EPA - New England

Clean Water Act NPDES Permitting Determinations for the Thermal Discharge and Cooling Water Intake Structures at Merrimack Station in Bow, New Hampshire

NPDES Permit No. NH 0001465

Executive Summary

Introduction

The United States Environmental Protection Agency ("EPA" or "the Agency") is issuing a new draft National Pollutant Discharge Elimination System ("NPDES") permit under the Federal Clean Water Act ("CWA") to the Merrimack Station power plant in Bow, New Hampshire. Merrimack Station's currently effective NPDES permit (No. NH0001465) was issued by EPA on June 25, 1992 ("the 1992 NPDES Permit"), with an expiration date of June 25, 1997. The 1992 NPDES Permit remains in effect, however, because it was administratively continued as a result of PSNH's timely application for renewal. *See* 40 C.F.R. § 122.6. Once effective, the new permit will supplant the 1992 NPDES Permit.

This Draft Permit Determinations Document presents and explains certain determinations made by EPA in support of the new draft NPDES permit. In particular, this document covers the application of CWA standards to control Merrimack Station's withdrawals of water from the Merrimack River for the facility's cooling needs and its discharges to the river of waste heat absorbed by the cooling water (i.e., thermal discharges). These water withdrawals and discharges result from operation of the facility's "open-cycle" (or "once-through") cooling system.

This document is a key part of the administrative record supporting the new Draft NPDES Permit for Merrimack Station. It is incorporated by reference in the Draft Permit's Fact Sheet and its key determinations are summarized therein. Other determinations (*i.e.*, those not related to thermal discharge and cooling water intake, such as those related to the control of metal cleaning wastewater) needed to support the Draft Permit are presented in the Fact Sheet and other supporting materials in the administrative record.

EPA will be soliciting public comment on the Draft Permit. Therefore, the determinations presented herein are subject to potential revision after EPA considers the comments and information submitted. Any changes will be explained in the documents supporting the Final Permit.

This document was prepared by EPA's New England Regional office in Boston, MA (also known as "EPA Region 1"). In connection with this effort, EPA Region 1 consulted with, and received assistance from, EPA's headquarters office in Washington, D.C., the New Hampshire Department of Environmental Services ("NHDES"), the United States Department of Interior's Fish & Wildlife Service ("USFWS"), and the New Hampshire Fish and Game Department. EPA also retained expert contractors to assist the Agency in its assessment of certain economic/financial issues. Furthermore, EPA also communicated extensively with Merrimack Station's owner and operator, Public Service of New Hampshire ("PSNH"), and carefully considered the views and information that it submitted to the Agency.

This Executive Summary is provided as a convenience to the reader. It touches on some of the key explanations, analyses and conclusions discussed in detail in subsequent sections of this Determinations Document. It is not a substitute for the full analysis.

Merrimack Station, Its Cooling System and the Affected Water Body

As stated above, Merrimack Station is owned and operated by PSNH, which is a subsidiary of The Northeast Utilities System ("NU"). Merrimack Station is a steam-electric power plant with two primary electrical generating units, Units I and II, which began operation in 1960 and 1968, respectively. The facility primarily burns coal and is a base-load plant with an electrical output of approximately 478 megawatts ("MW"). Unit 2 is the larger of the two units with a nameplate rating of 350 MW, while Unit 1 has a nameplate rating of 120 MW.

Merrimack Station is located on the banks of the Merrimack River in Bow, New Hampshire, across the river from the towns of Allenstown, Pembroke and Hooksett, New Hampshire. *See* Fig. 2-1, *infra.* The Merrimack River is both a water of the State of New Hampshire and a water of the United States. It is also an interstate waterway, travelling from central New Hampshire to meet the Atlantic Ocean in Newburyport, Massachusetts. The facility withdraws water from, and discharges water to, the "Hooksett Pool" portion of the Merrimack River. The Hooksett Pool is an approximately 5.8-mile long segment of the river bounded to the north by the Garvin's Falls Dam and to the south by the Hooksett Dam.

As a steam-electric power plant, Merrimack Station uses the "steam cycle" to generate electricity and must have a method of condensing (or cooling) the steam used in the electrical generating process. Some steam-electric facilities use "dry" cooling processes, while others use "wet" cooling processes (either "open-cycle" cooling or "closed-cycle" cooling with "wet cooling towers").`` In a typical wet cooling system, the facility withdraws water from a water body through a cooling water intake structure ("CWIS") and uses it to condense the steam. (Other sources of water, such as municipal water or treated wastewater, could be used if adequate volumes of suitable quality water are available.) Through this process, the water absorbs the facility's waste heat and is heated well above ambient water temperatures prior to discharge.

In an open-cycle system, the water and waste heat are discharged back to the water body as a thermal effluent. In a wet closed-cycle system, however, cooling towers are used to chill the cooling water so that it can be re-used for condensing steam. Closed-cycle wet systems actually require some water withdrawals (as "makeup water" is needed to offset evaporative water loss and cooling tower blowdown) and have some thermal discharges (as a result of cooling tower "blowdown"), but they can reduce thermal discharges and water withdrawals by approximately *95 percent* as compared to an open-cycle system.

Merrimack Station currently utilizes an open-cycle cooling system, as mentioned above. The facility has two CWISs through which it withdraws a total design intake flow of 287 million gallons per day ("MGD") of Merrimack River water to use as its cooling medium for condensing steam in its condensers. In this process, the river water absorbs a large amount of heat and its temperature is substantially increased before the facility discharges it back to the river. Merrimack Station disposes of approximately 26.3 trillion British thermal units ("Btus") of waste heat into the river in this manner each year. The thermal effluent is sent through a lengthy open canal prior to discharge to the river, which allows some of the heat to dissipate. In addition, Merrimack Station installed 224 "power spray modules" ("PSMs") in the discharge canal in an effort to provide additional cooling of the thermal discharge under certain meteorological conditions by spraying the heated effluent into the air, after which it is discharged.

Adverse Effects of Cooling System Operations

Merrimack Station's withdrawal of river water for cooling, and discharge of thermal effluent to the river, alter and adversely affect the Merrimack River in a variety of ways. Withdrawals of water from the river kill and injure aquatic organisms in the water as a result of "entrainment" and "impingement." Entrainment occurs when very small organisms in the river water, such as fish eggs and larvae, are pulled with the water through the CWIS screens and into the cooling system. These organisms are subjected to physical impacts, high water temperatures, pressure changes and (potentially) exposure to harmful chemicals, such as chlorine. Impingement occurs when larger aquatic organisms, such as juvenile and adult fish, are caught and held against intake screens until the screens are rotated. Once the screens are rotated, a fish return system is supposed to safely return the organisms to the water. At Merrimack Station, the fish return does not reach the river so no survival of impinged organisms is expected.

At the same time, the facility's thermal discharges alter the river's natural thermal regime, such as its peak temperatures and the timing and range of its temperature variations. Depending on the amount of heat being discharged and conditions in the receiving water, thermal discharges can have a variety of adverse ecological effects because aquatic organisms and water quality may be affected in many ways by water temperature. For example, fish have optimal temperatures for growth. They also display preferences for certain water temperatures and may, if possible, leave or avoid an area if water temperatures exceed their preferred levels. Furthermore, altered water temperatures may benefit certain species at the expense of other species, causing shifts in the make-up of the community of organisms in the affected water. Finally, increasing water temperatures can also affect water quality in many ways, such as by promoting algal growth or contributing to reduced levels of dissolved oxygen.

Regulating Thermal Discharges & Cooling Water Withdrawals under the CWA

The CWA addresses both ends of the wet cooling process: *i.e.*, the withdrawal of water for cooling and the discharge of the thermal effluent. Specifically, cooling water withdrawals through CWISs must satisfy CWA § 316(b), as well as any applicable requirements based on state water quality standards. Discharges of heat must satisfy both technology-based and water quality-based requirements or the requirements of a variance under CWA § 316(a). EPA addresses each of these requirements independently, but brings them together to set permit limits that ensure that all applicable permit requirements will be satisfied. Both thermal discharge requirements and CWIS requirements can end up affecting the operation and design of a facility's cooling system.

Standards Governing Thermal Discharges

The point source discharge of pollutants to a water of the United States is prohibited by CWA § 301(a), unless authorized by an NPDES permit issued under CWA § 402. Heat is defined as a "pollutant" under the CWA. *See* 33 U.S.C. § 1362(6). As stated above, steam-electric power plants with wet cooling systems discharge their waste heat to nearby water bodies and must obtain authorization for these discharges from an NPDES permit.

Technology-Based Requirements – The BAT Standard

As with other pollutants, permit limits for the discharge of heat must, at a minimum, satisfy federal "technology-based" requirements. *See* CWA §§ 301, 304 and 306. More specifically, CWA § 301 requires that thermal discharges be limited consistent with levels achievable using the "best available technology economically achievable … which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants" ("BAT"). 33 U.S.C. § 1311(b)(2)(A). *See also* 33 U.S.C. § 1311(b)(2)(F). In determining the BAT, EPA investigates technological options to identify the best performing technology in terms of reducing pollutant discharges and then further assesses the options in light of a number of factors specified in the statute (e.g., cost, non-water environmental effects, energy requirements).

EPA applies technology standards, such as the BAT standard, to industrial categories when it develops national effluent limitation guidelines ("ELGs"). ELGs then govern the permit limits for individual facilities within that industry. If EPA has not developed an ELG for a particular pollutant or a particular industrial category, it develops technology-based requirements for individual permits by using its Best Professional Judgment ("BPJ") to apply the pertinent technology standard(s) on a site-specific basis. *See* 33 U.S.C. § 1342(a)(1)(B) and 40 C.F.R. § 125.3(c)(2). Given that EPA has not promulgated an ELG governing the discharge of heat from steam-electric power plants, the Agency sets technology-based permit limits for thermal discharges based on a BPJ, facility-specific application of the BAT standard.

Water Quality-Based Requirements

In addition to satisfying federal technology-based standards, NPDES permit limits must also satisfy any more stringent requirements needed to comply with state water quality standards ("WQS"). *See* CWA § 301(b)(1)(C). *See also* CWA §§ 401(a)(1), 401(d) and 510. Put differently, when both technology-based and water quality-based standards apply, whichever is more stringent governs the permit limits.

State WQS place the waters of the state into different classifications (e.g., Class A, Class B, etc.). The WQS also specify "designated uses" that water bodies in each class should support (e.g., fishing, primary contact recreation), numeric and narrative criteria that waters in each class should meet, and anti-degradation standards designed to protect existing water quality. NDPES permit limits must prevent discharges that would cause or contribute to violations of the WQS.

For this permit, the State of New Hampshire's WQS are at issue. The state has classified the Hooksett Pool portion of the Merrimack River as a Class B water. Therefore, limits on thermal discharges must prevent non-compliance with Class B designated uses and water quality criteria.

CWA § 316(a) - Thermal Discharge Variances

As an exception to the general rule that permit limits governing discharges of heat are to be derived from technology-based and water quality-based standards, whichever are more stringent, CWA § 316(a) allows permittees to seek a variance from these otherwise applicable limits if certain criteria are met. Specifically, CWA § 316(a) provides, in pertinent part, that:

> … whenever the owner or operator of any … [point] source … can demonstrate to the satisfaction of the Administrator … that any effluent limitation proposed for the control of the thermal component of any discharge from such source will require effluent limitations more stringent than necessary to assure the pro[t]ection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the body of water into which the discharge is to be made, the Administrator … may impose an effluent limitation … for such plant, with respect to the thermal component of such discharge (taking into account the interaction of such thermal component with other pollutants), that will assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on that body of water.

33 U.S.C. § 1326(a). The guiding principle of CWA § 316(a) is that thermal discharge limits may be based on a variance from the otherwise applicable technology-based and water quality-based standards if the limits will nevertheless assure the protection and propagation of the receiving water body's balanced, indigenous population of shellfish, fish, and wildlife ("BIP"). In determining whether the protection and propagation of the BIP will be assured, other environmental stresses must be taken into account.

An existing facility operating under an NPDES permit with thermal discharge limits based on a § 316(a) variance may seek renewal of the variance-based limits by attempting to demonstrate that existing operations have not caused "appreciable harm" to the BIP (a "retrospective" demonstration), or by trying to demonstrate that operations going forward will assure the protection and propagation of the BIP (a "prospective" demonstration). In some cases, an existing facility may attempt both types of demonstrations in seeking renewal of its variance.

Standards Governing Cooling Water Withdrawals

Technology-Based Requirements – The BTA Standard Under CWA § 316(b)

The CWA addresses facilities that take water for cooling from a water of the United States in much the same way that the statute addresses discharges of pollutants. Such facilities are subject to technology-based standards under CWA § 316(b), which requires "that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact." This is referred to as the Best Technology Available ("BTA") standard. In determining the BTA for CWISs, EPA compares technological alternatives, determines which are feasible and which achieve the greatest reductions in adverse environmental impacts (primarily entrainment and impingement), and considers various additional factors such as each option's cost, non-water environmental effects, energy effects, and a comparison of its costs and benefits).

While EPA has promulgated regulations creating categorical BTA requirements under CWA § 316(b) for CWISs at *new* facilities, *see* 40 C.F.R. Part 125, Subpart I, no such categorical requirements are currently in effect for *existing* facilities, such as Merrimack Station. (On April 20, 2011, EPA issued proposed regulations for public comment that would set categorical BTA requirements for existing facilities. While EPA is planning to sign final regulations by July 27, 2011, the Agency cannot be certain exactly when final regulations may be issued and go into effect. *See* 76 FR 22174-22288 (April 20, 2011).) As with setting effluent limits, in the absence of categorical requirements for CWISs, BTA requirements for CWISs are determined on a case-by-case, BPJ basis for individual NPDES permits. *See, e.g.,* 40 C.F.R. § 125.90(b).

Water Quality-Based Requirements

Furthermore, NPDES permits must include any more stringent CWISs requirements needed to comply with any applicable state WQS. New Hampshire's WQS apply to the effects of cooling water withdrawals from the state's waters, stating as follows:

> [t]hese rules shall apply to any person who causes point or nonpoint source discharge(s) of pollutants to surface waters, or who undertakes hydrologic modifications, such as dam construction or water withdrawals, or who undertakes any other activity that affects the beneficial uses or the level of water quality of surface waters.

N.H. Code R. Env-Wq 1701.02(b) (Applicability). *See also id.* 1708.03 (Submittal of Data). Therefore, permit conditions on cooling water withdrawals must comply with (or not interfere with the attainment of) relevant water quality criteria, designated uses, and antidegradation requirements.

Given that withdrawals of water for cooling can result in the entrainment and impingement of aquatic life, such withdrawals must comply with the designated uses and water quality criteria included in the state's WQS for the purpose of protecting aquatic organisms and their habitat.

Permitting History and Existing Permit Conditions

The history of NPDES permitting at Merrimack Station is described in Section 3 of this document. The facility's two primary generating units (Units I and II) began operation with open-cycle cooling in the 1960's, prior to the 1972 enactment of the CWA and its NPDES permitting program. With the advent of the NPDES permit program, however, Merrimack Station's pollutant discharges and withdrawals of river water for cooling became subject to regulation under NPDES permits issued by EPA and certified by the NHDES with respect to compliance with state WQS.

