DARTER	I		I	R, S	F		
SHORTNOSE GAR	I		P, I, C	S, M	TP		
GRASS PICKEREL	I		P, I, C	P, V	TP, R		
NORTHERN PIKE	I		P, C, T	P, V	TP, R		
GRASS CARP	I	X	H, S	V	N		
SHOAL CHUB	I		B, I	S, Rn	F		
SILVER CHUB	I		B	P, S	F		
GREATER REDHORSE	I		B	D, Rn, H, St	--	X	
WESTERN SAND DARTER	I		I	C, S	F	X	
RAINBOW DARTER	I		I	R, Rn, S	F		
BIGMOUTH BUFFALO	I		I, Z	B, P, M	R, C		
BLACK REDHORSE	I		B, I, C	P, St	R		
TADPOLE MADTOM	I		C, I	B, M, V	F		
STRIPED BASS	I	X	P, C	C, P, Pg	TP, R		
YELLOW PERCH	I		O	P, B, V, St	R		
SPOTTED GAR	I		P	P, V	TP		
MOONEYE	I		O	Rn, H	--		
CHINOOK SALMON	I	X	P	GL	TP, R		
RAINBOW SMELT	I	X	I, C, Z	Pg	R		
SILVER CARP	I	X	--	--	N		
SILVERJAW MINNOW	I		I	R, S	F		
PUGNOSE MINNOW	I		I, C	P, M, V	F		
CHANNEL SHINER	I		I, IV, C	Pg,	F		

Table B-4 (Continued)

Species	Frequency[a]	Non-Native	Feeding Habits[b,c]	Habitat[c,d]	Ecosystem Role[c,e]	State-Listed	RIS
CREEK CHUB	I		O	M, St	F		
BLACK BULLHEAD	I		B, O	D, P, B, M	R		
STONECAT	I		I, C, P	R, H, S	F		
BANDED KILLIFISH	I		I, Z	Pg, P, B, V	F	X	
BLUNTNOSE DARTER	I		I, C	B, M	F		
RIVER DARTER	I		I, C	C, Rn, S	F		
RIVER SHINER	I		I, C, A	Rn, S	F		
BIGMOUTH SHINER	I		I, A, D	Rn, S	F		
ALEWIFE	I	X	P, PH, Z	Pg, S	F		
STEELCOLOR SHINER	I		I, IV, V	Rn, r, S	F		
ORANGETHROAT DARTER	I		I	R, P, S	F		

a. D=dominant (all segments and average more than 15 years); C=common (4 segments and average 10-15 years); O=occasional (3-4 segments and average 4-10 years); I=incidental (1-4 segments and average fewer than 4 years)

b. A=algae; B=bottom feeder; C= crustaceans; D=detritivore; H=herbivore I=insectivore; IV=invertebrates; M=mollusks ; O=omnivore; P=piscivore; PH=phytoplankton; S=scavenger; T=terrestrial; V=vegetation; Z=zooplankton

c. From Smith (1979), *Fishes of Illinois* ; Pflleger (1997), *Fishes of Missouri* ; and Scott and Crossman (1973) *Freshwater Fishes of Canada;* Etnier and Starnes (1993) *The Fishes of Tennessee* ; Becker (1983) *Fishes of Wisconsin* ; Page and Burr (2011).

d. B=backwater, sloughs; C=channel; D=demersal; H=hard bottom; M=mud, muck; Pg=pelagic; P=pools; R=riffles; Rn=run, fast current; S=sand/gravel; St=structure; V=vegetation/detritus; GL=Great Lakes

e. F=forage; TP=top predator; R=recreational; C=commercial; N=Invasive/Nuisance

Table B-5. River Flow and Temperature and DNS Discharge Temperature for Typical and Typical High Temperature Conditions.

Parameter	June	July	August	Sept
Typical Conditions				
Flow (cfs) (50%)				
Des Plaines	4,350	3,870	4,801	4,026
Kankakee	5,370	2,370	1,549	1,340
Total	9,720	6,240	6,350	5,366
Temperature (F) (60%)				
Des Plaines	79.9	82.9	83.1	80.1
Kankakee	74.5	76.1	77.4	68.9
Flow Wgt Av	76.9	80.3	81.7	77.3
Discharge Temp (F)				
50%	85.7	87.4	87.0	83.5
Delta	8.8	7.1	5.3	6.2
Unusually Warm Conditions				
Flow (cfs) (5%)				
Des Plaines	2,794	2,214	2,243	2,119
Kankakee	1,340	849	808	913
Total	4,134	3,063	3,051	3,032
Temperature (F) (95%)				
Des Plaines	82.8	88.9	86.9	85.5
Kankakee	76.8	85.6	81.0	77.0
Flow Wgt Av	80.9	88.0	85.3	82.9
Discharge Temp (F)				
95%	89.2	91.8	90.7	88.8
Delta	8.3	3.8	5.4	5.9

Table B-6. River Flow and Water Temperature Conditions During Extremely Warm Event, 6-8 July 2012.

River Flow

Date	Flow (cfs)[1]			Percentiles[2]	
	DesPlains	Kankakee	Total	DesPlains	Kankakee
6-Jul	2,170	1,000	3,270	4.6	19.8
7-Jul	1,910	910	2,820	2.0	18.5
8-Jul	1,610	770	2,380	1.0	15.3

Water Temperature[3]

Date	Temperature (F)		Percentiles[4]	
	Min	Max	Min	Max
6-Jul	90.0	91.7	96	97
7-Jul	91.0	93.9	96.5	99
8-Jul	89.5	91.7	95	97

1. Flow percentiles relative to 2005-2013 historical data
2. DNS design flow = 2,265 cfs
3. Intake temperatures used as proxy for upstream historical ambient water temperature.
4. Temperature percentiles relative to 2003-2014 DNS intake temperatures.

Table B-7. Cross-Sectional Temperature Distribution at Nine Transects in the Illinois River for Typical and Typical High Temperature (95 percentile) River Conditions during June.

Typical Temperature Conditions

Percentile (%)	Temperature (F) in Cross-Section at Transect								
	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	79.6	74.5	79.6	79.0	84.3	82.8	81.6	80.6	79.7
Min	79.3	73.8	73.8	74.4	76.6	77.4	77.9	78.3	78.6
90	79.6	74.4	79.4	78.9	81.8	81.6	80.7	80.3	79.5
75	79.6	74.3	79.3	78.6	78.8	79.4	79.6	79.8	79.4
50	79.4	74.0	78.6	78.4	78.5	78.6	78.7	79.0	79.2
25	79.3	73.9	74.2	76.7	77.8	78.2	78.4	78.7	79.1
10	79.3	73.8	73.9	74.5	77.5	77.7	78.1	78.5	78.9

High (95%) Temperature Conditions

Percentile (%)	Temperature (F) in Cross-Section at Transect								
	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	82.5	77.7	82.4	82.6	88.1	87.2	86.7	86.5	86.0
Min	82.2	76.1	76.8	82.1	82.9	83.8	84.4	85.0	85.5
90	82.5	76.8	82.4	82.3	87.5	86.8	86.5	86.2	85.9
75	82.4	76.7	82.3	82.2	86.8	86.5	86.2	86.0	85.8
50	82.3	76.4	82.2	82.1	85.7	85.8	85.8	85.7	85.7
25	82.2	76.2	81.5	82.1	84.1	85.0	85.2	85.6	85.6
10	82.2	76.1	78.7	82.1	83.5	84.5	84.9	85.3	85.6

Note: Temperature at cross-sectional area percentile

June River Conditions

Source	Average		Hign (95%)	
	Temp (F)	Flow (cfs)	Temp (F)	Flow (cfs)
Des Plaines River	79.9	4,350	82.8	2,794
Kankakee River	74.5	5,370	76.8	1,340
Dresden Discharge	85.7	2,265	89.2	2,265

Table B-8. Cross-Sectional Temperature Distribution at Nine Transects in the Illinois River for Typical and Typical High Temperature (95 percentile) River Conditions during July.

Typical Temperature Conditions

Percentile (%)	Temperature (F) in Cross-Section at Transect								
	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	82.6	76.1	82.6	81.9	86.6	85.7	85.2	84.6	84.0
Min	82.3	75.4	75.6	81.5	81.7	81.9	82.2	82.7	83.3
90	82.6	76.0	82.5	81.8	85.9	85.1	84.7	84.3	84.0
75	82.5	75.9	82.3	81.7	84.2	84.4	84.3	84.1	83.9
50	82.4	75.7	82.0	81.7	82.6	83.6	83.8	83.9	83.8
25	82.3	75.5	79.2	81.6	82.0	82.7	83.1	83.4	83.7
10	82.3	75.4	76.2	81.6	81.8	82.3	82.6	83.1	83.5

High (95%) Temperature Conditions

Percentile (%)	Temperature (F) in Cross-Section at Transect								
	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	88.5	87.6	88.5	90.0	91.3	91.0	90.9	90.8	90.6
Min	88.3	84.9	87.3	88.5	89.5	90.1	90.3	90.5	90.5
90	88.5	86.2	88.5	89.4	91.1	90.9	90.8	90.7	90.6
75	88.5	85.7	88.5	88.9	90.9	90.8	90.7	90.7	90.6
50	88.4	85.3	88.4	88.6	90.6	90.6	90.6	90.6	90.6
25	88.4	85.1	88.4	88.5	90.2	90.5	90.5	90.5	90.5
10	88.3	84.9	88.3	88.5	89.8	90.3	90.4	90.5	90.5

Note: Temperature at cross-sectional area percentile

July River Conditions

	Average		Hign (95%)	
Source	Temp (F)	Flow (cfs)	Temp (F)	Flow (cfs)
Des Plaines River	82.9	3,870	88.9	2,214
Kankakee River	76.1	2,370	85.6	849
Dresden Discharge	87.4	2,265	91.8	2,265

Table B-9. Cross-Sectional Temperature Distribution at Nine Transects in the Illinois River for Typical and Typical High Temperature (95 percentile) River Conditions during August.

Typical Temperature Conditions

Percentile (%)	Temperature (F) in Cross-Section at Transect								
	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	82.8	77.5	82.8	82.7	86.4	85.7	85.3	84.8	84.3
Min	82.5	76.7	77.7	82.4	82.5	82.6	82.9	83.2	83.7
90	82.8	77.3	82.7	82.6	85.8	85.3	84.9	84.5	84.3
75	82.8	77.2	82.6	82.5	84.5	84.7	84.6	84.4	84.2
50	82.6	77.0	82.5	82.5	83.0	83.9	84.1	84.2	84.1
25	82.5	76.8	82.0	82.5	82.6	83.2	83.5	83.8	84.1
10	82.5	76.7	79.5	82.5	82.5	82.9	83.2	83.5	83.9

High (95%) Temperature Conditions

Percentile (%)	Temperature (F) in Cross-Section at Transect								
	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	86.5	86.1	86.5	88.4	90.0	89.6	89.4	89.4	89.1
Min	86.3	80.3	82.0	86.2	87.5	88.3	88.6	88.7	88.7
90	86.5	84.9	86.5	87.6	89.8	89.5	89.4	89.2	89.0
75	86.5	83.1	86.4	86.9	89.5	89.4	89.3	89.1	89.0
50	86.4	80.9	86.4	86.5	89.1	89.1	89.1	89.0	89.0
25	86.4	80.6	86.2	86.4	88.5	88.8	88.9	88.9	88.9
10	86.3	80.4	84.9	86.3	88.0	88.6	88.8	88.9	88.8

Note: Temperature at cross-sectional area percentile

August River Conditions

Source	Average		Hign (95%)	
	Temp (F)	Flow (cfs)	Temp (F)	Flow (cfs)
Des Plaines River	83.1	4,801	86.9	2,243
Kankakee River	77.4	1,549	81.0	808
Dresden Discharge	87.0	2,265	90.7	2,265

Table B-10. Cross-Sectional Temperature Distribution at Nine Transects in the Illinois River for Typical and Typical High Temperature (95 percentile) River Conditions during September.

Typical Temperature Conditions

Percentile (%)	Temperature (F) in Cross-Section at Transect								
	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	79.8	78.0	79.8	79.5	82.9	82.3	81.9	81.5	81.1
Min	79.5	68.2	69.2	78.9	79.0	79.3	79.7	80.2	80.6
90	79.8	73.2	79.7	79.3	82.5	81.9	81.5	81.3	81.0
75	79.7	70.1	79.5	79.1	81.4	81.4	81.3	81.1	81.0
50	79.6	68.6	79.1	79.0	80.2	80.9	80.9	81.0	80.9
25	79.5	68.4	77.8	78.9	79.5	80.1	80.4	80.7	80.9
10	79.5	68.2	72.3	78.9	79.2	79.8	80.1	80.4	80.8

High (95%) Temperature Conditions

Percentile (%)	Temperature (F) in Cross-Section at Transect								
	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	85.1	84.7	85.1	86.6	88.1	87.8	87.6	87.6	87.2
Min	84.9	76.3	77.3	84.4	85.8	86.5	86.8	86.9	86.9
90	85.1	83.4	85.0	85.8	88.0	87.7	87.6	87.4	87.2
75	85.1	80.6	84.9	85.1	87.7	87.6	87.4	87.3	87.2
50	85.0	77.0	84.5	84.8	87.3	87.3	87.2	87.2	87.2
25	85.0	76.6	83.8	84.7	86.8	87.1	87.1	87.1	87.1
10	85.0	76.4	80.8	84.6	86.2	86.8	87.0	87.1	87.0

Note: Temperature at cross-sectional area percentile

September River Conditions

Source	Average		Hign (95%)	
	Temp (F)	Flow (cfs)	Temp (F)	Flow (cfs)
Des Plaines River	80.1	4,026	85.5	2,119
Kankakee River	68.9	1,340	77.0	913
Dresden Discharge	83.5	2,265	88.8	2,265

Table B-11. Bottom Temperature Distribution Upstream and Downstream of the DNS Discharge for Typical and Typical High (95%) River Conditions, June to September

June River Conditions

Percentile	Bottom Temperature (F)			
	Typical		High (95%)	
(%)	Upstr	Dstr	Upstr	Dstr
Max	79.8	85.7	82.7	89.2
Min	73.8	74.4	76.1	80.9
90	79.6	79.4	82.4	86.2
75	79.3	79.1	82.3	85.7
50	76.5	78.6	82.1	85.3
25	74.2	78.2	79.2	84.1
10	73.8	77.4	76.2	82.5

July River Conditions

Percentile	Bottom Temperature (F)			
	Typical		High (95%)	
(%)	Upstr	Dstr	Upstr	Dstr
Max	82.8	87.4	89.6	91.8
Min	75.4	80.8	84.9	87.8
90	82.6	84.1	88.5	90.7
75	82.3	83.7	88.5	90.6
50	81.2	83.1	88.4	90.5
25	76.2	82.1	87.8	90.2
10	75.4	81.7	85.0	89.2

August River Conditions

Percentile	Bottom Temperature (F)			
	Typical		High (95%)	
(%)	Upstr	Dstr	Upstr	Dstr
Max	83.0	87.0	87.8	90.7
Min	76.7	82.4	80.3	84.3
90	82.8	84.3	86.5	89.2
75	82.5	84.1	86.4	89.0
50	82.4	83.6	86.3	88.9
25	78.9	82.7	84.2	88.4
10	76.8	82.5	80.4	87.1

September River Conditions

Percentile	Bottom Temperature (F)			
	Typical		High (95%)	
(%)	Upstr	Dstr	Upstr	Dstr
Max	80.0	83.5	86.0	88.8
Min	68.2	77.2	76.3	82.5
90	79.8	81.2	85.1	87.4
75	79.5	80.9	85.0	87.2
50	78.9	80.5	84.5	87.1
25	75.1	79.5	82.4	86.7
10	68.3	79.0	76.4	85.4

Table B-12. Percent of Cross-section Predicted at Less than Modeled Temperatures at 4 Transects Upstream and 5 Transects Downstream of the DNS Discharge During Peak of Heat Wave on 7-8 July 2012 (Shaded Cells Indicate Portions of Cross-section with Temperatures equal to or above 93.0°F)

Percent of X-Section	Upstream of DNS Discharge				Downstream of DNS Discharge				
	Temperature (°F) at Percent of Cross-Section								
7-7 1200	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	92.07	92.44	91.47	92.48	93.20	93.02	92.91	92.75	92.53
Min	90.50	90.41	90.59	90.36	91.72	92.10	92.16	92.07	91.99
95	91.99	92.25	91.40	92.17	93.15	92.95	92.84	92.57	92.41
90	91.89	92.03	91.35	91.99	93.09	92.91	92.78	92.50	92.34
75	91.71	91.64	91.11	91.58	92.95	92.75	92.61	92.39	92.26
50	91.49	91.02	90.84	91.20	92.73	92.55	92.43	92.28	92.17
25	91.26	90.68	90.68	90.90	92.38	92.39	92.30	92.18	92.12
10	91.10	90.43	90.61	90.68	91.98	92.26	92.24	92.16	92.07
5	91.06	90.41	90.61	90.52	91.86	92.20	92.21	92.12	92.05
7-7 1400	**DP-1700**	**KP-1800**	**IL-1000**	**IL-200**	**IL125**	**IL275**	**IL475**	**IL720**	**IL1000**
Max	93.02	93.54	92.28	92.88	93.67	93.45	93.38	93.33	92.89
Min	91.65	90.43	90.59	91.04	92.10	92.55	92.61	92.50	92.32
95	92.92	93.34	92.17	92.62	93.63	93.42	93.31	93.09	92.77
90	92.85	93.14	92.07	92.40	93.59	93.38	93.24	93.01	92.73
75	92.68	92.44	91.78	92.03	93.45	93.24	93.07	92.86	92.66
50	92.44	91.39	91.31	91.65	93.22	93.00	92.89	92.73	92.59
25	92.10	90.88	90.88	91.36	92.87	92.86	92.77	92.63	92.52
10	91.91	90.53	90.72	91.20	92.41	92.73	92.70	92.58	92.42
5	91.86	90.47	90.64	91.18	92.27	92.64	92.66	92.54	92.37
7-7 1600	**DP-1700**	**KP-1800**	**IL-1000**	**IL-200**	**IL125**	**IL275**	**IL475**	**IL720**	**IL1000**
Max	93.42	93.87	92.73	92.62	93.94	93.69	93.58	93.49	93.07
Min	92.05	90.81	90.72	91.54	92.89	93.13	93.07	92.82	92.55
95	93.36	93.75	92.60	92.52	93.89	93.63	93.54	93.36	93.03
90	93.33	93.65	92.46	92.35	93.85	93.60	93.51	93.33	93.00
75	93.22	93.17	92.14	92.23	93.62	93.51	93.43	93.22	92.97
50	92.93	92.69	91.59	92.05	93.34	93.38	93.30	93.09	92.91
25	92.71	92.13	91.11	91.80	93.24	93.27	93.16	93.02	92.80
10	92.38	91.65	90.88	91.74	93.08	93.20	93.13	92.91	92.62
5	92.23	91.31	90.82	91.69	93.00	93.18	93.11	92.87	92.59

Table B-12 (Continued)

Percent of X-Section	Upstream of DNS Discharge				Downstream of DNS Discharge				
	Temperature (°F) at Percent of Cross-Section								
7-7 1800	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	93.47	93.87	92.89	92.62	93.31	93.36	93.42	93.38	93.25
Min	91.53	90.82	90.95	91.27	92.68	92.77	93.00	92.89	92.34
95	93.43	93.61	92.77	92.56	93.24	93.36	93.40	93.38	93.24
90	93.39	93.52	92.66	92.50	93.16	93.33	93.38	93.36	93.20
75	93.31	93.29	92.38	92.39	93.07	93.29	93.38	93.34	93.15
50	93.14	92.94	91.76	92.23	92.98	93.24	93.36	93.31	93.02
25	92.89	92.51	91.31	91.87	92.91	93.18	93.31	93.22	92.89
10	92.53	92.39	91.11	91.60	92.86	93.06	93.22	93.10	92.69
5	92.35	91.72	91.05	91.53	92.81	92.98	93.16	93.03	92.64
7-7 2000	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	93.22	93.43	92.71	92.44	92.77	92.95	93.13	93.25	93.20
Min	89.65	89.38	89.92	90.57	92.19	91.92	92.25	92.37	91.17
95	93.19	93.32	92.61	92.34	92.73	92.91	93.08	93.20	93.17
90	93.16	93.22	92.53	92.31	92.71	92.89	93.02	93.16	93.13
75	93.11	93.00	92.31	92.26	92.68	92.84	92.98	93.13	93.00
50	93.06	92.76	91.80	92.17	92.61	92.79	92.88	93.04	92.82
25	92.85	91.99	91.40	91.71	92.53	92.68	92.74	92.88	92.64
10	92.38	91.73	91.20	91.18	92.46	92.52	92.57	92.68	92.48
5	91.63	90.77	91.06	91.08	92.37	92.44	92.50	92.59	92.34
7-7 2200	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	92.88	92.82	92.52	92.03	92.37	92.48	92.61	92.79	92.79
Min	86.92	88.36	88.84	89.56	91.53	91.42	91.71	91.62	90.19
95	92.84	92.79	92.44	92.00	92.32	92.43	92.56	92.73	92.71
90	92.78	92.66	92.35	91.96	92.29	92.41	92.53	92.66	92.66
75	92.66	92.43	92.17	91.90	92.14	92.37	92.49	92.61	92.55
50	92.55	91.63	91.74	91.84	92.07	92.29	92.38	92.48	92.43
25	92.16	90.90	91.40	91.49	92.01	92.14	92.18	92.28	92.16
10	91.11	90.74	91.15	90.48	91.92	91.99	92.02	92.07	91.98
5	90.58	89.94	90.77	90.32	91.87	91.92	91.94	91.96	91.79
7-8 0000	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	92.39	92.28	92.61	91.72	91.83	91.90	92.08	92.26	92.26
Min	85.42	87.12	88.65	88.70	91.15	91.18	91.26	91.24	90.09
95	92.31	92.11	92.48	91.69	91.78	91.85	92.05	92.22	92.24
90	92.27	91.99	92.42	91.63	91.72	91.83	92.00	92.17	92.21
75	92.17	91.63	92.17	91.59	91.54	91.78	91.95	92.12	92.14
50	92.04	90.53	91.90	91.53	91.44	91.71	91.83	92.01	92.01
25	91.44	90.12	91.49	91.20	91.35	91.56	91.69	91.85	91.81
10	90.26	89.83	91.23	89.83	91.28	91.42	91.53	91.65	91.52
5	89.93	89.11	90.82	89.62	91.24	91.35	91.45	91.54	91.29

Table B-13. Estimated Avoidance Temperatures at Selected Ambient/Acclimation Water Temperatures for DNS RIS for Which Avoidance Test Data are Available.

	Avoidance Temperature (°F)						
Acclimation Temperature (°F)	80.0	86.0	87.0	88.0	91.4	93.2	95.0
Gizzard shad	90.5	93.1	93.5	93.9	95.4	96.1	97
Channel catfish	95	95.6	96	96.4	97.9	98.6	99.4
Largemouth bass	92.5	95.5	95.9	96.3	98.1	98.9	99.8
Smallmouth bass	91.5	93	93.2	93.4	94.3	94.6	95
Bluegill	90.7	94.1	94.8	95.2	97.2	98.2	99.3

Table B-14. Temperature Range for Optimum Growth and Upper and Lower Zero Growth Temperatures for DNS RIS.

	Upper Zero-Growth		Otpimum Growth Range		Lower Zero-Growth	
	°C	°F	°C	°F	°C	°F
Gizzard shad	34	93.2	29-32	84.2-89.6	--	--
Emerald shiner	34	93.2	24-31	75.2-87.8	7	44.6
Common Carp	35	95	14.5-32	58.1-89.6	10-13.8	50.0-56.8
Golden redhorse	--	--	--	--	--	--
White sucker	29.6	85.3	16-27	60.8-80.6	12	53.6
Channel catfish	34.7	94.5	20-32	68.0-89.6	10	50
Largemouth bass	36	96.8	23-31	73.4-87.8	10	50
Smallmouth bass	34	93.2	16-31	60.8-87.8	--	
Bluegill	32.8	91	23-31	73.4-87.8	13	55.4
Black crappie	30.5	86.9	13-25	55.4-77.0	11	51.8
Logperch	--	--	--	--	--	--
Freshwater drum	32.6	90.7	22-31	71.6-87.8	10	50

APPENDIX B

Information Supporting Representative Important Species Rationale: Biothermal Assessment – Predictive Demonstration

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1.0 ANALYTICAL METHODOLOGY – COMPARISON WITH PRIOR 316(A) ASSESSMENT

Commonwealth Edison (Edison) filed a §316(a) Demonstration (Edison 1980) with the Illinois Pollution Control Board to support its request for alternative thermal limits (ATLs) for the DNS. That Demonstration used a retrospective analysis of aquatic community monitoring data collected during DNS operations in indirect open-cycle mode, between 15 June and 30 September. These biological data were used to demonstrate that the existing thermal limitation requiring closed cycle cooling year-round was "more stringent than necessary to assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife." The Demonstration showed no prior appreciable harm to the aquatic community resulted from indirect open cycle operations (between 15 June and 30 September) that took place between September 1971 and October 1974. The DNS Simulation Model provided a qualitative analysis of thermal conditions in the Dresden Pool under two operating scenarios (closed cycle year round and indirect open cycle 15 June through 30 September).

The present Demonstration, conducted to consider whether the existing ATLs continue to satisfy the §316(a) criteria, utilizes two technical approaches to evaluate the effects of Station operations on water temperature, aquatic habitat utilization, and the condition of the aquatic community. The first approach (Appendix C), similar to the 1980 Demonstration, presents a retrospective analysis of the balanced indigenous community (BIC) to demonstrate the absence of prior appreciable harm to this community, relying on an expanded database of nearly 20 years of additional monitoring of the aquatic community collected subsequent to the 1980 Demonstration. This extensive database, collected under operating conditions similar to the proposed ATLs, provides a rigorous test for demonstrating the absence of prior appreciable harm. The second approach, not included in the 1980 Demonstration, uses quantitative hydrothermal modeling to predict thermal conditions under various operating and ambient flow conditions, integrated with metrics of thermal requirements and tolerance limits identified in scientific literature for selected aquatic species representative of the BIC. This prospective analysis is used to predict the response of the aquatic community to the effects of the DNS thermal discharge plume on the biological community and receiving water body. For this Demonstration, a three-dimensional mathematical model (MIKE 3) that was used to estimate ambient temperatures under various river flow conditions and DNS thermal plume conditions under 3 representative flow and temperature scenarios (Appendix D), including conditions representative of the proposed ATLs. The model was calibrated and validated using a recent bathymetric survey and three field surveys of water temperature and velocity conducted under various river flow and weather conditions during 2013-2014. The calibrated model was used to estimate water temperature within each model cell under various ambient flow and station operating scenarios to estimate dilution and dispersion of elevated thermal plume temperatures. Model estimated cross section and bottom water temperatures are compared to biothermal metrics to estimate the extent of otherwise available aquatic habitat that would be excluded or would be at less than optimum conditions for selected life history functions (e.g., spawning, growth, survival) of representative important species (RIS) due to water temperature.

2.0 ENVIRONMENTAL CONDITIONS STUDIED AND HYDRODYNAMIC MODEL INPUTS

2.1 Hydrodynamic Model

Thermal modeling utilized DHI's MIKE3 model (DHI, 2012), which provides a state-of-art, three-dimensional modeling framework. The model domain included portions of both the Des Plaines and Kankakee Rivers upstream of their confluence and extended downstream to the Dresden Island Lock and Dam. Bathymetric mapping, three-dimensional field surveys of water temperature and flow, and meteorological conditions were used as inputs to calibrate and validate the MIKE3 model used to predict the configuration and temperature distribution of the DNS thermal plume under selected operating, river flow, and weather conditions. The model grid (Appendix D, Figure D-12) is composed of 1,530 rectangular or triangular cells divided into 12 vertical layers. The upper three layers were confined to a maximum 1.0 m depth. Below 1.0 m, layer thickness increased from 0.5 m to 1.0 m in the deepest layer. These additional layers were adjusted as necessary to extend to the river bottom. The shape and horizontal dimensions of the cells vary depending on complexity of mixing conditions in that portion of the model grid; the finest model grid was constructed in the vicinity of the thermal plume to increase the model resolution in the primary area of interest for the biothermal analysis.

2.2 Station Operating and Environmental Conditions Evaluated

This analysis examines three scenarios of flow and water temperature in conjunction with operation of DNS at full load using indirect open cycle cooling between 15 June and 30 September. These scenarios include:

1. Typical flow (50th percentile) and water temperature (60th percentile);

2. Typical high temperature conditions (5th percentile flow and 95th percentile water temperature); and

3. Extreme meteorologic/high temperature conditions similar to those that occurred during the exceptional heat wave in early July 2012.

More detailed discussion of flow and ambient river temperature conditions for these scenarios is presented in Section 2.5.1.

2.3 Biothermal Metrics Evaluated

The prospective analysis of potential thermal effects on aquatic biota integrates sophisticated hydrothermal modeling (Appendix D) of the dynamics of the thermal plume under selected DNS operations and river flow conditions with critical thermal response metrics for the selected RIS (Appendix B, Section 3). Data from scientific literature are used to characterize the thermal sensitivity of each of the RIS and critical life stages that could potentially utilize the area influenced by the DNS thermal discharge plume. The potential effects of the DNS thermal discharge on RIS were evaluated for five categories of thermal effects as recommended in the Draft *Interagency Technical Guidance Manual* (USEPA and NRC 1977) (Interagency Guidance Manual):

1. Temperature requirements for survival of juveniles and adults.

2. Avoidance temperature.

3. Temperature requirements for early development.

4. Optimum temperature for performance and growth.

5. Thermal shock tolerance.

This information was then compared to the spatial and temporal characteristics of, and thermal gradients in the thermal plume to predict the potential effects of the plume on the RIS under each assessment scenario. The primary biothermal metrics used in this analysis were:

- Spawning temperature range
- Optimum temperature for growth
- Temperature avoidance
- Chronic thermal mortality (prolonged exposure).

2.3.1 Spawning

For many aquatic species the maturation of gonadal tissue, the onset of spawning migration and spawning, and completion of spawning are closely tied to water temperature (among other environmental and physiological triggers). Most records of spawning temperatures are based on field observation of spawning runs and physiological condition of gonads at various locations within the geographic range of the species. When adequate thermal range data have been documented, a polygon was plotted on the thermal effects figure that indicates the reported temperature range for spawning based on the seasonal period during which spawning typically occurs in the vicinity of DNS.

2.3.2 Growth

Water temperature plays a significant role in the growth of aquatic species, affecting metabolic rates and the energy expended seeking and capturing food material. The optimum temperature range for growth occurs when there is a balance between the energy expended capturing food, energy for maintenance, and for growth. Most freshwater fish species exhibit seasonal patterns in growth; for most temperate species growth is minimal during the winter and peaks between spring and fall, while boreal species often exhibit minimal growth during peak summer temperatures or move to deeper, cooler waters. Much available data for temperature and growth is for smaller species or early life stages that are more readily reared under laboratory or hatchery conditions. The relationship between temperature and growth varies. During some periods of the year, portions of the thermal plume may provide optimal temperatures for growth that are not present with available ambient temperatures (e.g., spring and fall for many species). Outside of the optimum temperature range, growth can continue to occur at a lower rate. Aquatic organisms typically prefer water temperatures that are within the optimum range for growth; preferred temperatures can be used as a surrogate for the optimum range of growth and performance.

2.3.3 Temperature Avoidance

Many species of fish and invertebrates actively avoid potentially stressful temperatures, both high and low, depending on their acclimation conditions. Although this ability minimizes the potential exposure of organisms to temperatures that could result in mortality, avoidance of elevated temperatures may preclude access to critical habitat located within a thermal discharge plume. When avoided temperatures exist over a large enough cross-section of the receiving water body, passage of organisms upstream or downstream of the discharge location may be inhibited. As with many other thermal effects parameters, the water temperatures avoided by an organism are typically dependent on an organism's acclimation history.

2.3.4 Thermal Mortality

Mortality associated with temperature has been measured using several metrics (e.g., Upper Incipient Lethal temperature [UILT], Critical Thermal Maximum [CTM], TL50, TL95, LD 50, and LD100). These data can also be qualified by rate of temperature increase and by the exposure duration ranging from seconds (thermal shock, typical of rapid entrainment into higher temperature portion of the thermal mixing zone) to days (typical of the experience of organisms exposed to temperatures in the more diluted portion of the plume).