Since the 1960's, state and federal authorities have expressed persistent concern that Merrimack Station's thermal discharges would cause serious harm to aquatic organisms in the Merrimack River. Whether or not closed-cycle cooling should be required at the facility to reduce thermal discharges has been a recurring subject of debate. In 1969, Merrimack Station proposed cooling ponds to make closed-cycle cooling possible, but later obtained approval not to use cooling ponds and, instead, to rely on the above-mentioned extended discharge canal and PSMs to reduce thermal discharges. This approach demonstrated only limited effectiveness at reducing thermal discharges, however, and concerns continued that closed-cycle cooling using cooling towers could be needed at Merrimack Station. Ultimately, closed-cycle cooling was not required, however, and permits were issued that set thermal criteria to guide the use of the PSMs and imposed various narrative conditions requiring protection of the river's water quality and its aquatic life. Approximately 40 years since they were installed, Merrimack Station continues to rely on the extended discharge canal and PSMs to attempt to moderate its thermal discharges.

Merrimack Station's current permit was issued in 1992 and contains thermal discharge requirements based on a CWA § 316(a) variance. The permit requires operation of the PSMs to maintain water temperatures at Merrimack River monitoring station S-4 of 69˚F or less, or to limit temperature increases to 1˚F when the ambient river temperature exceeds 68˚F. Whenever both of these conditions are exceeded at Station S-4, the permit requires operation of all available PSMs. The permit conditions do not, however, prohibit discharges when these conditions are exceeded. Instead, they only require operation of the PSMs under such circumstances. Temperature data indicate that the above-described in-river temperature criteria have regularly been exceeded in the summer under current conditions.

The permit also specifies more generally that discharges must not violate WQS and that the facility's thermal plumes should not block zones of fish passage, alter the river's balanced indigenous population of aquatic organisms, or have more than minimal contact with the surrounding shorelines. *See id.*, Part I.A.1.g. Moreover, the permit calls for monitoring and studies to determine whether different, more protective thermal discharge limits are needed.

Finally, on a BPJ basis, EPA concluded that at the time of the 1992 NPDES Permit, Merrimack Station's CWISs and open-cycle cooling system satisfied the BTA standard of CWA § 316(b). This conclusion was embodied in the permit along with certain additional conditions, such as the requirement that organisms caught on the intake screens be returned to their aquatic habitat.

EPA Determinations for the New Draft NPDES Permit

Thermal Discharges

CWA § 316(a) Variance Determination

PSNH requested renewal of its thermal discharge variance under CWA § 316(a) and a new permit with thermal discharge conditions matching those in the existing permit. Such conditions would be compatible with continued year-round open-cycle cooling at Merrimack Station.

Based on a detailed evaluation of the pertinent data and analyses, however, EPA concluded that:

- PSNH failed to demonstrate that Merrimack Station's thermal discharge has not caused appreciable harm to the Hooksett Pool's BIP;
- To the contrary, the evidence as a whole indicates that Merrimack Station's thermal discharge *has* caused, or contributed to, appreciable harm to Hooksett Pool's BIP. For example:
    - The Hooksett Pool fish community has shifted from a mix of warm and coolwater species to a community now dominated by thermally-tolerant species;
    - The abundance for all species combined that comprised the BIP in the 1960's has declined by 94 percent, and
    - The abundance of some thermally-sensitive resident species, such as yellow perch, has significantly declined.
- PSNH did not demonstrate that its proposed alternative thermal discharge limits – namely, limits consistent with open-cycle cooling – would reasonably assure the protection and propagation of the BIP; and
- PSNH did not demonstrate that thermal discharge limits based on applicable technology-based and water quality-based requirements would be more stringent than necessary to assure the protection and propagation of the BIP.

Therefore, EPA determined that it must reject Merrimack Station's request for a CWA § 316(a) thermal discharge variance. *See* Sections 4, 5 and 6 of this document.

As a result, EPA turned its attention to determining appropriate thermal discharge limits for the facility that will satisfy federal technology-based requirements and any more stringent requirements that may apply based on state WQS.

Technology-Based Requirements under the BAT Standard

EPA has determined that among the available alternatives, converting Merrimack Station's open-cycle cooling system to a closed-cycle cooling system using wet or wet-dry hybrid mechanical draft cooling towers, and operating on a year-round basis, would be the best performing technology for reducing the facility's discharges of its waste heat to the Merrimack River. *See* Section 7 of this document. This technology would be technologically and economically feasible at Merrimack Station and could reduce thermal discharges by 95 percent or more. In light of its capacity to reduce thermal discharges, and having considered a variety of alternatives and the relevant regulatory BAT factors, EPA has determined that this alternative is the BAT for reducing Merrimack Station's thermal discharges.

In particular, EPA considered engineering and technological factors, process effects, cost, the age of the facilities, energy requirements, various secondary environmental effects (e.g., air, noise), and effects on electric rates. EPA found that retrofitting mechanical draft wet cooling towers in a closed-cycle configuration at Merrimack Station would present a complicated, but feasible, construction project. EPA also found that the cost of retrofitting mechanical draft cooling towers for both Units I and II at Merrimack Station would be significant but economically achievable for PSNH. EPA estimated that for Merrimack Station to install hybrid wet-dry mechanical draft cooling towers and operate in a closed-cycle mode year-round to control thermal discharges would result in a total after-tax cash flow cost to PSNH (present value at 5.3 percent) of $111.8 million, with an annual equivalent cost of $9.0 million (at 5.3 percent over 21 years) on an after-tax, nominal dollar basis (i.e., including the effects of inflation). These present value costs are based on after-tax, one-time costs of approximately $52.9 million and after-tax annual expenses (including operations & maintenance expenses and "energy penalties") of approximately $58.9 million.

EPA also recognizes that under New Hampshire's regulated energy market, PSNH may be able to pass all or much of the cost for converting to closed-cycle cooling along to its consumers, but EPA's analysis concludes that this would have only a relatively small effect on consumer electric rates. EPA estimates that the resulting increase in electricity costs per household customer over a 20-year period would range from approximately $0.0018 or 0.18¢ per kWh to $0.0022 or 0.22¢ per kWh. Based on average electricity sales per residential customer, and the estimated range of increases in electricity rates stated above, the estimated increase per household customer in electricity costs over the 20-year period would range from approximately $13.83 annually or $1.15 monthly, to approximately $16.19 annually or $1.35 monthly. These values translate into an estimated increase in the average residential customer bill for 2010 ranging from approximately 1.1 percent to approximately 1.3 percent. EPA does not take *any* resulting increase in electric rates lightly, but judges this increase, both as a dollar amount and as a percentage increase in the current bill, to be affordable and reasonable. Overall, EPA finds that the cost of upgrading Merrimack Station's decades-old cooling system is not only affordable, but it is reasonable in relation to the major reduction in pollutant discharges to the river that the technology can achieve (i.e., a 95% or greater reduction in thermal discharges).

EPA also considered a variety of possible secondary, non-water environmental effects that could result from converting to closed-cycle cooling at Merrimack Station, such as air emissions, sound emissions, and visual effects. Furthermore, EPA considered energy requirements and effects (*i.e.*, reductions in the electricity available for sale by Merrimack Station), the possibility of effects on the reliability of the electrical system, possible traffic safety effects from water vapor plume-induced fogging or icing of roadways, reduced entrainment and impingement of aquatic organisms as a result of reduced water withdrawals, and the possibility of reduced water levels in the river. While EPA found that there could be certain adverse effects with regard to some of these parameters (*e.g.*, reduced energy available for public sale due to the "efficiency and auxiliary energy penalties" associated with closed-cycle cooling), and certain beneficial effects associated with at least one consideration (*i.e.*, reduced entrainment and impingement), EPA did not find that any of the adverse effects, whether taken alone or in combination, were significant enough to disqualify the closed-cycle wet or wet-dry hybrid mechanical draft cooling tower options from being the BAT for thermal discharge reduction.

Having determined that converting to wet or wet-dry hybrid mechanical draft cooling towers in a closed-cycle configuration constitutes the BAT for Merrimack Station, EPA also determined specific thermal discharge limits achievable using this technology. These limits are set forth farther below.

Requirements Based on New Hampshire Water Quality Standards

In consultation with the state, EPA also determined thermal discharge limits necessary to satisfy the NHWQS. *See* Section 8 of this document. This effort was necessary because, among other reasons, of EPA's obligation under CWA § 301(b)(1)(C) to ensure that its permit limits satisfy state WQS. *See also* 33 U.S.C. §§ 3141(a)(1) and (d).

New Hampshire's WQS include a number of provisions that address the effects of discharges on aquatic life and habitat and that address thermal discharges in particular. From these provisions, EPA distilled the following criteria to guide its determination of water quality-based permit limits:

(a) thermal discharges may not be “inimical to aquatic life”;

(b) thermal discharges must provide, wherever attainable, for the protection and propagation of fish, shellfish, and wildlife, and for recreation, in and on the receiving water;

(c) thermal discharges may not contribute to the failure of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to, and with only non-detrimental differences in community structure and function from, that of similar natural habitats in the region; and

(d) [a]ny stream temperature increase associated with thermal discharge must not appreciably interfere with fishing, swimming and other recreational purposes.

EPA’s analysis concludes that Merrimack Station’s current thermal discharges are not satisfying these criteria.

EPA then determined temperatures that need to be maintained *in the river* to adequately protect aquatic life under the state WQS. EPA’s analysis focused on resident and diadromous species of fish and the effects of heat on their health and behavior during their different life stages (e.g., as larval, juvenile and adult fish). Ultimately, EPA prepared a table (Table 8.5) identifying specific temperatures not to be exceeded in the Hooksett Pool over the course of each year and the species (and life stage) that is driving that temperature.

In addition, New Hampshire statutory law, N.H. Rev. Stat. Ann. § 485-A:8(VIII), provides that:

> [i]n prescribing minimum treatment provisions for thermal wastes discharged to interstate waters, the department [of environmental services] shall adhere to the water quality requirements and recommendations of the New Hampshire fish and game department, the New England Interstate Water Pollution Control Commission, or the United States Environmental Protection Agency, whichever requirements and recommendations provide the most effective level of thermal pollution control.

This provision has also been incorporated within New Hampshire’s WQS. N.H. Code R. Env-Wq 1703.13(b). Given that Merrimack Station discharges to the Merrimack River, an interstate waterway, NHDES is required to prescribe treatment requirements for the facility’s thermal discharges that will “adhere” to the “most effective” water quality requirements and recommendations for “thermal pollution control” offered by the listed agencies. In this case, the most effective water quality requirements and recommendations are those developed by EPA in section 8 of this document and they become the state’s water quality requirements by operation of state law.

Determination of Thermal Discharge Limits for the New Draft Permit

As explained above, when setting effluent limits for an NPDES permit, EPA determines technology-based and water quality-based requirements and applies whichever are most stringent in order to ensure that both types of standards are satisfied.

Since EPA determined that converting Merrimack Station to closed-cycle cooling using wet or hybrid wet/dry mechanical draft cooling towers is the BAT for controlling thermal discharges, EPA specified thermal discharge limits that could be achieved using that technology on a year-round basis. More specifically, EPA calculated the maximum monthly heat load (in millions of British thermal units per month (MBtus/month)) that Merrimack Station would discharge to the Merrimack River (in its cooling tower blowdown) with closed-cycle cooling in place. Based on this analysis, the technology-based thermal discharge limits are as follows:

Month	Maximum Heat Load (MBtu/ Month)
January	6856
February	5613
March	7428
April	7210
May	6164
June	4064
July	3264
August	3393
September	4396
October	5950
November	7795
December	6920

See Table 9-1, third column. *See also* Draft NPDES Permit Condition I.A.5.b.

Turning to water quality-based requirements, EPA concluded that maintaining specific protective temperatures in the river was necessary to satisfy New Hampshire's WQS. Accordingly, Merrimack Station's thermal discharges must be small enough not to cause river temperatures to exceed the stated values. The data demonstrate that after converting to closed-cycle cooling, the effect of Merrimack Station's thermal discharge on river temperatures will be small (in all cases, less than 0.05°F). This is so even under conditions of maximum hourly temperature and lowest mean river flow.

EPA compared the water quality-based maximum mean ambient river temperatures that would be adequately protective to satisfy New Hampshire WQS with the ambient river temperatures that would result from Merrimack Station's thermal discharges after the facility's conversion to closed-cycle cooling. In all cases, EPA found that the technology-based thermal limits would be more stringent than the water quality-based limits. *See* Table 9.3. This also demonstrates that compliance with the technology-based limits would satisfy state WQS.

Therefore, EPA based the thermal discharge limits included in the new Draft Permit on the technology-based requirements. *See also* Draft NPDES Permit Condition I.A.5.b. These limits set performance standards for the Merrimack Station's thermal discharges based on levels that can be met using the specified BAT, but the permit does not directly mandate that a particular technology be used. Merrimack Station may meet the permit limits using any lawful approach that it chooses. For example, if PSNH found that dry cooling was feasible and decided for some reason that it preferred that technology, the permit does not preclude the company from taking that approach.

Potential Alternative Basis for Thermal Discharge Limits

As discussed above, CWA § 316(a) allows permit limits based on a variance from the otherwise applicable technology-based and water quality-based requirements for thermal discharges if certain criteria are met. PSNH requested such a variance but EPA determined that the company's application for a § 316(a) variance has not met these criteria and must be rejected. EPA focused, therefore, on determining technology-based and water quality-based requirements.

In Section 9.5 of this document, however, EPA explains that thermal discharge limits that satisfy New Hampshire WQS designed to protect aquatic habitat, aquatic organisms and recreational uses may also satisfy the criteria of CWA § 316(a), which require limits that assure the protection and propagation of the receiving water's BIP. If the water quality-based limits do satisfy CWA § 316(a), then EPA would be authorized to include these limits in the permit based on a variance from the more stringent technology-based limits. This would not be the variance requested by PSNH, but would be a variance independently determined by EPA to satisfy CWA § 316(a).

EPA considered making such an independent CWA § 316(a) variance determination in this case. Had the Agency done so, it would have based the Draft Permit's thermal discharge limits on state water quality requirements and a variance under CWA § 316(a) from federal technology-based requirements. EPA ultimately decided, however, not to take this approach for the Draft Permit because it wants to further evaluate and consider public comment on, among other things, the following questions:

(1) Has EPA correctly rejected PSNH's variance request?
(2) Has EPA properly applied New Hampshire's water quality standards, including the biologically-driven standards?
(3) Will limits satisfying New Hampshire's water quality standards also satisfy CWA § 316(a)?

As a result, EPA is affirmatively requesting public comment on these questions and any other matters pertinent to these issues. Moreover, EPA is providing express notice that it plans to further consider this approach for the Final Permit, taking into account any public comments received. EPA will also, of course, be considering whether the technology-based limits included in the Draft Permit should be retained for the Final Permit.

Water Withdrawals for Cooling

Determination of the BTA Under CWA § 316(b)

Merrimack Station withdraws approximately 287 million gallons of water per day from the Merrimack River for its cooling process for generating Units 1 and 2. This withdrawal adversely affects the river by causing the entrainment and impingement of its aquatic organisms.

Entrainment. Merrimack Station currently entrains approximately 3.8 million fish eggs and larvae (predominantly larvae). The facility has also at times entrained juvenile fish. Entrainment levels might be higher still if Hooksett Pool fish populations had not declined as they have.

At Merrimack Station, entrainment is essentially a seasonal problem. Specifically, the facility entrains aquatic organisms primarily from April through August. This is when virtually all fish eggs and larvae are found in the river due to seasonal spawning patterns.

A significant portion of the Hooksett Pool's icthyoplankton may be lost to entrainment by Merrimack Station because the facility tends to withdraw a sizable percentage of the Pool's flow for cooling. Moreover, this percentage grows in the early summer as river levels drop (and larvae are still present). For example, on average, Merrimack Station has withdrawn approximately 19 percent of the available flow in Hooksett Pool during July. It has withdrawn even more during some years and peak day withdrawals as high as 75 percent have been recorded. Even greater percentages of available flow have been withdrawn in August, although larval abundance is typically reduced during that month.