Exposure to rapid short-term changes in water temperature can cause mortality to organisms passing through, or resident within, portions of the thermal discharge plume. Thermal shock can occur in conjunction with a rapid decrease in water temperature, cold shock, or a rapid increase in water temperature associated with plume entrainment. The attraction of some species to thermal discharge plumes during winter and early spring when ambient temperatures are low has been well documented. During a station shutdown when the heat source is suddenly discontinued, organisms acclimated to warm plume temperatures can be stressed to the point of mortality when they are suddenly returned to colder ambient temperatures, depending on the rate and magnitude of the temperature decrease. In contrast, planktonic organisms entrained into the

thermal plume near the discharge point with ambient dilution water can experience rapid short-term increases in temperature that may be capable of causing mortality. Similar to general thermal mortality discussed above, thermal shock has been measured using various metrics including the TL95, TL50, and LD50 from high temperature, short exposure tests, and CTM.

CTM is estimated with tests where organisms are subjected to a controlled rate of temperature increase over time (e.g., 0.5 °C/min [0.9°F/min]) until loss of equilibrium; resulting CTM metrics can be difficult to compare to real-world conditions due to the variation in test methods (e.g., temperature step, rate of increase, observed test end point). The tolerance limit for 95 percent of test organisms (TL95) measures the temperature at which 95 percent of the organisms survive for the exposure period; that is, negligible mortality associated with temperature. In contrast, lethal dose to 50 percent of the test organisms (LD50) measures the temperature causing mortality to 50 percent of the test organisms. Thus a TL50 and LD50 would be equivalent and the TL95 would be comparable to an LD5.

Information for metrics in each of these categories was identified through review of scientific literature including peer-reviewed literature, compilation reviews, and utility industry project reports for studies conducted to support various §316(a) Demonstrations. Other measures of organism response to temperature (including preference, thermal shock, cold shock) were also reviewed as the relative relationship of these various metrics provides a level of quality assurance for evaluating the reliability of individual values reported in the scientific literature and project laboratory or field study reports.

As water temperature increases, organisms progressively exhibit a range of integrated physiological and behavioral responses including avoidance, impaired growth and reduced feeding, impaired swimming ability, loss of equilibrium, and finally mortality. Genetics and acclimation history affect the physiological response of species and individual organisms to abiotic factors, such as temperature, in their environment. Laboratory studies are able to control a range of variables that can affect an organism's physiology in order to isolate and assess the specific influence of temperature under those specific conditions. In contrast, organism in their natural environment rarely experiences constant abiotic conditions, but are adapted to considerable variability. Because most of these physiological and behavioral responses are affected by acclimation temperature, it is important that the results from laboratory studies of thermal effects are evaluated relative to acclimation history. It is also important to understand, that while potentially lethal temperatures may exist in a waterbody or near a thermal discharge, it is unusual to observe mortality related to elevated water temperatures because of the ability of many organisms to avoid potentially lethal temperatures.

2.4 Representative Important Species (RIS) Evaluated

2.4.1 Selection of RIS

Candidate RIS were selected from a checklist of native fish species collected during surveys of Dresden Pool near DNS and downstream of the Dresden Island Lock and Dam. Surveys of the Dresden Pool were conducted during 17 years between 1994 and 2014 and surveys downstream of Dresden Island Lock and Dam were conducted during 15 years between 1994 and 2014

(Appendix G). Electrofishing and seining between 1994 and 2014 documented the presence of 96 fish species in the vicinity of DNS (Table B-1). The catch included 20 species that dominated the abundance or biomass of the fish community over much of this period (Tables B-2 and B-3). These 20 species were collected in all four river survey segments (Des Plaines River, Kankakee River, and Illinois River upstream and downstream of the Dresden Island Lock and Dam) and during 18 of 19 survey years in at least one segment between 1991 and 2013 (Table B-2). Seventy-one species were collected in at least three of the survey river segments while 19 species were collected in only one river survey segment. Twenty-six species were collected during only one or two annual surveys (Table B-2).

To adequately assess the potential effects of DNS's thermal discharge plume and operating conditions on all of these species would be extremely difficult and, in the case of many species with minimal available data on their thermal requirements, nearly impossible. Recognizing this, the Interagency Guidance Manual proposes an approach for predictive demonstrations (Type II[1]) that relies on selection and assessment of effects on a subset of RIS. The rationale for this approach is that the species selected for detailed analysis of potential thermal effects are representative of key species or groups of species that comprise the dynamic, complex aquatic community affected by the thermal discharge, that is, a BIC. Some species are selected because they fill critical roles seasonally or during occasional years. Interagency Guidance Manual list six categories of fish that may be considered RIS:

1. Commercially or recreationally important species;
2. Threatened or endangered species;
3. Species critical to ecosystem structure and function of the receiving water body;
4. Species potentially capable of becoming a localized nuisance;
5. Species necessary in the food chain; and
6. Species representative of critical thermal requirements, but which themselves may not be important.

Factors considered in the selection of RIS for the DNS prospective biothermal analysis include:

- Numerical dominance or prominence in the BIC (see Appendix C);
- Their role in energy transfer through the aquatic food chain as important forage or predator species;

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[1] The Interagency Guidance Manual also discusses two other predictive demonstrations Type 111 Low Potential Impact and Type 111 Regular (Biological, Engineering, and Other Data) and a Non-Predictive Demonstrations - Type I (Absence of Prior Appreciable Harm). RIS discussions are not required in the Type 1 or in the Regular Type 111 and TYPE 111 Low Potential Impact unless a particular biotic category has a high potential impact

- Important links between primary producers, primary consumers, and secondary consumers;

- Similarity of their food, habitat, and life history requirements to groups of other species utilizing aquatic habitat in the vicinity of the DNS thermal plume;

- Support of important commercial or recreational fisheries;

- Thermally sensitive species;

- Species of special interest or concern (e.g., rare, threatened, or endangered species);

- Non-native and potential nuisance species; and

- Species with unique or critical habitat or life history stages in the vicinity of the thermal discharge.

Only fish species were selected as RIS for the DNS thermal evaluation because fish represent the top of the food chain, are important to the public because of their recreational and/or commercial value, and because their overall wellbeing shows that the lower trophic levels are supporting the trophic levels occupied by the RIS. Lower trophic levels (e.g., phytoplankton, zooplankton, periphyton, and benthic macroinvertebrates) were not selected as RIS because of a general lack of thermal endpoint data and historical §316(a) studies have shown only localized thermal effects on lower trophic levels that have not resulted in adverse harm (Duke/Fluor Daniel 1992). The potential effects of thermal discharges from DNS on these lower trophic levels are addressed as part of the retrospective assessment (Appendix C of this Demonstration) demonstrating no prior appreciable harm to the BIC.

Twelve fish species were selected as RIS (Table B-4) for the DNS thermal evaluation. Each of these species represents one or more of the categories listed above from the Interagency Guidance Manual. In order to be a candidate, species had to have published thermal tolerance endpoints in order to conduct the required thermal evaluation. Based on these criteria, the following 12 species were selected as RIS:

- Gizzard shad
- Common carp
- Golden redhorse
- White sucker
- Channel catfish
- Emerald shiner
- Largemouth bass
- Smallmouth bass
- Bluegill
- Black crappie
- Logperch
- Freshwater drum

Except for common carp, hybrids and exotic species were excluded. Forty-two species considered incidental (I) and occasional (O) constituents of the community were excluded from the RIS list; these species were collected in only 1 study reach and/or during less than 5 sampling years (shaded in Table B-4). When several congeneric species were common in the vicinity of DNS, generally only one was selected as an RIS. For example, of the abundant minnows collected near DNS (emerald shiner, spotfin shiner, bluntnose minnow, and bullhead minnow), only emerald shiner was chosen as it has slightly lower thermal endpoints than the other three species. One exception, both congeneric smallmouth bass and largemouth bass were selected because both are the target in recreational fisheries.

Federally threatened and endangered (T&E) fish species have not been collected in Dresden Pool or adjacent study areas in the upstream Des Plaines and Kankakee Rivers, or downstream of Dresden Island Lock and Dam. Five state-listed fish species were collected. The state-listed threatened river redhorse (*Moxostoma carinatum*) and endangered greater redhorse (*M. valenciennesi*) were collected infrequently and in low numbers upstream and downstream of the Dresden Island Lock and Dam. The pallid shiner (*Hybopsis amnis*), also state-endangered in Illinois, was first collected from the DNS study area in 2001 and has been collected each year since. It was also collected upstream and downstream of the Dam but primarily upstream in the Kankakee River. The state-endangered western sand darter (*Ammocrypta clara*) was collected infrequently in low numbers and downstream of the Dresden Island Lock and Dam. The state-threatened banded killifish (*Fundulus diaphanus*) was first collected as part of the DNS monitoring program in 2013 and were collected again in 2014.

The selected RIS include species that feed primarily on one or several of the following: detritus, phytoplankton, zooplankton, crustaceans, mollusks, insect larvae, other invertebrates and benthos, and fish. They include pelagic and demersal species that utilize habitats in channel, pool, run, riffle, or backwater areas. Individual RIS have preferences for a variety of substrate, including hard or soft bottom with mud, muck, and silt, sand, gravel, cobble, and rock; some RIS prefer dense vegetation or structure (e.g., roots, woody debris, and boulders). The selected RIS include species representative of various levels of the food chain including primary consumers, omnivores, forage species, and top predators, and species that are common targets for recreational or commercial fisheries.

In general, species that occur infrequently or in low abundance (I or O in Table B-4) in the vicinity of DNS were excluded from consideration as RIS, except for state or federally listed sensitive species (e.g., pallid shiner, river redhorse, greater redhorse) where thermal data are available or species considered to be thermally sensitive (e.g., white sucker, black crappie). The area in the vicinity of DNS does not provide unusual, unique, or critical habitat that would be necessary to complete important life history functions (Table B-4) for any of the incidental or occasional species that were excluded (Table B-4, shading).

Other dominant and common species not selected as RIS have habitat, feeding, and life history requirements very similar to the selected RIS, which is the rationale for use of RIS to evaluate the effects of the discharge on aquatic biota. The trophic relationships within the aquatic community in the vicinity of DNS for which each of the selected RIS are representative are

summarized below and in Table B-4:

- Gizzard shad – the most common and abundant pelagic species in the vicinity of DNS feeding primarily on invertebrates in mud substrate as well as zooplankton and phytoplankton. Juvenile gizzard shad are an important component of the forage base.

- Common carp – omnivore and scavenger; non-native species that is considered a nuisance species where it occurs in high abundance.

- Golden redhorse – representative of a diversity of 15 species in the sucker family (Catostomidae) collected in the area of DNS including other redhorse species, buffalo, sucker, and carpsucker. Golden redhorse is a surrogate for the state-listed river redhorse and greater redhorse.

- White sucker – considered a thermally sensitive member of the sucker family, although rarely collected in the study area.

- Channel catfish – representative of a variety of catfish species collected in the vicinity of DNS and can be an important recreational target species.

- Emerald shiner – one of the most abundant forage species in the area and is representative of the diversity of shiners and minnows in the aquatic community. Emerald shiner is a surrogate for the state-listed pallid shiner.

- Largemouth bass and smallmouth bass – representative of an array of piscivorous top predators in the vicinity of DNS and important targets of recreational anglers.

- Bluegill – representative of a variety of sunfish species (Centrarchidae) collected near DNS and is an important target for recreational anglers.

- Black crappie – considered a thermally sensitive recreational species also in the Centrarchid family, but relatively uncommon in the vicinity of DNS.

- Logperch – representative of a variety of darter species collected occasionally in the vicinity of DNS.

- Freshwater drum – an important demersal species feeding extensively on mollusks and crawfish that support commercial and recreational fisheries. The species is also an important host species for glochidia, the larval life stage of several freshwater mussel species.

More detailed life history information and thermal requirements relevant to their interaction with the DNS thermal discharge are summarized for each RIS in the following subsections. Sources of the life history information summarized below include Scot and Crossman (1973), Smith (1979), Trautman (1981), Etnier and Starnes (1993), Pflieger (1997), and Page and Burr (2011).

2.4.2 Gizzard shad (*Dorosoma cepedianum*)

Gizzard shad is an important forage species in the aquatic ecosystem near DNS. It is a prolific warmwater species that produces abundant juvenile year classes used as forage by top predators such as largemouth bass. Gizzard shad is typically one of the most abundant species captured during electrofishing and seining surveys of the Des Plaines, Kankakee, and Illinois Rivers. It occurs throughout the state and the Illinois River drainage. This schooling species is most common in large rivers and reservoirs and is often seen in large schools in the upper water column. Gizzard shad is in the simple breeding guild (i.e., broadcast spawning without parental care) producing adhesive eggs that adhere to vegetation and substrate. In the Illinois River and its tributaries, spawning occurs in open water from about late April through June. No gizzard shad eggs were collected during the 2005-2006 ichthyoplankton surveys at DNS.

Ambient water temperatures when the first yolk-sac larvae were observed in the vicinity of DNS during 2005-2006 were between 10°C (50°F) and 15°C (59°F) (EA 2007). Peak densities of yolk-sac larvae occurred from mid-May to mid-June in 2005 and late-May to early July in 2006; water temperatures during these periods were 14°C (57.2°) to 27°C (80.6°F). Post yolk-sac larvae were most abundant during June in 2005 and mid-June to mid-July 2006 at a temperature range of 18°C (64.4°F) to 28°C (82.4°F).

Annual electrofishing catches from 1991 through 2014 near DNS averaged 1,075 gizzard shad (range = 422 to 2,019). It was the most or second most abundant species collected during 19 of the 20 years surveyed (Table B-3). Gizzard shad were among the 10 most abundant species in beach seine sampling during the same period. Annual mean electrofishing catch rates were generally higher in the Kankakee and Illinois Rivers upstream of the Dresden Island Lock and Dam than in the Des Plaines River or downstream of the Dresden Island Lock and Dam. Its average biomass since 2000 has ranked second highest accounting for 15 percent of the mean biomass. Abundance of gizzard shad increased from a seasonal low in spring (prior to 15 June), through summer, and into fall (after 30 September).

2.4.3 Common carp (*Cyprinus carpio*)

Common carp, a non-native, warmwater species introduced to Lake Michigan in the 1800s (Fuller et. al 1999), was collected during all fish survey years in the vicinity of DNS. When abundant, common carp are considered a nuisance species; particularly during spawning season common carp can be responsible for high turbidity levels as they thrash about in shallow weed beds and over silty substrates. Since 2000 common carp has not ranked higher than 12th (average rank, 15) in abundance and except in 2001, fewer than 100 common carp have been collected in all gear annually since 1994 (Table B-3). They are in the Illinois River up and downstream of Dresden Island Lock and Dam and in the Kankakee River carp have generally declined in abundance over the last decade compared to the early 1990s. Although they were not numerically abundant (Table B-3), common carp comprised at least 16 percent of the annual biomass (Appendix C). The disparity between the numerical rank and biomass rank reflects the large average size of common carp routinely collected.

Common carp spawn in shallow weedy areas during spring and early summer; eggs are broadcast over debris and vegetation. Eggs were collected on one sampling date in mid-May 2006 during ichthyoplankton sampling in the vicinity of DNS; no eggs were collected in 2005 (EA 2007). Yolk-sac and post yolk-sac larvae were collected in the Kankakee River and at the DNS cooling water intake and discharge between mid-May and the first week of July during 2005. During 2006 larvae were collected intermittently between early May and late August. During the week prior to collection of the first carp yolk-sac larvae, water temperatures in the Kankakee River upstream of DNS were between 10°C (50°F) and 15°C (59°F). Common carp eggs and larvae accounted for less than one percent of the ichthyoplankton collected in the vicinity of DNS during 2005 and 2006.

2.4.4 Emerald shiner (*Notropis atherinoides*)

Emerald shiner is a native forage species that utilizes nearshore habitats in shallow water. It is most common in open water near the surface and avoids dense vegetation (Trautman1981). Emerald shiner is in the simple breeding guild (i.e., broadcast spawning without parental care). Spawning occurs in open water from about May through June when water temperatures are 22°C (71.6°F) to 24°C (75.2°F) (ESE 1992). Few emerald shiner larvae and early juveniles were identified in samples collected during the 2005-2006 ichthyoplankton survey in the vicinity of DNS (EA 2007). Yolk-sac larvae, post yolk-sac larvae, and early juveniles of the Cyprinid family were collected between mid-May and late August. Water temperatures during the week prior to the first observation of cyprinid yolk-sac larvae were between 15°C (59°F) and 20°C (68°F). Peak larval abundance occurred between early June and early July in both years (EA 2007). Early juveniles were most abundant in early August during 2005 and from early July through mid-August during 2006 (EA 2007).

Mature and immature shiner were collected during all except one year and was the most abundant minnow species collected near DNS (Table B-3). It was generally the first or second most common species collected by beach seine and electrofishing between 1991 and 2014.

2.4.5 Golden redhorse (*Moxostoma erythrurum*)

Golden redhorse is a native riverine species in the sucker family, widely distributed in Illinois that prefers clear rivers and medium-sized streams with gravelly riffles, permanent pools, and moderate currents. Habitat preference, spawning habits, and food preference is similar to many other redhorse sucker species including the state-listed river redhorse. Adults grub in the bottom substrate in riffles and adjacent pools, selectively feeding on insect larvae and other benthic invertebrates. Juveniles feed in backwater areas on algae and micro-crustaceans. Redhorse are a popular sport fish for hook and line anglers.

Golden redhorse typically spawn in riffle habitat during April and May; eggs are dispersed over sand and gravel substrate with no parental care. In larger rivers, adults move into tributaries to spawn as water temperatures increase in the spring. During the 2005-2006 ichthyoplankton survey at DNS, early life stages of golden redhorse were not specifically identified in collections taken in the vicinity of DNS (EA 2007). *Moxostoma* spp. yolk-sac larvae and post yolk-sac larvae were collected in the Kankakee River between mid-May and late June with peak densities

(120-140 organisms per million gallons) in early June. Water temperatures during the week prior to the first observation of *Moxostoma* yolk-sac larvae were between 15°C (59°F) and 20°C (68°F). Early juveniles were collected in June during the 2006 survey. *Moxostoma* spp. was not collected in the vicinity of the Dresden cooling water intake or discharge (EA 2007).

Mature and immature golden redhorse were collected each sampling year from 1991-2014; it was the ninth most abundant species collect by electrofishing and fifteenth collected by beach seine over this period (Table B-3). It is the most abundant of five redhorse species collected near DNS. Its average biomass ranked seventh highest since 2000 accounting for 4 percent of the ten-year mean biomass. Golden redhorse accounted for two to four percent of the annual numerical electrofishing catch between 1991 and 2014 (Table B-3). The beach seine catch per haul for golden redhorse increased steadily between 2000 and 2007 in the Kankakee and Des Plaines Rivers, followed by a sharp decline between 2008 and 2014. Abundance in the Illinois River upstream and downstream of the Dresden Island Lock and Dam remained low in beach seines and demonstrated no trend over this period. The catch per hour for electrofishing was also relatively high, particularly in the Kankakee and Des Plaines Rivers from 2002 to 2008 and declined after 2008.

2.4.6 White sucker (*Catostomus commersonii*)

White sucker is a native, demersal warmwater species, widely distributed in Lake Michigan and throughout Illinois. It prefers sand and coarse substrates in clear creeks and small rivers (Smith 1979), but can be found in habitat with silt and fine sediment. White sucker is not common in the vicinity of DNS, but is included in this thermal assessment because it is considered to be relatively sensitive to increases in summer water temperatures above ambient. Spawning occurs during April and May over gravel substrate in riffles and pools; eggs are broadcast with no parental care and typically hatch in approximately three weeks depending on water temperature. During 2005 ichthyoplankton surveys (EA 2007), white sucker post yolk-sac larvae were collected in the Kankakee River during the second week of June. Yolk-sac and post yolk-sac larvae were collected in the Kankakee River during 2006 between the last week of May and late June. Water temperatures during the week prior to the first observation of white sucker yolk-sac larvae were between 17°C (62.6°F) and 23°C (73.4°F). Post yolk-sac larvae were collected near the DNS cooling water intake once in mid-July 2006; no early life stages of white sucker were collected in the vicinity of the DNS cooling water discharge in either year.

White sucker comprise less than one percent of the overall catch in surveys between 1994 and 2014 and have been collected in four or fewer years over that period in the study reaches of the Illinois, Des Plaines, and Kankakee Rivers (Table B-3). They were only collected in the Kankakee River upstream of DNS in one annual survey. White sucker was not collected between 1993 and 2004 by electrofishing or between 1993 and 2006 by beach seine.

2.4.7 Channel catfish (*Ictalurus punctatus*)

Channel catfish is a common native sport and food fish widely distributed in Illinois. It is usually found in greatest abundance in fast-flowing, medium to large rivers with sand and gravel-substrates, but can tolerate a wide range of habitats that exist near DNS. Adults typically

inhabit deep water in large pools near submerged logs, debris, and other cover. Juvenile catfish feed primarily on small insects; adults are omnivores and scavengers, feeding on fish, crayfish, mollusks, insects, plant material, and other organic material. Channel catfish is in the complex breeding guild. They use natural cavities and undercut banks to lay their eggs. The male builds the nest and remains over the nests to fan the fertilized eggs and guard hatched larvae. As a result of this behavior, eggs and larvae are uncommon in ichthyoplankton surveys. Spawning typically occurs in June and July. A few yolk-sac larvae were collected in the Kankakee River and at DNS cooling water intake and discharge during July in 2005; no post yolk-sac larvae were collected (EA 2007). Water temperatures during the week prior to the first observation of channel catfish ichthyoplankton were between 21°C (69.8°) and 24°C (75.2°F) during 2005. No channel catfish larvae were collected during the 2006 surveys. Early juveniles leave the nest and become more vulnerable to the sampling gear. Juveniles were collected in the Kankakee River and in the vicinity of the DNS cooling water intake and discharge from late June through mid-August during the 2005 and 2006 surveys (EA 2007).

Channel catfish have been collected each year upstream and downstream of Dresden Island Lock and Dam and was the most abundant of six catfish species collected near DNS accounting for 88 percent of the catfish in the Dresden Pool electrofishing catch since 2000 (Table B-3). Its average biomass ranked third highest since 2000 accounting for 12 percent of the 10-year mean biomass. Since 2000, channel catfish have generally been more abundant in the Illinois River downstream of Dresden Island Lock and Dam than upstream or in the Des Plaines or Kankakee Rivers.

2.4.8 Smallmouth bass (*Micropterus dolomieu*)

Smallmouth bass is a popular recreational species widely distributed in much of northern Illinois. It prefers clear streams and rivers with gravel and rocky substrate, moderate to fast currents, and relatively cooler summer conditions than do largemouth bass. They utilize cover and structure in large pools, but will forage for minnows and other fish in shallow water near the shoreline. They are relatively intolerant of turbidity and siltation. Insect larvae and micro-crustaceans are the primary food for young bass; adults feed primarily on crayfish and fish, but also opportunistically consume insects. Spawning occurs in May and June. Males excavate nests in gravel and guard the developing eggs, larvae, and young fry. Nests are typically constructed in sheltered areas near shore with negligible flow. No larvae or early fry were collected in the 2005-2006 ichthyoplankton surveys, a reflection of nesting habitat, nest building and parental protection that minimizes their vulnerability to ichthyoplankton sampling gear.

Numerically smallmouth bass ranged from 3rd to 13th in annual electrofishing surveys between 1994 and 2014, averaging 7th overall. Annual abundance was variable among the study reaches, but was considerably higher in the Des Plaines River between 2003 and 2008 than the other study reaches. Abundance of smallmouth bass was highest in the spring/early summer sampling periods and generally declined through the summer and fall sampling periods. This may reflect the use of deeper, cooler areas as seasonal water temperatures increase through the summer that are deeper than the effective depth of the electroshocking equipment.

2.4.9 Largemouth bass (*Micropterus salmoides*)

Largemouth bass is closely related to smallmouth bass and are also a popular recreational species. It is widely stocked in ponds and lakes to support recreational fishing. It utilizes a wide range of habitat from small streams to large rivers and lakes and is common throughout Illinois. It prefers shallow weedy lakes and river backwaters, the type of habitat preferred by bluegill. Adults feed predominantly on crustaceans and fish and may feed more actively in shallow areas in the evening. Adults prefer deeper habitat with structure such as boulders snags and root wads during daylight hours. They are relatively intolerant of turbidity and siltation. Spawning typically occurs in May and June with nest construction in sand gravel and around vegetation with the male guarding the nest and early life stages similar to smallmouth bass. Largemouth bass larvae or early fry were not collected in the 2005-2006 ichthyoplankton surveys (EA 2007), a reflection of spawning habitat, nest building, and parental protection by this species which minimizes their vulnerability to ichthyoplankton sampling gear.

Largemouth bass were more abundant than smallmouth bass in the DNS study reaches (Table B-3). Between 1994 and 2014 largemouth bass numerically ranked from 2nd to 8th annually and averaged 6th over this period in electrofishing surveys. Abundance in beach seines was relatively low as beach seines are relatively ineffective in habitat frequented by largemouth bass except during spawning. The species exhibited a general trend of increasing abundance in the vicinity of DNS since 2000, particularly in the Des Plaines River and Illinois River upstream of Dresden Island Lock and Dam (Table B-3).

2.4.10 Bluegill (*Lepomis macrochirus*)

Bluegill is a widely distributed native species that is usually most abundant in clear lakes with aquatic vegetation, but can tolerate a wide range of habitats as exists near DNS. Bluegill is widely distributed target for recreational fishing. They are gregarious and occur in small schools. Bluegill feed primarily on aquatic insects, small crustaceans, and small fish; peak feeding activity typically occurs around dawn and dusk. They prefer gravel substrates to build nests, but will utilize most substrates. Nests are constructed in relatively high density in shallow water. Spawning begins in late May and often continues into August. Male bluegill guards eggs and larvae on the nest, but do not guard the young fry as do smallmouth and largemouth bass. Bluegill were not specifically identified in the 2005-2006 ichthyoplankton samples; however, *Lepomis* spp. yolk-sac and post yolk-sac larvae were collected from early June through late August both years (EA 2007). Water temperatures during the week prior to the first observation of *Lepomis* yolk-sac larvae were between 23°C (73.4°F) and 27°C (80.6°F). Early juveniles were also collected from early July through the end of sampling in August (EA 2007).

Bluegill was the most abundant of six sunfish species collected by electrofishing near DNS, accounting for over 50 percent of the sunfish collected between 2000 and 2014 (Table B-3). It ranked 1st to 7th annually in abundance in electrofishing surveys from 1994 -2014 and averaged 2nd overall. It was the 4th in abundance in beach seine collections between 2000 and 2014. Bluegill abundance has generally trended higher since 2000 (Table B-3). Its average biomass ranked ninth since 2000 accounting for 3 percent of the mean biomass over that period.

2.4.11 Black crappie (*Pomoxis nigromaculatus*)

Black crappie is a popular sportfish widely distributed in Illinois. It is relatively intolerant of turbidity and silt, avoids areas with strong currents, and is common in well-vegetated habitat. Black crappie do not school, but can be found in loose aggregations around cover, such as root wads, woody debris, boulders and aquatic vegetation. Aquatic insects, crustaceans, and small fish are primary food for crappie. Spawning begins when water temperatures rise above 13°C (55.4°F); males fan fine sediment and debris from a nest, but nest building is minimal compared to the activities of bluegill and bass. Nests are often created in close proximity to each other and near underwater structure and cover. Males guard the nest until fry leave the nest. Black crappie was not identified to species during the 2005-2006 ichthyoplankton surveys; however, *Pomoxis* spp. was collected in relatively low abundance in the Kankakee River. Yolk-sac larvae were collected between late April and late June in 2005 and between mid-May and early June in 2006 (EA 2007). Water temperatures during the week prior to the first observation of *Pomoxis* yolk-sac larvae were between 15°C (59°) and 20°C (68°F) during both years. Post yolk-sac larvae occurred from early May through mid-June in 2005 and late May to late June in 2006. *Pomoxis* larvae were not collected at the DNS cooling water intake or discharge during 2006 (EA 2007). A few larvae were collected at the intake on one sampling date in 2005.

Black crappie was never abundant in the DNS study area, but was collected in low numbers during electrofishing surveys during most years in all four study reaches (Tables B-2 and B-3). It ranked 51st in relative abundance in all sampling gear between 1991 and 2014 and 45th in electrofishing collections.

2.4.12 Logperch (*Percina caprodes*)

Logperch is a widely distributed darter species that occurs throughout Illinois where streams are large and stable enough to provide habitat. It is particularly common in the sluggishly flowing and sand-bottomed Illinois River and associated pools. It is a demersal species that prefers mixed sand and gravel substrates. In riffle habitat, it often takes cover in brush and woody debris and commonly buries itself in sandy substrates. Its primary food consists of immature stages of aquatic insects. Logperch spawn over gravel in strong riffles during April. Logperch early life stages were not identified to the species level during the 2005-2006 ichthyoplankton surveys. Nine species of darter have been identified during fish surveys in the vicinity of DNS between 1991 and 2014 (Table B-3); most have been occasional or incidental occurrences. Logperch was the only darter among the common dominant taxa collected; most of the darter early life stages collected during the 2005-2006 ichthyoplankton surveys are likely to have been logperch. Darter yolk-sac larvae were collected between the beginning of sampling in early April through late June in 2005-2006; during the 2006 ichthyoplankton survey a few yolk-sac larvae were collected again on one date in mid-July and again in late August (EA 2007). Water temperatures at the time of the first observation of darter yolk-sac larvae were between 10° (50°) and 15°C (59°F). Post yolk-sac darter larvae were collected from mid-April to mid-July in 2005 and early May to mid- August in 2006. Early juveniles were only collected during 2005, between mid-June and mid-July.

Logperch was collected every sampling year between 1991 and 2014 in at least one sampling gear; it was collected in every year in the Kankakee River and all but one year in the Illinois

River upstream and downstream of the Dresden Island Lock and Dam (Table B-3). Their presence in the Des Plaines River was more sporadic; logperch was not collected in 6 of 19 sampling years. It was the most abundant of nine darter species collected near DNS accounting for 77 percent of the darters collected in the four study reaches since 1991 (Tables B-2 and B-3). The catch of the other eight darter species totaled 237 individuals compared to 795 logperch (Table B-3). Logperch catches were low relative to the other RIS as they contributed less than one percent of the total numerical catch since 2000 and ranked 17th in the electrofishing catch from 1994 through 2014.

2.4.13 Freshwater drum (*Aplodinotus grunniens*)

Freshwater drum is a native species in Illinois that prefers large rivers, but also occurs in large lakes and may ascend smaller rivers. It is the target of both sport and commercial fisheries. In rivers, it is most common in large pools and avoids strong currents. It is a bottom-dwelling species most abundant in turbid water over a bottom of mixed sand and silt. It feeds on mollusks, crayfish, and fish, and generally forages for food organisms in bottom substrates. Information on spawning habits of drum is limited, but it appears that spawning occurs during May and June and may be preceded by migration from lakes and large rivers into smaller tributaries. Eggs are released and float to the surface and hatch quickly. During the 2005-2006 ichthyoplankton surveys, freshwater drum eggs were the most abundant taxa/lifestage by an order of magnitude and were common from mid-May to late June; during 2006 eggs continued to be abundant into early July (EA 2007). When eggs first appeared in ichthyoplankton surveys water temperatures were 18-20°C (64.4-68°F) in the Kankakee River. Yolk-sac larvae occurred in much lower numbers than eggs from early June into early July (EA 2007). A few post yolk-sac larvae were observed in late June and early July.

Freshwater drum was collected in all four study reaches during almost every survey year since 1991 (Table B-2) and probably continuously since the early 1970s. Beach seines were ineffective sampling drum, but it was common in electrofishing samples. Numerically it ranked 13th in abundance in the electrofishing catch between 1994 and 2014 (Table B-3). Abundance is variable from year to year, but freshwater drum has generally been most abundant in the study reach of the Illinois River downstream of Dresden Island Lock and Dam since 2000. Since 2000 average biomass of freshwater drum ranked 4th highest, accounting for 11 percent of the mean biomass of all species collected over this period. It was most abundant in the spring (prior to 15 June); abundance declined slightly through the summer and into the fall (after 15 September).

2.5 Methods Employed and Species-Specific Information Used

The prospective analysis developed for evaluation of the DNS thermal discharge plume combines information on the response (behavioral and physiological) of aquatic organisms to temperatures associated with the predicted hydrodynamic characteristics of the thermal plume under selected ambient flow and station operating conditions. The primary steps in this analysis include:

- Prediction of the spatial and temporal configuration and characteristics of the DNS thermal plume using output of the three-dimensional MIKE 3 model (Appendix D).

Selection of operating and environmental scenarios for model simulation.

- Determination of ambient/acclimation temperature for the MIKE3 model grid using ambient temperatures recorded upstream in the Kankakee and Des Plaines Rivers and at the DNS cooling water intake (Appendix D).

- Identification of thermal endpoints related to growth, avoidance, chronic mortality, and temperature shock for each of the 12 RIS, as available (Appendix D).

- Identification of the period of occurrence of key life stages of the RIS in the vicinity of DNS (Section 2.5.3).

- Comparison of identified thermal endpoints for RIS with the predicted thermal plume temperatures (Section 3).