A number of species of importance to the Merrimack River that have suffered significant declines (e.g., yellow perch, white sucker, American shad) are particularly vulnerable to entrainment. Moreover, entrainment of icthyoplankton and other zooplankton may represent a significant reduction in available forage for the fish and other aquatic organisms that typically prey on them. All of this is particularly problematic given the poor health of the Hooksett Pool fish community and its apparent inability to recover under current conditions. Reducing entrainment should not only help facilitate the recovery of the resident fish community, but should also benefit efforts to restore anadromous American shad in the Merrimack River watershed.

Impingement. At Merrimack Station, impingement occurs on a year-round basis, substantial impingement events occur at times, and significant numbers of the fish that are impinged die as a result. Both resident and anadromous fish are impacted by impingement, and rates of impingement might be even higher if fish populations were healthy. Furthermore, the loss of significant numbers of juvenile and adult fish to impingement is likely to combine with other stressors to interfere with the recovery of fish populations.

Evaluation of BTA Options. In order to determine the BTA for minimizing adverse environmental impacts at Merrimack Station on a BPJ basis under CWA § 316(b), EPA evaluated a variety of alternatives with regard to their ability to reduce entrainment and impingement mortality while still providing Merrimack Station with adequate condenser cooling. For example, EPA evaluated Merrimack Station's existing open-cycle cooling system, considering the CWIS design, the volume and velocity of water withdrawals, and the fish return system's effectiveness at safely returning impinged fish to the river. EPA also evaluated a variety of other technological approaches in terms of their ability to reduce entrainment and impingement mortality, as well as in terms of their technological and economic feasibility, operational concerns, cost, secondary environmental effects, energy considerations, and other pertinent factors.

EPA "screened out" some of the options and evaluated others in greater detail, including comparing their costs and benefits. EPA assessed cost based on monetized estimates of one-time and recurring costs to the company ("private costs"). For purposes of cost/benefit comparison, EPA also converted these private costs to "social costs" (i.e., costs to society). Benefits were assessed in terms of the number of organisms saved and a qualitative assessment of the public value of the organisms saved and the aquatic habitat improved. EPA then considered a comparison of the social costs and social benefits in determining the BTA in this case.

EPA determined that the most effective available means of reducing entrainment by Merrimack Station would be to convert both the Unit 1 and Unit 2 cooling systems to closed-cycle cooling using wet or hybrid wet-dry cooling towers. This would reduce water withdrawal volumes and, as a result, entrainment by 95 percent, saving 3.616 million eggs and larvae (out of 3.8 million). No other "available" approach (such as converting to closed-cycle cooling at only one unit or installing a modified screening system) was nearly as effective. At the same time, because of the seasonal nature of the entrainment problem at this facility, EPA also found that operating in a closed-cycle mode only from April through August was *as effective* for reducing entrainment as operating closed-cycle cooling year-round. *See* Tables 12.4 of this document. At the same time, seasonal closed-cycle cooling was significantly less expensive. *See* Tables 12.2 and 12.3 of this document.

In addition, EPA found that closed-cycle cooling is also the most effective method of reducing impingement mortality, but that other substantially less expensive approaches could also achieve major improvements. These other methods include improving the facility's traveling screens and fish return system to increase the rate at which impinged fish are safely returned to the river.

Ultimately, EPA concluded that installing closed-cycle cooling using wet or hybrid wet/dry mechanical draft cooling towers and operating in a closed-cycle cooling mode *from April through August* (i.e., during the entrainment season) is a component of the BTA to minimize entrainment at Merrimack Station. (*See* Section 12 of this document.) This approach would achieve the greatest reduction in entrainment of the available alternatives that were evaluated in detail, and it is affordable and technologically feasible. EPA estimated the total, after-tax present value cost to the company of this option (including certain screening system improvements discussed below) to be $79.2 million, with an equivalent annual cost of $6.4 million per year over 21 years. *Year-round* closed-cycle cooling provides essentially the same entrainment reduction benefit but was rejected as the BTA for entrainment reduction because it was more expensive (with a total, after-tax present value cost of $112.7 million, with an equivalent annual cost of $9.1 million per year over 21 years) without further reducing entrainment. Providing closed-cycle cooling at only one of Merrimack Station's two generating units was rejected because it reduced entrainment far less. *See* Tables 12.3 and 12.4 of this document.

With regard to reducing impingement mortality, EPA first decided that under any circumstance, the BTA includes a number of relatively inexpensive steps that can be taken to improve Merrimack Station's currently ineffective fish return system so that more impinged fish are safely returned to the river. EPA then concluded that although closed-cycle cooling is the most effective technology for reducing impingement mortality in this case, the marginal benefits of operating the closed-cycle cooling year-round did not warrant its additional cost as compared to the less expensive option of installing certain screening system improvements to reduce impingement mortality from September through March. These improvements can provide much of the impingement mortality reduction that closed-cycle cooling would achieve at much lower cost. (Compare Options 4 and 5 in Table 12-2 of this Document, and compare Options 3 and 5 in Table 12-3 of this document.)

As with the determination of technology-based discharge limits under the BAT standard, in evaluating the closed-cycle cooling and screening system technologies under the BTA standard of CWA § 316(b), EPA considered various technological factors, secondary environmental effects, energy considerations, cost (as discussed above), consumer electric rate effects and a comparison of the costs and benefits of the technological approaches. While closed-cycle cooling would have certain adverse effects, and would involve considerable expense, none of these issues justified rejecting the technology. (No serious concerns were raised regarding the screening system improvements.) Given that EPA's analysis of these issues found nothing that disqualified year-round closed-cycle from being the BAT for thermal discharge control, it follows that none of the issues would disqualify *seasonal* closed cycle cooling from constituting the BTA for minimizing adverse environmental impacts from CWIS operation. Furthermore, as EPA explains in Section 12 of this document, in the Agency's judgment, the costs of these improvements to Merrimack Station's decades-old CWISs costs are warranted by the substantial environmental benefits that should result.

In sum, EPA determined that the BTA for Merrimack Station involves closed-cycle cooling using wet or wet-dry hybrid mechanical draft cooling towers from April through August to minimize entrainment. During this time period, the technology would also serve to minimize impingement mortality. Under CWA § 316(b), open-cycle operations would be allowed from September to March, but specific screening system improvements to minimize impingement mortality would be required during any such periods of open-cycle operation. EPA also determined that the BTA required certain fish return system improvements to be installed and operated on a year-round basis.

Based on this BTA determination, EPA crafted a number of specific permit conditions consistent with the use of this combination of technologies. These permit conditions are as follows:

- ❖ Units I and II must limit intake flow volume to a level consistent with operating in a closed-cycle cooling mode from, at a minimum, April 1 through August 31 of each year.
    - ▪ a low-pressure ($\leq$30 psi) spray wash system for each traveling screen (to remove fish prior to high-pressure washing for debris removal), the location of which has been optimized for transferring fish gently to the return sluice; and
- ❖ A new fish return sluice with the following features shall be installed for each CWIS:
    - ➢ Maximum water velocities of 3–5 ft/sec within the sluice;
    - ➢ A minimum water depth of 4–6 inches at all times;
    - ➢ No sharp-radius turns (*i.e.*, no turns greater than 45 degrees);
    - ➢ A point of discharge to the river that is slightly below the low water level at all times;
    - ➢ A removable cover to prevent access by birds, etc;
    - ➢ Escape openings in the removable cover along the portion of the sluice that could potentially be submerged; and

- ➢ A slope not to exceed 1/16 foot drop per linear foot, unless the plant can demonstrate that this is not feasible; and
- ➢ the fish return sluice will be in place and operational at all times.

While PSNH is most likely to comply with the permit's intake flow requirements using closed-cycle cooling, it is free to meet these permit conditions using any lawful method that it chooses. For example, if PSNH found that dry cooling was feasible and decided for some reason that it preferred that technology, the permit does not preclude the company from taking that approach. As another example, if PSNH was able lawfully to purchase makeup water from a willing seller rather than take it from the Merrimack River, the permit would not prevent it.

EPA considered but ultimately rejected the BTA options proposed by PSNH. Specifically, PSNH proposed to continue its open-cycle cooling operation, but (possibly) to use wedgewire screens with certain specific design features (e.g., mesh size of 1.5 mm or more) from April to July, and to schedule its annual one-month maintenance outage for Unit 2 each year from mid-May to mid-June to reduce entrainment. EPA considered PSNH's proposals in depth but determined that they did not satisfy the BTA standard of CWA § 316(b). EPA rejected the wedgewire screen proposal for a number of reasons, including that it was unlikely to be effective at the Merrimack Station site due to local river conditions. EPA agrees that it makes sense, to the extent feasible, to schedule the annual Unit 2 maintenance outage at a time that will minimize entrainment, but this proposal (with or without wedgewire screens) would be far less effective than operating both units in a closed-cycle cooling mode throughout the entrainment season and EPA concludes that it would not satisfy the BTA standard by itself.

New Hampshire Water Quality Standards

New Hampshire's WQS apply to the effects of cooling water withdrawals from state waters. EPA concludes that continued year-round open-cycle operations, with their associated levels of entrainment and impingement mortality, would not satisfy the state's water quality criterion requiring protection of the integrity of the biological and aquatic community of the Hooksett Pool. At the same time, EPA concludes that the BTA-based permit requirements described above not only satisfy CWA § 316(b), but also satisfy New Hampshire's WQS. As a result, no additional, more stringent CWIS-related permit requirements are needed to satisfy state WQS. At the same time, EPA concludes that it would be inconsistent with the state's WQS to make the permit's CWIS-related requirements significantly less stringent because doing so would allow increased entrainment and impingement mortality that would likely interfere with attaining the state's water quality criterion for protecting the integrity of the river's biological and aquatic community.

Interplay of Thermal Discharge and Cooling Water Withdrawal Permit Limits

For the most part, the draft permit's limits create performance standards for reducing thermal discharges and entrainment and impingement mortality that are based on the capabilities of closed-cycle cooling using wet or hybrid wet-dry mechanical draft cooling towers. (Additional impingement mortality reduction requirements are specified as CWIS design standards.) As explained above, however, the permittee may use any lawful method of meeting those limits.

The draft permit's thermal discharge and cooling water withdrawal limits have separate, independent foundations, and *both sets of limits must be complied with*. Therefore, to the extent that the permittee decided to meet thermal discharge limits by using closed-cycle cooling year-round, this approach would also satisfy the permit's CWIS requirements based on seasonal closed-cycle cooling. In other words, if closed-cycle cooling is in operation year-round to meet thermal discharge limits, then Merrimack Station would also satisfy the permit's requirements for entrainment reduction and impingement mortality control (as long as the required fish return system improvements are also installed). As a result, the facility would not need to install the intake screening system improvements that are only needed if and when open-cycle cooling is used.

The reverse is not true, however. Intake requirements based on seasonal closed-cycle cooling do not excuse the facility from the need to comply with thermal discharge limits based on year-round closed-cycle cooling. If the draft permit's thermal discharge limits were changed, however, so that open-cycle cooling was possible during certain months, then the facility could use open-cycle cooling during those months to the extent that it would also be allowed by the permit's CWIS requirements.

TABLE OF CONTENTS

FIGURES

<u>TABLES</u>

ACRONYMS AND ABBREVIATIONS

BIP	-	balanced indigenous population of shellfish, fish and wildlife
BIC	-	balanced indigenous community
BPJ	-	best professional judgment
Btu	-	British thermal unit
cfs	-	cubic feet per second
CPUE	-	catch per unit effort
CWA	-	Clean Water Act
CWIS	-	cooling water intake structure
DMR	-	Discharge Monitoring Report
DO	-	dissolved oxygen
EPA	-	U.S. Environmental Protection Agency
FAR	-	Fisheries Analysis Report
FERC	-	Federal Energy Regulatory Commission
MBtu	-	millions of British thermal units
MGD	-	million gallons per day
MW	-	megawatt
MWh	-	megawatt hour
NHFGD	-	New Hampshire Fish and Game Department
NHDES	-	New Hampshire Department of Environmental Services
NHWQS	-	New Hampshire water quality standards
NOAA	-	National Oceanic and Atmospheric Administration
NPDES	-	National Pollutant Discharge Elimination System
PSNH	-	Public Service of New Hampshire
RIS	-	Representative Important Species
TAC	-	Technical Advisory Committee
TCAFMMRB	-	Technical Committee for Anadromous Fishery Management of the Merrimack River Basin
UILT	-	upper incipient lethal temperature
USFWS	-	United States Fish and Wildlife Service
USGS	-	United States Geological Survey
VANR	-	Vermont Agency of Natural Resources, Department of Environmental Conservation
WSPCC	-	New Hampshire Water Supply and Pollution Control Commission
7Q10	-	represents the lowest consecutive seven-day flow measured over a 10-year period

1.0 INTRODUCTION

1.1 Background

This document presents the determinations of the New England regional office of the United States Environmental Protection Agency ("EPA," "Region 1," or "the Region") regarding appropriate thermal discharge and cooling water intake requirements for the new Draft National Pollutant Discharge Elimination System permit (No. NH0001465) ("Draft NPDES Permit") that EPA is developing under the Clean Water Act, 33 U.S.C. §§ 1251 *et seq.* ("CWA"), for the Merrimack Station power plant in Bow, New Hampshire. Merrimack Station is currently owned and operated by Public Service of New Hampshire ("PSNH"), and is referred to herein as Merrimack Station, PSNH, the station, the plant, the facility, the permittee, the applicant, or the company, unless otherwise noted.

Merrimack Station's currently effective NPDES permit was issued by EPA on June 25, 1992 ("1992 NPDES Permit"). This permit expired on June 25, 1997, but was administratively continued and remains in effect by virtue of PSNH's timely application for permit renewal. *See* 40 C.F.R. § 122.6. The new permit, once it becomes effective, will supplant the 1992 NPDES Permit.

This document is a key part of the administrative record supporting the new Draft NPDES Permit for Merrimack Station and is incorporated by reference in the permit's Fact Sheet. In addition, this document's key determinations are described in the Fact Sheet. Other necessary determinations to support the new Draft NPDES Permit for Merrimack Station (*i.e.*, issues not related to thermal discharge and cooling water intake) are discussed in the Fact Sheet and other supporting materials in the administrative record, but not in this document. Because the determinations presented in this document are being developed to support a draft permit, EPA and the New Hampshire Department of Environmental Services ("NHDES") will be soliciting public comment on the draft permit. Therefore, these determinations are subject to potential revision, after consideration of the comments received, if the permitting agencies conclude that changes are warranted. Any such changes would, however, be explained by the agencies in documents supporting the Final permit.

1.2 Consultations

EPA consulted closely with a number of State and Federal agencies in carrying out the analyses discussed herein. Such consultation was essential because, along with EPA, these other agencies also have relevant substantive expertise and regulatory responsibilities related to development and issuance of this permit, as well as public responsibility for ensuring protection of the natural resources of the Hooksett Pool ecosystem. Specifically, EPA consulted with NHDES because this state agency has substantive expertise in a number of relevant areas (*e.g.*, water quality, engineering, river flow requirements), and must determine which permit requirements are needed to satisfy New Hampshire's Surface Water Quality Standards, and any other requirements of state law. *See* 33 U.S.C. §§ 1341(a)(1) & (d). EPA also consulted with the New Hampshire Fish and Game Department ("NHFGD"), which has responsibilities and expertise related to New Hampshire fisheries. Further, NHFGD is specifically identified in New Hampshire's Surface Water Quality Standards ("WQS") as an agency that should be involved in establishing any WQS-based thermal discharge limits. *See* N.H. Rev. Stat. Ann. § 485-A:8(VIII).