- Tabulation of cumulative cross section and bottom area affected by water temperatures in excess of selected temperature endpoints (Section 3).

2.5.1 Acclimation-Ambient Temperature Thermal Assessment Scenarios

Acclimation temperature is an important factor in evaluating most of the biothermal metrics selected in order to relate them to the effects of temperature exposure in a thermal plume. Fish are cold blooded organisms, that is, they are unable to control their body temperature, which is consequently determined by the temperature of the surrounding water. The rates of various physiologic and metabolic processes are therefore affected by the water temperature to which the organism is acclimated. Acclimation temperature is the temperature to which an organism has been exposed for a period adequate to achieve physiological equilibrium; it can take a few days to more than a week for an organism to fully acclimate to a new temperature regime. The acclimation condition can affect the response of an organism to a water temperature gradient. As an example, a group of organisms acclimated to winter or early spring water temperatures typically exhibit avoidance or preference for temperatures significantly lower than the same organisms acclimated to warmer summer ambient water temperatures.

The behavioral or physiological response of many aquatic organisms to changes or gradients of water temperature is affected by the temperature and other physical and chemical conditions to which the organism has acclimated over a period of time. Under laboratory test conditions these conditions can be fixed and controlled; under natural conditions in a waterbody, natural ambient water temperature and other factors can vary spatially over short distances (e.g., shallow shore zone versus open water, or surface versus bottom in thermally stratified areas) and on the scale of hours (diel), days, weeks, and seasons. Thus, in the natural environment acclimation temperature represents an integration of an array of conditions to which the organism has been exposed over space and time. Consequently, in the assessment of potential thermal effects from exposure to the DNS thermal plume, laboratory thermal effects data that are tied to a controlled laboratory acclimation temperature need to be considered in the context of the acclimation history of organisms that might be exposed to the DNS thermal plume and conditions in

available proximal habitat (i.e., immediately upstream of the DNS thermal plume).

To predict potential thermal effects of the DNS thermal discharge plume based on results from laboratory studies, seasonal natural ambient temperature of the Illinois River predicted from upstream Des Plaines and Kankakee River temperatures and flows can be used to represent acclimation temperature. The assumption the ambient temperature represents the acclimation condition of the community is conservative because a portion of the community can be acclimated to higher temperatures in the DNS plume which could result in higher thermal tolerance and avoidance temperatures for some organisms. Several sources of water temperature data are available for the vicinity of DNS. Water temperature is continuously monitored at the DNS cooling water intake on the Kankakee River (0.4 miles upstream of the DNS discharge) in compliance with the DNS NPDES permit. As part of the §316(a) Demonstration studies, water temperature was monitored at the following three additional USGS monitoring sites, since September 2012:

- Des Plaines River at Channahon, 4.1 miles upstream of the DNS discharge;
- Kankakee River at Wilmington, 6 miles upstream of the DNS discharge;
- Illinois River at Seneca, 19 miles downstream of the DNS discharge.

Acclimation temperature curves were estimated (Figure B-1) using the 7-day running average ambient temperature for each of these monitoring stations and the cooling water intake; the 7-day average was selected as representative of an organism's acclimation state under variable natural water temperatures. Water temperatures in the Kankakee River are consistently cooler than those in the Des Plaines River; by as much as 8°C (14.4°F) during fall and winter and approximately 2-4°C (3.6-7.2°F) during spring and summer (Figure B-1). Water temperature at the Dresden cooling water intake typically falls between temperatures in the Des Plaines and Kankakee rivers; more similar to the Kankakee River during fall, winter, and spring and closer to the Des Plaines River during summer (Figure B-1). Water temperatures at Seneca also typically fall between those recorded in the Des Plaines and Kankakee rivers. During seasonal low-flow periods (summer-fall), flows in the Des Plaines River are generally higher than in the Kankakee River (Figure B-2); however, during high flow events Kankakee River flows are typically higher than flows in the Des Plaines River. Ambient temperature in the Illinois River downstream of the confluence of the Des Planes and Kankakee Rivers near the DNS discharge was estimated based on flow-weighted mixing of the respective upstream temperatures from the Des Plaines and Kankakee Rivers (Figure B-3). The flow-weighted temperatures in the upper Illinois River and measured temperatures downstream at Seneca are typically warmer than at the DNS cooling water intake which entrains primarily water from the Kankakee River.

For this analysis the following three scenarios of flow and water temperature (Tables B-5 and B-6, Figure B-4) were examined:

1. Typical flow (median, 50^{th} percentile) and water temperature (60^{th} percentile);

2. Typical high temperature conditions (5th percentile flow and 95th percentile water temperature); and

3. Extreme high temperature conditions reflected flow (<5 percentile in the Des Plaines and 15-20 percentile in the Kankakee River) and air and water temperatures (maximum water temperatures in the range of 97-99 percentile) that occurred during an exceptional heat wave in early July 2012 (Table B-6 and Figure B-4).

July flows under the typical high temperature scenario were about 60 percent of flows for the typical scenario and flows during the extreme event of July 2012 were 38-52 percent of flows under the typical conditions scenario. Under the typical high temperature scenario ambient July water temperature did not exceed 31.7°C (89°F) and DNS discharge temperatures did not exceed 33.3°C (92°F).

In order to more adequately evaluate the potential effects of the DNS discharge under the ATLs, the model was used to estimate thermal plume conditions during extremely warm meteorologic conditions that occurred during early July 2012. During July 2012, DNS operated under a provisional variance with significantly higher DNS intake and discharge temperatures than represented by the typical high temperature scenario. During the extremely warm event of July 2012, daily maximum air temperatures increased steadily from 30.0°C (86°F) on 1 July to 37.8°C (100°F) on 7 July, while maximum daily intake water temperatures increased from about 29.4°C to 34.4°C (85°F to 94°F) over the same period (Figure B-4). DNS discharge temperatures increased from about 31.1°C (88°F) to slightly more than 34.4°C (94°F) (Figure B-4). The heat wave broke during the 8-9 July overnight period with night-time low air temperature dropping to 16.7°C (62°F); during this 36-hr period intake and DNS discharge water temperatures decreased from about 34.4°C to 31.1°C (94°F to 88°F) (Figure B-4).

2.5.2 Thermal Assessment Diagrams for RIS

Thermal diagrams (Figures B-5 to B-16) were constructed for each RIS to graphically present the relationship of acclimation temperature and the selected biothermal response metrics (as discussed in Section 2.3) to help interpret the potential effects of thermal loading from the Dresden cooling water discharge on the RIS and the aquatic community that they represent. The diagrams illustrate the relative relationship and progression of the selected biothermal response metrics and the inherent variability among individual responses for each species. Figures B-5 to B-16 are used in Section 3 (Results of Biothermal Assessment), in conjunction with thermal plume modeling and habitat mapping (Section 2.5.4), to predict potential effects of the DNS thermal plume on the aquatic community represented by the RIS.

With regard to the data presented in Figures B-5 to B-16, for each metric, the individual test results reported in the scientific literature are graphed along with the associated linear regression line for these data when appropriate. For clarity in reading the diagrams, the markers and trend lines for each specific metric are plotted in the same color with different data sources represented by distinct marker styles, as listed in the legend. Acclimation temperature (X axis) and response

temperature (Y axis) are plotted at the same scale on the diagrams for all 12 RIS to facilitate comparison of relative thermal sensitivity among species. Although thermal water quality criteria are written in terms of °F, the majority of thermal data are reported in °C. To facilitate analysis of the thermal data and development of the Master Rationale (Section 3, Dresden 316(b) Demonstration Summary), thermal endpoints are plotted in °C against the left-hand vertical axis; for reference the equivalent °F scale is presented on the right-hand vertical axis. Also for reference and to facilitate interpretation, horizontal lines are plotted on each figure at key regulatory temperatures, 32.2°C, 33.9°C, and 35°C (90°F, 93°F, and 95°F, respectively).

2.5.2.1 Acute thermal mortality under short exposure duration (dark red line and markers)

This metric depicts the lethal response of organisms to dynamic temperature increases over a relatively short period. This response is measured by the CTM which is not necessarily an indication of final mortality, but frequently uses the loss of equilibrium as the test endpoint.

2.5.2.2 Chronic thermal mortality under prolonged exposure (light green line and markers)

This line depicts the species' mean tolerance limit; that is, the acclimation/exposure-temperature combinations at which 50 percent mortality would occur due to elevated temperatures for a prolonged exposure of more than 24 hours (typically 24 to 96 hours). Based on Coutant (1972), the temperature at which the species' chronic thermal mortality approaches zero is about 2°C (3.6°F) lower than the mean tolerance line (TL5024 to 96 hrs) shown in the thermal diagram. By extension, assuming a normal distribution, chronic thermal mortality would effectively be 100 percent at 2°C (3.6°F) higher than the TL50. This 2°C (3.6°F) range around the mean is an expression of the variable response of individuals within a population to a prolonged exposure to elevated temperatures. Chronic mortality is very conservative measure of potential thermal effects because it assumes that fish are unable to avoid potentially lethal elevated temperatures by moving to cooler temperatures along a temperature gradient, and thus could potentially succumb to elevated temperatures during a prolonged exposure.

2.5.2.3 Avoidance (dark blue line and markers)

A thermal avoidance response occurs when mobile species evade stressful high temperatures by moving to water with lower, more acceptable temperatures (Meldrim et al. 1974, Mathur et al. 1983). While the avoidance response can minimize the potential for thermal mortality associated with elevated water temperatures in portions of a thermal plume, it can also deter organisms from occupying otherwise useful or critical habitat that may occur in the vicinity of a thermal plume. The plotted avoidance data (acclimation/response temperature) and line represent the expected mean avoidance response of a population.

2.5.2.4 Thermal preference zone (orange line and markers)

The zone of thermal preference is defined by a range of laboratory acclimation/preferred

temperature response data reported for some RIS. The ideal temperature range for growth cannot be accurately characterized under controlled laboratory conditions for those species for which captive rearing methods have not been developed. The thermal preference polygon provides a surrogate to delineate the acclimation and exposure temperature combinations for which optimal growth (i.e., preferred temperatures) would be predicted (McCullough 1999). Optimal temperatures for growth are defined as the preferred temperature of fish in a thermal gradient; for "cold-blooded" organisms (ectotherms), such as fish, this is an adaptive mechanism that allows organisms to selectively utilize habitat within a waterbody where temperatures are such that they can maintain optimal physiological performance (Coutant 1977; Hutchison and Maness 1979).

The occurrence and distribution of both optimal and non-optimal water temperatures will naturally vary on a spatial, diel, and seasonal basis; the presence and configuration of the thermal plume overlays this natural variability. Maximum weekly average temperature for growth (MWAT) is a metric that attempts to account for this variability, using a 7-day running average of ambient water temperature to capture this variability and characterize the acclimation conditions of the organisms that affect growth. The RIS selected for DNS exhibit a period of zero growth between late fall and early spring when water temperatures are less than their threshold for growth. Peak summer ambient water temperatures in portions of the ecosystem and portions of the thermal plume can exceed the upper zero growth (bright red line on thermal diagram) temperature for some species. Thus, growth occurs to a greater or lesser extent over a range of temperatures and a thriving population can be maintained even when temperatures non-optimal during certain periods or in a segment of a waterbody. In the presence of a thermal plume, growth can begin earlier in the spring or continue later in the fall in some segments of the waterbody and fish have the ability to move from areas with non-optimal temperatures to areas with more optimal water temperatures. For this reason it is difficult to quantify the effect of the thermal plume on growth of individuals within a population utilizing habitat in the vicinity of the DNS thermal plume. Instead, this analysis looks at the relative amount and frequency of habitat affected by the thermal plume where water temperatures are outside of the optimum range for growth.

2.5.2.5 Thermal tolerance zone (purple line)

The thermal tolerance zone extends beyond the preference zone. It delineates the temperature regime over which each species can survive and continue to grow, but at less than optimum rates. Optimum temperatures for maximum growth do not consistently occur spatially or temporally in nature and delineation of a tolerance "zone" makes clear the fact that non-optimal temperatures are not necessarily adverse. Areas outside the polygon of the tolerance zone and below the onset of predicted chronic mortality (within the 2°C [3.6°F] range of variability below the chronic thermal mortality line discussed above), delineate the temperature regime over which a species can survive, but in which they may be stressed and experience near-zero or negative growth, that is, weight loss (Bevelhimer and Bennett 2000; Beitinger and Bennett 2000).

2.5.2.6 Thermal range for spawning (bright green line)

When adequate thermal range data have been documented, a polygon on the thermal effects figure indicates the reported temperature range for spawning based on the seasonal period during which spawning typically occurs in the vicinity of DNS. This range is typically based on field observations of natural spawning activity.

2.5.2.7 Lower lethal temperatures (teal line and markers)

Lower incipient lethal temperatures (chronic exposure) and cold shock (acute rapid exposure) measure mortality caused when organisms acclimated to warm temperatures in the thermal plume are exposed to significantly colder ambient water temperatures. This typically occurs when fish attracted to plume during the winter are exposed to cold ambient water temperatures in conjunction with a station outage. Similar to the upper chronic thermal mortality graphic the lower thermal threshold has a range of variation of ±2°C (3.6°F) and falls about 2°C (3.6°F) below the lower boundary of the tolerance zone polygon. When a station has multiple operating units, the potential for this source of mortality is mitigated in that all units are typically not taken offline and therefore organisms acclimated to the thermal plume do not experience a full decrease to ambient temperatures. Given that the focus of this Demonstration is the period of indirect once-through cooling (15 June through 30 September) lower incipient lethal temperatures and cold shock are presented for completeness but are not a significant issue for this analysis.

2.5.3 Periods of Occurrence

The temporal focus of this biothermal assessment is the period 15 June through 30 September when DNS operates in indirect once-through cooling mode. With the exception of cyprinids (e.g., emerald shiner) and freshwater drum, most of the RIS spawn prior to 15 June. Ichthyoplankton sampling during 2005-2006 collected few or no eggs of most of the RIS; most of the RIS have eggs that are demersal, adhesive, or deposited in nests in shallow areas protected by the adults and thus have limited vulnerability to the sampling gear, but also have minimal exposure to the DNS thermal plume. Freshwater drum was the only species for which eggs were collected in abundance during the 2005-2006 surveys. Their eggs are buoyant and pelagic and were collected between early May and mid-July with peak abundance between early June and early July.

During the 2005-2006 sampling program in the Kankakee River in the vicinity of the DNS cooling water intake, 85-88 percent of the ichthyoplankton drift occurred prior to 15 June, before DNS switches from closed cycle to indirect open cycle cooling (EA 2007, Figures 3-13 and 3-14). With the exception of emerald shiner and freshwater drum, peak abundance for yolk-sac larvae of most of the RIS also occurs before mid-June. Abundance of post yolk-sac larvae and early juvenile life stages of all RIS typically peaks during the period when DNS operates in indirect once-through cooling mode.

Young of the year and adults of the RIS occur throughout the summer when DNS operates in

indirect open cycle cooling mode and at which time the proposed ATLs would apply. The abundance of young of the year through adult life stages of the most common RIS (gizzard shad, emerald shiner, and bluegill) during the 2005-2006 surveys increased gradually from spring (before 15 June), through summer into fall (after 30 September). Smallmouth bass and channel catfish, in much lower abundance, exhibited the reverse trend, decreasing in numbers from spring through fall. All other RIS occurred in relatively low and variable abundance with no apparent seasonal trend. Thus, during the summer period of interest, when ambient temperatures are at maximum and river flows are typically at annual lows, the abundance of RIS fish in the vicinity of DNS is generally at an intermediate level, compared to spring and fall.

2.5.4 Species Habitats

Habitat in the area encompassed by the thermal model (approximately 544 acres), from Dresden Island Lock and Dam upstream to the lower reaches of the Des Plaines and Kankakee Rivers above their confluence, is dominated by relatively deep channel (greater than 2.5 meters) accounting for approximately 53 percent of the study area (Figure B-17). The channel area in the modeled reach of the Kankakee River is dominated by sand substrates, whereas substrates in the channels of the Des Plaines River and Illinois River is a variable mix of silt, sand, gravel, hardpan, and debris.

Between the DNS discharge and Dresden Island Lock and Dam, habitat less than 2.5 m accounts for about 15 percent of available aquatic habitat. Within the larger boundaries of the hydrothermal model and bathymetric survey, depths less than 2.5 meters account for about 47 percent of the area. Several large depositional areas, primarily located upstream of the DNS discharge, significantly increase the diversity and available shallow habitat of the reach including: upstream of the discharge along the left bank at the inside bend of the Illinois River between the DNS intake and discharge (hard bottom compact sand and silt with limited lotus beds close to shore); and the point and backwater areas between the channels of the Des Plaines and Kankakee Rivers at their confluence (submerged macrophytes and lotus beds with sand or detritus/mud over gravel and cobble). A small area along the right bank immediately upstream from Dresden Island Lock and Dam (lotus beds with detritus/mud substrate) provides limited shallow water habitat downstream of the DNS discharge. The shallow shore zone habitat throughout much of the rest of the study reach extends only a short distance from the shoreline with submerged and limited emergent vegetation generally over rocky, sand, or silt substrate. These habitat types are delineated on Figure B-17 including a summary of the areas encompassed by each habitat type.

These shallows typically have substrates comprised of silt and detritus overlaying sand, gravel, or cobble. These areas could provide spawning habitat for the four centrarchid RIS (largemouth and smallmouth bass, bluegill, and black crappie). Large woody debris provides cover in the shallow right bank embayment immediately upstream of the dam and is typical of channel catfish spawning habitat. Scattered submerged aquatic vegetation (SAV) occurs along the inside bend of the Illinois River upstream of the Dresden discharge. Lotus beds are common in the shallow and backwater habitat between the Des Plaines and Kankakee Rivers. Habitat with SAV and other floating vegetation beds (approximately 153 acres or 23 percent of the area within the

reach) could provide spawning habitat for common carp and other cyprinids (e.g., emerald shiner). Aquatic vegetation in these shallow areas can also provide cover and foraging habitat for top predator species such as smallmouth and largemouth bass.

Riffles, typically used by logperch, golden redhorse, and to some extent by white sucker as spawning habitat, do not occur within the geographic boundaries of the hydrothermal model. The closest riffle/run habitat occurs downstream below the Dresden Island Lock and Dam and in tributary habitat in Aux Sable Creek about 3 miles below the dam. Upstream of the DNS discharge, the closest riffle habitat is about 5 miles in the Kankakee River, near the I-55 bridge. Additional riffle habitat is also found in Grant Creek, a tributary to the Des Plaines River about 3 miles upstream of the DNS discharge.

3.0 RESULTS OF THE BIOTHERMAL ASSESSMENT

3.1 Thermal Plume Assessment Scenarios

3.1.1 Typical river conditions

The typical condition assessment scenario used median monthly flows in the upper Illinois River (combined flows from the Des Plaines and Kankakee Rivers) that ranged from 9,720 cfs in June to 5,366 cfs in September (Table B-5). The associated typical ambient Illinois River temperatures (60 percentile flow-weighted for the Des Plaines and Kankakee Rivers) ranged from about 25°C (77°F) in June and September to 27.6°C (81.7°F) in August. The median DNS discharge temperatures ranged from 29.8°C (85.7°F) in June to 30.8°C (87.4°F) in July, and 28.6°C (83.5°F) in September (Table B-5).

The cross-sectional and bottom areas affected by the DNS thermal plume are used to assess the potential effects of the plume on aquatic habitat and RIS populations in the vicinity of the DNS discharge. The hydrothermal model was used to estimate the percent of the cross-sectional area at fixed transects below specified water temperatures for each of the four months evaluated (Table B-7 to B-10) and percent of the bottom area upstream and downstream of the DNS discharge below specified water temperatures (Table B-11). The area encompassed by selected temperatures was compared to the biothermal metrics for each of the RIS, and presented in Sections 3.2 to 3.7, below. Zone of passage (ZOP) was evaluated against a 75% benchmark to determine if temperatures in at least 75 percent of the plume cross section are less than the avoidance temperature for an RIS.

Under the typical condition scenario, river flows and temperatures and DNS discharge temperatures are most constraining during July and August. At the upstream transect, in July the Kankakee River (KP-1800) ranged from 24.1°C to 24.5°C (75.4°F to 76.1°F), while water temperatures in the Des Plaines ((DP-1700) were 6-7°F higher (Table B-8). At a median DNS discharge temperature of 30.8°C (87.4°F) in July (Table B-5), temperatures immediately downstream of the discharge (IL125) ranged from 27.6°C to 30.3°C (81.7°F to 86.6°F); temperatures in 75 percent of the cross-section were less than 29.0°C (84.2°F) (Table B-8). Moving downstream to the Dresden Island Lock and Dam, in July the range of cross-section

(IL1000) temperatures narrowed (28.5°C to 28.9°C [83.3°F to 84°F]) with mixing and dilution. Predicted water temperatures near the bottom upstream of the DNS discharge are 24.1-28.2°C (75.4-82.8°F) and 27.1-30.8°C (80.8-87.4°F) downstream of the discharge in July (Table B-11). Water temperatures in 75 percent of bottom habitat upstream of the DNS discharge are less than 27.9°C (82.3°F), and downstream of the discharge are less than 28.7°C (83.7°F) (Table B-11). Water temperatures in bottom habitat upstream of the DNS discharge are about 2.2-2.8°C (4-5°F) lower than downstream.

During August, the median DNS discharge temperature is about 0.3°C (0.5°F) lower than July, but temperatures at the upstream Des Plaines and Kankakee Rivers transects are about 1.7°C (3°F) higher than in July (Table B-9); combined flow from the Des Plaines and Kankakee Rivers is about 900 cfs lower (15 percent) than in July. During typical August conditions, the highest temperature immediately downstream of the DNS discharge (transect IL125) is predicted to be 0.1°C (0.2°F) lower than in July, but the coolest temperatures in the transect are 0.4°C (0.8°F) higher than in July. Water temperatures at transect IL125 are less than 29.2°C (84.5°F) in 75 percent of the cross-section. Downstream near Dresden Island Lock and Dam (IL1000), water temperatures are about 0.3-0.4°F higher than in July, and 75 percent of the cross-section is predicted to be below 29.0°C (84.2°F) (Table B-9), with a maximum temperature of 29.1°C (84.3°F). Predicted water temperatures near the bottom upstream of the DNS discharge are 24.8-28.3°C (76.7-83.0°F) and 28.0-30.6°C (82.4-87.0°F) downstream of the discharge in August (Table B-11). Water temperatures in 75 percent of bottom habitat upstream of the DNS discharge are less than 28.1°C (82.5°F) and downstream of the discharge are less than 28.9°C (84.1°F) (Table B-11). Water temperatures in bottom habitat upstream of the DNS discharge are about 2.2-2.8°C (4-5.5°F) lower than downstream.

3.1.2 Typical high temperature conditions

The typical high temperature condition assessment scenario used 5 percentile monthly flows in the upper Illinois River (combined flows from the Des Plaines and Kankakee Rivers) that ranged from 4,134 cfs in June to 3,032 cfs in September (Table B-5). These flows are 42-56 percent of those used for the typical condition scenario (Section 2.3.1.1). The associated typical ambient Illinois River temperatures (95 percentile flow-weighted for the Des Plaines and Kankakee Rivers) ranged from about 27.2°C (81°F) in June to 31.1°C (88°F) in July and 28.3°C (83°F) in September. The 95 percentile DNS discharge temperatures ranged from 31.8°C (89.2°F) in June to 33.2°C (91.8°F) in July and 31.6°C (88.8°F) in September (Table B-5).

Under the typical high temperature scenario, river flows and temperatures and DNS discharge temperatures are most constraining during July and August. At the upstream transect, in July the Kankakee River (KP-1800) ranged from 29.4°C to 30.9°C (84.9°F to 87.6°F), while water temperatures in the Des Plaines ((DP-1700) were 31.3-31.4°C (88.3-88.5°F) (Table B-8). At a 95 percentile, DNS discharge temperature of 33.2°C (91.8°F) in July (Table B-5), the temperatures immediately downstream of the discharge (IL125) ranged from 31.9 to 32.9°C (89.5°F to 91.3°F); temperatures in 75 percent of the cross-section were less than 32.7°C (90.9°F) (Table B-8). Moving downstream to the Dresden Island Lock and Dam, in July the range of cross-section (IL1000) temperatures narrowed (32.5°C to 32.6°C [90.5°F to 90.6°F])

with mixing and dilution. Predicted typical high temperature condition water temperatures near the bottom upstream of the DNS discharge are 29.4-32.0°C (84.9-89.6°F) and 31.0-33.2°C (87.8-91.8°F) downstream of the discharge in July (Table B-11). Water temperatures in 75 percent of bottom habitat upstream of the DNS discharge are less than 31.4°C (88.5°F) and downstream of the discharge are less than 32.6°C (90.6°F) (Table B-11). Water temperatures in bottom habitat upstream of the DNS discharge are about 1.1-1.7°C (2-3°F) lower than downstream.

During August, the 95 percentile DNS discharge temperature is about 0.6°C (1°F) lower than July, but temperatures at the upstream Des Plaines and Kankakee river transects are about 1.1°C (2°F) and 2.5°C (4.5°F) lower, respectively, than in July (Table B-9); combined flow from the Des Plaines and Kankakee rivers in August are about the same as in July. During typical high temperature conditions in August, the highest temperature immediately downstream of the DNS discharge (IL125) is predicted to be 0.7°C (1.3°F) lower than in July, and the coolest temperatures in the transect are 0.6°C (1°F) lower than in July. Water temperatures at transect IL125 are less than 31.9°C (89.5°F in 75 percent of the cross-section, about 0.8°C (1.5°F) less than July. Downstream, near Dresden Island Lock and Dam (IL1000), water temperatures are about 0.8°C (1.5°F) lower than in July and 75 percent of the cross-section is predicted to be below 31.7°C (89°F), with a maximum temperature of 31.7°C (89.1°F) (Table B-9). Predicted high temperature scenario water temperatures near the bottom upstream of the DNS discharge are 26.8-31.0°C (80.3-87.8°F) and 29.1-32.6°C (84.3-90.7°F) downstream of the discharge in August (Table B-11). Water temperatures in 75 percent of bottom habitat upstream of the DNS discharge are less than 30.2°C (86.4°F) and downstream of the discharge are less than 31.7°C (89.0°F) (Table B-11). Water temperatures in bottom habitat upstream of the DNS discharge are about 1.7-2.2°C (3-4°F) lower than downstream.

3.1.3 Extreme high temperature conditions

Typical high temperature scenario conditions can occur about 5 percent of the time; under these conditions DNS discharge temperature approaches 33.3°C (92°F) only during July and does not exceed 32.8°C (91°F) in August or 32.2°C (90°F) in June. Consequently, to evaluate the potential effects of the proposed ATLs on the RIS, the extreme high temperature conditions that occurred during July 2012, that were similar to the temperatures that could be experienced under the proposed ATLs, were evaluated.

During these extreme temperature and river flow events, intake temperatures increase rapidly, due to upstream intrusion of more buoyant (i.e., warmer) water from the Des Plaines River over the less buoyant (i.e., cooler) water from the Kankakee. Temperatures typically moderate downstream of the confluence, upstream of the DNS discharge where the Des Plaines and Kankakee Rivers mix. To evaluate thermal plume characteristics under infrequent, more extreme meteorological conditions, the hydrothermal model was used to assess unusual conditions of high air temperatures and low flow that occurred during July 2012.

During early July 2012, maximum daily air temperatures steadily increased from about 30°C (86°F) on 1 July to 37.8°C (100°F) on 7 July (Figure B-4); overnight temperatures were in the low to high 70s°F and also increased during this period. The heat wave broke the evening of 7-8

July and DNS intake and discharge temperatures responded relatively quickly, decreasing by about 3.1°C (5.5°F) over the next 36 hours. Maximum daily intake temperatures during 6-8 July 2012 were in the upper 3 percent of the period of record (2003-2014) (Table B-6); the maximum recorded intake water during this 3-day period was 34.4°C (93.9°F) which occurred at about 1500 hours, the afternoon of 7 July 2012. DNS cooling water intake temperatures were above 33.9°C (93°F) for about 9 hours between 1100 and 2000 hours on 7 July (Figure B-18). The DNS discharge temperature peaked a few hours later at about 34.9°C (94.9°F); the discharge temperature exceeded 34.4°C (94°F) for about 3 hours and exceeded 33.9°C (93°F) for about 11 hours. Night-time low water temperatures were in the upper 4-5 percent of the record. The diurnal cycle of air temperature and its effect on intake temperature and DNS discharge temperature is apparent in Figure B-4. The combined flow from the Des Plaines and Kankakee Rivers during this period ranged from slightly below to slightly above the 7Q10 (2456 cfs) calculated from the upstream USGS gages (Appendix D) scaled to the confluence of the two rivers.

Under the proposed ATLs, the plant's discharge could exceed 93°F (up to 95°F) for up to 24 hours when intake temperatures exceed 90°F (32.2°C). Using the July 2012 extreme heat event, modeled mixed ambient water temperatures at surface, middle, and bottom depths upstream of the DNS discharge (transect IL-200) peaked above the 90°F (32.2°C) threshold at 33.3°C (92°F) for 1-4 hours on 7 July (Figure B-18). The duration that ambient water temperatures were above 32.8°C (91°F) increased with depth (Figure B-18) as cooling of surface waters was enhanced by overnight cooling of water over the large shallow habitat (Figure B-17) in the immediate vicinity of transect IL-200 upstream of the DNS discharge. Downstream of the DNS discharge (transect IL475), modeled water temperatures at surface, middle and bottom depths exceeded 33.3°C (92°F) on 6 July for about 15 hours, declining below 33.3°C (92°F) for about three hours near dawn on 7 July, then increasing again to the peak for the 3-day period on the afternoon of 7 July. Temperatures at this transect exceeded 33.9°C (93°F) for approximately 6 hours on 7 July (Figure B-19). Temperatures at all depths were below 32.8°C (91°F) by 0300 on 8 July. Temperatures at this transect again exceeded 32.8°C (91°F) briefly on the afternoons of 17, 18, and 19 July (Figure B-20); temperatures upstream of DNS discharge did not exceed 32.5°C (90.5°F) on these three dates and bottom temperatures remained below 90°F (Figure B-21). Temperatures for the remainder of July and August were typically below 31.1°C (88°F) upstream at transect IL-200 and below 31.7°C (89°F) downstream at transect IL475.

3.2 Potential for Thermal Mortality at Elevated Temperatures

Acute and chronic thermal mortality data are known for the following RIS:

Species	Acute	Chronic
Gizzard shad		x
Emerald shiner	x	x
Common carp	x	x
Golden redhorse	x	
White sucker	x	x
Channel catfish	x	x
Largemouth bass	x	x
Smallmouth bass	x	
Bluegill	x	x
Black crappie	x	x
Logperch	x	
Freshwater drum	x	

Acute mortality data represent effects of short term (minutes to hours) exposure to high temperatures, while chronic mortality data are the result of longer exposures (48-96 hours) to elevated temperatures. Acute data are shown as dark red lines and markers at top of Figures B-5 to B-16 and chronic data are shown as light green lines and markers several °F below the acute data on Figures B-5 to B-16. At ambient/acclimation temperatures above 29.4°C (85°F), acute mortality is not predicted for the RIS until temperatures in the thermal plume exceed 35-37.2°C (95-99°F), which is well above temperatures predicted under the three scenarios evaluated in this assessment.

Based on these data (Figures B-5 to B-16), no acute or chronic mortality is predicted for any of the RIS under the typical conditions scenario. For this scenario, upstream ambient temperatures are below 28.3°C (83°F) and DNS discharge temperatures are below 31.1°C (88°F) (Tables B-7 to B-9) during July and throughout the indirect open cycle period from June through September. At this acclimation temperature, chronic mortality is typically not observed for most of the RIS until exposure temperatures exceed 32.2°C (90°F (Figures B-5 to B-16), 1.7°C (3°F) higher than the highest discharge temperatures under this scenario.

Under the typical high temperature scenario, upstream ambient temperature (95 percentile) near the DNS discharge is 31.1°C (88°F) in July and less than 30°C (86°F) the remainder of the indirect open cycle period. Discharge temperatures (95 percentile) are 32.6°C (90.7°F) in June and 33.2°C (91.8°F) in July. Chronic mortality data indicate that white sucker is the most thermally sensitive of the RIS selected for this analysis; at an acclimation temperature of 31.1°C (88°F) the predicted threshold for chronic thermal mortality is about 32.2°C (90°F). Because fish may be acclimated to temperatures higher than the upstream ambient, if they reside in portions of the plume, the assumption that ambient is representative of acclimation temperatures is conservative and could predict higher potential for thermal mortality than would actually be observed in the DNS thermal plume. It should also be noted, that although white sucker have been included as an RIS due to their thermal sensitivity, it occurs incidentally in the vicinity of DNS and has only been collected during three of the past 20 sampling years.

During July, the typical high temperature scenario with a DNS discharge temperature of 33.2°C (91.8°F), the Illinois River between the DNS discharge and Dresden Island Lock and Dam becomes relatively well mixed with temperatures at each of the modeled transects generally between 32.2°C (90°F) and 32.8°C (91°F) (Tables B-8 and B-11). Although temperatures in this range could create stressful conditions for white sucker under an extended period of exposure (e.g., 48-96 hour typical thermal mortality test durations), the exposure conditions in the DNS thermal plume are unlikely to result in any thermal mortality due to several mitigating factors. As discussed previously, DNS intake and discharge temperatures vary diurnally in response to daily cycles in air temperature (Figure B-4). Consequently, aquatic organisms are not exposed to constant elevated temperatures, but experience thermal reductions each evening as air temperatures decline. In addition, under various thermal mortality test protocols, the test organisms are exposed in a test chamber with well mixed and constant temperature, whereas, in natural riverine habitat, a range of temperatures are often available and organisms are capable of avoiding stressful temperatures (Section 3.3). Although the thermal model predicts that much of the area between the DNS discharge and the Dresden Island Lock and Dam is well mixed at 32.2-32.7°C (90-91°F), the majority of aquatic habitat immediately upstream of the DNS discharge is predicted to be less than 31.7°C (89°F) during July under the typical high temperature scenario (Tables B-8 and B-11). The majority of aquatic habitat downstream of the DNS discharge consists of deeper channel which is also abundant upstream (Figure B-17); other shallow water habitat found downstream is significantly more abundant upstream of the DNS discharge for temporary utilization by organisms potentially displaced for brief periods by elevated thermal plume temperatures.

The heat wave that occurred July 2012 provides extremely unusual natural thermal conditions to evaluate potential effects of the DNS thermal plume on aquatic resources in the area of the upper Illinois River. During these extreme temperature conditions, intake temperatures exceeded 32.2°C (90°F) for 3 days from the afternoon of 5 July to the evening of 8 July with a peak of 34.4°C (93.9°F). DNS discharge temperatures exceeded 32.2°C (90°F) intermittently from 2 July to 8 July. Discharge temperatures were above 33.9°C (93°F) for about 6 hours on the evening of 5 July and about 11 hours during the day on 7 July with a maximum of 34.6°C (94.3°F) (Table B-6; Figures B-4 and B-19). Between 1200 and 1600 on 7 July the percent of the cross-sectional area downstream of the DNS discharge in excess of 33.9°C (93°F) (yellow shaded cells in Table B-12) increased from less than 5 percent at the transect 125 m (IL125) downstream to greater than 95 percent 475 m downstream. During this same period upstream transects in the Des Plaines and Kankakee Rivers had ambient temperatures above 33.9°C (93°F) in 75 percent of the cross-sectional area. Between 1800 and 2000 on 7 July discharge temperatures began to decrease and the area with temperatures above 93°F began to contract, cool immediately downstream of the DNS discharge, and shift farther downstream toward Dresden Island Lock and Dam (Table B-12). Although the area influenced by 33.9°C (93°F) temperatures began to decrease downstream of DNS during this period, the area with ambient temperatures above 33.9°C (93°F) increased upstream in the Des Plaines and Kankakee Rivers as a result of atmospheric conditions. By 2200, 7 July, water temperatures throughout the reach were below 33.9°C (93°F).

Most RIS for which chronic temperature tolerance data are available are able to tolerate water temperatures above 35°C (95°F) for extended periods of time (48-96 hours) at acclimation temperatures above 29.4°C (85°F), with the exception of white sucker. For white sucker, the upper thermal tolerance limit for chronic exposure for juveniles appears to be about 35°C (93°F) at an acclimation of 32.2°C (90°F); the highest thermal tolerance chronic exposure for adults is 32.5°C (90.5°F) at an acclimation temperature of 26°C (78.8°F). However, under the extreme conditions observed during early July 2012, the maximum exposure duration was approximately 11 hours, considerably less than the exposure durations for the test data. During this period, ambient water temperatures beyond the influence of the DNS thermal plume that are predicted to have been less than 32.5°C (90.5°F) were available in 10-25 percent of the habitat upstream of the DNS discharge to allow white sucker the opportunity to avoid habitat with warmer temperatures downstream.

Although under extreme conditions, temperatures exist within the DNS thermal plume with the potential to cause mortality under extended chronic exposure, these conditions are rare and of relatively short duration. Refuge for fish avoiding these high water temperatures is available in extensive habitat upstream of the DNS discharge. Consequently, temperatures in the plume, even under extreme meteorological condition, are unlikely to result in any significant mortality. In fact, during the 2012 July heat event no fish kills were observed in the vicinity of the DNS and the Dresden Island Lock and Dam. While white sucker may be relatively more sensitive than the other RIS to elevated water temperatures in the DNS thermal plume during extreme conditions, the species occurs only incidentally in the Des Plaines, Kankakee, and upper Illinois Rivers in the vicinity of DNS.

3.3 Thermal Avoidance and Habitat Loss

As discussed in the previous section, except in unusual circumstances, mortality of fish as a result of exposure to high water temperatures is rare because many species have demonstrated the ability to sense and avoid stressful elevated temperatures when areas with cooler temperatures are available. Even in the event of the extreme heat event of July 2012, substantial channel and shallow water habitat is available upstream of the DNS discharge with cooler water temperatures for fish that may avoid portions of the thermal plume. While the ability to avoid stressful water temperatures minimizes the potential for fish mortality, it could result in avoidance of important habitat areas that may be affected by portions of the thermal plume.

Avoidance data were identified and reviewed for gizzard shad, channel catfish, largemouth bass, smallmouth bass, and bluegill; these data are plotted in dark blue in Figures B-6 and B-10 to B-13. As would be expected these avoidance data plot a few degrees below the chronic mortality data on these figures.

Avoidance temperature test data (Table B-13; Figures B-6, B-10, B-11, and B-13) indicate that at ambient/acclimation temperatures (30.6-33.3°C [87-92°F]) representative of the three assessment scenarios (Table B-5 and B-6), gizzard shad, channel catfish, largemouth bass, smallmouth bass, and bluegill would not avoid any portions of the plume under typical, typical warm, and extreme warm conditions. For each of these RIS the temperatures avoided are

typically several degrees higher than the highest plume cross-section (Tables B-8 and B-12) and bottom (Table B-11) temperature estimated for each assessment scenarios. These avoidance temperatures are also typically several degrees below the chronic mortality temperatures.

RIS for which avoidance data were not available generally exhibited acute and/or chronic mortality metrics within a similar range to the five RIS with avoidance information discussed above. For species where avoidance has been documented, fish typically avoid temperatures slightly below the threshold of chronic mortality. Thus, it is likely that the RIS for which avoidance data are not available exhibit a similar pattern of avoidance and would not be expected to avoid significant areas of habitat in the vicinity of the DNS thermal plume. This assessment supports the finding that the DNS thermal plume would not be expected to cause avoidance of aquatic habitat for any of these species, even at very low river flow conditions (1-4 percentile), high air temperatures (37.8°C [100°F]), and high DNS discharge temperatures (34.79°C [4.5°F]) (1-3 percentile).

3.4 Potential for Blockage of Migration

Given that this assessment indicates that the RIS and the aquatic community that they represent are not likely to avoid significant areas of habitat in the vicinity of the DNS thermal plume, it is unlikely that the thermal plume would interfere with the migration and localized movement patterns (e.g., diel and seasonal onshore/offshore, upstream/downstream, or spawning) of the fish community in the upper Illinois River. As discussed in Sections 3.2 and 3.3, more than 75 percent of the cross-section at selected transects within the DNS thermal plume and more than 75 percent of the channel bottom habitat is predicted to have water temperatures below the chronic mortality and avoidance temperatures of most of the RIS under a likely range of station operating, hydrologic, and meteorological conditions to be encountered in the upper Illinois River in the vicinity of DNS.

Reported thermal mortality metrics indicate that white sucker would be the most sensitive of the RIS to elevated plume temperatures, particularly under rare, extreme high temperature conditions such as occurred during July 2012. Although it is likely that white sucker might avoid significant areas of the DNS thermal plume during such extreme conditions, moving to more moderate upstream habitat, the duration that avoided temperatures persist is short, less than 24 hours. Such short durations when white sucker might avoid portions of the DNS thermal plume are unlikely to have any extended effect on habitat utilization by this species which, in any event, has been only an incidental component of the aquatic community over the historical operation of DNS (Appendixes A, C, F, and G).

3.5 Temperature during Critical Reproductive Seasons

Most spawning by the RIS in the vicinity of DNS appears to occur prior to 15 June during the period of closed cycle cooling operation and is, therefore, not affected by indirect open cycle cooling operation that is the subject of this assessment. It should be noted that the reported range of spawning temperatures for a given species is typically based on the observation of spawning across the geographic range of the species and may not be indicative of conditions at a given site. Gizzard shad, white sucker, golden redhorse, black crappie, and logperch typically finish

spawning prior to mid-June and the start of indirect open cycle cooling operation at DNS and would, therefore, not be affected.

Emerald shiner, common carp, smallmouth bass, largemouth bass, and freshwater drum typically spawn during May and June and could, therefore, be affected by indirect open cycle cooling operation of DNS during the final quarter of the spawning season. The reported (Wisconsin 2007) upper range of spawning temperatures for emerald shiner is about 27.2°C (81°F); water temperature exceeds 27.2°C (81°F) in less than 10 percent of the cross-section of the Illinois River for a distance of about 475 m downstream of the DNS discharge under the typical condition scenario in June. Under the typical high temperature scenario, ambient temperatures are predicted to exceed 27.8°C (82°F) in the Illinois and Des Plaines River upstream of DNS discharge in June. Thus, it is likely that emerald shiner spawning would end as a result of rising ambient temperatures during typical and extremely warm years prior to initiation of indirect open cycle cooling at DNS.

The reported (Wismer and Christie 1987) upper range of spawning temperatures for common carp is about 27.8°C (82°F); water temperature rarely exceeds 82°F in any portion of the cross-section of the Illinois River downstream of the DNS discharge under the typical condition scenario in June. Under the typical high temperature scenario, ambient temperatures are predicted to exceed 27.8°C (82°F) in the Illinois and Des Plaines Rivers upstream of DNS discharge in June as well as most of the Illinois River cross-section downstream of the DNS discharge. Thus, it is likely that common carp spawning would end as a result of rising ambient temperatures during typical and extremely warm years prior to initiation of indirect open cycle cooling at DNS.

The reported (Wisconsin 2007) upper range of spawning temperatures for largemouth bass and smallmouth bass is about 22.8°C (73°F). Under the typical and typical high temperature scenarios ambient temperatures are predicted to exceed 24.4°C (76°F) in the Illinois and Des Plaines River upstream of DNS discharge in June; even in the cooler Kankakee River, ambient temperatures are predicted to exceed 23.3°C (74°F) (Table B-7). Thus, it is likely that largemouth bass and smallmouth bass spawning would end as a result of rising ambient temperatures during typical years, prior to initiation of indirect open cycle cooling at DNS. Since smallmouth bass and largemouth bass spawn in shallow weed free habitat which would tend to warm faster, it is likely that bass spawning ends before June in the Illinois River. In addition preferred spawning habitat is considerably more common upstream of the DNS discharge (Figure B-17).

The reported (Small and Bates 2001) upper range of spawning temperatures for freshwater drum is about 28.9°C (84°F). Under the typical temperature scenario, ambient temperatures are not predicted to exceed 28.9°C (84°F) in the Illinois, Des Plaines, and Kankakee Rivers upstream of DNS discharge or in any portion of the DNS thermal plume in June (Table B-7). Under the typical high temperature scenario, water temperatures above 28.9°C (84°F) occupy more than 90 percent of the cross-section of the Illinois River downstream of the DNS discharge. Thus, it is likely that freshwater drum spawning would not occur downstream of the DNS discharge during the latter half of June under typical high temperature conditions, but would continue to spawn

into the end of June upstream of DNS. Open water spawning habitat utilized by freshwater drum is abundant upstream in the Illinois, Des Plaines, and Kankakee Rivers (Figure B-17).

The only RIS likely to spawn after June are channel catfish and bluegill, which may continue to spawn into July or August in some parts of their range. The reported (Wismer and Christie 1987) upper range of spawning temperatures for channel catfish and bluegill is about 28.9-29.4°C (84-85°F). Under the typical temperature scenario, ambient temperatures are not predicted to exceed 28.9-29.4°C (84-85°F) in the Illinois, Des Plaines, and Kankakee Rivers upstream of DNS discharge or in most of the DNS thermal plume in June-August (Tables B-7 through B-9). Under the typical high temperature scenario, water temperatures above 28.9°C (84°F) occupy more than 90 percent of the cross-section of the Illinois River downstream of the DNS discharge during June-August. Thus, it is likely that channel catfish and bluegill spawning would not occur downstream of the DNS discharge later than mid-June under typical or extreme high temperature conditions, but would continue to spawn into the end of June upstream of DNS. Ambient temperatures in the Illinois and Des Plaines Rivers upstream of DNS are generally 86-31.7°C (89°F) during July and August (Tables B-8 and B-9), well above the reported upper spawning temperature. Thus, it is unlikely that channel catfish and bluegill continue to spawn past the end of June in the vicinity of DNS during typical high temperature years.

Ichthyoplankton drift sampling in the Kankakee River in the vicinity of the DNS cooling water intake during 2005-2006 (EA 2007) indicate that 85-88 percent of the annual production of early life stages of fish in the vicinity of DNS occur prior to 15 June. This is consistent with the findings above, that most spawning by RIS and the species they represent occurs prior to initiation of indirect open cycle cooling at DNS on 15 June.

For ichthyoplankton that do occur into late June and July mortality is not predicted based on available thermal tolerance data. Early life stages frequently have higher thermal tolerance than adults. Eggs and larvae of several RIS (common carp, channel catfish, and bluegill) acclimated to temperatures of 10-33°C (50-91.4°F) tolerate acute exposure to temperatures of 31-41°C (87.8-105.8°F) and chronic exposure up to 38.8°C (101.8°F) (Wismer and Christie 1987; Beitenger et al. 2000). These temperatures are considerably higher than those predicted in the vicinity of the DNS thermal plume even under the modeled extreme high temperature scenario.

3.6 Critical Temperatures for Growth

Reported optimum thermal conditions for growth are generally difficult to interpret and are frequently qualitative or anecdotal. The rate of growth is variable and is affected in individuals and populations by a number of factors including water temperature, food availability, habitat availability, physico-chemical conditions, and population density, among others. Because the methods and resources to hold and test adult and larger fish species are limited, quantitative data on growth is frequently limited to early life stages or species that are reared in hatcheries as part of commercial or recreational fisheries management programs. Laboratory results where constant temperatures and food rations can be regulated provide quantifiable results, but are difficult to interpret in the context of variability that occurs in the natural environment and habitat of these species. It is often reported that the range of temperatures preferred by a species

is representative of the temperature range promoting optimum growth. As a result the range of optimum growth reported for many of the RIS can appear to be artificially constrained given the seasonal range of temperatures over which growth occurs.

The RIS all exhibit a seasonal growth pattern typical of temperate zone fishes with zero growth over winter beginning when temperatures decline below some critical temperature in the fall. Growth resumes in the spring as temperatures rise above that critical temperature and peak during the summer. If peak temperatures rise above a critical level, growth may decline or cease for a period during the summer. Between reported upper temperature for optimum growth and upper zero growth temperature, growth continues, but at a slower rate. While elevated temperatures in portions of a thermal plume may inhibit growth during peak summer periods, they may also stimulate growth earlier and later in the year than typically observed without the artificial source of heat in the water body.

The reported upper zero growth temperatures for gizzard shad, emerald shiner, common carp, channel catfish, largemouth bass, and smallmouth bass exceed 33.9°C (93°F) (Table B-14). It is unlikely that temperatures in the DNS thermal plume, even under the extreme conditions of July 2012, would adversely affect growth or cause a cessation of growth for these RIS.

The upper zero growth temperature for bluegill and freshwater drum is about 32.8°C (91°F) (Table B-14). During conditions reflected by the typical high temperature scenario, July temperatures in much of the thermal plume between the DNS discharge and the Dresden Island Lock and Dam are in the range of 32.2-32.8°C (90-91°F) (Table B-8), approaching the zero growth temperature. However, temperatures immediately upstream of DNS are within the optimum range for these two species. Under the extreme high temperatures scenario of July 2012, upstream ambient temperatures as well as DNS thermal plume temperatures (Table B-12) are above the zero growth temperatures for these two species. During the period 6-8 July 2012, it is possible that growth of bluegill and freshwater drum diminished to zero, but would have resumed as ambient and DNS discharge and plume temperatures cooled below 32.8°C (91°F) on 8 July (Figures B-20 and B-21).

Black crappie and white sucker have been included as RIS because they are expected to be more sensitive to high temperatures. These two species have the lowest reported zero growth temperatures of the RIS, 30.5°C and 29.6°C (86.9°F and 85.3°F, respectively). Under the typical scenario, ambient and plume temperatures are below the zero growth temperature throughout the summer for both species. For the typical high temperature scenario during June ambient temperatures and at least 90 percent of the DNS plume are below the zero growth temperature for black crappie (30.5°C [86.9°F], Tables B-7 and B-14).

During July, ambient temperatures in the upstream Illinois River, Des Plaines River, and throughout the DNS thermal plume (Table B-8) exceed the zero growth temperature for black crappie. During August, ambient temperatures in the upstream Illinois and Des Plaines Rivers approach or exceed the zero growth temperature for black crappie (Table B-9); temperatures throughout the DNS thermal plume also exceed the zero growth temperature. In September, under the typical high temperature scenario, upstream ambient temperatures are below the black

crappie upper zero growth temperature, but higher than the upper temperature range for optimum growth except in a portion of the Kankakee River (Table B-10). At least 90 percent of the DNS thermal plume exceeds the black crappie upper zero growth temperature by 0.1-0.6°C (0.2-1.1°F). During the extreme high temperature scenario of July 2012, the entire modeled reach, including ambient temperatures in upstream areas, exceeded the black crappie zero growth temperature by 2.2-3.3°C (4-6°F) (Table B-12).

White sucker occur incidentally within the Des Plaines, Kankakee, and upper Illinois Rivers. During July and August under the typical conditions scenario, ambient temperatures in the Des Plaines and upper Illinois Rivers exceed the upper range for optimum growth of white sucker. During July-September under the typical high temperature scenario, ambient temperatures in the Des Plaines and upper Illinois Rivers exceed 27°C (80.6°F), the upper range of temperatures for optimum growth of white sucker (Tables B-8, B-9, and B-14). During these periods under both typical and typical high temperature scenarios, ambient temperatures in the Kankakee River remain within the range for optimum growth of white sucker. During July and August under the typical high temperature scenario ambient temperatures in much of the upstream area exceed the white sucker zero growth temperature (29.6°C [85.3°F]; Tables B-8 and B-9). During July-September the entire DNS thermal plume and during June about 50 percent of the plume exceed the white sucker zero growth temperature (Tables B-7 to B-11). During the extreme high temperature scenario of July 2012 the entire modeled reach, including ambient temperatures in upstream areas, exceeded the white sucker zero growth temperature by 3.3-4.4°C (6-8°F) (Table B-12).

This analysis indicates that for most of the RIS and the community they represent, temperatures in the DNS thermal plume are not expected to adversely affect normal patterns of growth. For white sucker (which occurs only incidentally in the upper Illinois, Des Plaines, and Kankakee Rivers) and black crappie under typical high temperature and extreme high temperature conditions, even ambient temperatures during July and August can exceed the upper temperature for optimum growth and the zero growth temperature.

3.7 Potential for Cold Shock Mortality

Cold shock can occur when fish are quickly exposed to much lower temperatures than those to which they are acclimated such as when fish attracted and acclimated to a thermal plume during winter are returned to much colder ambient temperatures in the event of a station shutdown. DNS operates using closed cycle between October and mid-June; the risk of cold shock is minimal because the winter thermal plume is relatively small with less differential over ambient temperatures. Although for completeness, cold chock data are presented when available for each of the RIS (Figures B-5 to B-6), the proposed ATLs do not affect the period during cooler ambient temperatures between 1 October and 14 June, when DNS operates in closed cycle cooling mode.

4.0 CONCLUSIONS OF BIOTHERMAL ASSESSMENT

This biothermal assessment has been prepared to support Exelon's request for renewal and revision of the alternative thermal standards in the DNS NPDES Permit. During the period 15 June-30 September, when water temperatures at the DNS intake exceed 90°F, Exelon has requested that the temperatures at the DNS discharge be allowed to exceed 33.9°C (93°F) up to a maximum excursion of 35°C (95°F), for a duration not to exceed 24 hours per episode and for a total of no more than 10 percent of the hours available during this time period - 259 hours. This predictive assessment used the MIKE3 model to characterize and predict hydrothermal conditions in the lower Des Plaines and Kankakee Rivers and the Illinois River from their confluence downstream to the Dresden Island Lock and Dam located approximately 1,000 meters downstream of the DNS discharge (Sections 1.3 through 1.6). The MIKE 3-predicted thermal plume dimensions and distribution in the Illinois River were compared to available biothermal metric data (Section 2.1.4) related to survival, avoidance, spawning, and growth of fish. This assessment evaluated the predicted effects of DNS thermal plume temperatures (Section 2.3) on the aquatic community represented by 12 selected RIS (Section 2.1.5) under 3 scenarios (Section 2.3.1) of river flow and ambient water temperature conditions (Tables B-5 and B-6):

1. Typical Scenario—50th percentile river flow and 60th percentile ambient river temperature;

2. Typical High Temperature Scenario—5th percentile river flow and 95th percentile ambient river temperature; and

3. Extreme High Temperature Scenario—equivalent to the proposed ATLs. Based on modeled conditions for the unusual heat wave event of July 2012 when intake temperatures exceeded 32.2°C (90°F), the 97th or higher percentile for ambient temperature. Flows were in the lower 1-4th percentile for the Des Plaines River and 15-20th percentile for the Kankakee River.

Ambient temperatures did not exceed 32.2°C (90°F), the proposed ATLs' threshold, under either the Typical or Typical High Temperature scenarios. DNS discharge temperatures did not exceed 88°F under the Typical Scenario or 33.3°C (92°F) under the Typical High Temperature Scenario. Thus, both scenarios did not exceed the 33.9°C (93°F) maximum discharge temperature excursion allowed under the existing permit.

The Extreme High Temperature Scenario, based on the July 2012 event, provides a good match for analysis of the proposed ATLs. Under this assessment scenario, intake temperatures upstream of the DNS cooling water discharge reached 34.4°C (93.9°F) and the maximum discharge temperature reached 34.9°C (94.9°F), the approximate maximum excursion temperature requested by Exelon. Conditions similar to those modeled for the July 2012 Extreme High Temperature Scenario are unusual occurrences; during the July 2012 event modeled for scenario 3, ILEPA issued a provisional variance for continued DNS operations. The worst case conditions during this extreme event extended from 6 to 8 July 2012 with peak

temperatures in portions of the DNS thermal plume of 33.9-34.4°C (93-94°F) for a continuous period of about 12 hours on 7 July and in more than 50 percent of the plume for 6-8 hours.

The following findings are drawn from the biothermal assessment developed in Section 3:

1. **Potential for Thermal Mortality**—although under extreme conditions, temperatures exist within the DNS thermal plume that have the potential to cause mortality under extended chronic exposure, these conditions are rare and of relatively short duration. Refuge for Fish have the ability to avoid these high water temperatures and extensive and diverse aquatic habitat is available upstream of the DNS discharge. Most of the aquatic habitat affected by the DNS thermal plume is open deep channel habitat; significant channel habitat is available upstream of the DNS thermal plume. There is little shallow water habitat available downstream of the DNS thermal discharge and is typically limited to a narrow margin near the shoreline; extensive shallow water habitat is available immediately upstream of the DNS discharge. Consequently, temperatures in the plume, even under extreme meteorological conditions, are unlikely to result in any significant mortality. During the 2012 July heat event (the Extreme High Temperature Scenario) no fish kills were observed during monitoring in the vicinity of DNS and the Dresden Island Lock and Dam.

   For white sucker, the upper thermal tolerance limit for chronic exposure for juveniles appears to be about 35°C (93°F) at an acclimation of 32.2°C (90°F); however, the highest thermal tolerance chronic exposure for adults is at an acclimation temperature of 26°C (78.8°F). White sucker is the only RIS for which the potential exists for mortality associated with chronic exposure to temperatures above 32.5°C (90.5°F) in the DNS thermal plume that are predicted to occur during these extreme conditions. These conditions did not persist for more than 24 hours in the thermal plume and throughout this period ambient temperatures in 10-25 percent of the area immediately upstream of the DNS discharge was less than 32.5°C (90.5°F) and would have provided refuge for white sucker avoiding the potentially stressful high thermal plume temperatures. While white sucker may be relatively more sensitive than the other RIS to elevated water temperatures in the DNS thermal plume during extreme conditions, the species occurs only incidentally in the Des Plaines, Kankakee, and Illinois River in the vicinity of DNS.

2. **Temperature Avoidance and Habitat Avoidance**—Except in unusual circumstances, mortality of fish as a result of exposure to high water temperatures in their natural habitat is rare because fishes have a demonstrated ability to sense and avoid stressful elevated temperatures when areas with cooler temperatures are available. While the ability to avoid stressful water temperatures minimizes the potential for fish mortality, it could result in avoidance of important habitat areas that may be affected by portions of the thermal plume. Avoidance data available for gizzard shad, channel catfish, largemouth bass, smallmouth bass, and bluegill indicate that these RIS would not avoid any portions of the plume under extreme ambient and discharge temperature conditions. For each of these RIS, the temperatures avoided are typically several degrees higher than the highest plume cross-section and bottom temperature estimated during extreme conditions. Other

RIS for which avoidance data were not available, generally exhibited acute and/or chronic mortality metrics within a similar range to the five RIS with avoidance information. For species where avoidance has been documented, fish typically avoid temperatures slightly below the threshold of chronic mortality. It is likely that the RIS without upper avoidance temperature data would exhibit a similar pattern of avoidance and would not be expected to avoid significant areas of habitat in the vicinity of the DNS thermal plume. This assessment supports the finding that the DNS thermal plume would not be expected to cause avoidance of aquatic habitat for any of these species, even at very low river flow conditions (1-4 percentile), high air temperatures (37.8°C [100°F]), and high DNS discharge temperatures (34.9°C [94.9°F]) (1-3 percentile). Although it is likely that white sucker might avoid significant areas of the DNS thermal plume during such extreme conditions, moving to more moderate upstream habitat, the duration that avoided temperatures persist is short, less than 12 hours. Such short durations when white sucker would avoid portions of the DNS thermal plume are unlikely to have any extended effect on habitat utilization by this species which has been only an incidental component of the aquatic community. Because avoidance is predicted to be minimal and of short duration the DNS thermal plume is unlikely to inhibit local movement or diel and seasonal migrations of RIS.

3. **Temperatures during Critical Spawning Periods**—Most spawning by the RIS in the vicinity of DNS appears to occur prior to 15 June during the period of closed cycle cooling operation and is, therefore, not affected by indirect open cycle cooling operation that is the subject of this assessment. Gizzard shad, white sucker, golden redhorse, black crappie, and logperch typically finish spawning prior to mid-June and the start of indirect open cycle cooling operation at DNS and would, therefore, not be affected. Over their geographic range emerald shiner, common carp, smallmouth bass, largemouth bass, and freshwater drum typically spawn during May and June; the only RIS reported to spawn after June across their geographic range are channel catfish and bluegill which may continue to spawn into July or August in some regions. However, ambient temperatures in the Des Plaines, Kankakee and Illinois Rivers typically exceed the reported upper temperatures range for spawning by these species before the end of June, particularly during warmer years. Ichthyoplankton drift sampling in the Kankakee River in the vicinity of the DNS cooling water intake indicate that 85-88 percent of the annual production of early life stages of fish in the vicinity of DNS occur prior to 15 June. This is consistent with the findings above, that most spawning by RIS and the species they represent occurs prior to initiation of indirect open cycle cooling at DNS on 15 June and would therefore, not be affected by the proposed ATLs..

4. **Critical Temperatures for Growth**—This analysis indicates that for most of the RIS and the community they represent, temperatures in the DNS thermal plume are not expected to adversely affect normal patterns of growth. The RIS all exhibit a seasonal growth pattern typical of temperate zone fishes with zero growth over winter beginning when temperatures decline below some critical temperature in the fall. Growth resumes in the spring as temperatures rise above that critical temperature and peak during the

summer. If peak temperatures rise above a critical level, growth may decline or cease for a period during the summer. Between the reported upper temperature for optimum growth and the upper zero growth temperature, growth continues, but at a slower rate. While elevated temperatures in portions of a thermal plume may inhibit growth during peak summer periods, they may also stimulate growth earlier and later in the year than typically observed without the artificial source of heat in the water body. The reported upper zero growth temperatures for gizzard shad, emerald shiner, common carp, channel catfish, largemouth bass, and smallmouth bass exceed 33.9°C (93°F). It is unlikely that temperatures in the DNS thermal plume even under the extreme conditions of July 2012 would adversely affect growth or cause a cessation of growth for these RIS. For white sucker (which occurs only incidentally in the upper Illinois, Des Plaines, and Kankakee River) and black crappie under typical high temperature and extreme high temperature conditions, ambient temperatures during July and August can exceed the upper temperature for optimum growth and the zero growth temperature and the DNS Thermal plume would not exacerbate this condition. During rare, but extremely warm years represented by July 2012, the observed high ambient temperatures are predicted to limit growth for a brief period of several days for thermally sensitive species such as white sucker and black crappie. The brief period of extreme ambient temperatures is not predicted to have an extended long-term effect on growth patterns. Both of these species are uncommon in the fish community in the vicinity of DNS.

The findings from this predictive assessment indicate that temperatures in the DNS thermal plume under the proposed ATLs are unlikely to have more than minimal and transitory effects on incidental components of the aquatic community even under rare and extreme meteorological conditions.

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FIGURES

Figure B-1. Seven-day rolling average of water temperatures at four monitoring locations, Sept 2012 - Sept 2014.

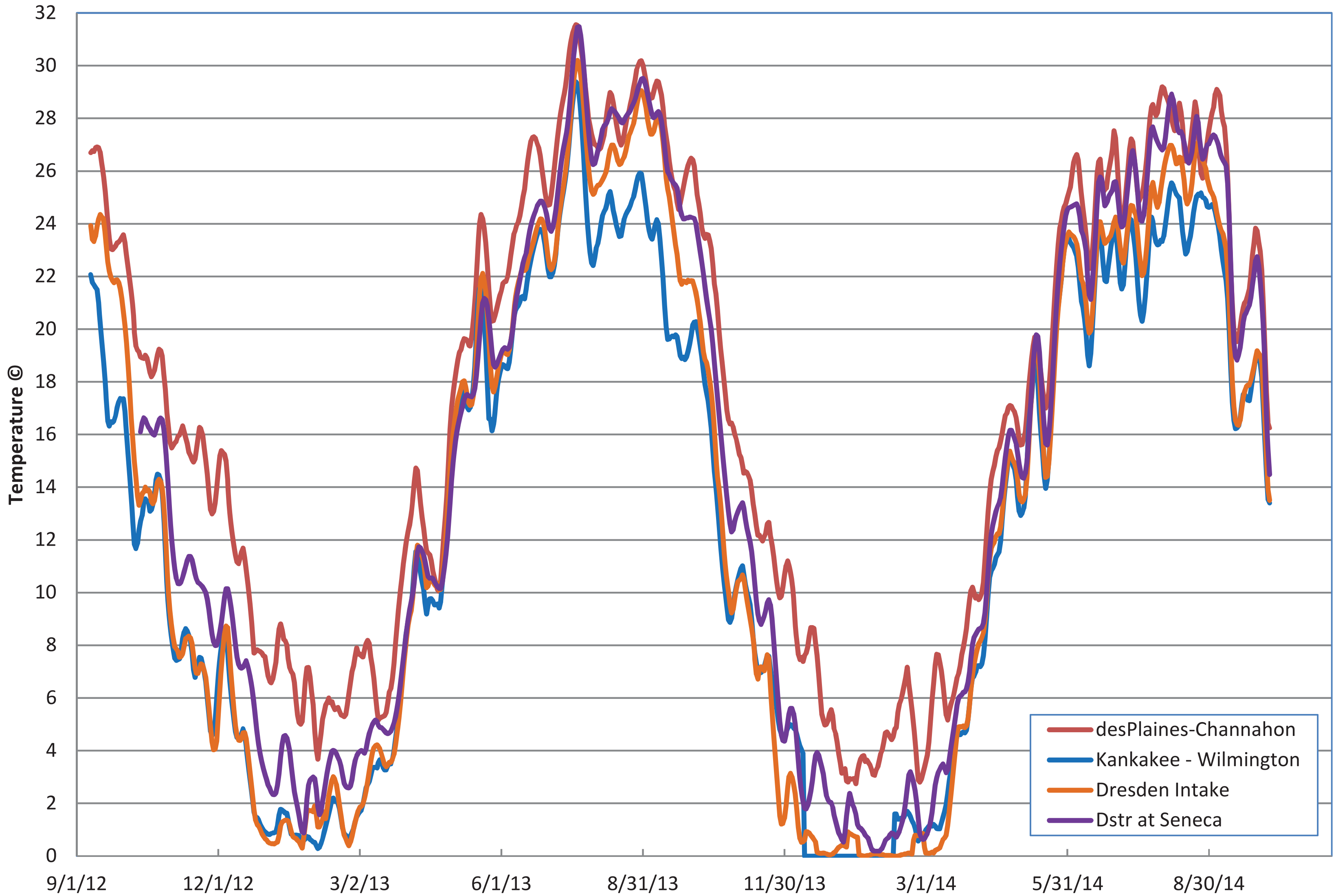


Figure B-2. Measured flows from USGS gages on the Kankakee and Des Plaines rivers, Sept 2012 - Oct 2014.