EPA also consulted with, or is in the process of consulting with, the United States Fish and Wildlife Service ("USFWS") of the Department of Interior, and the National Marine Fisheries Service ("NOAA Fisheries") of the National Oceanic and Atmospheric Administration ("NOAA") within the Department of Commerce. USFWS has expertise on fisheries issues, flow requirements and fish passage at dams, as well as with the restoration of anadromous fish populations (*e.g.*, Atlantic salmon, American shad) in the Merrimack River. Further, USFWS biologists have been involved in previous reviews of fisheries studies related to Merrimack Station's discharge permit. For its part, NOAA Fisheries has regulatory responsibility for applying the Essential Fish Habitat requirements of the Magnuson-Stevens Act, 16 U.S.C. §§ 1801 *et seq.*, and NOAA Fisheries and the USFWS share responsibility for applying the requirements of the Endangered Species Act, 16 U.S.C. §§ 1531 *et seq*. *See* 40 C.F.R. §§ 124.59(b) & (c); and 40 C.F.R. § 122.49(d). In addition, by consulting with USFWS and NOAA Fisheries, EPA satisfies the directive in 40 C.F.R. § 125.72(d) that it consult with the Secretaries of Interior and Commerce regarding applications for thermal discharge variances under CWA § 316(a).

EPA, and the state and federal agencies listed above, collectively referred to as "the agencies" in this document, have carefully considered the data and analyses presented by Merrimack Station, both in writing and at meetings. The company has provided data and analyses on a variety of subjects relevant to this draft permit. EPA appreciates the time and effort expended by the agencies, and Merrimack Station and its consultants, in the development of this draft permit.

2.0 ECOLOGICAL SETTING

2.1 Merrimack River

Merrimack Station is located in Bow, New Hampshire along the west bank of the Merrimack River. The second-largest river in New England, the Merrimack runs approximately 116 miles from the confluence of the Pemigewasset and Winnipesaukee rivers in Franklin, New Hampshire, to the Atlantic Ocean in Newburyport, Massachusetts. The river segment in Bow is located south of Garvins Falls Dam and north of the Merrimack-Bedford town line and therefore is considered to be within the Middle Merrimack River, according to NHDES. It should be noted that the Army Corps of Engineers included the Hooksett Pool in the river segment covered in its Upper Merrimack River Watershed Assessment Study.

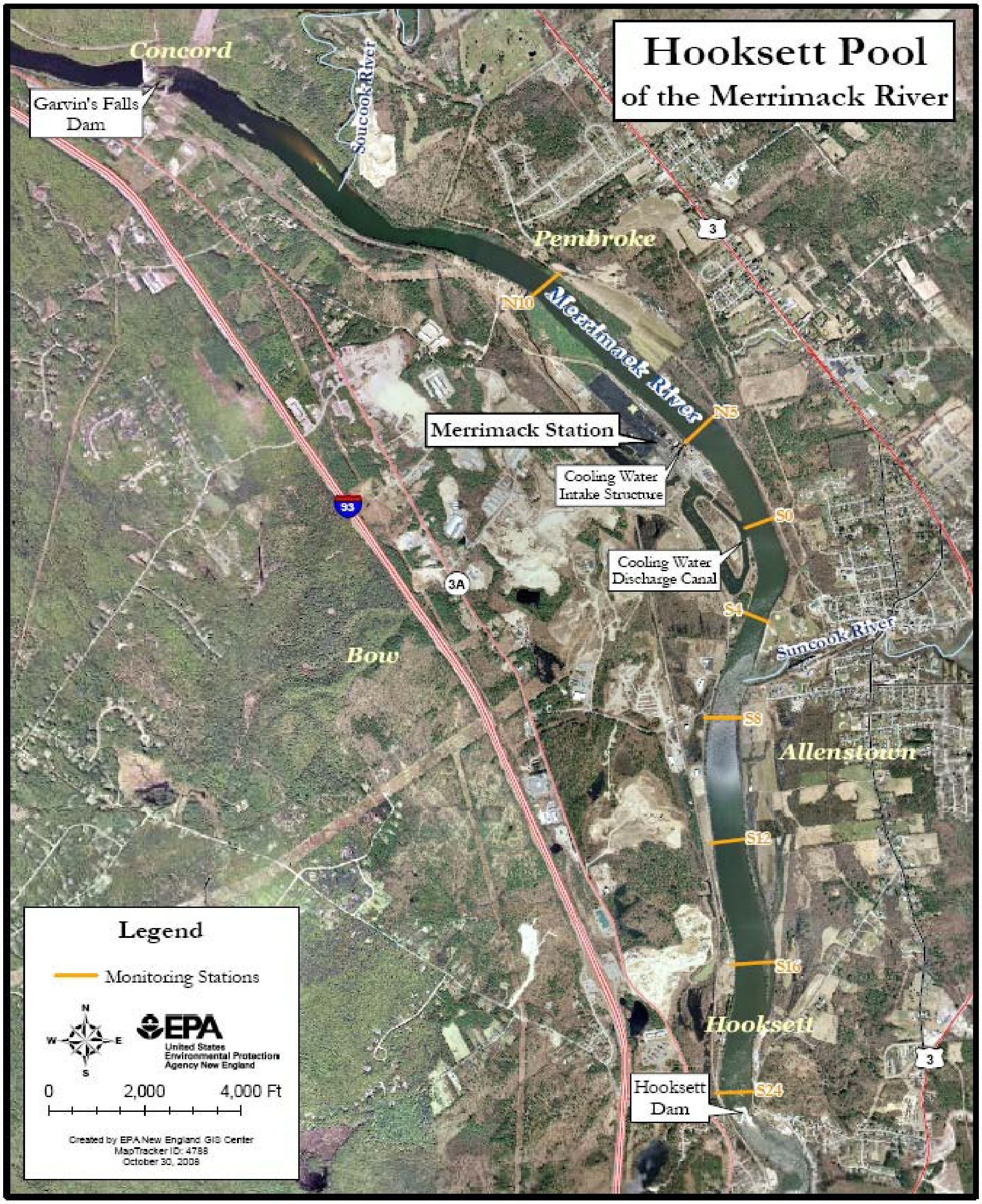
2.2 Physical Characteristics and Aquatic Habitat of Hooksett Pool

Merrimack Station discharges wastewater into, and withdraws water for cooling from, an impounded section of the Merrimack River known as the "Hooksett Pool." The pool is approximately 5.8 miles long and is bounded by the Garvins Falls Dam located upstream in Concord, and the Hooksett Dam which is downstream in the Town of Hooksett. Garvins Falls Dam was built in 1901, and Hooksett Dam in 1927. Merrimack Station is located approximately midway between these dams.

Hooksett Pool has a surface area of 350 acres and a volume of 130 million cubic feet at full-pond level (Normandeau 2007d). There are two major tributaries feeding into Hooksett Pool. The Soucook River enters the Merrimack River approximately 1.2 miles upstream from the discharge canal, and the Suncook River enters just over a half-mile below the canal (Figure 2-1). Bow Bog Brook, a relatively small stream, enters the Merrimack River approximately one mile above the plant's discharge canal.

Hooksett Pool ranges in width from 500 to 700 feet (Normandeau undated), and is relatively shallow, with depths between 6 and 10 feet under most flow conditions (Normandeau 2007d). According to the Merrimack River Monitoring program Summary Report (Normandeau 1979b), the reach from Garvins Falls downstream to the Soucook River changes quickly from a rapidly flowing tailrace to a broad, shallow stretch with several extensive sandbars (Figure 2-1). A short distance below the Soucook River confluence, the river narrows, resulting in stronger currents and a predominantly cobble substrate. Submerged macrophyte beds have been observed in this area late in the season. Below Merrimack Station to the Suncook River, Hooksett Pool is fairly uniform with a mixed sand and cobble bottom, and macrophyte beds along the banks. The pool becomes progressively wider and deeper from the Suncook River southward, with more varied substrate (Normandeau 1979b).

Figure 2-1 Map of Hooksett Pool



2.3 Hydrology

Typical of many river impoundments, the restricted flow caused by damming has transformed much of Hooksett Pool into a lentic, or pond-like, environment, particularly during periods of low flow, which are common during summer months. According to information provided by Merrimack Station, the estimated mean annual flow for the river at Merrimack Station based on the 100-year period of record is 4,551 cubic feet per second (cfs) ± 455 cfs (Normandeau 2007d). The hydraulic retention time of Hooksett Pool is approximately eight hours under mean annual flow conditions, and about five days under 7Q10 flow conditions (Normandeau 2007d). The term "7Q10" represents the lowest consecutive seven-day flow measured over a 10-year period. The 7Q10 for Hooksett Pool, as calculated by NHDES, is 587.75 cfs.

River flow into and out of Hooksett Pool is regulated by operations at Garvins Falls and Hooksett dams, both which are owned and operated by PSNH. According to PSNH, Garvins Falls Dam is operated for peaking power, and Hooksett Dam is operated to maintain suitable head for the cooling system at Merrimack Station, to generate hydroelectric power, and to regulate flow for Amoskeag Dam, downstream (Normandeau 1979b). The range of flows at these two dams can vary significantly (Table 2-1). Flow limits, as licensed by the Federal Energy Regulatory Commission ("FERC"), require that these dams be operated in an instantaneous run-of-river mode, which means that flow into Hooksett Pool essentially equals outflow from it (FERC 2008). Under some circumstances, such as planned or emergency maintenance, drawdowns affecting run-of-river operation are permitted with certain requirements specified by the FERC license.

Table 2-1 Recorded flows at Garvins Falls and Hooksett dams, based on data provided by PSNH (2003)

Dam	Recorded Flows in Cubic Feet per Second		
	Minimum	Mean	Maximum
Garvin's Falls	77	4,187	74,418
Hooksett	89	4,838	85,984

Mean monthly flow during summer months (*i.e.*, July, August, September) was calculated for the two dams bounding Hooksett Pool (Garvins Falls and Hooksett) for the years 1993 through 2007 using data provided by the U.S. Geological Survey. According to information provided by PSNH (2003), flows at theses dams can be calculated by adjusting the data collected at the Goffs Falls gaging station (No. 01092000). The monthly mean flow was adjusted by a factor of 0.907 for Hooksett Dam and 0.785 for Garvins Fall Dam (Table 2-2)

Table 2-2 Monthly averaged minimum, mean, and maximum flows (cfs) of the Merrimack River at Hooksett and Garvins Falls dams for July, August and September (1993-2007), based on data from USGS surface water website and adjustment factors provided by PSNH (2003)

Month	Monthly Flow (cfs) at Garvins Falls			Monthly Flow (cfs) at Hooksett Dam		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
July	771	2347	5920	891	2712	6841
August	613	1523	3799	708	1760	4389
September	595	1601	5318	688	1850	6144

2.4 Water Quality

Under the state water use classification system, NHDES has designated Hooksett Pool as Class B waters. State statute N.H. Rev. Stat. Ann. § 485-A:8(II) identifies the designated uses of Class B waters as

> *. . .[o]f the second highest quality,. . .[these waters] shall be considered as being acceptable for fishing, swimming and other recreational purposes and, after adequate treatment, for use as water supplies.*

More broadly, New Hampshire State Water Quality Standards, N.H. Administrative Rule Env-Wq 1703.01, states,

> *All surface waters shall provide, where attainable, for the protection and propagation of fish, shellfish and wildlife, and for recreation in and on the surface waters.*

PSNH monitored water quality in Hooksett Pool, as well as the impoundments immediately above and below Hooksett, monthly from May 2002 through April 2003 in support of its FERC relicensing requirements for Hydroelectric Projects located at the Garvins Falls, Hooksett, and Amoskeag dams. Sampling was conducted for total suspended solids, chlorophyll *a*, nutrients, dissolved oxygen ("DO"), water transparency, and temperature. Conclusions provided in PSNH's water quality report (Gomez and Sullivan 2003) states that all three impoundments generally displayed excellent water quality with DO and temperature usually well-mixed. The report indicates that nutrient concentrations were relatively low, and water clarity high. The report did note that while Garvins Falls and Amoskeag impoundments are very well-mixed and well-oxygenated, there were some exceptions in Hooksett Pool. The report (p.46) stated that,

> *At Hooksett, thermal stratification was shown to occur, and dissolved oxygen levels fell below 75% in the bottom portions of the water column.*

The report suggests that the temperature regime in Hooksett Pool is dictated somewhat by the cooling water used at Merrimack Station upstream of the Hooksett Dam. Further, the report notes that the depressed DO levels found at depth are unusual since temperatures at depth are colder, and as such, can hold more DO. The report offers temperature increases from the cooling water discharge upstream as a possible cause for low DO levels at the bottom of Hooksett Pool. The report also identifies as possible causes: the lack of submergent aquatic vegetation at the sampling site, and the cumulative effects of wastewater treatment discharges into the river above Hooksett Dam (Gomez and Sullivan 2003).

Algae blooms have been observed in sections of the Merrimack River below Hooksett Pool. Limited nutrient and turbidity data collected by NHDES suggest that elevated concentrations of nutrients, particularly phosphorus, exist in the river.

2.5 Hooksett Pool Uses

Hooksett Pool is used by Merrimack Station as its source of water for cooling as well as its receiving water for wastewater discharges. It also is the receiving water for the Town of Allenstown's wastewater treatment facility located near the mouth of the Suncook River. The design flow for the Suncook plant is 1.05 million gallons per day (MGD). Much of the shoreline along the pool is undeveloped. Hooksett Pool also provides some recreational fishing and boating opportunities. (For more information regarding uses of the Upper Merrimack River, including Hooksett Pool, see the United States Army Corps of Engineers' "Upper Merrimack River Watershed Assessment Study," which can be found at http://www.nae.usace.army.mil/projects/nh/umrwas/upperMerrimack.htm).

2.6 Biological Resources

The biological resources of the Merrimack River and Hooksett Pool are discussed in Sections 5 and 8 in the context of thermal discharges and cooling water withdrawals.

3.0 PERMITTING HISTORY

3.1 Facility Overview and Commencement of Operations

Merrimack Station is a steam-electric power plant operated by PSNH, which primarily burns coal and operates as a base-load plant with an electrical output of 478 megawatts (MW). The facility has a design intake flow of 287 MGD of river water for once-through condenser cooling.

The station has two primary power generating units: Unit 1 began operation in 1960 and has a nameplate rating of 120 MW, while Unit 2 began operation in 1968 and has a nameplate rating of 350 MW.

Construction and operation of Units I and II predated the 1972 CWA and the NPDES permitting scheme created by the statute. Originally, Merrimack Station's thermal discharges were evaluated by the New Hampshire Water Supply and Pollution Control Commission ("WSPCC"), with input from NHFGD. Later, EPA became the permit issuing authority, with input from the state agencies. EPA issued the currently effective permit in 1992; it governs the volume and temperature of thermal discharges as well as a range of other pollutant discharges.[1] It also regulates the facility's cooling water intake structures.

3.2 Discharge Volume Permitting & Performance

Unit 1 has a maximum design intake flow of 85 MGD, while Unit 2 has a maximum design intake flow of 202 MGD. The current permit allows Merrimack Station to discharge a maximum of 275.4 MGD of non-contact cooling water into the Merrimack River, not to exceed a monthly average of 265.3 MGD. The mean monthly discharge flow during summer (July, August, and September), based on flow monitoring data provided by Merrimack Station for the years 1992 – 2006, averaged 238 MGD. The daily maximum discharge flow for the same period averaged 256 MGD.