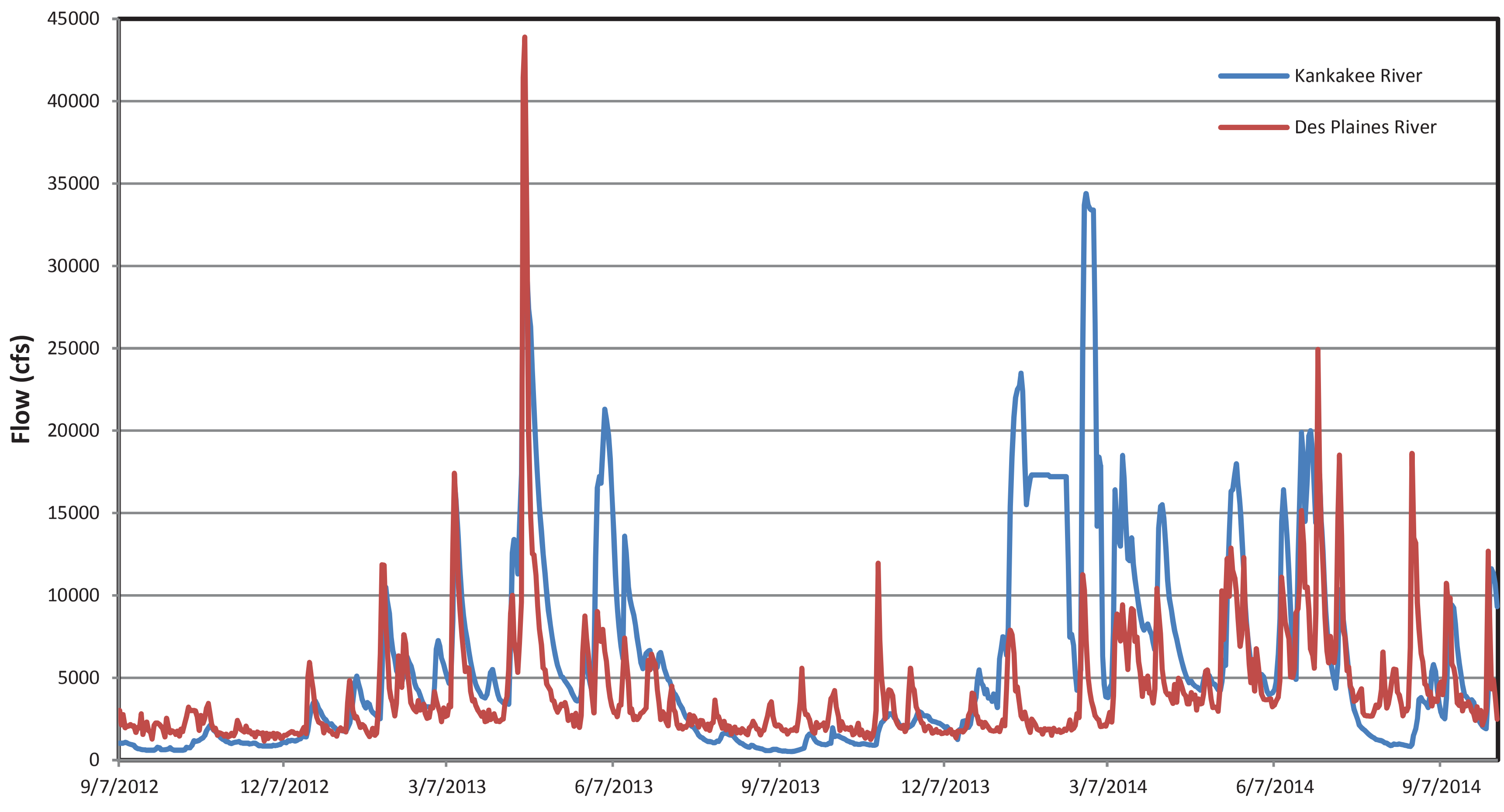


Figure B-3. Seven-day rolling average of estimated flow-weighted ambient water temperatures in the Illinois River downstream of the confluence of the Kankakee and Des Plaines Rivers, Sept 2012 - Sept 2014.

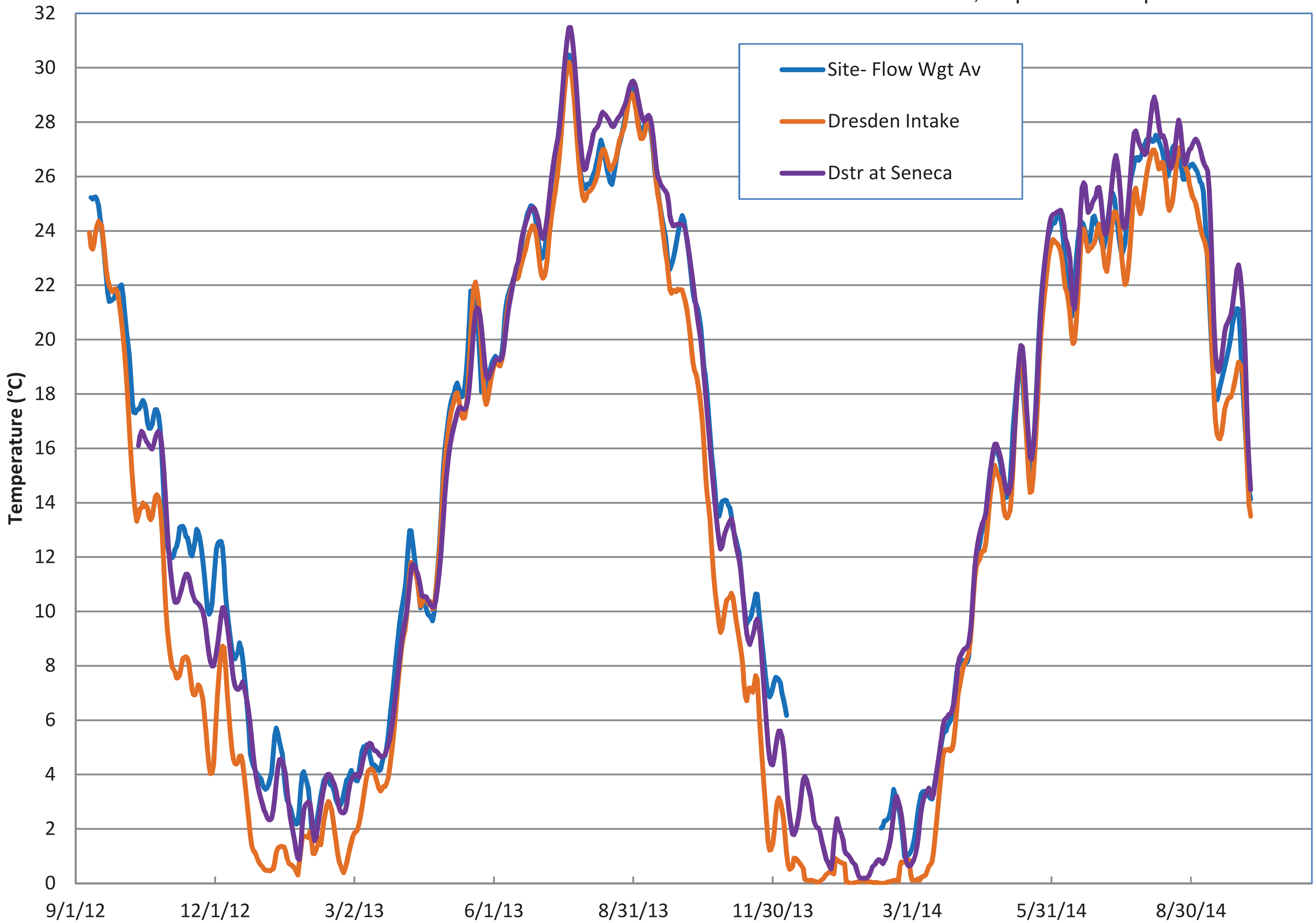


Figure B-4. DNS intake and discharge temperatures and air and wet bulb temperatures, 1-11 July 2012.

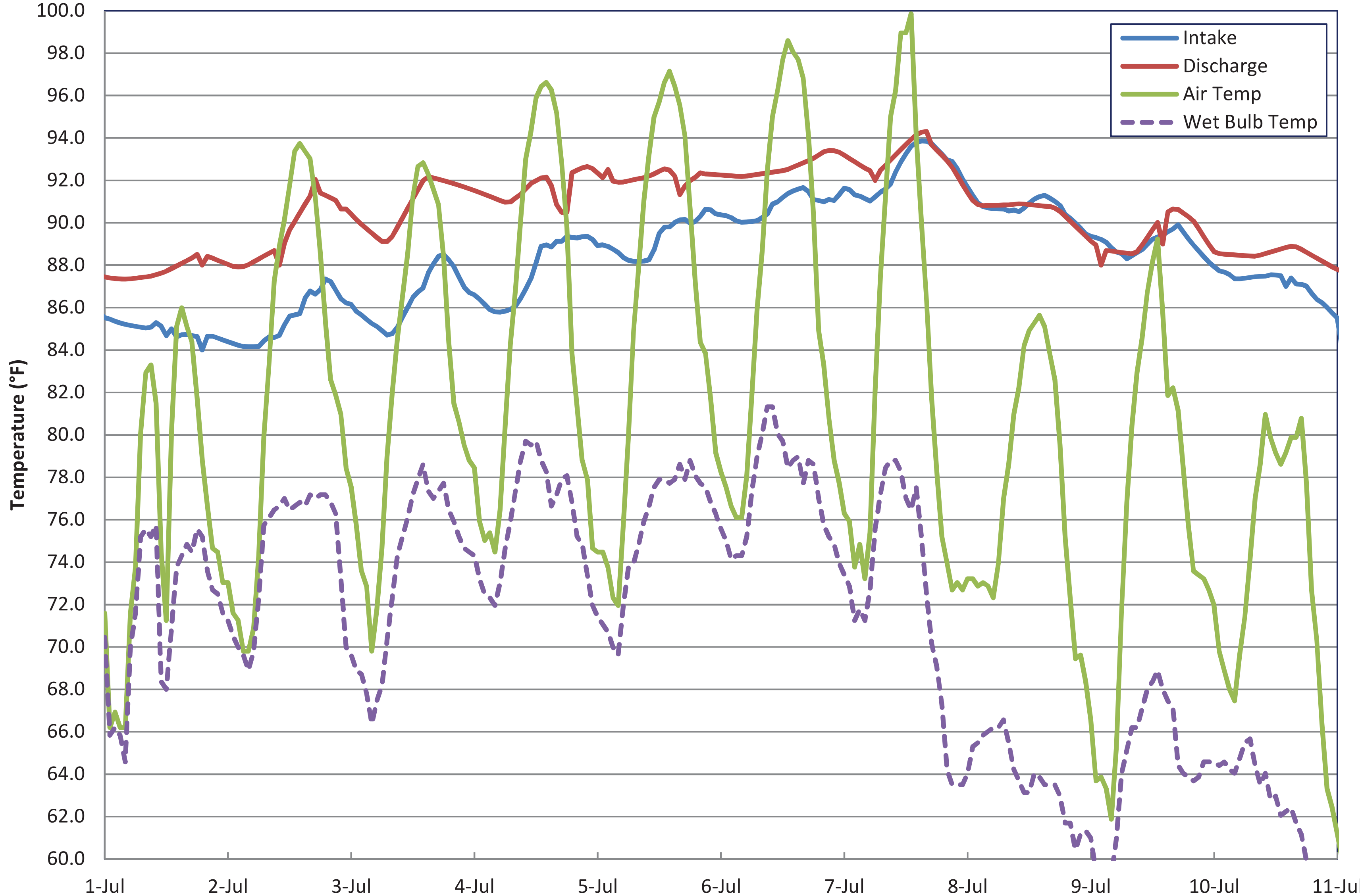


Figure B-5. Diagram of thermal parameter data for gizzard shad.

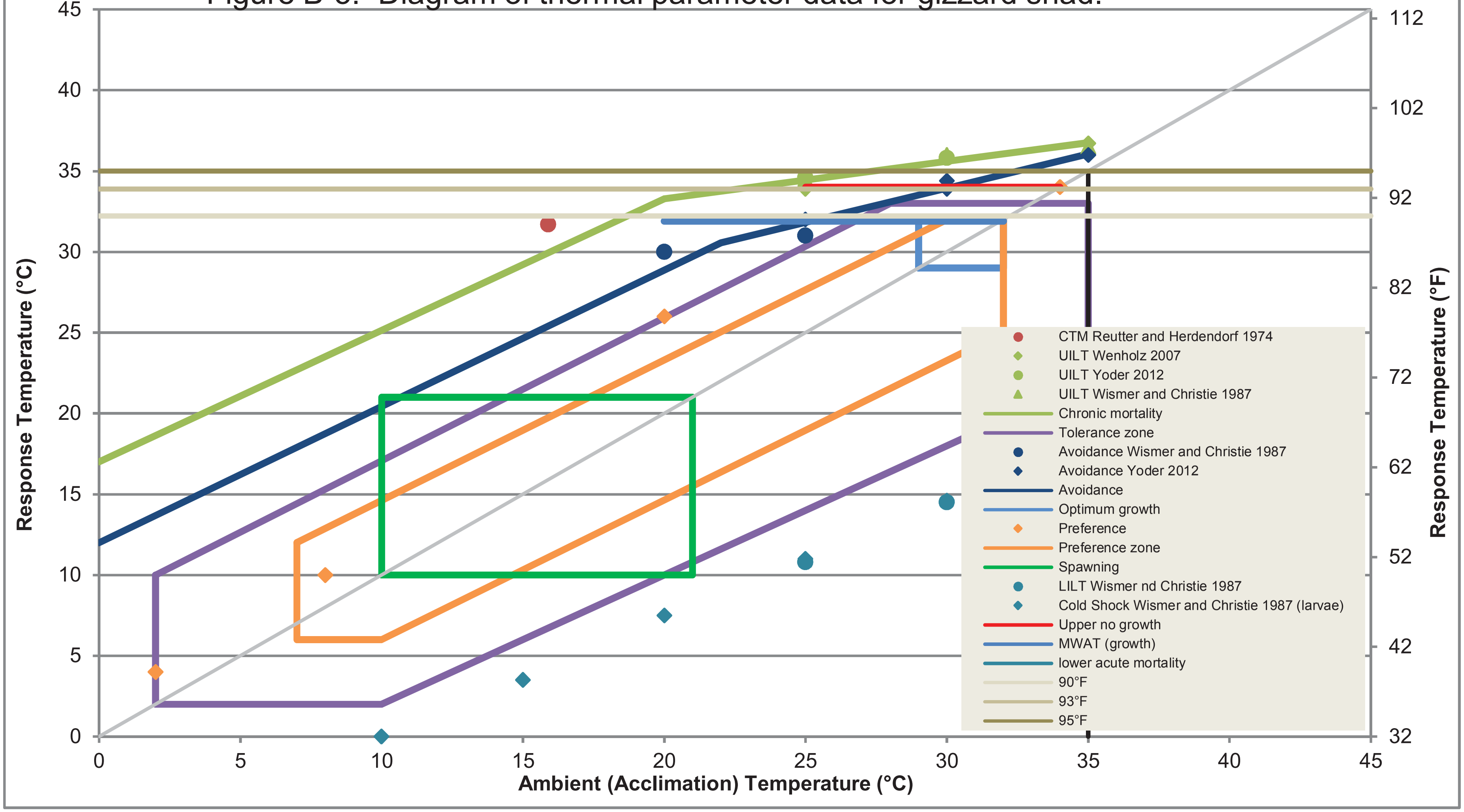


Figure B-6. Diagram of thermal parameter data for emerald shiner.

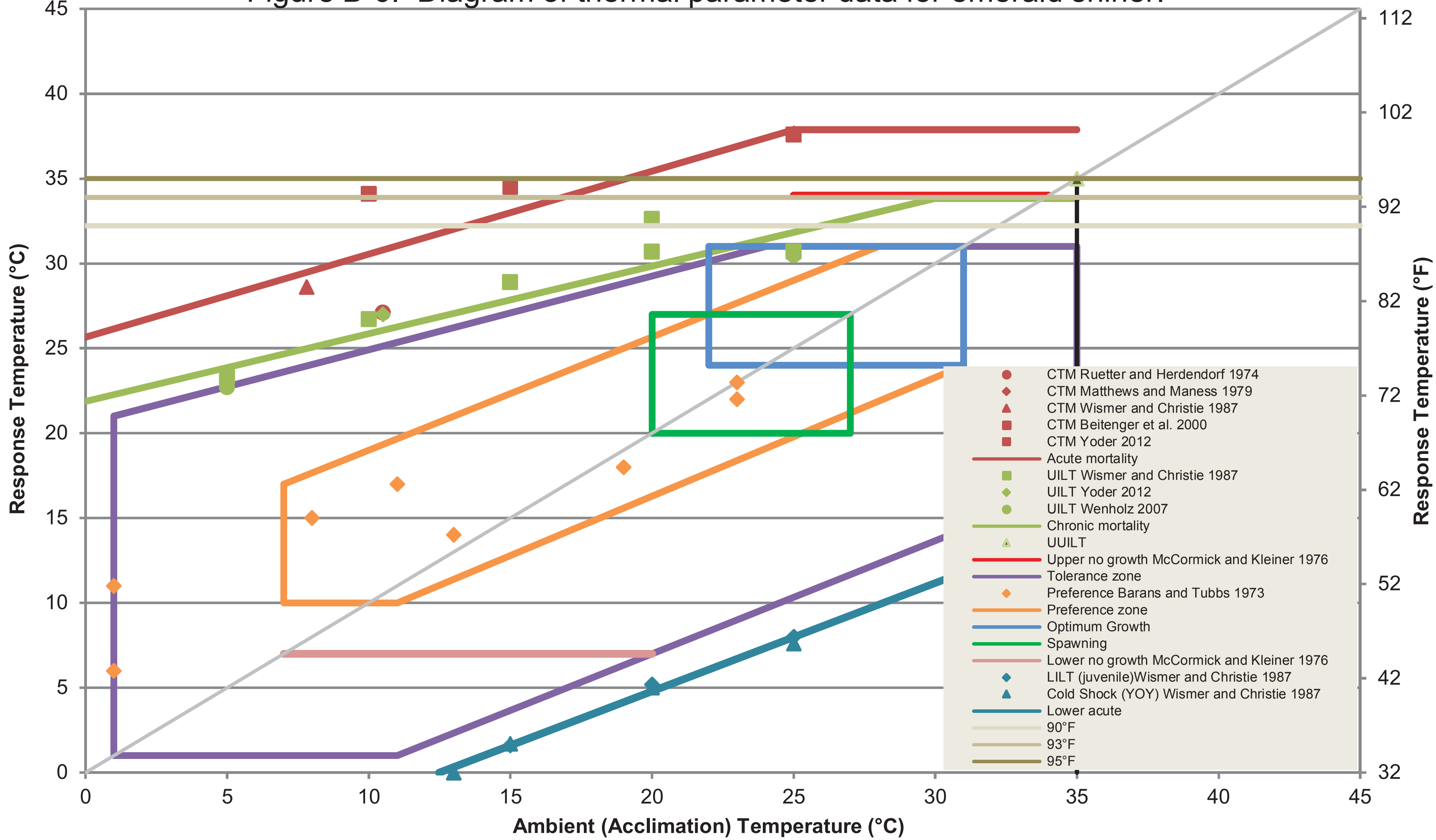


Figure B-7. Diagram of thermal parameter data for common carp.

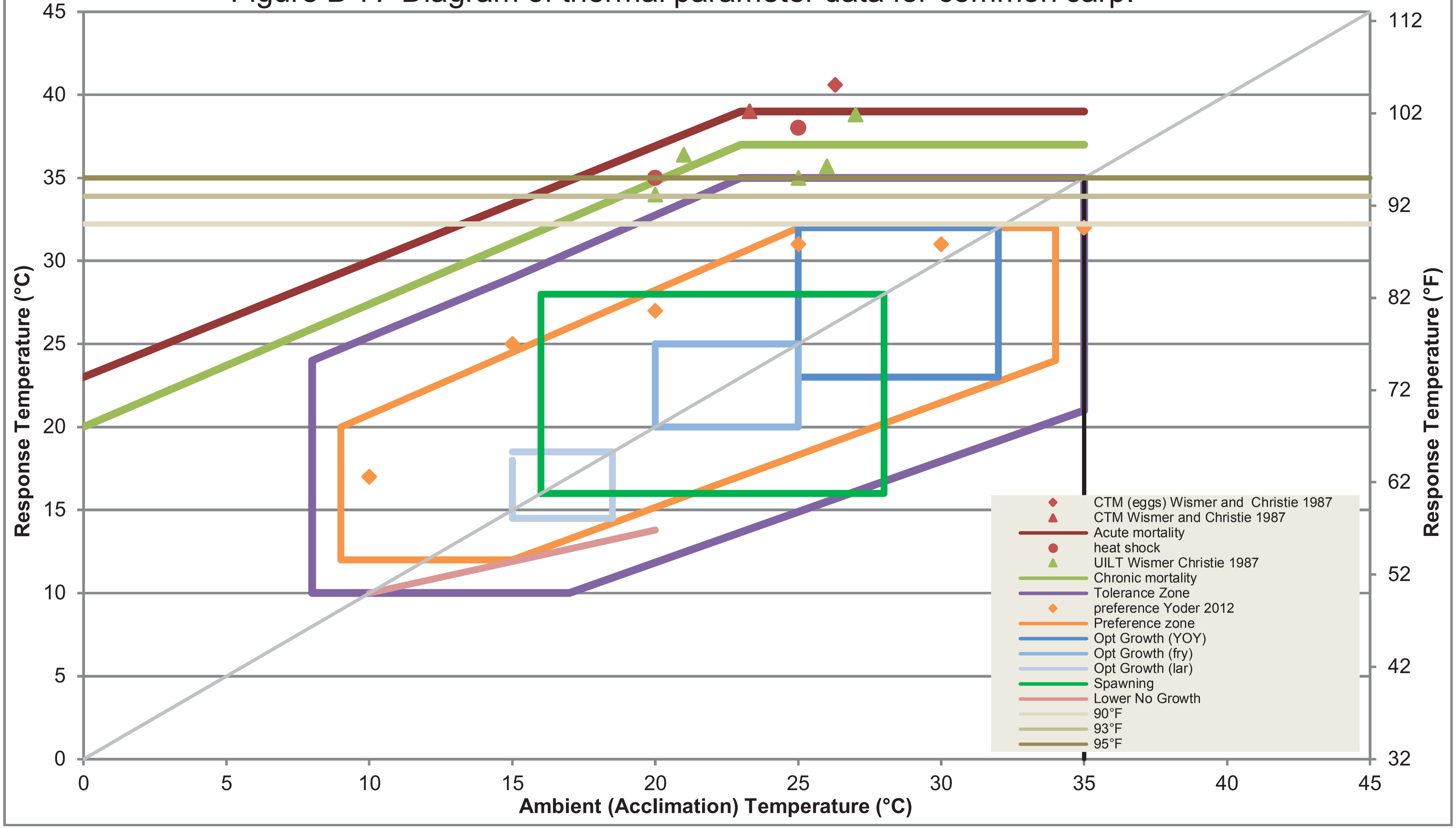


Figure B-8. Diagram of thermal parameter data for golden redhorse.

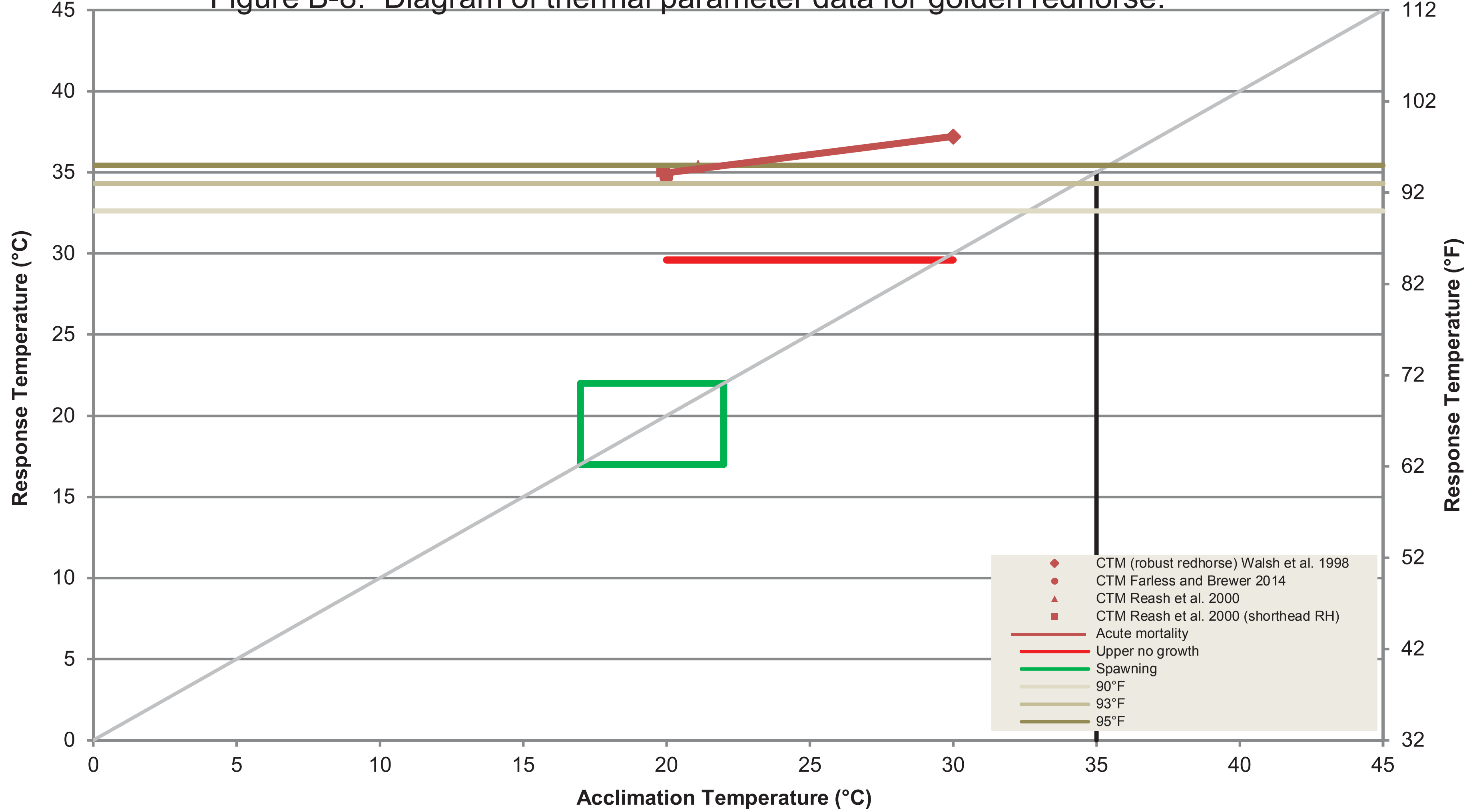


Figure B-9. Diagram of thermal parameter data for white sucker.

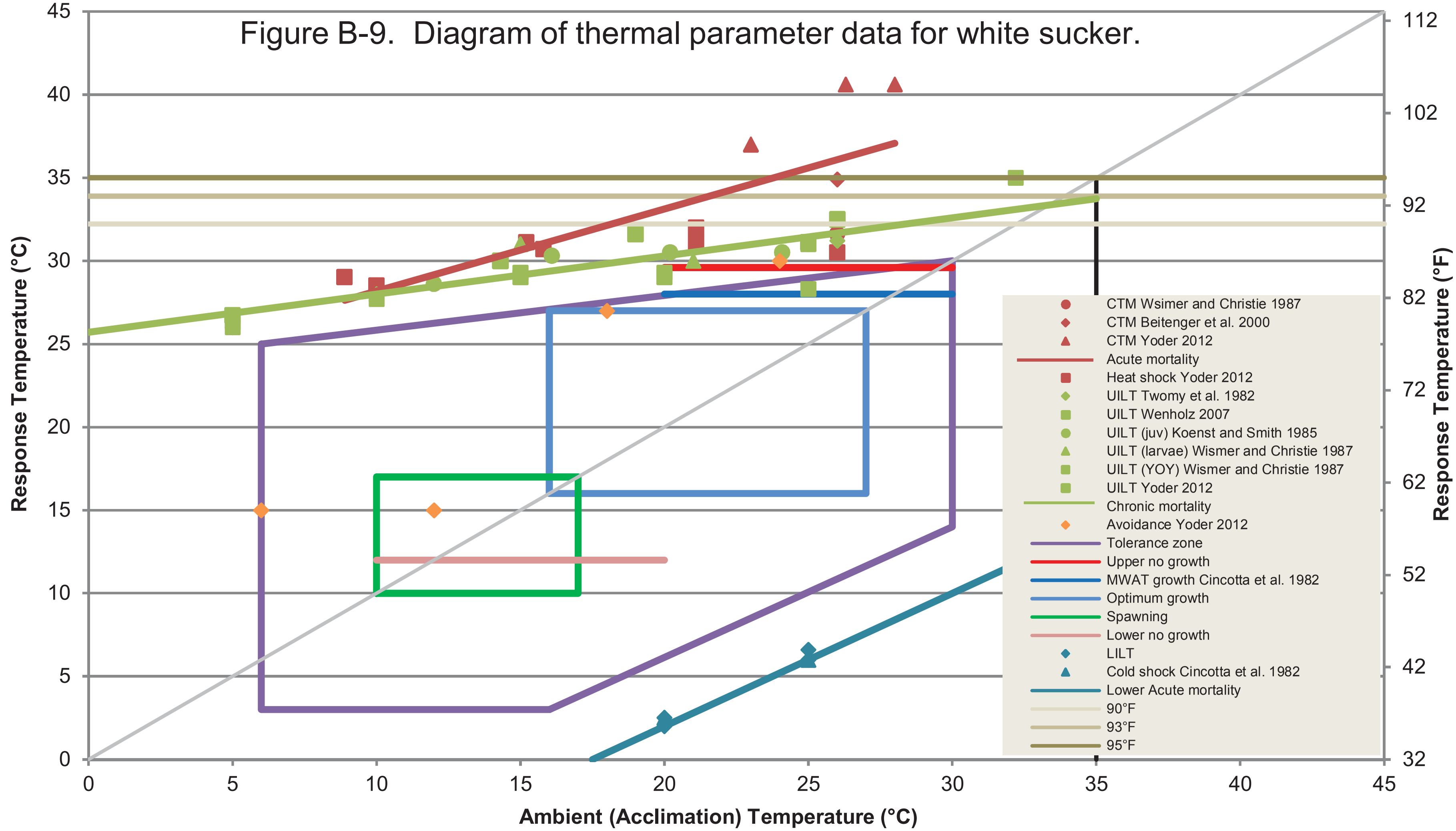


Figure B-10. Diagram of thermal parameter data for channel catfish.