3.3 Thermal Discharge Permitting

3.3.1 Thermal Discharge Permitting by the State of New Hampshire

The permitting agencies have long been concerned with the effect of heated discharge water on aquatic life in the Merrimack River. In the 1960s, the State had plans to implement an anadromous fish restoration project in the River and was concerned about how Merrimack Station's thermal discharge might affect this program. Accordingly, in 1966, in anticipation of the construction of Unit 2, NHFGD outlined the thermal discharge standards that it considered acceptable given the fish restoration plans:

a) when ambient water temperature was below 58˚F (14˚C), the total increase in ambient temperature (ΔT) resulting from the discharge should not exceed 5˚F; *and*

b) when ambient water temperature was 58˚F (14˚C) or greater, the discharge should be cooled to the ambient water temperature ($\Delta T = 0^{\circ}$).

See "Chronology of Events – Bow Plant" document on file at EPA (entry for Oct. 19, 1966, referencing letter from Jack Kamman, NHFGD, to William A. Healy, WSPCC). PSNH,

[1] These other pollutants are discussed in the Fact Sheet supporting the current Draft NPDES Permit.

WSPCC, and NHFGD then conducted a cooperative study to learn more about the native fish population. *See id.* (entry for Apr. 27, 1967). WSPCC later assured NHFGD that any thermal discharge limits would be set so as not to interfere with NHFGD's anticipated cold water fish restoration program. *See id.* (entry for December 27, 1968, referencing letter from Bernard W. Corson, NHFGD, to William A. Healy, WSPCC).

Merrimack Station applied to WSPCC for a thermal discharge permit for both Units I and II in the spring of 1969. As the permit proceeding progressed, NHFGD again emphasized that while warm water standards would be temporarily acceptable, once the Atlantic salmon and American shad restoration program began, cold water habitat standards would be needed. *See id.* (entry for May 16, 1969, referencing letter from Bernard W. Corson, NHFGD, to William A. Healy, WSPCC). Around this time, a NHFGD fisheries biologist reported that a recording instrument measuring the temperature of the station's discharge had recently "pegged beyond its maximum of 112˚F" during low-flow conditions. Letter from Phillip H. Wightman, NHFGD, to Arthur E. Newell, NHFGD, July 16, 1969.

Shortly thereafter, PSNH acknowledged that "closed circuit" operation would be necessary for part of the year. *See* "Chronology of Events – Bow Plant" document on file at EPA (entry for Oct. 2, 1969, referencing letter from Eliot Priest, PSNH, to William A. Healy, WSPCC). The facility rejected using cooling towers for this purpose, however, and instead proposed a cooling pond and sprays. *See id.* The proposed design also involved the facility discharging its heated water through a 1,700-foot (518 m) discharge canal to the Merrimack River at Station S-0 (Figure 2-1).

WSPCC issued the final permit on October 8, 1969, noting that in a "spirit of joint intent," the permit incorporated some of PSNH's desired revisions. *See id.* (entry for Oct. 8, 1969, referencing letter from William A. Healy, WSPCC to Eliot Priest, PSNH). The permit gave Merrimack Station two years to achieve compliance and provided that:

a) when ambient water temperature was below 68˚F (20˚C), ΔT should not exceed 5˚F unless PSNH demonstrated to WSPCC's satisfaction that greater increases "will not be harmful to fish, other aquatic life, or other uses"; and

b) any artificial temperature increase should not cause the river temperature to exceed 68˚F (20˚C) for cold water fisheries or 83˚F (28˚C) for warm water fisheries.

Just eight months later, Merrimack Station sought to modify the permit, requesting permission to discontinue use of the spray ponds and to study a new technology for a year. *See id.* (entry for Jun. 1, 1970, referencing letter from Eliot Priest, PSNH, to William A. Healy, WSPCC). The facility proposed to extend the discharge canal and replace the ponds with spray modules designed to aerate, and thereby to cool, heated effluent prior to discharge to the river. NHFGD was extremely wary of this proposal because if, as it expected, this untested technology failed to produce acceptable results, the one-year testing period would leave only a single month in the original permit schedule to achieve compliance. Letter from Bernard W. Corson, NHFGD, to William A. Healy, WSPCC, Jun. 17, 1970. To assuage this concern, Merrimack Station offered its assurance that the proposed system would be effective, but also agreed to work simultaneously on an acceptable alternative that could be in place by September 1972 (eleven months after the required date of compliance) if the proposed new system was not effective. *See* "Chronology of Events – Bow Plant" document on file at EPA (entry for Jul. 16, 1970, referencing letter from Eliot Priest, PSNH, to Terrence P. Frost, WSPCC). The agencies acquiesced to the requested changes. *See id.*

On June 30, 1972, Merrimack Station completed installation of its supplemental cooling system. This system consisted of a 3,901-foot (1,189 m) discharge canal equipped with 54 power spray modules. The modification decreased the station's ΔT, but not enough to bring the facility into compliance with its permit. The average summer ΔT between the discharge canal mouth and ambient river water during the 1968 to 1971 period was 18.4˚F (10.2˚C), according to the Merrimack River Monitoring Program Summary Report ("1979 Summary Report") (Normandeau 1979). The mean summer ΔT from intake to discharge following the modification was 10.8˚F (6.0˚C), according to the 1979 Summary Report.

In August 1973, NHFGD reported several ΔT exceedances and expressed to WSPCC its serious doubts as to whether "the existing facility is adequate to perform within the temperature standards established." Letter from Phillip H. Wightman, NHFGD, to Terrence P. Frost, WSPCC, Aug. 3, 1973. NHFGD reminded WSPCC that the thermal discharge limitations had been set by experts in "fish-temperature relations," and suggested that closed-cycle cooling might be "the only way to solve the heated water problem" at the facility. *Id.*

Around this same time, and possibly in response to its compliance problems, PSNH introduced a new interpretation of the permit requirements. Rather than simply measure the maximum temperature rise between the monitoring stations, the company now began averaging the temperature rise in the river. Letter from Arthur E. Newell, NHFGD, to Terrence Frost, WSPCC, Nov. 15, 1973.[2] NHFGD described this new method as "different[] than what we believed at the time of our acceptance of the permit and. . . different[] from what the Water Supply and Pollution Control Commission intended." *Id.* NHFGD further explained that had this interpretation been permissible, it would have negated the need for the supplemental cooling system in the first place. *Id.*

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[2] The letter references the "cross-section of the river" which suggests a horizontal measure, but appears to mean "water column," a vertical measure. *See, e.g.*, Letter from Terrence P. Frost and Russell A. Nylander, WSPCC, to William A. Healy, WSPCC, Dec. 20, 1974; "Chronology of Events – Bow Plant" document on file at EPA (entry for Jan. 16, 1974, referencing letter from Bernard W. Corson, NHFGD, to William A. Healy, WSPCC).

Then, in December 1973, Merrimack Station requested permission to discontinue use of the spray modules over the winter in light of the developing energy crisis. WSPCC underscored that it had anticipated that use of the cooling system would continue uninterrupted and noted that it "went along" with PSNH's request to experiment with the "relatively untried spray module cooling" on the understanding that it would be continued until either proven successful or impractical for achieving compliance. Letter from Terrence B. Frost and Russell A. Nylander, WSPCC, to William A. Healy, WSPCC, Jan. 23, 1974. PSNH reportedly "believe[d] it has reached this goal," presumably buttressed by its revised interpretation method, but based on data from PSNH's own consultant's 1972 report, the agencies disagreed. Letter from Terrence B. Frost and Russell A. Nylander, WSPCC, to William A. Healy, WSPCC, Jan. 23, 1974 at 1 (stating that the report "clearly demonstrates that the permit requirements are not being met consistently in the Merrimack River at Bow"). Nonetheless, persuaded that planned flow augmentation in the river would sufficiently increase the flow at Bow, *see id.* at 2, the agencies acceded to the request based on the facility's assurance that it would demonstrate the capability to limit ΔT to 1˚F "at any point in the water column" when the ambient river temperature reached 68˚F (20˚C). *See* "Chronology of Events – Bow Plant" document on file at EPA (entry for Jan. 16, 1974, referencing letter from Bernard W. Corson, NHFGD, to William A. Healy, WSPCC).

3.3.2 Thermal Discharge Permitting by EPA

Following enactment of the CWA, Merrimack Station applied to EPA for a NPDES permit in September 1974. During development of the permit, NHFGD voiced strong concern that the spray module technology was not working, that the permit conditions had not consistently been met, and that the required monitoring had been "haphazard and capricious." *See* Letter from Arthur E. Newell, NHFGD, to Jeffrey G. Miller, U.S. Envtl. Prot. Agency (Oct. 3, 1974). Shortly thereafter, however, NHFGD wrote to EPA to state its intent to "withdraw" its October 3, 1974 letter outlining these concerns. *See* Letter from Arthur E. Newell, NHFGD, to Jeffrey G. Miller, U.S. Envtl. Prot. Agency (Dec. 11, 1974). *See also* "F&G: Bow Plant 'Not Even Close' to Heat Standard," Concord Monitor, Dec. 16, 1974 at 1; "Corson Clamps Muzzle on F&G Sensitive News," Jan. 4, 1975 (copy of unidentified newspaper article on file at EPA).

In January 1975, EPA issued Merrimack Station its first NPDES permit, providing a two-year period for the facility to achieve compliance. The permit required, among other things, that:

a) ΔT should not exceed 5˚F when ambient water temperature was below 68˚F (20˚C) or 1˚F when ambient temperature was 68˚F (20˚C) or higher, unless PSNH could demonstrate to WSPCC and EPA's satisfaction that greater increases "will not be harmful to fish, other aquatic life, or other uses;"

b) at no time should ΔT exceed 1˚F per hour; and

c) any study undertaken to show an absence of harm to the resident and migratory fish population *in lieu* of meeting the thermal discharge limits should include certain enumerated parameters.

Not long after, a NHFGD memorandum lamented the previous nine years of noncompliance and expressed its lack of confidence that the planned biological studies would show that Merrimack Station could safely meet the required standards. Memorandum from Inland and Marine Fisheries Div. to All NHFGD Comm'rs, Feb. 18, 1975. Given that expectation, and in order to reduce the time needed to achieve compliance, the department recommended that PSNH be required to "complete engineering design for closed cycle operation coincident with their biological survey." *Id.* ("This procedure would, in all probability, save one entire year and yet not place undue financial burden on upon the utility.")

In December 1975, NHFGD alerted Merrimack Station that a recent report, entitled "Merrimack River Monitoring Program 1974," indicated that the facility was "still not coming any closer to meeting the requirements" in its permit and that the agency considered it "rather disturbing. . .to see such a wide discrepancy after so many years of operation." Letter from Arthur E. Newell, NHFGD, to Bruce Smith, PSNH, Dec. 22, 1975. Further, the report showed that at certain times, river flow was inadequate for the cooling system to function properly and NHFGD predicted that this would create problems "disastrous to the aquatic environment." *Id.* Indeed, studies indicated that wildlife was suffering from the discharge, potentially threatening the anadromous fish restoration program. *See id.* ("[L]ess desirable, more heat tolerant species are continuing to replace the more desirable game species. . . .").[3] Given the permit exceedances and the studies clearly demonstrating "that the discharge is in fact having an adverse affect upon the existing warmwater fish population," NHFGD strongly suggested PSNH "be prepared to develop the capabilities for closed cycle operation as soon as possible after January 1, 1977," when the period for coming into compliance with the NPDES permit would expire. *Id.*

At the time of permit renewal, however, PSNH sought less stringent permit requirements. Among other changes, it proposed to limit temperature monitoring only to times when ambient water temperature exceeded 40˚F (4.4˚C). Later, PSNH requested that its operation of the power spray modules be limited to only those times between June 1 and October 1 when sufficient flow volume existed and any time that ambient river temperature exceeded 68˚F (20˚C). Letter from Warren A. Harvey, PSNH, to Envtl. Prot. Agency Permit Branch, Att. 3 at 3 (Feb. 16, 1979). NHFGD agreed and WSPCC "unanimously voted to accept the requested modifications" on behalf of the state. Letter from Russell A. Nylander, WSPCC, to Warren A. Harvey, PSNH, Mar. 7, 1979.

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[3] *See also, e.g.*, Letter from James R. Beltz, Normandeau Assoc., Inc. to Wayne Nelson, PSNH (Dec. 22, 1978), at 4 (". . .surface plume has at times exceeded the 34˚C lethal temperature for shad larvae").

The 1979 and 1985 permits issued by EPA incorporated these modifications: 1) the temperature monitoring period at monitoring stations N-10 and S-4 was limited to when the ambient river temperature was above 40˚F; and 2) the operation of the power spray modules was only required when the temperature exceeded 69˚F or ΔT (clarified as the difference in temperatures between the monitoring stations N-10 and S-4) exceeded 1˚F. The permits did not set maximum temperature limits for the thermal discharge or for the receiving water; rather, it required full operation of the power spray modules under certain conditions. The 1985 permit also specified that discharges should not violate any applicable water quality standards, *see* 1985 Permit, Part I.A.1.c, that the thermal plume should not interfere with the "natural reproductive cycles, movements, or migratory pathways of the indigenous populations" in that area of the Merrimack River, *see id.* Part I.A.g, and that the plume should be managed so as not to interfere with the passage of migratory fish. *See id.* Part I.A.h.

In anticipation of the 1992 permit renewal, EPA looked further at the effects of Merrimack Station's thermal discharges on the Merrimack River. The record indicates that EPA was concerned about possible adverse effects from these discharges but also was uncertain about how best to proceed due to, among other things, a dearth of information. One EPA staff memorandum cited measurements showing several average monthly ΔT temperatures that were "elevated well above background," and expressed "significant concerns" that thermal discharge limits were not being met. Memorandum from William Beckwith, U.S. Envtl. Prot. Agency, to Nick Prodany, U.S. Envtl. Prot. Agency (Feb. 10, 1992). *See also* Letter from Donald A. Normandeau, NHFGD, to Robert Varney, N.H. Dept. of Envtl. Srvcs. (Jul. 2, 1991) (citing recent annual monitoring reports revealing several ΔT exceedances of 9˚ to 10˚F and exclaiming that one 1989 reading "exceeds the ΔT by 40˚F!"). In addition to noting that the recorded temperature levels "exceeded incipient lethal temperatures" for certain adult fish and that adult fish can tolerate higher temperatures than what is needed for spawning and embryo survival, the memorandum stated that the permit needed stronger language regarding the enforcement of the thermal discharge limits. *Id.* The memorandum also expressed concern that the thermal discharge was resulting in an inadequate zone for fish passage. *Id.* Meanwhile, a separate, earlier EPA staff memorandum stated that the author could not make any recommendation as to the appropriate thermal discharge limits because he lacked essential information.[4] This memorandum emphasized the need to study the thermal effects on the aquatic biota in the River. *Id.*

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[4] This memorandum is neither signed nor dated and provides no other indication as to its author. The document was found, however, in an EPA file labeled as "T. Landry file" and which contains several other memoranda and documents authored by T.E. Landry. T.E. Landry was at the time an NPDES permit writer on EPA's staff who worked on the Merrimack Station permit. Mr. Landry has since retired. EPA presumptively concludes that Mr. Landry drafted the unsigned memorandum. In addition, it was written some time after September 10, 1991, because it references events as of that date.

In light of the lack of information, an EPA permit writer concluded that EPA had two options for the next permit: 1) use limits similar to the existing permit but require studies to gather information and set up a Technical Advisory Committee ("TAC") to review the studies and help define appropriate limits, or 2) delay reissuing the permit until a multi-year study could be completed, thereby delaying action to address the non-thermal aspects of the permit during that time. *See* Memorandum from T.E. Landry, U.S. Envtl. Prot. Agency, Oct. 15, 1991. EPA essentially chose the former option.

The new permit, which is still currently in effect, was issued on June 25, 1992. The permit included discharge limitations and monitoring requirements. Among other limitations, the permit again specified that discharges should not violate any applicable water quality standards. *See* 1992 Permit, Part I.A.1.b. The permit required the power spray modules to be operated so as either to maintain a temperature at S-4 of 69˚F or less, or to limit ΔT to 1˚F when the ambient river temperature exceeded 68˚F. It also specified that thermal plumes from the station should not block the zone of fish passage, should not change the balanced indigenous population of the receiving water, and should have minimal contact with the surrounding shorelines. *See id.*, Part I.A.1.g.

Impingement and entrainment monitoring was to be conducted during certain periods of the summer. Temperature monitoring at Station S-0 was to be performed year-round, while monitoring at the N-10 and S-4 stations would commence in the spring when ambient river temperatures (measured at N-10) exceed 50˚F[5] and end in the fall when the ambient temperatures decreased to 40˚F. PSNH was also required to work with the newly-formed TAC to design, develop, and implement a study to address, among other things, a range of information deficiencies with regard to the resident and anadromous fish in the River, their migration and life cycles, the temperatures that support them, and the manner in which they are affected by Merrimack Station's thermal discharges.

3.4 Thermal Discharge Performance

Merrimack Station's designed ΔT associated with condenser cooling is 23.04ºF (12.8˚C) above ambient water temperatures (Normandeau 1979). The degree to which the cooling system reduces the temperature of heated effluent appears to vary with changes in humidity, with high relative humidity resulting in reduced cooling efficiency. EPA reviewed mean and maximum daily ambient and discharge temperature data provided by PSNH covering the 21-year period

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[5] The temperature triggering the installation of the temperatures probes presumably was increased to 50˚F to ensure the safety of PSNH personnel. Environmental Monitoring Program Annual Reports from several years indicate that the temperature probes often could not safely be installed when the temperature reached 40˚F due high river flows. Consequently, probes often were not installed until around June 1. *See, e.g.*, Annual Report 1988-1989 at 9; Annual Report 1987-1988 at 8; Annual Report 1986-1987 at 8.

from 1984 to 2004 (Normandeau 2007b). According to this data set, the change in the mean discharge over intake temperatures for the summer months ranged from 15.9˚F (8.8˚C) in July to 16.9˚F (9.4˚C) in September (Table 3-1). These temperatures are substantially higher than the mean summer intake-to-discharge ΔT of 10.8˚F (6.0˚C) presented in the 1979 Summary Report.

Measured average daily maximum temperatures collected during the same 21-year period (1984-2004) illustrate the frequency and extent to which discharge temperatures exceed ambient temperatures during the summer (Appendix A). Temperatures reaching or exceeding 100.0˚F (37.8˚C) were recorded at the discharge (Station S-0) on 13 days in July, and 17 days in August, with the highest average daily maximum temperature (104.2˚F (40.1˚C)) occurring on August 16. The average ΔT for the days in July and August that reached or exceeded an average maximum temperature of 100.0˚F (37.8˚C) was 19.5˚F (10.8˚C).

Table 3-1 Averaged Mean Daily Temperatures and ΔTs for the Months of July, August, and September at Three Monitoring Stations in Hooksett Pool, Based on Data Collected from 1984 – 2004 by Merrimack Station (Normandeau 2007b)

Month	Monitoring Stations and ΔT from Ambient				
	N-10 (Ambient)	S-0 (Discharge)	ΔT N-10/S-0	S-4 (Mixing Zone Boundary	ΔT N-10/S-4
July	75.2˚F/24.0˚C	91.1˚F/32.8˚C	15.9˚F/8.8˚C	81.4˚F/27.4˚C	6.2˚F/3.4˚C
August	75.0˚F/23.9˚C	91.0˚F/32.8˚C	16˚F/8.9˚C	81.9˚F/27.7˚C	6.9˚F/3.8˚C
September	66.6˚F/19.2˚C	83.5˚F/28.6˚C	16.9˚F/9.4˚C	74.7˚F/23.7˚C	8.1˚F/4.5˚C

3.5 Summary

Operation of Units I and II, the two primary generating units at Merrimack Station, began in the 1960s, before the advent of the CWA's NPDES permit program. Concern among regulators about the effects that the thermal discharges from these units would have on the Merrimack River and its aquatic life also pre-dated the NPDES permit program. These concerns became especially acute as the commencement of Unit 2 operations came near. While additional cooling technology – namely, the discharge canal and PSM system – was added to Merrimack Station in the early 1970s in response to these concerns, regulators also expressed concern that this technology would be insufficient to avoid harmful thermal discharge effects, and that installation of cooling towers to enable closed-cycle cooling might be necessary. Further cooling technology has not been added to Merrimack Station since that time, more than 30 years ago.

Regulators have also been concerned over the years that additional information was needed to better evaluate these issues. Therefore, as a precursor to developing this new Draft NPDES Permit for Merrimack Station, EPA both developed substantial new information and requested substantial new information from PSNH. EPA has considered this new information, among other things, in making the necessary determinations to support the new Draft NPDES Permit. These determinations are set forth in subsequent chapters of this permit's Determinations Document. As part of this work, EPA has had to evaluate, among other things, any adverse effects on aquatic life and water quality from Merrimack Station's thermal discharges and cooling water withdrawals. EPA has also evaluated technologies, including closed-cycle cooling with cooling towers, which might be available for reducing any such adverse effects.

Thus, many of the key questions addressed in this Permit Determinations Document are not new, but EPA has brought a fresh eye to this work and has conducted new analyses based on new, up-to-date information.

4.0 NPDES PERMITTING REQUIREMENTS FOR THERMAL DISCHARGES

4.1 Introduction

Steam-electric power plants, such as Merrimack Station, take advantage of the "steam cycle" to generate electricity and must have a method of condensing (or cooling) the steam used in the electrical generating process. Some facilities use dry cooling, while others use some type of "wet" cooling process (either "open-cycle" cooling or "closed-cycle" cooling using "wet cooling towers").

In a wet cooling system, the facility typically withdraws water from a water body through a cooling water intake structure ("CWIS") and uses the water to condense the steam. Alternatively, a facility could use municipal water or treated wastewater for cooling, if an adequate volume and quality of such water was available. As a result of condensing the steam, the cooling water is heated above ambient water temperatures. In an open-cycle or "once-through" system, the water (including the waste heat absorbed from the steam) is discharged back to the water body as a thermal effluent. Closed-cycle systems using wet cooling towers chill the cooling water so that it can be re-used for condensing steam. Some thermal discharges, in the form of cooling tower blowdown, will remain necessary even for "closed-cycle" wet systems, and evaporative water losses in the cooling towers will necessitate some continued water withdrawals to provide "makeup water." In a closed-cycle system, however, the thermal discharges and water withdrawals can be reduced by approximately 95%.

The CWA addresses both ends of the wet cooling process: *i.e.*, the withdrawal of water for cooling and the discharge of the thermal effluent. Specifically, cooling water withdrawals through CWISs must satisfy CWA § 316(b), as well as any applicable requirements based on state water quality standards. Discharges of heat must satisfy both technology-based and water quality-based requirements, or the requirements of a variance under CWA § 316(a). Thermal discharge and cooling water intake issues will be discussed in detail below. A facility's thermal wastewater may also contain other pollutants regulated by Merrimack Station's NPDES permit, such as chlorine or other biocides, but the derivation of limits for these pollutants is addressed in other parts of the administrative record for the new Draft NPDES. This document addresses only the thermal discharge and CWIS issues.

4.2 Legal Requirements and Context

4.2.1 Setting Thermal Discharge Limits

As stated above, steam-electric power plants that use once-through cooling systems heat up their cooling water as a result of condensing the steam and then discharge the heated effluent to a receiving water. Heat is defined as a "pollutant" in CWA § 502(6). 33 U.S.C. § 1362(6). The point source discharge of pollutants to a water of the United States is prohibited by CWA § 301(a), unless authorized by an NPDES permit issued under CWA § 402.

Permit limits for thermal discharges must, at a minimum, satisfy federal technology-based requirements, *see* CWA §§ 301, 304, & 306, as well as any more stringent requirements based on state water quality standards that may apply. *See* CWA § 301(b)(1)(C). Technology-based and water quality-based requirements for Merrimack Station's thermal discharges are discussed in Sections 7 and 8 of this Determinations Document, respectively. Alternatively, thermal discharge limits may be based on a variance from applicable technology-based and water quality-based standards if the standards of CWA § 316(a) are satisfied. The applicability of a CWA § 316(a) variance for Merrimack Station is discussed in Sections 4, 5 and 6 of this document. In addition, the interaction of all three types of thermal discharge standards is discussed in Section 9, while the interaction of thermal discharge and CWIS requirements is discussed in Section 13.

Whatever their legal basis, permit limits for thermal discharges can be designed in a variety of ways to control the discharge of heat to a receiving water. For example, limits can be imposed (a) on the maximum temperature of a discharge (Max-T), (b) on the increase in the temperature of the discharge as compared to the temperature of the intake water (ΔT), (c) on the number of British thermal units (Btus) of heat in a discharge,[6] and/or (d) on the extent of the changes in ambient water temperatures that will be allowed as a result of the thermal discharge under various conditions.

4.2.2 CWA § 316(a)

While NPDES permits generally must include effluent limits that, at a minimum, satisfy federal technology-based standards, and that also satisfy any more stringent requirements based on state water quality standards that apply. CWA § 316(a) provides an exception to this general rule. It authorizes permitting agencies to grant a variance from both technology-based and water quality-

[6] Btus will be a function of the ΔT and the volume of the heated water being discharged.

based limits and, instead, to impose alternative, less stringent thermal discharge limits if certain criteria are met. Specifically, CWA § 316(a) provides, in pertinent part, as follows:

> *[w]ith respect to any point source otherwise subject to the provisions of section 1311 of this title or section 1316 of this title, whenever the owner or operator of any such source, after opportunity for public hearing, can demonstrate to the satisfaction of the Administrator (or, if appropriate, the State) that any effluent limitation proposed for the control of the thermal component of any discharge from such source will require effluent limitations more stringent than necessary to assure the pro[t]ection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the body of water into which the discharge is to be made, the Administrator (or, if appropriate, the State) may impose an effluent limitation under such sections for such plant, with respect to the thermal component of such discharge (taking into account the interaction of such thermal component with other pollutants), that will assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on that body of water.*

33 U.S.C. § 1326(a). *See also* 40 C.F.R. § 125.70. A determination to approve alternative thermal discharge limits under this statutory provision is commonly referred to as a CWA "Section 316(a) variance." *See* 40 C.F.R. § 125.71(a) & 125.72 (heading).

4.2.3 Criteria for Assessing § 316(a) Variance Applications

CWA § 316(a) authorizes alternative thermal discharge limits when it is demonstrated to EPA that the limits "will assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on that body of water" (sometimes referred to hereinafter as the "BIP"). This criterion is reiterated in EPA regulations promulgated at 40 C.F.R. § 125.73(a).

The terms "protection" and "propagation" are not defined in the statute or regulations. However, the American Heritage Dictionary (2d College Ed. 1982) defines "protection," in pertinent part, as "[t]he act of protecting . . . [or t]he condition of being protected," while it defines "protect" as "[t]o keep from harm, attack, or injury; guard." In addition, it defines "propagation" as "[to i]ncrease or spread, as by natural reproduction." Thus, thermal discharge limits based on a CWA § 316(a) variance must assure that the receiving water's BIP will be safe from harm from the thermal discharge, and that the thermal discharge will not interfere with the BIP's ability to increase or spread naturally in the receiving water.

The CWA also does not define the term "balanced, indigenous population." Some clarification of Congress' intent is provided, however, in the CWA's legislative history. The Report of the Conference Committee on S. 2770, the bill that was enacted as the CWA of 1972 and originated the current § 316(a), stated the following with regard to § 316(a):

> *It is not the intent of this provision to permit modification of effluent limits required pursuant to Section 301 or Section 306 where existing or past pollution has eliminated or altered what would otherwise be an indigenous fish, shellfish and wildlife population. The owner or operator must show, to the satisfaction of the Administrator, that a "balanced indigenous population of fish, shellfish and wildlife" could exist even with a modified 301 or 306 effluent limit. Additionally, such owner or operator would have to show that elements of the aquatic ecosystems which are essential to support a "balanced indigenous population of fish, shellfish and wildlife" would be protected.*

Congressional Research Service, "A Legislative History of the Water Pollution Control Act Amendments of 1972, Vol. 1," 93d Cong., 1st Session, at 175 (cited hereinafter as the "1972 Legislative History") (Senate Consideration of the Report of the Conference Committee (Oct. 4, 1972)). This indicates that Congress did not intend that a thermal discharger would be able to "take advantage" of pollution-induced harm to the BIP to justify alternative thermal discharge limitations under § 316(a) that would only be sufficient to protect a damaged, diminished BIP. It also makes clear that Congress intended that "elements of the aquatic ecosystem" necessary to support the protection and propagation of the BIP would also be protected under § 316(a).[7]

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[7] In the legislative history of the 1977 CWA Amendments, Senator Muskie further discussed the meaning of the phrase "balanced indigenous population of fish, shellfish and wildlife" as used in the "interim [national] water quality standard." He explained that:

> *As in 1972, it was intended that the interim water quality standard be that condition of aquatic life which existed in the absence of pollution. There is no question that man's activities have radically altered receiving water ecosystems in this country and that alteration is continuing at an accelerated pace in many areas. Restoration of aquatic ecosystems which existed prior to the introduction of pollution from man's activities is an important element of the restoration and maintenance of the biological, physical, and chemical integrity of receiving waters. It is an essential aspect of assuring that future generations will have an adequate supply of basic life support resources.*
>
> *The concept of indigenous does not anticipate the removal of structures from waterways. It does not anticipate the existence of ecosystems which existed in the absence of those structures. But it does fully anticipate the analysis of aquatic populations in terms of man's activities prior to, and subsequent to, pollution.*

1977 Legislative History at 448. While EPA appreciates that this type of *post hoc* legislative history is often accorded little weight, the Agency also thinks that any remarks by Senator Muskie are worthy of careful consideration given his role as the primary legislative architect of the CWA.

Consistent with Congressional intent, EPA regulations define "balanced indigenous population" as follows:

> *The term balanced, indigenous community is synonymous with the term balanced, indigenous population in the Act and means a biotic community typically characterized by diversity, the capacity to sustain itself through cyclic seasonal changes, presence of necessary food chain species and by a lack of domination by pollution tolerant species. Such a community may include historically non-native species introduced in connection with a program of wildlife management and species whose presence or abundance results from substantial, irreversible environmental modifications. Normally, however, such a community will not include species whose presence or abundance is attributable to the introduction of pollutants that will be eliminated by compliance by all sources with section 301(b)(2) of the Act; and may not include species whose presence or abundance is attributable to alternative effluent limitations imposed pursuant to section 316(a).*

40 C.F.R. § 125.71(c). It is clear under this definition that a satisfactory BIP under § 316(a) need not in all circumstances match some sort of estimated aboriginal assemblage of organisms. At the same time, however, the BIP must satisfy the listed indicia of an ecologically healthy community of organisms. It cannot be dominated by pollution-tolerant species or species whose presence or abundance is attributable to § 316(a) variance-based permit limits or pollutant discharges that will be eliminated pursuant to technology-based effluent limitations under § 301(b)(2). *See National Pollutant Discharge Elimination System; Revision of Regulations*, 44 Fed. Reg. 32,854, 32,894 (Jun. 7, 1979) (Preamble to Revised 40 C.F.R. Part 125 Subpart H); *see also Thermal Discharges*, 39 Fed. Reg. 36,176, 36,178 (Oct. 8, 1974) (preamble to earlier version of EPA definition regulation containing substantially similar definition).