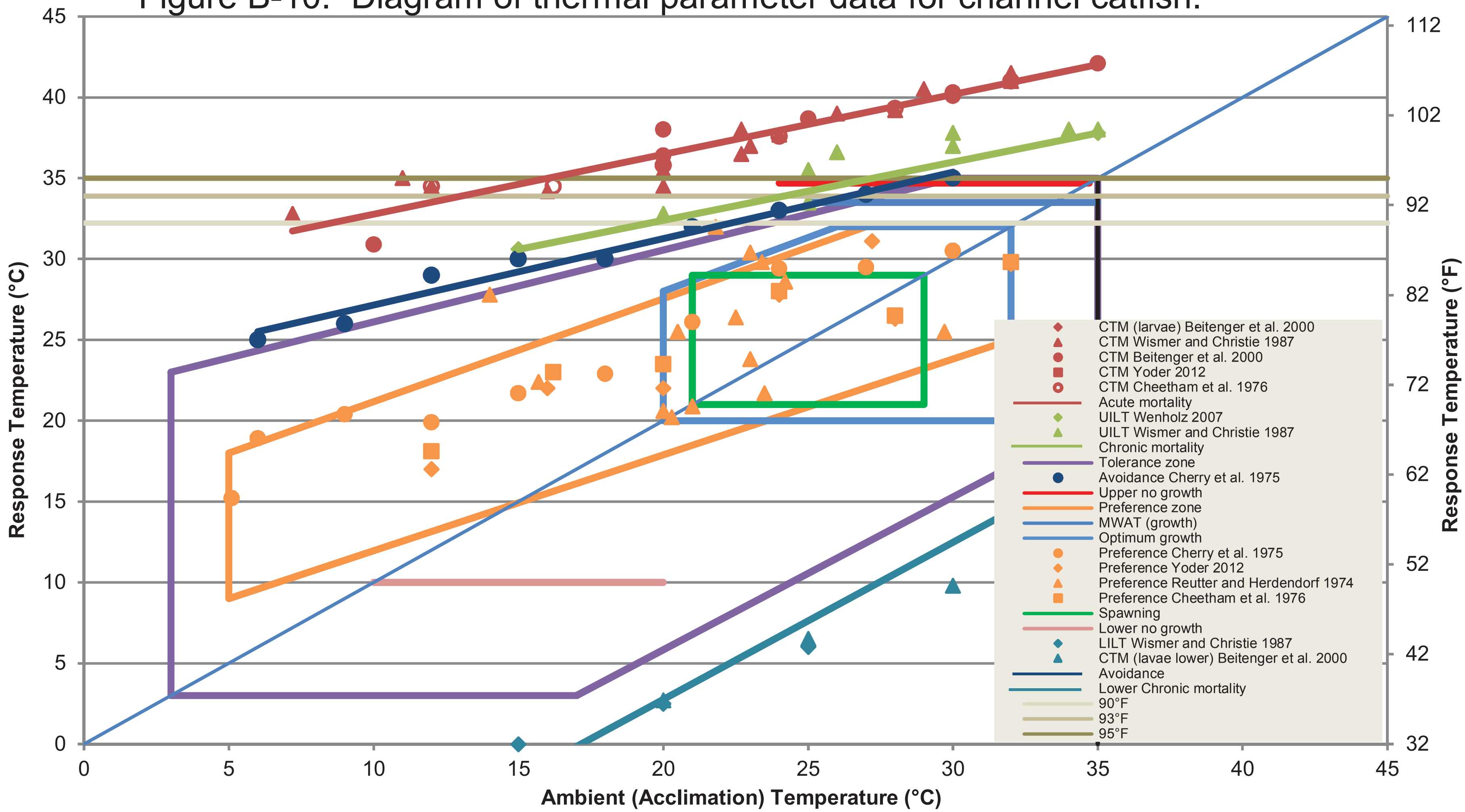


Figure B-11. Diagram of thermal parameter data for largemouth bass.

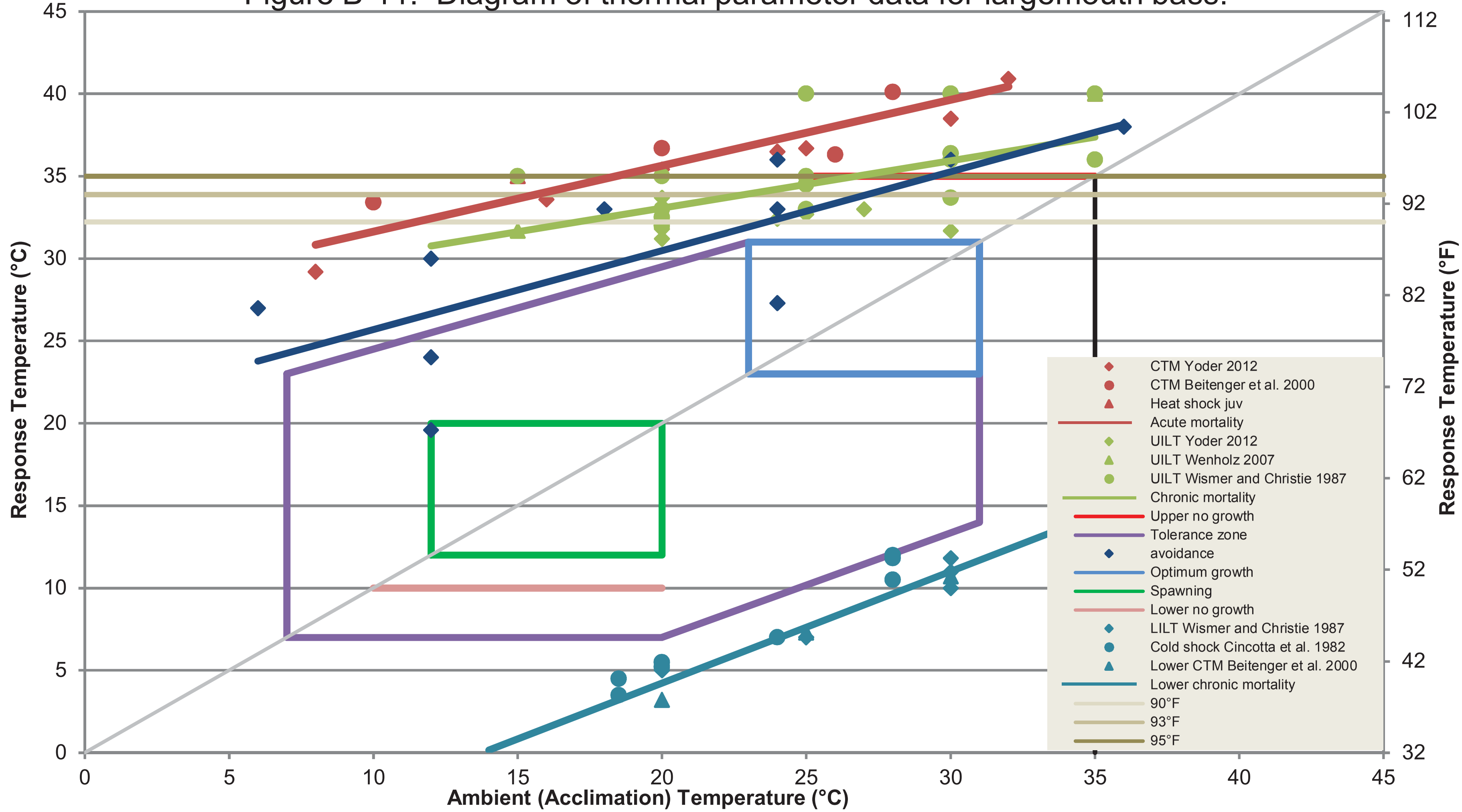


Figure B-12. Diagram of thermal parameter data for smallmouth bass.

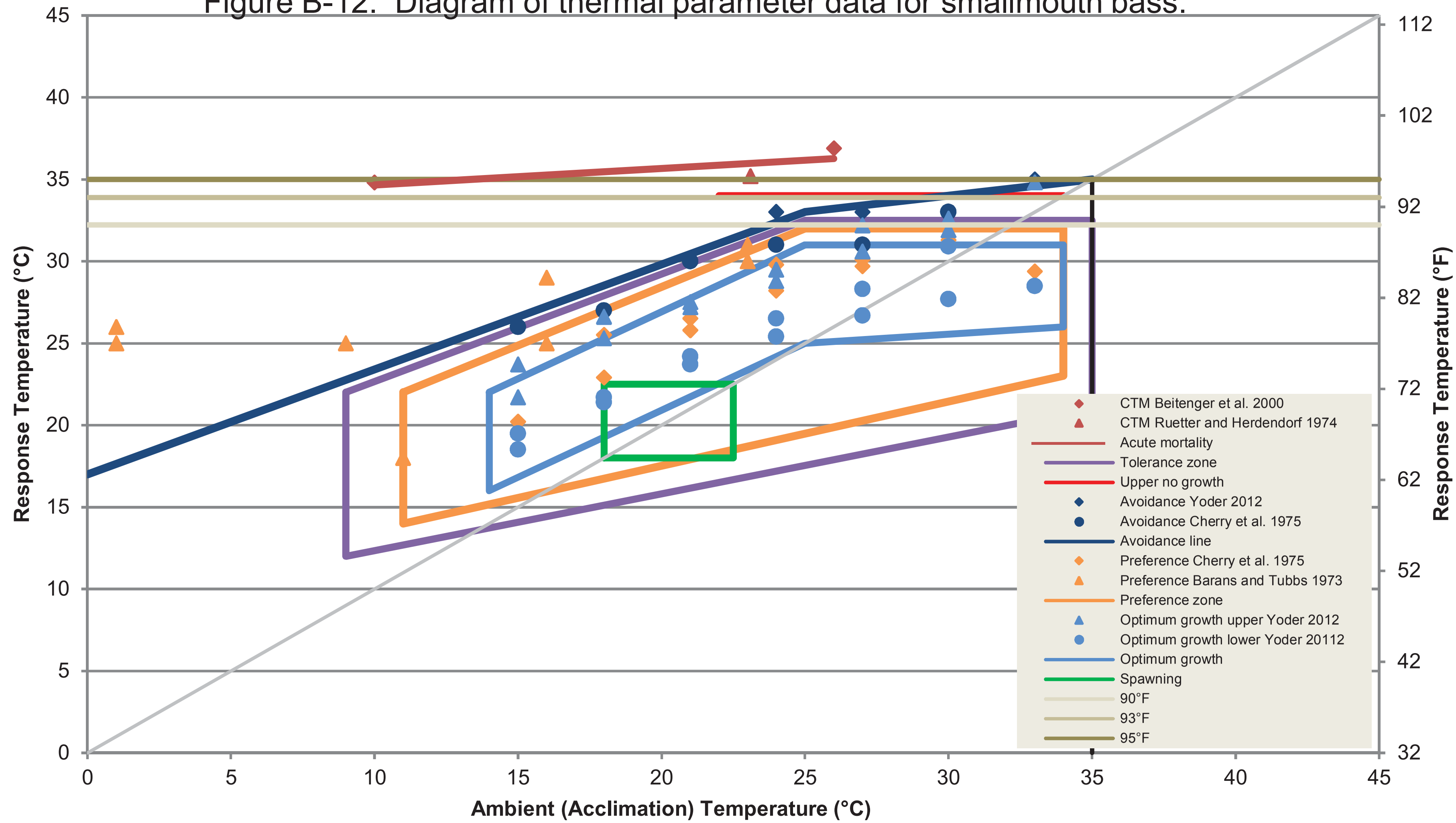


Figure B-13. Diagram of thermal parameter data for bluegill.

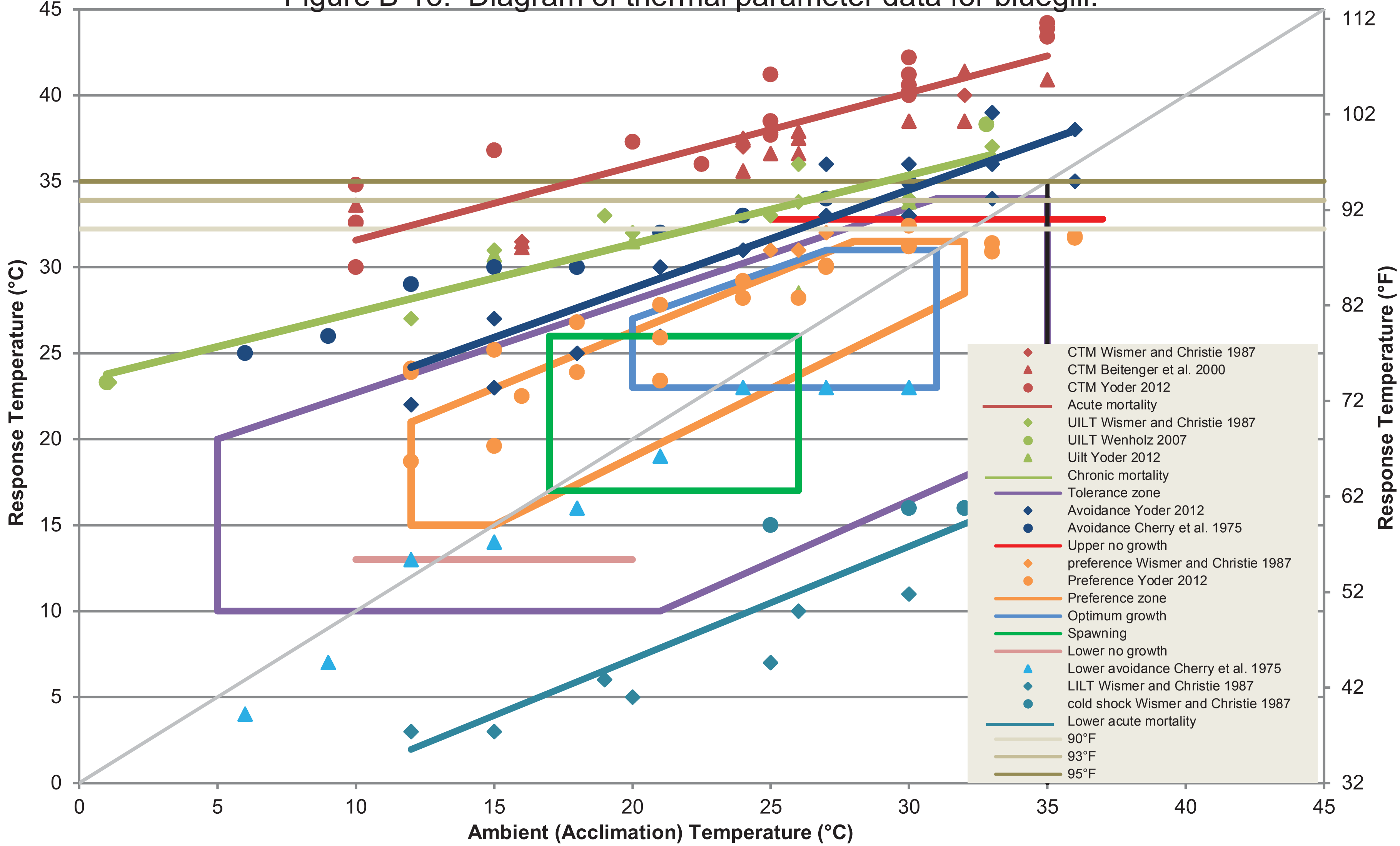


Figure B-14. Diagram of thermal parameter data for black crappie.

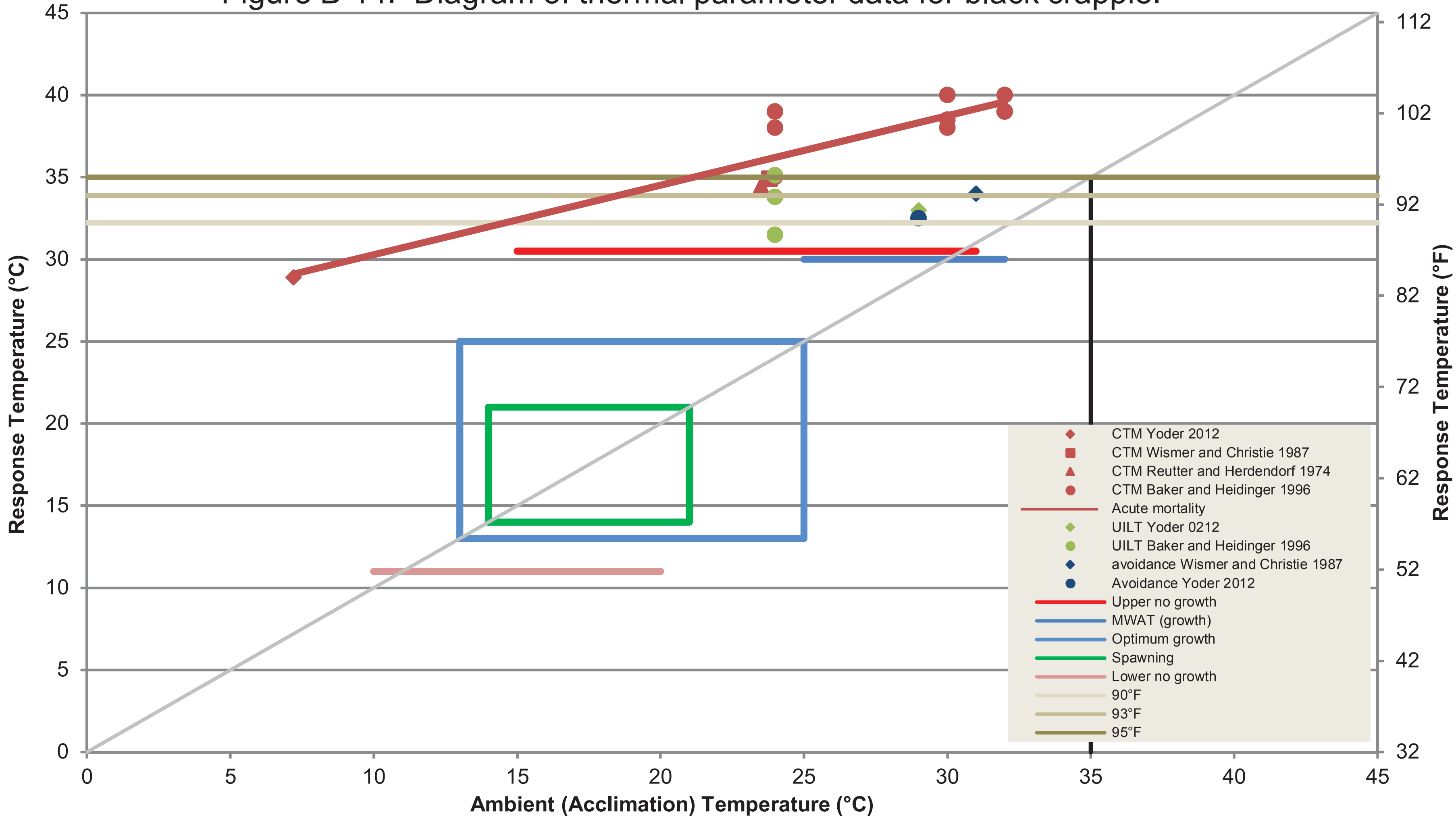


Figure B-15. Diagram of thermal parameter data for logperch.

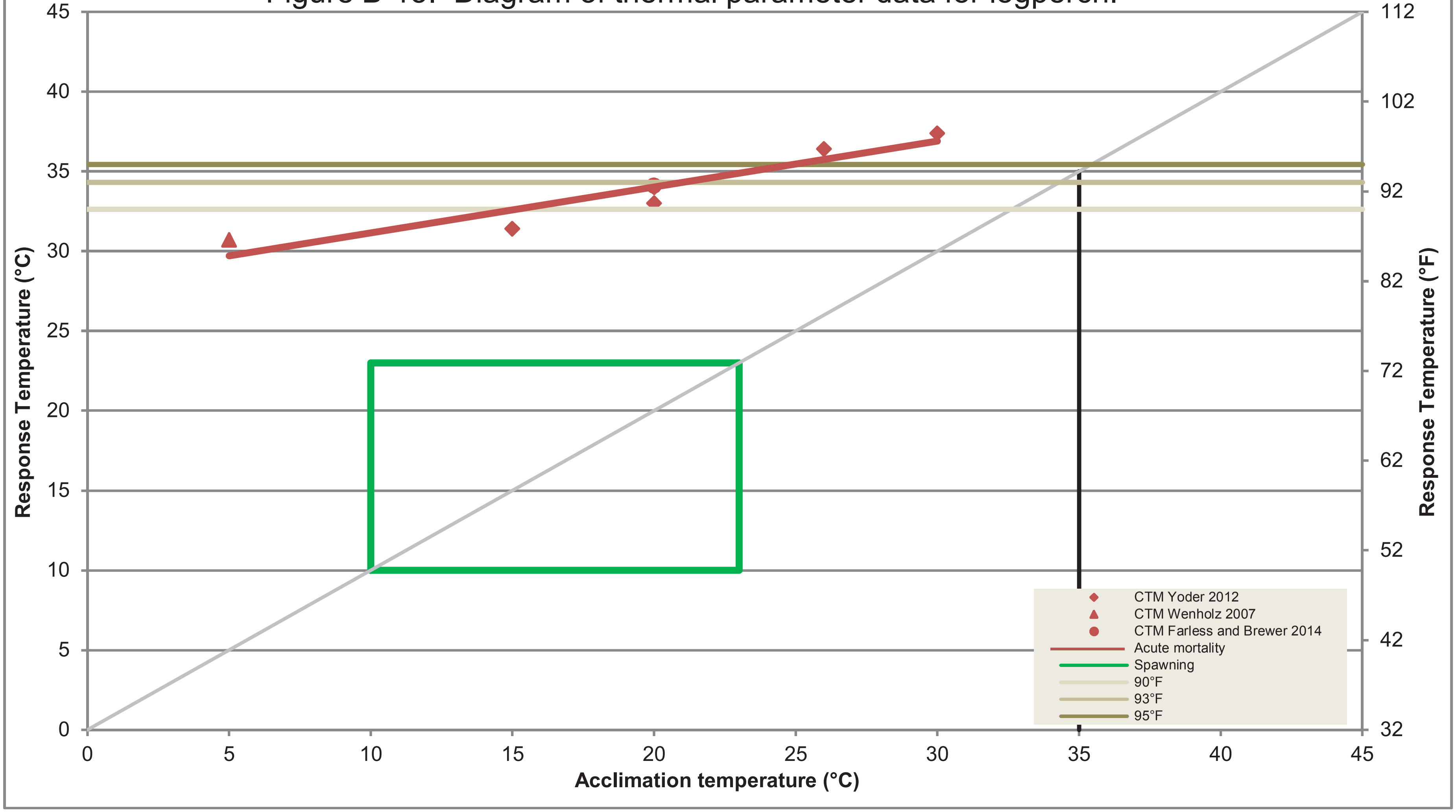
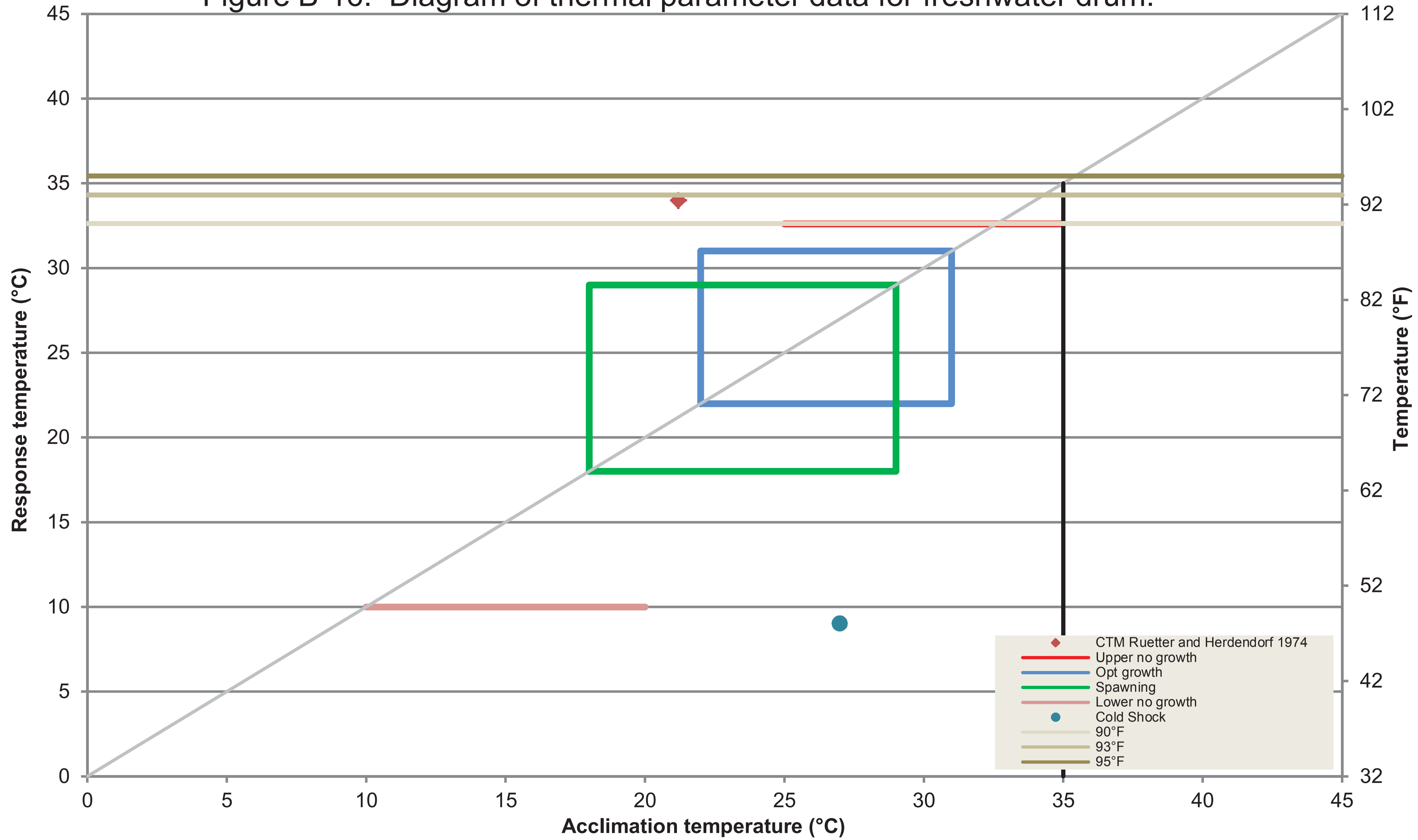


Figure B-16. Diagram of thermal parameter data for freshwater drum.



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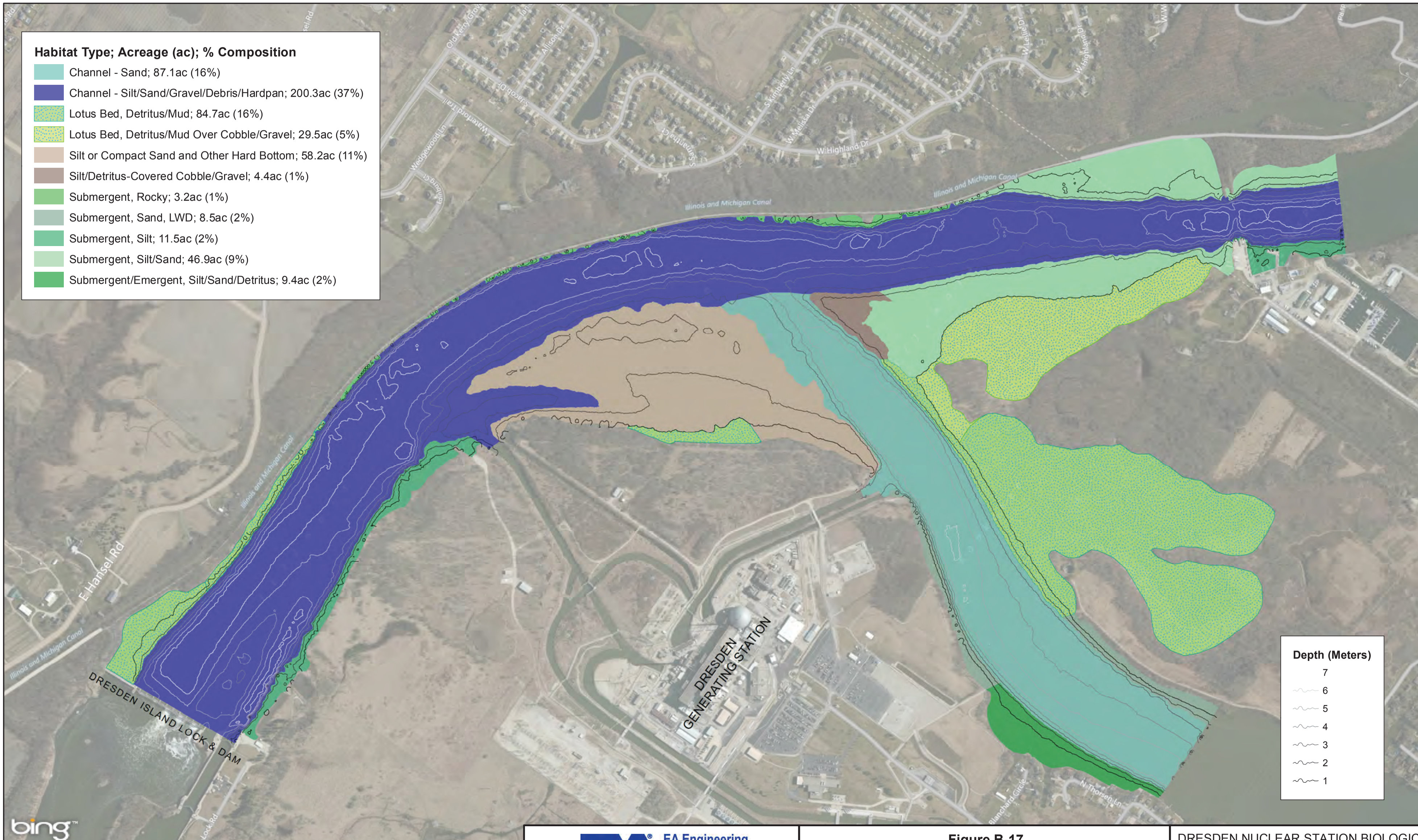

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Figure B-17
Distribution of habitat in the Illinois, Des Plaines, and Kankakee Rivers within the area bounded by the hydrothermal model for the DNS cooling water discharge.