Similarly, in the case of *In Re Pub. Serv. Co. of Ind., Wabash River Generating Station* ("*Wabash*"), 1979 EPA App. LEXIS 4, 1 E.A.D. 590 (EAB 1979), EPA made clear that it is not acceptable that a discharge will allow the propagation of *some* community of fish with a certain degree of diversity and abundance; the thermal discharge limits must be sufficient to protect *the* BIP as defined in the regulations. As EPA explained:

> *Section 316(a) must, like any other provision of the Act, be read in a manner which is consistent with the Act's general purposes. Consequently, § 316(a) cannot be read to mean that a balanced indigenous population is maintained where the species composition, for example, shifts from a riverine to a lake community or, as in this case, from thermally sensitive to thermally tolerant species. Such shifts are at war with the notion of "restoring" and "maintaining" the biological integrity of the Nation's waters. Thus, even though it may be*

> *difficult or even impossible to define what the precise balanced indigenous population would be in the absence of heat, it is generally sufficient, as the regulations provide, that it "will not include species whose presence or abundance is attributable to the introduction of pollutants," such as heat, and that it should be characterized by "non-domination of pollution tolerant species."*

Wabash, 1979 EPA App. LEXIS 4, at *28–*29 (citation omitted). See also In re Dominion Energy Brayton Point, LLC (Formerly USGen New England, Inc.) Brayton Point Station, 12 E.A.D. 490, 555–60 (EAB 2006) [hereinafter "Dominion"].

Furthermore, in *Wabash*, EPA made clear that in assessing the BIP, EPA must look not only at the community as a whole but also at the effects on individual species of fish that should make up the BIP. 1970 EPA App. LEXIS 4, at *21 ("it is clear that both individual [species] and community considerations are relevant"). EPA explained that

> *. . . in attempting to judge whether the effects of a particular thermal discharge are causing the system to become imbalanced, it is necessary to focus on the magnitude of the changes in the community as a whole and in individual species i.e., whether the changes are "appreciable."*

Id. at *22.

Another step in applying CWA § 316(a) is to define the "the body of water into which the discharge is to be made" and for which the BIP must be protected. Obviously, many water bodies connect to other water bodies – *e.g.*, a river or bay flowing into the ocean – and a point of reference must be selected for analysis. Neither the statute nor regulations dictate how this should be done. In applying CWA § 316(a), EPA has in the past focused on discrete water bodies, water body segments, or even sub-areas within a water body segment, that may be influenced by the thermal discharge, appropriately shaping the approach to the facts of each case. In *Appalachian Power Co. v. Train*, the court described (and upheld) EPA's reasoning as follows:

> *EPA points out that state water quality standards typically apply to an entire waterway or a relatively large segment of it. By way of contrast, EPA views § 316(a) as providing for consideration of specific site conditions in the setting of thermal limitations for individual power plants. Thus, while a greater level of thermal effluent by a generating unit might well fall within the general requirements of an approved state standard, EPA takes the position that such discharge might nevertheless cause serious harm to a particular spawning ground, for example, located just below the plant's discharge point. It is such specific site conditions to which EPA contends § 316(a) is directed.*

545 F.2d 1351, 1372 (4th Cir. 1976).[8] This approach makes ecological sense and is consistent with the CWA's overall purpose of restoring and maintaining the chemical, physical, and biological integrity of the Nation's waters.

The statute and regulations are also clear that in applying CWA § 316(a), the permitting agency must take account of the cumulative effects of other stresses to the BIP. CWA § 316(a) states that the permitting authority may propose variance-based thermal discharge limitations, "(taking into account the interaction of such thermal component with other pollutants), that will assure the protection and propagation of a balanced, indigenous population . . . ." Accordingly, EPA regulations promulgated at 40 C.F.R. § 125.73(a) state that a discharger's request for a § 316(a) variance "must show that the alternative effluent limitations desired by the discharger, *considering the cumulative impact of its thermal discharge together with all other significant impacts on the species affected*, will assure the protection and propagation of" the BIP. (emphasis added). *See also* 40 C.F.R. § 125.73(c)(1)(i). In the preamble to 40 C.F.R. Part 125 Subpart H, EPA stated:

> *Several commenters argued that applicants should not be required to analyze cumulative effects of thermal discharges together with other sources of impact upon the affected species as required by proposed § 125.47(a) (now 125.72(a)). This issue was addressed in the Administrator's first Seabrook decision which concluded that analysis of cumulative effects is required.*

44 Fed. Reg. at 32,894 (emphasis added).

In the *Seabrook* permit appeal decision referenced above, EPA's Administrator stated the following:

> *The RA [(i.e., the Regional Administrator)] ruled that a determination of the effect of the thermal discharge cannot be made without considering all other effects on the environment, including the effects of the intake (i.e., entrainment and entrapment); the applicant must persuade the RA that the incremental effects of the thermal discharge will not cause the aggregate of all relevant stresses (including entrainment and entrapment by the intake structure) to exceed the 316(a) threshold. I believe this is the correct interpretation of Section 316(a). The effect of the discharge must be determined not by considering its impact on some hypothetical unstressed environment, but by considering its impact on the*

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[8] It should be noted that in the situation described in the quotation, a proposed discharge might satisfy numeric thermal water quality criteria but fail to satisfy § 316(a). In such a case, thermal discharge standards would need to be based on any more stringent technology standards, or perhaps any more stringent water quality-based limits necessary to protect designated uses.

> *environment into which the discharge will be made; this environment will necessarily be impacted by the intake. When Congress has so clearly set the requirement that the discharge not interfere with a balanced indigenous population, it would be wrong for the Agency to put blinders on and ignore the effect of the intake in determining whether the discharge would comply with that requirement.*

In re Pub. Serv. Co. of N. H. (Seabrook Station, Units I & II), 1977 EPA App. LEXIS 16, *19-*20; 1 E.A.D. 332 (Adm'r 1977) [hereinafter "*Seabrook*"]. Thus, discharge limits imposed under CWA § 316(a) must be sufficient to ensure the protection and propagation of the BIP, taking into account other environmental stresses to the relevant population, including from any CWISs.

It should be mentioned here that "mixing zones" in the generic sense *can* be used "as a mechanism for dealing with thermal discharges pursuant to section 316(a) of the Act." *In Re Sierra Pac. Power Co.*, U.S. EPA, Decision of the Gen. Counsel No. 31, at 2 (Oct. 14, 1975). Although "mixing zone" is a term of art under the CWA that specifically refers to a tool used in the application of State water quality standards, *see* 40 C.F.R. § 131.13, the legislative history of CWA § 316(a) indicates that Congress felt that mixing zones in the generic sense could be used in designing permit limitations based on a CWA § 316(a) variance from applicable technology standards. *See Sierra Pac.*, Decision of the Gen. Counsel No. 31, at 2. Of course, to satisfy § 316(a), any such mixing zone would have to be designed to assure the protection and propagation of the BIP. *See* 39 Fed. Reg. at 36,178.

In applying CWA § 316(a), technological and cost or economic issues are not a consideration. The plain language of § 316(a) makes clear that variance decisions are to be based on a determination of the limits needed to ensure the protection and propagation of the BIP. No mention is made of technological or cost considerations being brought to bear with regard to a variance decision. The legislative history also indicates that Congress did not intend costs to be considered in applying § 316(a). 1972 Legislative History at 175. Similarly, EPA's regulations do not provide for costs or technological issues to be considered in making a CWA § 316(a) variance determination. *See* 40 C.F.R. § 125.73. EPA has also interpreted CWA § 316(a) in this manner in practice. *See Wabash*, 1979 EPA App. LEXIS at *41–*43. Thus, while cost and technological factors are considered in developing technology-based standards for thermal discharges, which are to be based on the Best Available Technology economically achievable ("BAT") under CWA §§ 301(b)(2) and 304(b)(2), they are not considered in determining whether or not to grant a variance from such limits under § 316(a).

4.2.4 “Burden of Proof,” Level of Evidence Required, and Different Types of § 316(a) Demonstrations

The statute plainly places the “burden of proof” in justifying alternative thermal discharge limitations under a CWA § 316(a) variance on the permit applicant. The statute provides that the permitting authority may impose such alternative thermal discharge limits, “*whenever the owner or operator of any such source . . . can demonstrate to the satisfaction of the Administrator (or, if appropriate, the State)* that any effluent limitation proposed [under CWA §§ 301 or 306] for the control of the thermal component of any discharge from such source will require effluent limitations more stringent than necessary to assure the pro[t]ection and propagation of” the BIP. 33 U.S.C. § 1326(a) (emphasis added). The legislative history underlying § 316(a) confirms the plain meaning of the statutory language. The Report of the Conference Committee on the Clean Water Act of 1972 stated the following, in pertinent part, with regard to § 316(a), “under the conference agreement thermal pollutants will be regulated as any other pollutant *unless an owner or operator can prove* that modified thermal limit can be applied which will assure ‘protection and propagation’ of . . . [the BIP].” 1972 Legislative History at 175 (emphasis added).

EPA’s regulations further confirm that the burden is on the permit applicant to persuade the permitting authority that the non-variance limits are more stringent than is needed and that an alternative set of limitations will be sufficient to protect the BIP. 40 C.F.R. § 125.73(a). Moreover, in the *Seabrook* permit appeal decision quoted above, EPA’s Administrator also clearly stated that the burden of proof under § 316(a) lay with the permit applicant. 1977 EPA App. LEXIS 16, at *19, *21. This was reaffirmed by the EPA’s Environmental Appeals Board in *Dominion*. 12 E.A.D. at 552–53.

Moreover, it is clear that “the burden of proof in a 316(a) case is a stringent one.” *Seabrook,* 1977 EPA App. LEXIS 16, at *31. CWA § 316(a) states that the applicant must demonstrate *to the permitting authority’s satisfaction* that the applicable non-variance-based permit limitations are more stringent than necessary to *assure* the protection and propagation of the BIP. Moreover, the statute directs that the permitting authority may include alternative thermal discharge limitations in a permit only if such limits will *assure* the protection and propagation of the BIP. In the legislative history of the Clean Water Act Amendments of 1977, Senator Muskie[9] stated the following with respect to § 316(a):

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[9] Senator Muskie’s comments from the legislative history have been given great weight by the courts in interpreting the CWA because he was the “principal Senate sponsor of the Act....” *U.S. Envtl. Prot. Agency v. Nat’l Crushed Stone Ass’n*, 449 U.S. 64, 71 n.10 (1980). *Accord, e.g., Nat’l Res. Def. Council v. Costle*, 568 F.2d 1369, 1374 (D.C. Cir. 1977); *Am. Iron & Steel Ass’n v. U.S. Envtl. Prot. Agency*, 526 F. 2d 1027, 1041 (3d Cir. 1975); *Am. Meat Inst. v. U.S. Envtl. Prot. Agency,* 526 F.2d 442, 451 (7th Cir. 1975).

> *[t]he Congress intended that there be a very limited waiver for those major sources of thermal effluents which could establish beyond any question the lack of relationship between federally established effluent limitations and that water quality which assures the protection of public water supplies and the protection and propagation of a balanced, indigenous population of fish, shellfish, and wildlife, and allows recreational activities, in and on the water.*

Congressional Research Service, "A Legislative History of the Water Pollution Control Act Amendments of 1977," Vol. IV, 95th Cong., 2nd Session, (cited hereinafter as the "1977 Legislative History"), at 642 (Senate Report); *see also id.* at 457.

EPA has not, however, interpreted § 316(a) to require absolute certainty before a variance could be granted. *Seabrook*, 1977 EPA App. LEXIS 16, at *32. In reality, achieving absolute certainty about a § 316(a) determination is likely to be impossible. *See id.* EPA has stated, however, that "[t]he greater the risk, the greater the degree of certainty that should be required." *Id. See also* 44 Fed. Reg. at 32,894.

The above material suggests that EPA should take a conservative approach to assessing variance applications in order to ensure that the standard of assuring the protection and propagation of the BIP is satisfied. Such an approach is also appropriate in light of the fact that the applicant for a § 316(a) variance is asking to be excused from the otherwise applicable limitations, and given the CWA's overarching goal of restoring and maintaining the "biological integrity of the Nation's waters," 33 U.S.C. § 1251(a), and attaining "water quality which provides for the protection and propagation of fish, shellfish and wildlife." 33 U.S.C. § 1251(a)(2).

While the variance applicant's burden is a stringent one, EPA's NPDES permit decisions are subject to the "arbitrary and capricious" standard of review under the Administrative Procedures Act. 5 U.S.C. §§ 701–706. Thus, EPA decisions regarding whether a permit applicant has carried its burden in seeking a § 316(a) variance, and in setting the thermal discharge limits included in the permit, must have a rational basis and be consistent with applicable law.

With respect to the question of how much evidence is needed to support a § 316(a) variance, EPA has explained that, "no hard and fast rule can be made as to the amount of data that must be furnished . . . and much depends on the circumstances of the particular discharge and receiving waters." *Seabrook*, 1977 EPA App. LEXIS 16, at *31. At the same time, information requirements are likely to increase to the extent that there is greater reason for concern over the protection and propagation of the BIP. As EPA stated in the preamble to its current § 316(a)-related regulations in 40 C.F.R. Part 125, Subpart H:

> *Section 125.72 accordingly gives the Director the flexibility to require substantially less information in the case of renewal requests. This does not mean, however, that the Director may not require a full demonstration for a*

> *renewal in cases where he has reason to believe that circumstances have changed, that the initial variance may have been improperly granted, or that some adjustment in the terms of the initial variance may be warranted.*

44 Fed. Reg. at 32,894. *See also* 39 Fed. Reg. at 36,177. EPA has stated that it "'must make decisions on the basis of the best information reasonably attainable.'" *Seabrook*, 1977 EPA App. LEXIS 16, at *33, *quoting* U.S. Envtl. Prot. Agency, "Draft § 316(a) Technical Guidance – Thermal Discharges" at 7 (Sept. 30, 1974) [hereinafter, "1974 Draft EPA § 316(a) Guidance"]. At the same time, the Agency has also explained that it "may not speculate as to matters for which evidence is lacking," *id*. at *31, and that if "'deficiencies in information are so critical as to preclude reasonable assurance, then alternative effluent limitations should be denied.'" *Id*. at *33 (quoting 1974 Draft EPA § 316(a) Guidance). *See also Wabash*, 1979 EPA App. LEXIS 4, *34–*40 (Administrator remanded permit to Regional Administrator where Region had decided to grant variance-based thermal discharge limitations despite lack of data regarding thermal effects under worst case, low-flow conditions). The question is what "an informed scientific judgment," *Seabrook*, 1977 EPA App. LEXIS 16, at *32, would be in light of the data in the record and absent from the record.

The regulations and guidance provide for different types of § 316(a) demonstrations. These demonstrations may be structured to utilize existing information and minimize the amount of new information that must be collected. The demonstrations required will likely vary depending, in part, on whether the variance is sought by a new facility or an existing facility. *See* 40 C.F.R. § 125.73(c)(1) (two types of demonstrations for existing dischargers); U.S. EPA, "Draft– Interagency 316(a) Technical Guidance Manual and Guide for Thermal Effects Sections of Nuclear Facilities Environmental Impact Statements" at 11 (May 1, 1977) [hereinafter, "Draft 1977 316(a) Technical Guidance"]. *See also* 39 Fed. Reg. at 36,177; *Wabash*, 1979 EPA App. LEXIS 4, at *15.