DRESDEN NUCLEAR STATION BIOLOGICAL MONITORING: MUSSEL SURVEY GRUNDY COUNTY, ILLINOIS

SCALE	FIGURE
1 inch = 800 feet	1

2014.12.05 C:\Users\bonelli\Desktop\Exelon\Dresden_Biological.mxd EA-Deerfield bonelli

Figure B-18. DNS Intake and Discharge Temperatures and Modeled Surface, Mid, and Bottom Temperatures at IL-200 , 6-8 July 2012

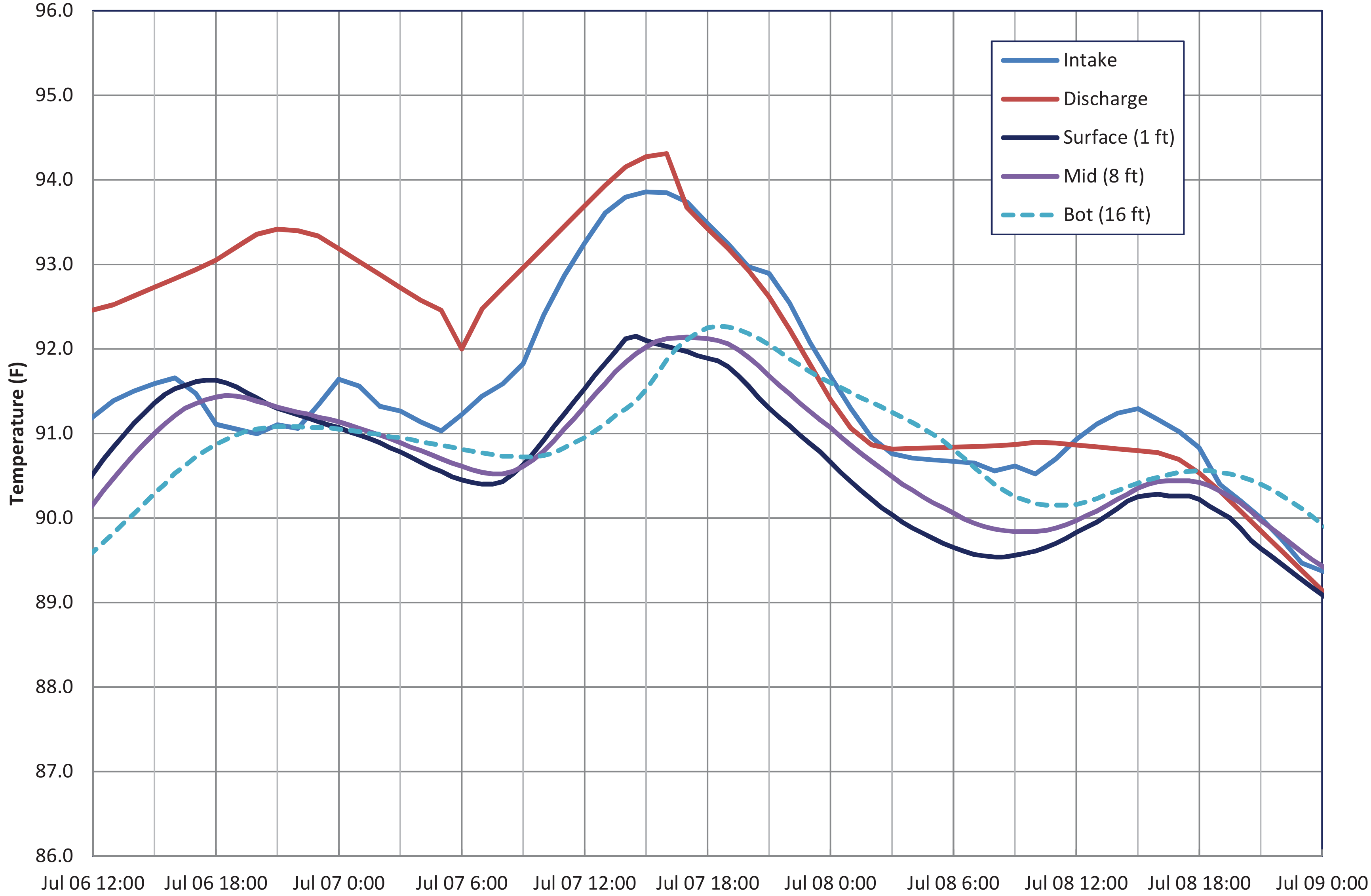


Figure B-19. DNS Intake and Discharge Temperatures and Modeled Surface, Mid, and Bottom Temperatures at IL475 , 6-8 July 2012

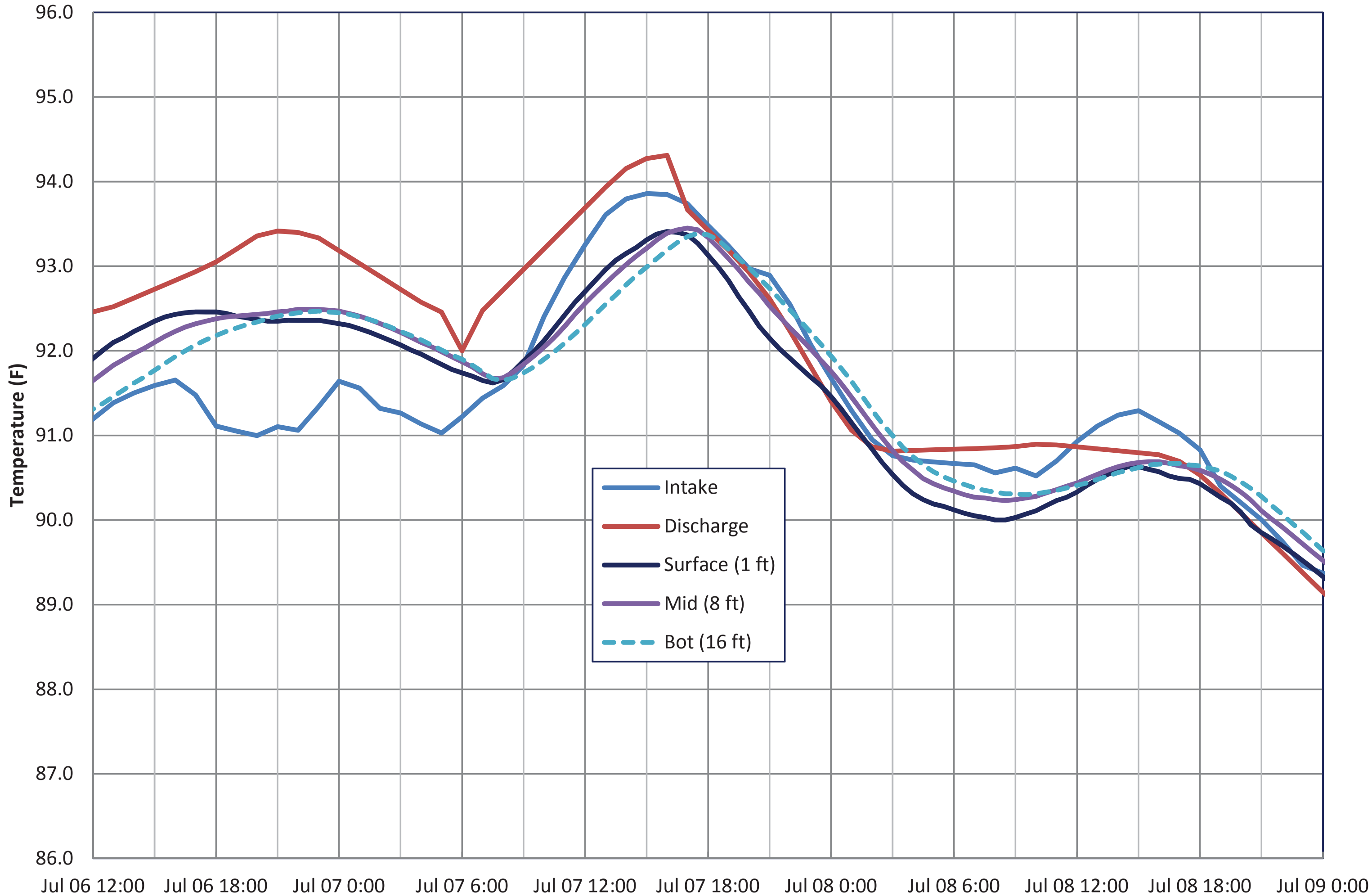


Figure B-20. DNS Intake and Discharge Temperatures and Modeled Surface, Mid, and Bottom Temperatures at IL475 , 1-20 July 2012

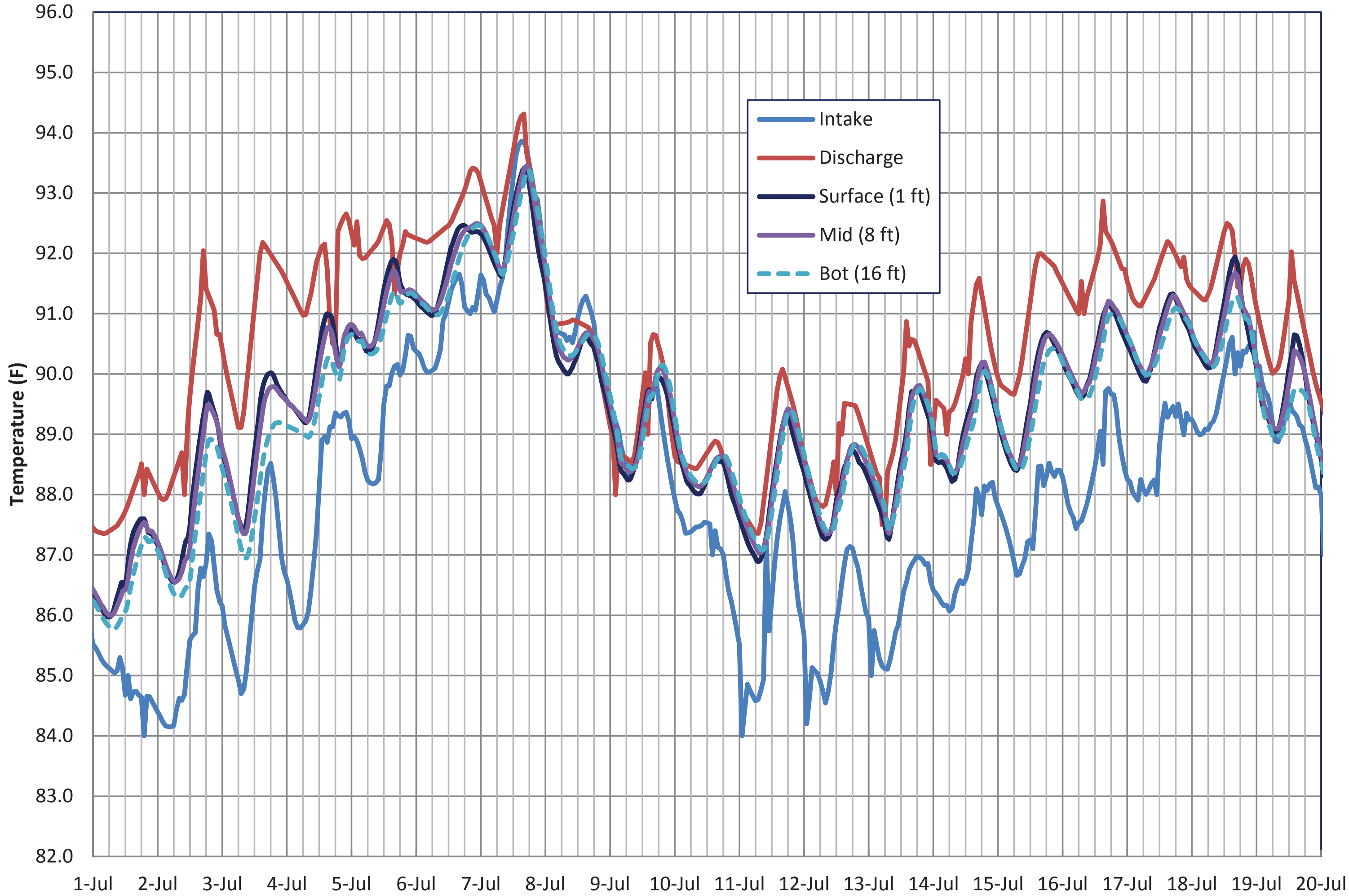
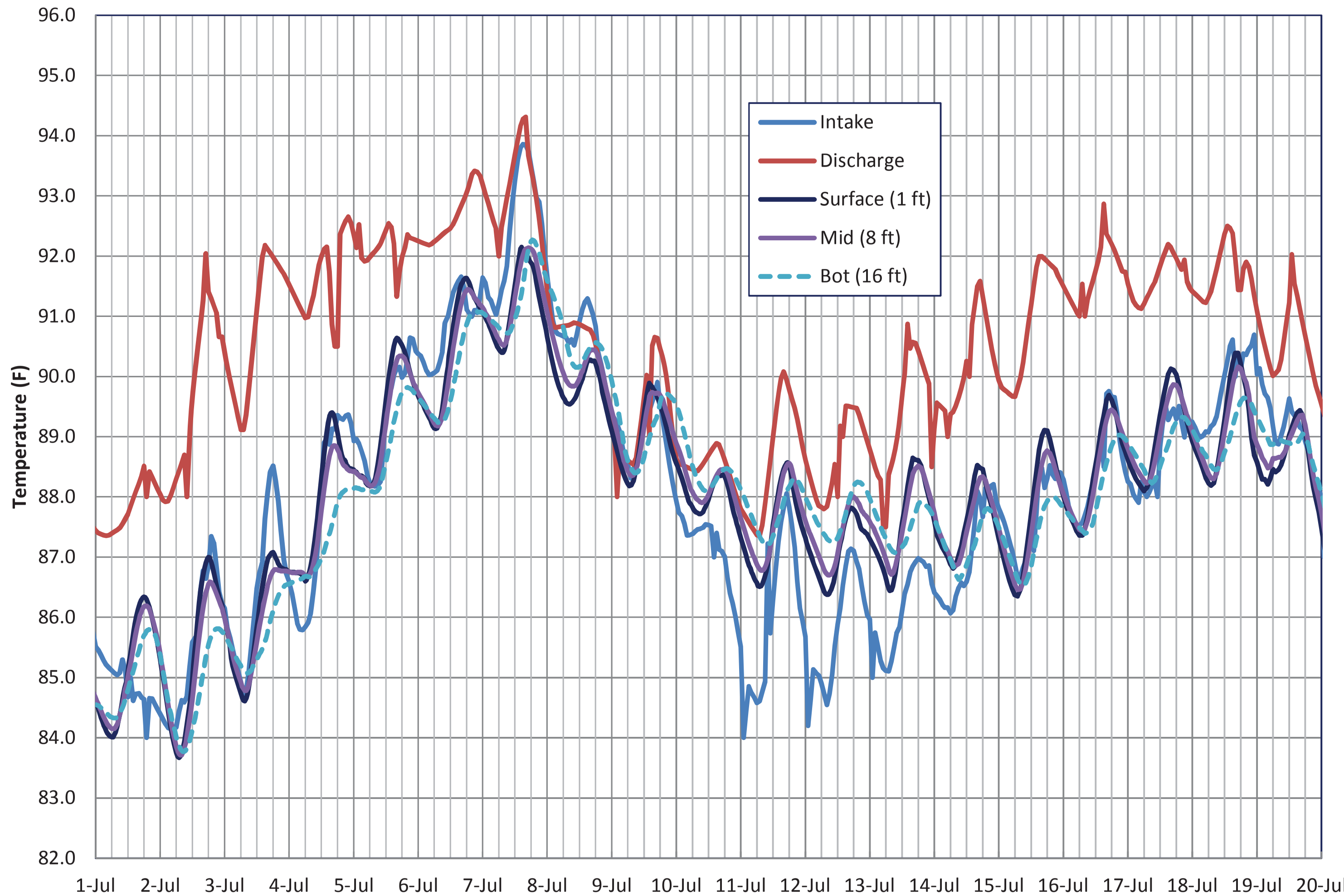


Figure B-21. DNS Intake and Discharge Temperatures and Modeled Surface, Mid, and Bottom Temperatures at IL-200 , 1-20 July 2012



TABLES

Table B-1. Taxa Collected by Various Techniques in the Vicinity of Dresden Station, 1991-2014.

Common Name	Scientific Name	Electrofishing	Seine	Gillnet
SPOTTED GAR	*Lepisosteus oculatus*	X	--	--
LONGNOSE GAR	*Lepisosteus osseus*	X	X	X
SHORTNOSE GAR	*Lepisosteus platostomus*	X	--	X
SKIPJACK HERRING	*Alosa chrysochloris*	X	X	X
GIZZARD SHAD	*Dorosoma cepedianum*	X	X	X
THREADFIN SHAD	*Dorosoma petenense*	X	X	X
GOLDEYE	*Hiodon alosoides*	X	--	X
MOONEYE	*Hiodon tergisus*	--	--	X
CHINOOK SALMON	*Oncorhynchus tshawytscha*	--	--	X
RAINBOW SMELT	*Osmerus mordax*	--	X	--
GRASS PICKEREL	*Esox americanus vermiculatus*	X	--	--
NORTHERN PIKE	*Esox lucius*	X	X	X
CENTRAL STONEROLLER	*Campostoma anomalum*	X	X	--
GOLDFISH	*Carassius auratus*	X	X	X
GRASS CARP	*Ctenopharyngodon idella*	X	--	--
COMMON CARP	*Cyprinus carpio*	X	X	X
SILVER CARP	*Hypophthalmichthys molitrix*	X	--	--
SILVERJAW MINNOW	*Notropis buccatus*	X	X	--
SHOAL CHUB	*Macrhybopsis hyostoma*	X	X	--
SILVER CHUB	*Macrhybopsis storeriana*	--	--	X
HORNYHEAD CHUB	*Nocomis biguttatus*	X	X	--
GOLDEN SHINER	*Notemigonus crysoleucas*	X	X	--
PALLID SHINER	*Hybopsis amnis*	X	X	--
EMERALD SHINER	*Notropis atherinoides*	X	X	X
GHOST SHINER	*Notropis buchanani*	X	X	--
STRIPED SHINER	*Luxilus chrysocephalus*	X	X	X
PUGNOSE MINNOW	*Opsopoeodus emiliae*	X	--	--
SPOTTAIL SHINER	*Notropis hudsonius*	X	X	X
RED SHINER	*Cyprinella lutrensis*	X	X	--
ROSYFACE SHINER	*Notropis rubellus*	X	X	--
SPOTFIN SHINER	*Cyprinella spiloptera*	X	X	X
SAND SHINER	*Notropis stramineus*	X	X	--
REDFIN SHINER	*Lythrurus umbratilis*	X	X	--
MIMIC SHINER	*Notropis volucellus*	X	X	--
CHANNEL SHINER	*Notropis wickliffi*	X	--	--
SUCKERMOUTH MINNOW	*Phenacobius mirabilis*	X	X	--
BLUNTNOSE MINNOW	*Pimephales notatus*	X	X	--
FATHEAD MINNOW	*Pimephales promelas*	X	X	--
BULLHEAD MINNOW	*Pimephales vigilax*	X	X	--
CREEK CHUB	*Semotilus atromaculatus*	X	X	--
RIVER CARPSUCKER	*Carpiodes carpio*	X	X	X
QUILLBACK	*Carpiodes cyprinus*	X	X	X
HIGHFIN CARPSUCKER	*Carpiodes velifer*	X	--	--
WHITE SUCKER	*Catostomus commersonii*	X	X	X

Table B-1 (Continued)

Common Name	Scientific Name	Electrofishing	Seine	Gillnet
NORTHERN HOG SUCKER	*Hypentelium nigricans*	X	X	--
SMALLMOUTH BUFFALO	*Ictiobus bubalus*	X	X	X
BIGMOUTH BUFFALO	*Ictiobus cyprinellus*	X	--	X
BLACK BUFFALO	*Ictiobus niger*	X	X	X
SPOTTED SUCKER	*Minytrema melanops*	X	--	X
SILVER REDHORSE	*Moxostoma anisurum*	X	X	X
RIVER REDHORSE	*Moxostoma carinatum*	X	X	X
BLACK REDHORSE	*Moxostoma duquesnei*	X	--	--
GOLDEN REDHORSE	*Moxostoma erythrurum*	X	X	X
SHORTHEAD REDHORSE	*Moxostoma macrolepidotum*	X	X	X
GREATER REDHORSE	*Moxostoma valenciennesi*	X	--	--
BLACK BULLHEAD	*Ameiurus melas*	X	--	X
YELLOW BULLHEAD	*Ameiurus natalis*	X	X	X
CHANNEL CATFISH	*Ictalurus punctatus*	X	X	X
STONECAT	*Noturus flavus*	--	X	--
TADPOLE MADTOM	*Noturus gyrinus*	X	X	--
FLATHEAD CATFISH	*Pylodictis olivaris*	X	--	X
TROUT-PERCH	*Percopsis omiscomaycus*	X	X	X
BANDED KILLIFISH	*Fundulus diaphanus*	--	X	--
BLACKSTRIPE TOPMINNOW	*Fundulus notatus*	X	X	--
WESTERN MOSQUITOFISH	*Gambusia affinis*	X	X	--
BROOK SILVERSIDE	*Labidesthes sicculus*	X	X	--
WHITE PERCH	*Morone americana*	X	X	X
WHITE BASS	*Morone chrysops*	X	X	X
YELLOW BASS	*Morone mississippiensis*	X	X	X
STRIPED BASS	*Morone saxatilis*	X	--	X
ROCK BASS	*Ambloplites rupestris*	X	X	X
GREEN SUNFISH	*Lepomis cyanellus*	X	X	X
PUMPKINSEED	*Lepomis gibbosus*	X	X	--
WARMOUTH	*Lepomis gulosus*	X	--	--
ORANGESPOTTED SUNFISH	*Lepomis humilis*	X	X	X
BLUEGILL	*Lepomis macrochirus*	X	X	X
REDEAR SUNFISH	*Lepomis microlophus*	X	--	--
NORTHERN SUNFISH	*Lepomis peltastes*	X	X	--
SMALLMOUTH BASS	*Micropterus dolomieu*	X	X	X
LARGEMOUTH BASS	*Micropterus salmoides*	X	X	X
WHITE CRAPPIE	*Pomoxis annularis*	X	X	X
BLACK CRAPPIE	*Pomoxis nigromaculatus*	X	X	X
WESTERN SAND DARTER	*Ammocrypta clara*	--	X	--
RAINBOW DARTER	*Etheostoma caeruleum*	--	X	--
BLUNTNOSE DARTER	*Etheostoma chlorosoma*	--	X	--
JOHNNY DARTER	*Etheostoma nigrum*	X	X	--
BANDED DARTER	*Etheostoma zonale*	X	X	--
YELLOW PERCH	*Perca flavescens*	X	X	--
LOGPERCH	*Percina caprodes*	X	X	--
BLACKSIDE DARTER	*Percina maculata*	X	X	--

Table B-1 (Continued)

Common Name	Scientific Name	Electrofishing	Seine	Gillnet
SLENDERHEAD DARTER	*Percina phoxocephala*	X	X	--
RIVER DARTER	*Percina shumardi*	X	--	--
SAUGER	*Sander canadensis*	X	--	--
WALLEYE	*Sander vitreus*	X	X	X
FRESHWATER DRUM	*Aplodinotus grunniens*	X	X	X
ROUND GOBY	*Neogobius melanostomus*	X	X	--
	Total Number of Species	87	73	46

Table B-2. Number of Years Collected for All Taxa in All Gear During the 19 Survey Years: 1991-1995, 1997-2008, 2011, and 2013

Species	Des Plaines River	Kankakee River	Illinois River Upstream L&D	Illinois River Downstream L&D
GIZZARD SHAD	19	19	19	17
COMMON CARP	19	19	19	17
BLUNTNOSE MINNOW	19	19	19	17
GOLDEN REDHORSE	19	19	19	17
CHANNEL CATFISH	19	19	19	17
GREEN SUNFISH	19	19	19	17
BLUEGILL	19	19	19	17
SMALLMOUTH BASS	19	19	19	17
EMERALD SHINER	18	19	19	17
SPOTFIN SHINER	18	19	19	17
LARGEMOUTH BASS	19	18	19	17
FRESHWATER DRUM	18	19	18	17
BULLHEAD MINNOW	16	19	19	17
SPOTTAIL SHINER	17	18	19	16
SMALLMOUTH BUFFALO	19	14	19	17
SHORTHEAD REDHORSE	13	19	18	17
LOGPERCH	13	19	18	17
ORANGESPOTTED SUNFISH	12	19	17	15
BROOK SILVERSIDE	10	18	18	16
NORTHERN SUNFISH	12	18	17	14
STRIPED SHINER	12	15	19	11
QUILLBACK	8	16	17	16
RIVER CARPSUCKER	17	7	15	16
SILVER REDHORSE	7	16	16	16
FLATHEAD CATFISH	8	17	16	9
SAND SHINER	5	13	14	17
LONGNOSE GAR	5	12	13	16
ROCK BASS	9	16	13	6
BLACK CRAPPIE	10	8	12	14
SKIPJACK HERRING	11	7	12	13
THREADFIN SHAD	6	11	12	12
BLACKSTRIPE TOPMINNOW	12	9	10	10
MIMIC SHINER	--	9	7	14
SLENDERHEAD DARTER	--	13	5	10
GHOST SHINER	5	10	9	13
WHITE BASS	2	11	8	14
GOLDEN SHINER	7	10	10	5
JOHNNY DARTER	2	15	8	7
WHITE CRAPPIE	--	7	3	10
ROUND GOBY	7	6	8	5
PALLID SHINER	5	10	5	4

Table B-2 (Continued)

Species	Des Plaines River	Kankakee River	Illinois River Upstream L&D	Illinois River Downstream L&D
TROUT-PERCH	2	11	6	5
REDFIN SHINER	8	3	6	6
Moxostoma sp.	3	6	8	5
WALLEYE	3	8	4	6
CENTRAL STONEROLLER	2	4	10	4
BLACK BUFFALO	7	1	7	5
REDEAR SUNFISH	--	5	--	--
RED SHINER	1	5	5	8
WHITE PERCH	--	2	3	9
GOLDEYE	--	3	5	5
YELLOW BASS	--	2	3	8
HORNYHEAD CHUB	3	2	8	3
WESTERN MOSQUITOFISH	4	1	1	10
SAUGER	--	--	--	4
PUMPKINSEED	1	5	6	3
BLACKSIDE DARTER	4	4	4	3
YELLOW BULLHEAD	6	--	4	1
WARMOUTH	--	4	3	--
SUCKERMOUTH MINNOW	--	3	3	4
NORTHERN HOG SUCKER	1	2	3	7
GOLDFISH	2	--	4	3
ROSYFACE SHINER	1	--	3	5
HIGHFIN CARPSUCKER	2	--	--	4
RIVER REDHORSE	1	1	5	5
WHITE SUCKER	3	1	3	4
FATHEAD MINNOW	--	2	2	4
SPOTTED SUCKER	3	4	1	--
BANDED DARTER	--	2	3	2
SHORTNOSE GAR	1	--	1	4
GRASS PICKEREL	1	--	3	2
NORTHERN PIKE	1	2	2	3
GRASS CARP	--	--	--	2
SHOAL CHUB	--	--	--	2
SILVER CHUB	--	--	--	2
GREATER REDHORSE	1	--	--	3
WESTERN SAND DARTER	--	--	--	2
RAINBOW DARTER	--	--	2	--
BIGMOUTH BUFFALO	3	2	1	1
BLACK REDHORSE	--	1	1	3
TADPOLE MADTOM	2	--	2	1
STRIPED BASS	--	1	--	2
YELLOW PERCH	--	--	2	1
SPOTTED GAR	--	--	--	1
MOONEYE	--	--	--	1

Table B-2 (Continued)

Species	Des Plaines River	Kankakee River	Illinois River Upstream L&D	Illinois River Downstream L&D
CHINOOK SALMON	--	--	1	--
RAINBOW SMELT	--	--	--	1
SILVER CARP	--	--	--	1
SILVERJAW MINNOW	--	--	1	--
PUGNOSE MINNOW	--	1	--	--
CHANNEL SHINER	--	--	1	--
CREEK CHUB	--	--	1	1
BLACK BULLHEAD	1	--	--	1
STONECAT	--	1	--	--
BANDED KILLIFISH	1	--	--	--
BLUNTNOSE DARTER	1	--	--	--
RIVER DARTER	--	--	--	1
Number Taxa in Segment	66	70	78	86

Table B-3. Total Abundance of Fish Taxa Collected in all Gear and River Segments, 1991-2014.

Common Name	1991	1992	1993	1994	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2011	2013	2014	AVG
EMERALD SHINER	1503	2430	976	655	2198	604	900	915	402	1262	3382	2376	972	2263	4023	2530	1670	172	73	923	1511
GIZZARD SHAD	2086	1465	809	729	565	441	634	1146	635	1582	1343	1189	636	1937	1561	2141	1918	518	426	2000	1188
BLUEGILL	244	1433	209	33	128	154	237	655	957	893	1829	2261	913	3038	1818	1189	1285	663	520	494	948
BLUNTNOSE MINNOW	236	879	409	163	186	70	183	177	378	543	1105	1846	700	2809	1161	1470	818	274	323	947	734
SPOTFIN SHINER	373	891	435	208	669	53	40	195	266	794	390	849	784	1492	1706	673	721	462	921	2274	710
BULLHEAD MINNOW	785	438	499	142	206	295	153	458	298	475	114	916	967	1049	319	333	305	142	192	887	449
GREEN SUNFISH	266	986	212	64	47	96	184	583	483	328	520	931	458	454	300	348	267	112	92	159	345
THREADFIN SHAD	1942	--	--	--	--	--	--	36	61	129	86	32	17	3	29	1	123	38	9	858	240
LARGEMOUTH BASS	116	166	72	35	55	51	62	138	89	227	305	325	203	441	355	415	259	188	126	596	211
SPOTTAIL SHINER	88	384	89	134	99	44	8	16	33	279	106	78	32	526	72	172	183	16	13	558	147
GOLDEN REDHORSE	160	76	166	41	101	44	53	71	78	76	272	369	138	189	284	321	279	45	26	100	144
SMALLMOUTH BASS	113	305	170	55	55	63	67	73	92	147	191	343	169	122	119	159	202	42	59	303	142
BROOK SILVERSIDE	27	111	17	29	10	1	11	10	46	51	72	380	121	331	321	190	241	128	226	357	134
COMMON CARP	293	254	184	97	84	29	29	82	54	100	71	53	45	94	56	58	67	37	19	88	90
FRESHWATER DRUM	176	264	118	65	34	47	16	11	61	97	142	138	79	90	96	103	100	14	14	99	88
PALLID SHINER	--	--	--	--	--	--	--	--	--	12	15	77	150	126	37	165	151	10	34	128	82
GHOST SHINER	--	15	324	10	193	32	--	--	2	9	4	61	16	83	32	386	123	--	1	12	81
CHANNEL CATFISH	159	118	46	65	42	37	15	23	63	61	126	139	101	100	132	78	98	37	25	129	80
NORTHERN SUNFISH	8	6	16	1	--	18	8	13	4	45	45	111	31	34	75	77	149	72	107	331	61
SAND SHINER	20	30	19	7	40	3	1	2	6	145	90	107	66	156	92	45	62	36	45	201	59
LOGPERCH	36	31	60	8	9	23	34	25	33	37	34	36	22	111	56	144	42	15	39	180	49
STRIPED SHINER	45	35	44	2	4	9	5	1	20	27	101	43	62	103	83	67	187	27	15	7	44
BLACKSTRIPE TOPMINNOW	--	--	--	--	--	--	1	--	4	9	6	35	39	51	63	76	45	54	130	62	44
SHORTHEAD REDHORSE	77	62	74	31	56	6	17	13	7	40	31	38	24	47	28	38	52	20	36	142	42
ORANGESPOTTED SUNFISH	19	72	19	5	11	14	8	2	7	56	56	264	25	41	29	42	56	11	6	59	40
SMALLMOUTH BUFFALO	61	51	42	31	12	9	11	31	50	79	69	42	39	28	40	42	51	12	7	61	38
MIMIC SHINER	3	7	41	4	5	15	--	--	1	1	10	49	1	46	38	23	10	1	16	345	34
QUILLBACK	195	46	36	26	56	3	5	4	5	13	6	5	10	91	16	8	12	1	6	10	28
ROUND GOBY	--	--	--	--	--	--	--	--	--	--	--	5	29	20	11	35	77	11	3	46	26
RIVER CARPSUCKER	78	88	40	56	21	3	6	7	6	15	16	6	16	14	5	11	9	1	3	13	21
SILVER REDHORSE	29	27	22	18	53	7	4	4	3	9	4	1	25	11	12	18	14	--	5	92	19
TROUT-PERCH	1	24	136	--	4	23	3	1	--	32	13	22	8	--	--	2	2	1	--	1	18
SKIPJACK HERRING	151	45	10	8	4	2	5	4	1	17	16	4	1	3	10	--	8	--	2	3	16
WESTERN MOSQUITOFISH	--	--	--	--	--	--	--	--	3	5	--	7	14	12	8	6	4	3	84	1	13
WHITE BASS	17	23	10	13	30	1	--	--	4	9	17	21	15	8	6	3	8	--	--	21	13
GOLDEYE	12	3	8	54	7	--	--	--	1	1	--	--	--	--	--	--	--	--	--	--	12
ROCK BASS	6	2	5	1	1	3	2	3	2	6	15	7	8	13	24	15	54	5	14	33	11
LONGNOSE GAR	28	18	15	12	12	1	--	3	6	11	6	11	3	8	9	6	23	4	1	25	11
REDFIN SHINER	--	1	26	2	8	--	--	--	--	--	--	23	--	16	14	4	6	3	10	9	10

Table B-3 (Continued)

Common Name	1991	1992	1993	1994	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2011	2013	2014	AVG
GOLDEN SHINER	25	8	3	--	3	1	2	--	1	9	--	--	7	60	7	6	9	12	2	5	10
JOHNNY DARTER	1	--	12	4	1	1	--	--	1	3	1	24	16	28	13	12	3	6	4	25	9
GOLDFISH	14	3	--	1	--	--	--	--	--	--	--	--	--	--	--	7	2	--	--	27	9
ROSYFACE SHINER	--	--	--	--	--	--	--	--	--	--	--	4	4	1	--	--	--	3	17	24	9
SUCKERMOUTH MINNOW	9	32	--	--	--	--	--	--	--	7	8	1	--	--	--	--	1	--	--	1	8
FLATHEAD CATFISH	8	3	7	--	--	4	1	3	6	9	16	18	8	7	9	14	7	8	8	12	8
NORTHERN HOG SUCKER	--	10	--	--	5	--	--	--	--	--	2	--	--	18	--	3	3	1	--	19	8
SHOAL CHUB	--	--	--	--	--	--	--	--	--	--	--	--	--	8	4	--	--	--	--	--	6
BANDED KILLIFISH	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	10	6
CENTRAL STONEROLLER	4	2	1	--	--	--	--	--	3	14	1	3	4	2	1	19	5	--	4	6	5
PUMPKINSEED	3	--	2	--	--	--	--	--	2	--	--	--	--	--	10	1	1	2	9	13	5
BLACK CRAPPIE	9	5	5	1	1	1	1	2	5	2	6	8	6	9	1	4	4	6	1	16	5
WALLEYE	3	3	5	--	2	1	--	--	--	3	5	4	3	--	3	1	3	--	--	23	5
SLENDERHEAD DARTER	2	1	13	3	--	1	4	1	1	1	1	15	3	--	7	5	9	2	1	--	4
FATHEAD MINNOW	2	--	--	--	--	--	--	--	--	--	16	1	3	1	--	--	3	--	--	2	4
RED SHINER	2	12	--	--	6	2	1	3	2	1	4	5	--	--	--	--	--	--	--	4	4
REDEAR SUNFISH	--	--	--	--	--	--	--	--	--	--	--	1	--	1	9	5	1	--	--	--	3
SILVERJAW MINNOW	--	--	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3
WHITE PERCH	2	4	1	--	--	--	--	--	--	3	4	3	1	1	--	1	2	--	--	11	3
WHITE CRAPPIE	5	4	5	--	--	--	--	--	1	2	4	1	2	2	--	1	5	2	--	3	3
BLACK BUFFALO	4	5	2	--	1	1	--	--	1	2	1	11	--	--	--	--	--	2	--	1	3
RIVER REDHORSE	8	--	3	1	2	--	3	--	2	--	2	--	--	--	--	--	--	--	--	1	3
YELLOW PERCH	1	2	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	6	3
BLACKSIDE DARTER	--	--	2	--	1	--	--	--	--	--	--	7	--	4	1	4	1	1	1	1	2
YELLOW BASS	5	1	2	1	--	--	--	4	1	--	2	--	--	1	--	1	3	--	--	1	2
MOONEYE	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2
BLACK REDHORSE	--	--	--	--	--	--	--	--	1	--	1	4	--	--	--	--	--	--	--	--	2
STRIPED BASS	1	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2
YELLOW BULLHEAD	--	1	--	--	--	--	--	--	--	1	2	3	1	--	--	1	--	4	--	3	2
HIGHFIN CARPSUCKER	1	4	1	--	1	--	--	--	--	--	--	1	--	--	--	--	--	--	--	4	2
BANDED DARTER	--	1	--	1	--	--	--	--	1	--	--	--	2	--	1	--	3	--	--	4	2
HORNYHEAD CHUB	1	1	1	--	--	--	--	--	--	--	--	2	1	4	1	1	4	1	2	--	2
NORTHERN PIKE	--	1	--	4	--	--	--	--	--	1	--	--	--	--	--	--	2	1	1	--	2
WHITE SUCKER	2	5	1	1	--	--	--	--	--	--	--	1	--	--	--	1	1	--	--	1	2
TADPOLE MADTOM	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--	--	2	1	1	2
SILVER CHUB	--	--	1	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2
GRASS PICKEREL	1	--	1	1	--	1	--	--	--	--	--	--	1	--	--	--	--	--	--	4	2
SILVER CARP	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	2	2
BIGMOUTH BUFFALO	1	--	--	1	--	--	--	--	1	2	--	--	--	--	--	--	--	--	--	2	1
GRASS CARP	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	1	--	--	--	2	1

Table B-3 (Continued)

Common Name	1991	1992	1993	1994	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2011	2013	2014	AVG
WESTERN SAND DARTER	--	--	--	--	--	--	--	--	--	--	--	1	--	--	1	--	--	--	--	2	1
WARMOUTH	--	--	1	--	--	--	1	--	--	--	1	1	1	2	2	--	--	--	--	--	1
SHORTNOSE GAR	1	2	--	--	--	--	--	--	--	--	1	1	--	--	--	--	--	--	--	1	1
SPOTTED SUCKER	--	1	1	--	--	--	--	--	1	2	--	1	1	--	--	--	--	--	1	1	1
SPOTTED GAR	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	1
CHINOOK SALMON	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1
RAINBOW SMELT	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1
PUGNOSE MINNOW	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	1
CHANNEL SHINER	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	1
CREEK CHUB	--	--	1	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	1
GREATER REDHORSE	1	1	1	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	1
BLACK BULLHEAD	1	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	1
STONECAT	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	1
RAINBOW DARTER	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	1	--	--	--	1
BLUNTNOSE DARTER	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	1
RIVER DARTER	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	1
SAUGER	--	--	--	--	--	--	--	--	--	--	--	--	1	--	1	1	1	--	--	--	1

Table B-4. Summary of Life History and Habitat Information for Species Collected During Monitoring Studies Conducted in the Vicinity of Dresden Nuclear Station, 1979-2014.

Species	Frequency[a]	Non-Native	Feeding Habits[b,c]	Habitat[c,d]	Ecosystem Role[c,e]	State-Listed	RIS
GIZZARD SHAD	D		Z, A, PH,I	P, M	F		X
COMMON CARP	D	X	O, S	P, M, V	F, R,C, N		X
BLUNTNOSE MINNOW	D		D, V, IV	P, H	F		
GOLDEN REDHORSE	D		B, I	Rn, H	--		X
CHANNEL CATFISH	D		O	P, Rn, S, St	R		X
GREEN SUNFISH	D		O	B, M	F		
BLUEGILL	D		O	P, B, V	R		X
SMALLMOUTH BASS	D		P, C, I	P, S, St	TP, R		X
EMERALD SHINER	D		I, C, A	Pg, S	F		X
SPOTFIN SHINER	D		I, V, P	Rn, S	F		
LARGEMOUTH BASS	D		P, C, I	B, P, H, St	TP, R		X
FRESHWATER DRUM	D		M, P, I, C	D, S, M	R, C		X
BULLHEAD MINNOW	D		O	Rn, B, M, S	F		
SPOTTAIL SHINER	D		I, A, V	Pg, H, S	F		
SMALLMOUTH BUFFALO	D		B	C, D, H	C		
SHORTHEAD REDHORSE	D		B, I	R, D, H, S	R, C		
LOGPERCH	D		I, C	R, S, V, St	F		X
ORANGESPOTTED SUNFISH	D		C, I, P	P, M	F		
BROOK SILVERSIDE	D		I, Z	B, P, S	F		
NORTHERN SUNFISH	D		I, IV, P	P, S	R		
STRIPED SHINER	C		O	Rn, H, S	F		
QUILLBACK	C		B, O	P, D, H, S	F, C		
RIVER CARPSUCKER	C		B, O	D, P, M, S	F		
SILVER REDHORSE	C		I	P, D, H, St	R, C		
FLATHEAD CATFISH	C		P, C	P, S, St, R	R		
SAND SHINER	C		O	Rn, S	F		
LONGNOSE GAR	C		P	P, V	TP		
ROCK BASS	C		I, C, P	P, S, V, St	R		
BLACK CRAPPIE	C		P, I, C	B, V	R		X
SKIPJACK HERRING	C		C, P	Pg, S	--		
THREADFIN SHAD	C	X	Z, I	P, M, S	F		
BLACKSTRIPE TOPMINNOW	C		I, C, A	P, V, St	F		
MIMIC SHINER	C		I, IV, C	Pg,	F		
SLENDERHEAD DARTER	O		I, C	R, Rn, S	F		
GHOST SHINER	O		I, C, A	Pg, P, M, S	F		
WHITE BASS	O		P	P, H, Pg	TP, R		
GOLDEN SHINER	O		O	P, V, M	F		
JOHNNY DARTER	O		I, C	P, S	F		
WHITE CRAPPIE	O		P, I, C	P, St	R		
ROUND GOBY	O	X	--	--	N		
PALLID SHINER	O			P, V	F	X	
TROUT-PERCH	O		B, I	P, B, M, S	F		
REDFIN SHINER	O		I	P, M	F		
WALLEYE	O		P, Z	V, St	TP, R		

Table B-4 (Continued)

Species	Frequency[a]	Non-Native	Feeding Habits[b,c]	Habitat[c,d]	Ecosystem Role[c,e]	State-Listed	RIS
CENTRAL STONEROLLER	O		A, D	R, S	F		
BLACK BUFFALO	O		B	C, D, H	--		
RED SHINER	O		I, IV	S	F		
WHITE PERCH	O		O	C, B, P,Pg	R		
GOLDEYE	O		I, P	Rn, S	--		
YELLOW BASS	O		P, I	P, H, Pg	TP, R		
HORNYHEAD CHUB	O		O	R, S	F		
WESTERN MOSQUITOFISH	O		I	B, P, V	F		
REDEAR SUNFISH	I		M, C, I, P	P, V	R		
SAUGER	I		P, C, I	B, V, St	TP, R		
PUMPKINSEED	I		I, M	P, V	R		
BLACKSIDE DARTER	I		I, C	P, H, R	F		
YELLOW BULLHEAD	I		B, O	D, B, P, V	R		
WARMOUTH	I		P,O	P, M, V, St	R		
SUCKERMOUTH MINNOW	I		B, I	R, S	F		
NORTHERN HOG SUCKER	I		B, I	D, R, P, S	--		
GOLDFISH	I	X	O, S	P, V	N		
ROSYFACE SHINER	I		IV, D, V	Pg, Rn, S	F		
HIGHFIN CARPSUCKER	I		B, O	R, P, H, S	--		
RIVER REDHORSE	I		M, I, B	D, R, H, S	--	X	
WHITE SUCKER	I		B, I, O	D, S, H	R, C		X
FATHEAD MINNOW	I		D, A, V	B, M	F		
SPOTTED SUCKER	I		M, I	D, H	--		
BANDED DARTER	I		I	R, S	F		
SHORTNOSE GAR	I		P, I, C	S, M	TP		
GRASS PICKEREL	I		P, I, C	P, V	TP, R		
NORTHERN PIKE	I		P, C, T	P, V	TP, R		
GRASS CARP	I	X	H, S	V	N		
SHOAL CHUB	I		B, I	S, Rn	F		
SILVER CHUB	I		B	P, S	F		
GREATER REDHORSE	I		B	D, Rn, H, St	--	X	
WESTERN SAND DARTER	I		I	C, S	F	X	
RAINBOW DARTER	I		I	R, Rn, S	F		
BIGMOUTH BUFFALO	I		I, Z	B, P, M	R, C		
BLACK REDHORSE	I		B, I, C	P, St	R		
TADPOLE MADTOM	I		C, I	B, M, V	F		
STRIPED BASS	I	X	P, C	C, P, Pg	TP, R		
YELLOW PERCH	I		O	P, B, V, St	R		
SPOTTED GAR	I		P	P, V	TP		
MOONEYE	I		O	Rn, H	--		
CHINOOK SALMON	I	X	P	GL	TP, R		
RAINBOW SMELT	I	X	I, C, Z	Pg	R		
SILVER CARP	I	X	--	--	N		
SILVERJAW MINNOW	I		I	R, S	F		
PUGNOSE MINNOW	I		I, C	P, M, V	F		
CHANNEL SHINER	I		I, IV, C	Pg,	F		

Table B-4 (Continued)

Species	Frequency[a]	Non-Native	Feeding Habits[b,c]	Habitat[c,d]	Ecosystem Role[c,e]	State-Listed	RIS
CREEK CHUB	I		O	M, St	F		
BLACK BULLHEAD	I		B, O	D, P, B, M	R		
STONECAT	I		I, C, P	R, H, S	F		
BANDED KILLIFISH	I		I, Z	Pg, P, B, V	F	X	
BLUNTNOSE DARTER	I		I, C	B, M	F		
RIVER DARTER	I		I, C	C, Rn, S	F		
RIVER SHINER	I		I, C, A	Rn, S	F		
BIGMOUTH SHINER	I		I, A, D	Rn, S	F		
ALEWIFE	I	X	P, PH, Z	Pg, S	F		
STEELCOLOR SHINER	I		I, IV, V	Rn, r, S	F		
ORANGETHROAT DARTER	I		I	R, P, S	F		

a. D=dominant (all segments and average more than 15 years); C=common (4 segments and average 10-15 years); O=occasional (3-4 segments and average 4-10 years); I=incidental (1-4 segments and average fewer than 4 years)

b. A=algae; B=bottom feeder; C= crustaceans; D=detritivore; H=herbivore I=insectivore; IV=invertebrates; M=mollusks ; O=omnivore; P=piscivore; PH=phytoplankton; S=scavenger; T=terrestrial; V=vegetation; Z=zooplankton

c. From Smith (1979), *Fishes of Illinois* ; Pflleger (1997), *Fishes of Missouri* ; and Scott and Crossman (1973) *Freshwater Fishes of Canada;* Etnier and Starnes (1993) *The Fishes of Tennessee* ; Becker (1983) *Fishes of Wisconsin* ; Page and Burr (2011).

d. B=backwater, sloughs; C=channel; D=demersal; H=hard bottom; M=mud, muck; Pg=pelagic; P=pools; R=riffles; Rn=run, fast current; S=sand/gravel; St=structure; V=vegetation/detritus; GL=Great Lakes

e. F=forage; TP=top predator; R=recreational; C=commercial; N=Invasive/Nuisance

Table B-5. River Flow and Temperature and DNS Discharge Temperature for Typical and Typical High Temperature Conditions.

Parameter	June	July	August	Sept
Typical Conditions				
Flow (cfs) (50%)				
Des Plaines	4,350	3,870	4,801	4,026
Kankakee	5,370	2,370	1,549	1,340
Total	9,720	6,240	6,350	5,366
Temperature (F) (60%)				
Des Plaines	79.9	82.9	83.1	80.1
Kankakee	74.5	76.1	77.4	68.9
Flow Wgt Av	76.9	80.3	81.7	77.3
Discharge Temp (F)				
50%	85.7	87.4	87.0	83.5
Delta	8.8	7.1	5.3	6.2
Unusually Warm Conditions				
Flow (cfs) (5%)				
Des Plaines	2,794	2,214	2,243	2,119
Kankakee	1,340	849	808	913
Total	4,134	3,063	3,051	3,032
Temperature (F) (95%)				
Des Plaines	82.8	88.9	86.9	85.5
Kankakee	76.8	85.6	81.0	77.0
Flow Wgt Av	80.9	88.0	85.3	82.9
Discharge Temp (F)				
95%	89.2	91.8	90.7	88.8
Delta	8.3	3.8	5.4	5.9

Table B-6. River Flow and Water Temperature Conditions During Extremely Warm Event, 6-8 July 2012.

River Flow

Date	Flow (cfs)[1]			Percentiles[2]	
	DesPlains	Kankakee	Total	DesPlains	Kankakee
6-Jul	2,170	1,000	3,270	4.6	19.8
7-Jul	1,910	910	2,820	2.0	18.5
8-Jul	1,610	770	2,380	1.0	15.3

Water Temperature[3]

Date	Temperature (F)		Percentiles[4]	
	Min	Max	Min	Max
6-Jul	90.0	91.7	96	97
7-Jul	91.0	93.9	96.5	99
8-Jul	89.5	91.7	95	97

1. Flow percentiles relative to 2005-2013 historical data
2. DNS design flow = 2,265 cfs
3. Intake temperatures used as proxy for upstream historical ambient water temperature.
4. Temperature percentiles relative to 2003-2014 DNS intake temperatures.

Table B-7. Cross-Sectional Temperature Distribution at Nine Transects in the Illinois River for Typical and Typical High Temperature (95 percentile) River Conditions during June.

Typical Temperature Conditions

Percentile (%)	Temperature (F) in Cross-Section at Transect								
	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	79.6	74.5	79.6	79.0	84.3	82.8	81.6	80.6	79.7
Min	79.3	73.8	73.8	74.4	76.6	77.4	77.9	78.3	78.6
90	79.6	74.4	79.4	78.9	81.8	81.6	80.7	80.3	79.5
75	79.6	74.3	79.3	78.6	78.8	79.4	79.6	79.8	79.4
50	79.4	74.0	78.6	78.4	78.5	78.6	78.7	79.0	79.2
25	79.3	73.9	74.2	76.7	77.8	78.2	78.4	78.7	79.1
10	79.3	73.8	73.9	74.5	77.5	77.7	78.1	78.5	78.9

High (95%) Temperature Conditions

Percentile (%)	Temperature (F) in Cross-Section at Transect								
	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	82.5	77.7	82.4	82.6	88.1	87.2	86.7	86.5	86.0
Min	82.2	76.1	76.8	82.1	82.9	83.8	84.4	85.0	85.5
90	82.5	76.8	82.4	82.3	87.5	86.8	86.5	86.2	85.9
75	82.4	76.7	82.3	82.2	86.8	86.5	86.2	86.0	85.8
50	82.3	76.4	82.2	82.1	85.7	85.8	85.8	85.7	85.7
25	82.2	76.2	81.5	82.1	84.1	85.0	85.2	85.6	85.6
10	82.2	76.1	78.7	82.1	83.5	84.5	84.9	85.3	85.6

Note: Temperature at cross-sectional area percentile

June River Conditions

	Average		Hign (95%)	
Source	Temp (F)	Flow (cfs)	Temp (F)	Flow (cfs)
Des Plaines River	79.9	4,350	82.8	2,794
Kankakee River	74.5	5,370	76.8	1,340
Dresden Discharge	85.7	2,265	89.2	2,265

Table B-8. Cross-Sectional Temperature Distribution at Nine Transects in the Illinois River for Typical and Typical High Temperature (95 percentile) River Conditions during July.

Typical Temperature Conditions

Percentile (%)	Temperature (F) in Cross-Section at Transect								
	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	82.6	76.1	82.6	81.9	86.6	85.7	85.2	84.6	84.0
Min	82.3	75.4	75.6	81.5	81.7	81.9	82.2	82.7	83.3
90	82.6	76.0	82.5	81.8	85.9	85.1	84.7	84.3	84.0
75	82.5	75.9	82.3	81.7	84.2	84.4	84.3	84.1	83.9
50	82.4	75.7	82.0	81.7	82.6	83.6	83.8	83.9	83.8
25	82.3	75.5	79.2	81.6	82.0	82.7	83.1	83.4	83.7
10	82.3	75.4	76.2	81.6	81.8	82.3	82.6	83.1	83.5

High (95%) Temperature Conditions

Percentile (%)	Temperature (F) in Cross-Section at Transect								
	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	88.5	87.6	88.5	90.0	91.3	91.0	90.9	90.8	90.6
Min	88.3	84.9	87.3	88.5	89.5	90.1	90.3	90.5	90.5
90	88.5	86.2	88.5	89.4	91.1	90.9	90.8	90.7	90.6
75	88.5	85.7	88.5	88.9	90.9	90.8	90.7	90.7	90.6
50	88.4	85.3	88.4	88.6	90.6	90.6	90.6	90.6	90.6
25	88.4	85.1	88.4	88.5	90.2	90.5	90.5	90.5	90.5
10	88.3	84.9	88.3	88.5	89.8	90.3	90.4	90.5	90.5

Note: Temperature at cross-sectional area percentile

July River Conditions

Source	Average		Hign (95%)	
	Temp (F)	Flow (cfs)	Temp (F)	Flow (cfs)
Des Plaines River	82.9	3,870	88.9	2,214
Kankakee River	76.1	2,370	85.6	849
Dresden Discharge	87.4	2,265	91.8	2,265

Table B-9. Cross-Sectional Temperature Distribution at Nine Transects in the Illinois River for Typical and Typical High Temperature (95 percentile) River Conditions during August.

Typical Temperature Conditions

Percentile (%)	Temperature (F) in Cross-Section at Transect								
	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	82.8	77.5	82.8	82.7	86.4	85.7	85.3	84.8	84.3
Min	82.5	76.7	77.7	82.4	82.5	82.6	82.9	83.2	83.7
90	82.8	77.3	82.7	82.6	85.8	85.3	84.9	84.5	84.3
75	82.8	77.2	82.6	82.5	84.5	84.7	84.6	84.4	84.2
50	82.6	77.0	82.5	82.5	83.0	83.9	84.1	84.2	84.1
25	82.5	76.8	82.0	82.5	82.6	83.2	83.5	83.8	84.1
10	82.5	76.7	79.5	82.5	82.5	82.9	83.2	83.5	83.9

High (95%) Temperature Conditions

Percentile (%)	Temperature (F) in Cross-Section at Transect								
	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	86.5	86.1	86.5	88.4	90.0	89.6	89.4	89.4	89.1
Min	86.3	80.3	82.0	86.2	87.5	88.3	88.6	88.7	88.7
90	86.5	84.9	86.5	87.6	89.8	89.5	89.4	89.2	89.0
75	86.5	83.1	86.4	86.9	89.5	89.4	89.3	89.1	89.0
50	86.4	80.9	86.4	86.5	89.1	89.1	89.1	89.0	89.0
25	86.4	80.6	86.2	86.4	88.5	88.8	88.9	88.9	88.9
10	86.3	80.4	84.9	86.3	88.0	88.6	88.8	88.9	88.8

Note: Temperature at cross-sectional area percentile

August River Conditions

Source	Average		Hign (95%)	
	Temp (F)	Flow (cfs)	Temp (F)	Flow (cfs)
Des Plaines River	83.1	4,801	86.9	2,243
Kankakee River	77.4	1,549	81.0	808
Dresden Discharge	87.0	2,265	90.7	2,265

Table B-10. Cross-Sectional Temperature Distribution at Nine Transects in the Illinois River for Typical and Typical High Temperature (95 percentile) River Conditions during September.

Typical Temperature Conditions

Percentile (%)	Temperature (F) in Cross-Section at Transect								
	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	79.8	78.0	79.8	79.5	82.9	82.3	81.9	81.5	81.1
Min	79.5	68.2	69.2	78.9	79.0	79.3	79.7	80.2	80.6
90	79.8	73.2	79.7	79.3	82.5	81.9	81.5	81.3	81.0
75	79.7	70.1	79.5	79.1	81.4	81.4	81.3	81.1	81.0
50	79.6	68.6	79.1	79.0	80.2	80.9	80.9	81.0	80.9
25	79.5	68.4	77.8	78.9	79.5	80.1	80.4	80.7	80.9
10	79.5	68.2	72.3	78.9	79.2	79.8	80.1	80.4	80.8

High (95%) Temperature Conditions

Percentile (%)	Temperature (F) in Cross-Section at Transect								
	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	85.1	84.7	85.1	86.6	88.1	87.8	87.6	87.6	87.2
Min	84.9	76.3	77.3	84.4	85.8	86.5	86.8	86.9	86.9
90	85.1	83.4	85.0	85.8	88.0	87.7	87.6	87.4	87.2
75	85.1	80.6	84.9	85.1	87.7	87.6	87.4	87.3	87.2
50	85.0	77.0	84.5	84.8	87.3	87.3	87.2	87.2	87.2
25	85.0	76.6	83.8	84.7	86.8	87.1	87.1	87.1	87.1
10	85.0	76.4	80.8	84.6	86.2	86.8	87.0	87.1	87.0

Note: Temperature at cross-sectional area percentile

September River Conditions

Source	Average		Hign (95%)	
	Temp (F)	Flow (cfs)	Temp (F)	Flow (cfs)
Des Plaines River	80.1	4,026	85.5	2,119
Kankakee River	68.9	1,340	77.0	913
Dresden Discharge	83.5	2,265	88.8	2,265

Table B-11. Bottom Temperature Distribution Upstream and Downstream of the DNS Discharge for Typical and Typical High (95%) River Conditions, June to September

June River Conditions

Percentile (%)	Bottom Temperature (F)			
	Typical		High (95%)	
	Upstr	Dstr	Upstr	Dstr
Max	79.8	85.7	82.7	89.2
Min	73.8	74.4	76.1	80.9
90	79.6	79.4	82.4	86.2
75	79.3	79.1	82.3	85.7
50	76.5	78.6	82.1	85.3
25	74.2	78.2	79.2	84.1
10	73.8	77.4	76.2	82.5

July River Conditions

Percentile (%)	Bottom Temperature (F)			
	Typical		High (95%)	
	Upstr	Dstr	Upstr	Dstr
Max	82.8	87.4	89.6	91.8
Min	75.4	80.8	84.9	87.8
90	82.6	84.1	88.5	90.7
75	82.3	83.7	88.5	90.6
50	81.2	83.1	88.4	90.5
25	76.2	82.1	87.8	90.2
10	75.4	81.7	85.0	89.2

August River Conditions

Percentile (%)	Bottom Temperature (F)			
	Typical		High (95%)	
	Upstr	Dstr	Upstr	Dstr
Max	83.0	87.0	87.8	90.7
Min	76.7	82.4	80.3	84.3
90	82.8	84.3	86.5	89.2
75	82.5	84.1	86.4	89.0
50	82.4	83.6	86.3	88.9
25	78.9	82.7	84.2	88.4
10	76.8	82.5	80.4	87.1

September River Conditions

Percentile (%)	Bottom Temperature (F)			
	Typical		High (95%)	
	Upstr	Dstr	Upstr	Dstr
Max	80.0	83.5	86.0	88.8
Min	68.2	77.2	76.3	82.5
90	79.8	81.2	85.1	87.4
75	79.5	80.9	85.0	87.2
50	78.9	80.5	84.5	87.1
25	75.1	79.5	82.4	86.7
10	68.3	79.0	76.4	85.4

Table B-12. Percent of Cross-section Predicted at Less than Modeled Temperatures at 4 Transects Upstream and 5 Transects Downstream of the DNS Discharge During Peak of Heat Wave on 7-8 July 2012 (Shaded Cells Indicate Portions of Cross-section with Temperatures equal to or above 93.0°F)

Percent of X-Section	Upstream of DNS Discharge				Downstream of DNS Discharge				
	Temperature (°F) at Percent of Cross-Section								
7-7 1200	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	92.07	92.44	91.47	92.48	93.20	93.02	92.91	92.75	92.53
Min	90.50	90.41	90.59	90.36	91.72	92.10	92.16	92.07	91.99
95	91.99	92.25	91.40	92.17	93.15	92.95	92.84	92.57	92.41
90	91.89	92.03	91.35	91.99	93.09	92.91	92.78	92.50	92.34
75	91.71	91.64	91.11	91.58	92.95	92.75	92.61	92.39	92.26
50	91.49	91.02	90.84	91.20	92.73	92.55	92.43	92.28	92.17
25	91.26	90.68	90.68	90.90	92.38	92.39	92.30	92.18	92.12
10	91.10	90.43	90.61	90.68	91.98	92.26	92.24	92.16	92.07
5	91.06	90.41	90.61	90.52	91.86	92.20	92.21	92.12	92.05
7-7 1400	**DP-1700**	**KP-1800**	**IL-1000**	**IL-200**	**IL125**	**IL275**	**IL475**	**IL720**	**IL1000**
Max	93.02	93.54	92.28	92.88	93.67	93.45	93.38	93.33	92.89
Min	91.65	90.43	90.59	91.04	92.10	92.55	92.61	92.50	92.32
95	92.92	93.34	92.17	92.62	93.63	93.42	93.31	93.09	92.77
90	92.85	93.14	92.07	92.40	93.59	93.38	93.24	93.01	92.73
75	92.68	92.44	91.78	92.03	93.45	93.24	93.07	92.86	92.66
50	92.44	91.39	91.31	91.65	93.22	93.00	92.89	92.73	92.59
25	92.10	90.88	90.88	91.36	92.87	92.86	92.77	92.63	92.52
10	91.91	90.53	90.72	91.20	92.41	92.73	92.70	92.58	92.42
5	91.86	90.47	90.64	91.18	92.27	92.64	92.66	92.54	92.37
7-7 1600	**DP-1700**	**KP-1800**	**IL-1000**	**IL-200**	**IL125**	**IL275**	**IL475**	**IL720**	**IL1000**
Max	93.42	93.87	92.73	92.62	93.94	93.69	93.58	93.49	93.07
Min	92.05	90.81	90.72	91.54	92.89	93.13	93.07	92.82	92.55
95	93.36	93.75	92.60	92.52	93.89	93.63	93.54	93.36	93.03
90	93.33	93.65	92.46	92.35	93.85	93.60	93.51	93.33	93.00
75	93.22	93.17	92.14	92.23	93.62	93.51	93.43	93.22	92.97
50	92.93	92.69	91.59	92.05	93.34	93.38	93.30	93.09	92.91
25	92.71	92.13	91.11	91.80	93.24	93.27	93.16	93.02	92.80
10	92.38	91.65	90.88	91.74	93.08	93.20	93.13	92.91	92.62
5	92.23	91.31	90.82	91.69	93.00	93.18	93.11	92.87	92.59

Table B-12 (Continued)

Percent of X-Section	Upstream of DNS Discharge				Downstream of DNS Discharge				
	Temperature (°F) at Percent of Cross-Section								
7-7 1800	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	93.47	93.87	92.89	92.62	93.31	93.36	93.42	93.38	93.25
Min	91.53	90.82	90.95	91.27	92.68	92.77	93.00	92.89	92.34
95	93.43	93.61	92.77	92.56	93.24	93.36	93.40	93.38	93.24
90	93.39	93.52	92.66	92.50	93.16	93.33	93.38	93.36	93.20
75	93.31	93.29	92.38	92.39	93.07	93.29	93.38	93.34	93.15
50	93.14	92.94	91.76	92.23	92.98	93.24	93.36	93.31	93.02
25	92.89	92.51	91.31	91.87	92.91	93.18	93.31	93.22	92.89
10	92.53	92.39	91.11	91.60	92.86	93.06	93.22	93.10	92.69
5	92.35	91.72	91.05	91.53	92.81	92.98	93.16	93.03	92.64
7-7 2000	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	93.22	93.43	92.71	92.44	92.77	92.95	93.13	93.25	93.20
Min	89.65	89.38	89.92	90.57	92.19	91.92	92.25	92.37	91.17
95	93.19	93.32	92.61	92.34	92.73	92.91	93.08	93.20	93.17
90	93.16	93.22	92.53	92.31	92.71	92.89	93.02	93.16	93.13
75	93.11	93.00	92.31	92.26	92.68	92.84	92.98	93.13	93.00
50	93.06	92.76	91.80	92.17	92.61	92.79	92.88	93.04	92.82
25	92.85	91.99	91.40	91.71	92.53	92.68	92.74	92.88	92.64
10	92.38	91.73	91.20	91.18	92.46	92.52	92.57	92.68	92.48
5	91.63	90.77	91.06	91.08	92.37	92.44	92.50	92.59	92.34
7-7 2200	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	92.88	92.82	92.52	92.03	92.37	92.48	92.61	92.79	92.79
Min	86.92	88.36	88.84	89.56	91.53	91.42	91.71	91.62	90.19
95	92.84	92.79	92.44	92.00	92.32	92.43	92.56	92.73	92.71
90	92.78	92.66	92.35	91.96	92.29	92.41	92.53	92.66	92.66
75	92.66	92.43	92.17	91.90	92.14	92.37	92.49	92.61	92.55
50	92.55	91.63	91.74	91.84	92.07	92.29	92.38	92.48	92.43
25	92.16	90.90	91.40	91.49	92.01	92.14	92.18	92.28	92.16
10	91.11	90.74	91.15	90.48	91.92	91.99	92.02	92.07	91.98
5	90.58	89.94	90.77	90.32	91.87	91.92	91.94	91.96	91.79
7-8 0000	DP-1700	KP-1800	IL-1000	IL-200	IL125	IL275	IL475	IL720	IL1000
Max	92.39	92.28	92.61	91.72	91.83	91.90	92.08	92.26	92.26
Min	85.42	87.12	88.65	88.70	91.15	91.18	91.26	91.24	90.09
95	92.31	92.11	92.48	91.69	91.78	91.85	92.05	92.22	92.24
90	92.27	91.99	92.42	91.63	91.72	91.83	92.00	92.17	92.21
75	92.17	91.63	92.17	91.59	91.54	91.78	91.95	92.12	92.14
50	92.04	90.53	91.90	91.53	91.44	91.71	91.83	92.01	92.01
25	91.44	90.12	91.49	91.20	91.35	91.56	91.69	91.85	91.81
10	90.26	89.83	91.23	89.83	91.28	91.42	91.53	91.65	91.52
5	89.93	89.11	90.82	89.62	91.24	91.35	91.45	91.54	91.29

Table B-13. Estimated Avoidance Temperatures at Selected Ambient/Acclimation Water Temperatures for DNS RIS for Which Avoidance Test Data are Available.

	Avoidance Temperature (°F)						
Acclimation Temperature (°F)	80.0	86.0	87.0	88.0	91.4	93.2	95.0
Gizzard shad	90.5	93.1	93.5	93.9	95.4	96.1	97
Channel catfish	95	95.6	96	96.4	97.9	98.6	99.4
Largemouth bass	92.5	95.5	95.9	96.3	98.1	98.9	99.8
Smallmouth bass	91.5	93	93.2	93.4	94.3	94.6	95
Bluegill	90.7	94.1	94.8	95.2	97.2	98.2	99.3

Table B-14. Temperature Range for Optimum Growth and Upper and Lower Zero Growth Temperatures for DNS RIS.

	Upper Zero-Growth		Otpimum Growth Range		Lower Zero-Growth	
	°C	°F	°C	°F	°C	°F
Gizzard shad	34	93.2	29-32	84.2-89.6	--	--
Emerald shiner	34	93.2	24-31	75.2-87.8	7	44.6
Common Carp	35	95	14.5-32	58.1-89.6	10-13.8	50.0-56.8
Golden redhorse	--	--	--	--	--	--
White sucker	29.6	85.3	16-27	60.8-80.6	12	53.6
Channel catfish	34.7	94.5	20-32	68.0-89.6	10	50
Largemouth bass	36	96.8	23-31	73.4-87.8	10	50
Smallmouth bass	34	93.2	16-31	60.8-87.8	--	
Bluegill	32.8	91	23-31	73.4-87.8	13	55.4
Black crappie	30.5	86.9	13-25	55.4-77.0	11	51.8
Logperch	--	--	--	--	--	--
Freshwater drum	32.6	90.7	22-31	71.6-87.8	10	50