An existing discharger may base its demonstration on a showing that there has been no "appreciable harm" to the BIP from "the thermal component of the discharge taking into account the interaction of such thermal component [of the discharge] with other pollutants and the additive effect of other thermal sources." 40 C.F.R. § 125.73(c)(1)(i). Alternatively, an existing discharger can attempt to show that "despite the occurrence of such previous harm, the desired alternative effluent limitations (or appropriate modifications thereof) will nevertheless assure the protection and propagation of . . . [the BIP]." *Id.* § 125.73(c)(1)(ii). At the same time, EPA has explained that proposed thermal discharge limits fail the § 316(a) variance test if those limits would, taking into account other stresses upon the BIP, cause appreciable harm to the BIP in the future. *Wabash*, 1979 EPA App. LEXIS 4, at *16–*17. In addition, thermal discharge limits which caused appreciable harm to the BIP in the past are not to be renewed under a § 316(a) variance unless those limits are modified to prevent future harm or it is demonstrated that other circumstances have changed so that appreciable harm is not expected to occur in the future.

4.3 Thermal Discharge Limits under the 1992 NPDES Permit

The thermal discharge requirements in the 1992 NPDES Permit, as well as prior permits, were based on a CWA § 316(a) variance. On December 5, 1991, EPA issued the Draft NPDES Permit and Fact Sheet that ultimately led to the 1992 NPDES Permit. This Fact Sheet (at p. 10) presented a history of the § 316(a) decisions for the Merrimack Station permit through that point in time, stating that in 1985 and 1986:

> *. . . the Regional Administrator granted a 316(a) variance based upon the previous hydrological and biological studies and upon the absence of detectable environmental impact upon the local indigenous fish during the operating history of the station. It is to be noted that neither the State nor EPA are aware of any fish kills associated with the thermal plume within the discharge canal or in the main stream of the river itself, since the station began operation.*

Prior to the current draft permit, EPA's § 316(a) variance determinations seem to have relied predominantly on the plant's assessment of the thermal discharge's impacts to Hooksett Pool based on the facility's assessment of its own data.

Merrimack Station's existing permit contains no numeric maximum discharge temperature limits. In fact, the plant has never been required to meet maximum discharge temperature limits. As compared with the permits for other large power plants in New England (e.g., Brayton Point Station (MA), Seabrook Station (NH), Vermont Yankee (VT), Newington Energy (NH)), this is an unusual, perhaps even unique, feature of Merrimack Station's past permits. Instead of numeric temperature limits above which discharges are prohibited, the existing permit requires that when temperature criteria specified in the permit are reached, the plant must operate its "power spray module" system. This system is intended to reduce the temperature of the heated effluent before it is discharged into Hooksett Pool.

Specifically, the permit states:

> *The power spray module system (PSM) shall be operated, as necessary, to maintain either a mixing zone (Station S-4) river temperature not in excess of 69°F, or a station N-10 to S-4 change in temperature (Delta-T) of not more than 1°F when the N-10 ambient river temperature exceeds 68°F. All available PSM's shall be operated when the S-4 river temperature exceeds both of the above criteria.*

These conditions were originally included in the NPDES permit issued to Merrimack Station on June 26, 1979, and then were retained in later permits. According to PSNH, these conditions were intended to protect cold water fisheries (PSNH 1983). In its report, "Predictive Model and

User Guide for Spring and Fall Optimization of Power Spray Module Operation at Merrimack Station," dated July 19, 1983, PSNH states,

> *The 69°F T_{mix} is recommended, for the present, since it represents the most environmentally conservative case under the State of New Hampshire's cold water fishery thermal limitations, i.e., 68°F ambient plus 1°F temperature rise.*

Permit records indicate that, at that time, these temperature conditions were considered achievable, based on a predictive model developed by PSNH. In addition, they were expected to be met. A July 7, 1983, letter from Russell Nylander (WSPCC) to Warren Harvey (PSNH) states,

> *Based on a review of the report by staff members from both this Commission and the Fish and Game Department, it is believed the company has demonstrated that compliance with the thermal elements of the NPDES permit can be achieved through the predictive model and user guide. Therefore, implementation of the recommendations contained in the report relative to power spray module operation is approved provided that the thermal effluent limitations specified in the NPDES permit are met, and that adequate model and user guide verification work is performed at Station S-4.*

Yet, the permit record does not indicate that any attempt was ever made to verify that the target temperatures were being achieved. EPA's present review of over 20 years of temperature monitoring data has demonstrated that, at least during summer months, the target temperatures have not been maintained.

4.4 Merrimack Station's CWA § 316(a) Variance Request

In April 2007, Merrimack Station submitted to EPA the report, "Merrimack Station Fisheries Survey Analysis of 1967 through 2005 Catch and Habitat Data," dated April 2007 ("Fisheries Analysis Report"). In addition, the plant submitted the report, "A Probabilistic Thermal Model of the Merrimack River Downstream of Merrimack Station," dated April 2007. According to Merrimack Station's cover letter, dated April 9, 2007, these documents, as well as all previously submitted historical technical studies and analyses, represent the company's demonstration that renewal of the existing variance will satisfy CWA § 316(a).

Whereas EPA's previous 316(a) variance request determinations appear to have relied heavily on Merrimack Station's interpretation of its own data in assessing thermal impacts to Hooksett Pool, EPA's assessment in support of this draft permit has gone further. To be sure, EPA has considered the plant's data and analyses, but it also has conducted a detailed independent evaluation of existing and new information. EPA has reviewed the bases for past § 316(a) determinations, but has also reviewed any new information collected since the last permit was issued. In this effort, EPA has also coordinated with both state and federal scientists and regulators.

5.0 BIOLOGICAL ANALYSIS OF CWA § 316(A) DEMONSTRATION

5.1 Introduction

This Section presents EPA's analysis of the biological analysis provided in Merrimack Station's CWA § 316(a) Demonstration. EPA reviewed all reports and data submitted by Merrimack Station concerning possible environmental impacts related to both its discharge of heated effluent and its cooling water withdrawal.

Power plants that utilize "once-through" (or "open-cycle") cooling systems, such as Merrimack Station, are capable of heating large volumes of water. These facilities withdraw water from a water body, heat that water up as a result of the cooling process, and then discharge the heated water (or "thermal effluent") to a receiving water body. This heated discharge can have a significant effect on the thermal environment of the receiving water. The extent of this effect depends on such factors as the magnitude, frequency, and duration of the discharge, ambient temperatures and the difference between ambient temperatures and the temperature of the discharge, the physical and hydrodynamic characteristics of the water body, and the characteristics of the water body's balanced indigenous community.

Freshwater fishes cannot regulate their body temperature through physiological means, so their body temperatures are very close to the temperatures of the water they inhabit (Moyle and Cech, Jr. 2004). Water temperature affects virtually all biochemical, physiological, and life history activities of fishes (Beitenger et al. 2000). Water temperature affects metabolic rate, energy reserves, growth, reproduction, migration of fish, egg maturation, incubation success, inter- and intraspecific competitive ability and resistance to parasites, diseases, and pollutants (Armor 1991). Water temperatures raised or lowered beyond their preferred ranges may cause fish to leave or avoid what would otherwise be their preferred habitat.

By increasing the temperature of a water body, fish populations may increase or decrease in abundance, may experience a range expansion or contraction, or face extinction (Ficke et al. 2007). As a result, the overall fish community may shift toward species more tolerant of elevated temperatures or large swings in temperature. A few degrees elevation in average monthly temperature can appreciably alter a community through changes in interspecies relationships (EPA 1987). Food sources may change, or no longer be available, for a given fish species as a result of water temperature increase. This may cause a species to shift to less desirable forage, or result in increased competition among species for limited forage. In addition, temperature affects the physical attributes of water, such as thermal stratification and dissolved oxygen capacity. Oxygen solubility in water has an inverse relationship with temperature. In addition, the aerobic metabolic rate of fishes increases with temperature.

Therefore, an increase in temperature both decreases oxygen supply and increases biological demand (Ficke et al. 2007).

Consequently, thermal discharges can have a profound effect on a receiving water's quality and suitability as a habitat and on many aspects of a species' ability to survive, both individually and as a population. These ecological effects can alter the composition of the aquatic community in the receiving water so that it no longer reflects the balanced community structure that existed prior to the addition of heat from the discharge. Shifts in the assemblage of species to a community more tolerant of thermal pollution are generally considered detrimental to the ecosystem, and would be inconsistent with the goals of the CWA § 316(a) and the Clean Water Act, generally.

5.2 Scope of Review

Merrimack Station's demonstration, as presented in the Fisheries Analysis Report, is organized into three major sections. The first provides a current assessment of the fish community in Hooksett Pool based on fish sampling conducted during 2004 and 2005. The second presents the results of a fish population trend analysis based on comparable abundance trapnet and electrofish data collected through the Merrimack River Fisheries Survey between 1972 and 2005. The third presents an assessment of the relationship between the Station's thermal discharge and nine species of fish observed in the Merrimack River in the vicinity of the Station.

In this section of the Determination Document, EPA reviews each section of Merrimack Station's demonstration. This review typically presents a summary of Merrimack Station's conclusions, as expressed in the Fisheries Analysis Report, followed by EPA's evaluation of the Station's analysis. In some cases, EPA provides the results of its own analyses utilizing data provided by Merrimack Station and/or information from published scientific literature. These reviews and analyses collectively form the basis of EPA's conclusions on the adequacy of Merrimack Station's demonstration. These conclusions are presented in Section 5.7. Section 5 also presents EPA's assessment on the status of the Hooksett Pool's balanced, indigenous community, based largely on Merrimack Station's fisheries data collected over 40 years.

5.3 Balanced Indigenous Community of Hooksett Pool

In the Introduction of the Fisheries Analysis Report, at p.1, Merrimack Station states:

> *This report, and other reports prepared by Normandeau Associates, Inc. (Normandeau) and submitted to the Advisory Committee members herewith, collectively demonstrate that:*
>
> (1) the Station's past and current operations have resulted in no appreciable harm to the balanced, indigenous populations of fish and other aquatic

organisms in the segment of the Merrimack River receiving the Station's thermal discharge (the "BIP"), and

(2) based on this lack of harm from past and current operations, and the reasonable expectation that the Station's operations will continue into the future at rates similar to those that prevailed in the past, there will be no future appreciable harm to the BIP.

While detailed studies of specific species of concern have been completed in the past, no formal, comprehensive CWA § 316(a) demonstration was ever previously provided by Merrimack Station.

In order to evaluate Merrimack Station's conclusion that the plant's thermal discharge has not resulted in appreciable harm to the balanced, indigenous population of fish and other aquatic organisms, EPA reviewed data collected in Hooksett Pool over a period of 38 years, from 1967 to 2005. For the purpose of evaluating Merrimack Station's thermal impacts, EPA and NHFGD conclude that the relevant balanced, indigenous community is comprised of all species that existed in Hooksett Pool immediately prior to the start-up of Unit 1, in 1960.[10] Unfortunately, no comprehensive biological sampling was conducted until 1967, after Unit 1 had already been operation for approximately seven years. Sampling by NHFGD took place prior to the May 1968 start-up of Unit 2, however, and continued for a year thereafter. Absent any earlier studies for Hooksett Pool, EPA considers the resident biotic community identified during sampling conducted from 1967 to 1969 to best represent the balanced, indigenous community for this assessment (Table 5-1). This is a reasonable approach in light of the best, reasonably available data because the 1967-1969 data is the earliest data available, and because the volume of heated cooling water discharged into Hooksett Pool more than tripled in 1968 after Unit 2 came on line, increasing from approximately 86.4 MGD to 286.6 MGD (design flow).

[10] As previously quoted above, the term "balanced indigenous population" is defined in EPA regulations at 40 C.F.R. § 125.71(c).

Table 5-1 Fish species collected during sampling conducted by NHFGD from 1967–1969 (Wightman 1971), and their respective temperature guild

Species and Temperature Guild

Coldwater Guild

Landlocked Atlantic salmon (*Salmo salar*) [1]

Coolwater Guild

Blacknose dace (Rhinichthys atratulus) [2]
Brown bullhead* (*Ameiurus nebulosus*) [8]
Burbot (*Lota lota*) [2]
Eastern chain pickerel (*Esox niger)* [3]
Fallfish (Semotilus corporalis) [4]
Longnose dace (Rhinichthys cataractae) [2]
Walleye (Stizostedium vitreum) [3]
White perch (Morone Americana) [4]
White sucker (Catostomus commersoni) [2]
Yellow perch (*Perca flavescens*) [6]

Warmwater Guild

American eel (*Anguilla rostrata*) [4]
Brown bullhead* (*Ameiurus nebulosus*) [5]
Golden shiner (Notemigonus crysoleucas) [5]
Largemouth bass (*Micropterus salmoides*) [5]
Madtom (*Notorus* sp.) [4]
Pumpkinseed (*Lepomis gibbosus*) [6]
Redbreast sunfish (*Lepomis auritus)* [7]
Redfin shiner (Notropis umbratilis) [8]
Smallmouth bass (*Micropterus dolomieu*) [2]
Yellow bullhead (Ictalurus natalis) [4]
* Classified under both cool and warmwater guilds

Based on information from:
[1] Morrow and Fischenich 2000
[2] Wehrly et al. 2003
[3] Buss et al. 1978
[4] Wismer and Christie 1987
[5] Eaton et al. 1995a
[6] Cincotta and Stauffer 1984
[7] Aho et al. 1986
[8] Eaton and Scheller 1996 (related species)

5.3.1 Fish Community

EPA reviewed changes in the Hooksett Pool fish community since the 1960s to assess whether the community had shifted appreciably. EPA also assessed changes in species abundance to determine whether they may reflect a shift in dominance towards pollution-tolerant species. Pollution tolerance in this review included tolerance to heat, a regulated pollutant under the CWA. According to the Draft 1977 316(a) Technical Guidance, "dominant species" is defined as any species representing five percent of the total number of organisms in the sample according to recommended sampling procedures. This "draft" guidance document was never supplanted by a subsequent "final" guidance document, and it is widely used by industry and regulators in the preparation and review of § 316(a) variance request demonstration documents. For example, Merrimack Station refers to it in the Fisheries Analysis Report.

The fish community in Hooksett Pool prior to the start-up of Unit 2 consisted largely as a mix of resident cool and warmwater species. According to the American Fisheries Society, the term "coolwater" is not rigorously defined, but refers generally to those species which are distributed by temperature preference between the "coldwater" salmonid communities to the north and the more diverse centrarchid-dominated "warmwater" assemblages to the south (Kendall 1978). Coolwater fishes have upper lethal temperature limits that are similar to, or slightly lower than, those of warmwater species, but require cooler average temperatures during the growing season (Morrow and Fischenich 2000). Examples of coolwater species include yellow perch, white sucker, and walleye (Table 5-1). Warmwater fishes can tolerate temperatures as high as 96.8˚F (36˚C). Examples of warmwater species include largemouth bass, bluegill, and pumpkinseed (Table 5-1).

In addition to resident species, diadromous species that once migrated freely through this reach of the Merrimack River are also considered part of the balanced, indigenous community. Diadromy is the collective term used for fish species that spend part of their life cycle in fresh water and part in salt water. There are three forms of diadromy, two of which – anadromy and catadromy – are represented by fish species found in the Merrimack River. Anadromous species are born in fresh water, mature in salt water, and return to fresh water to spawn. Conversely, fish born in salt water, mature in fresh water, and return to salt water to spawn are called catadromous species. Anadromous species that commonly inhabit Hooksett Pool during part of their life cycle are Atlantic salmon, American shad, and alewife. Blueback herring and sea lamprey may occasionally be present, as well. Only one catadromous species, American eel, is at times present in the pool.

One objective of Merrimack Station's original discharge permit related to temperature was to support state and federal efforts to restore anadromous Atlantic salmon and American shad to the Merrimack River watershed. These temperature-sensitive species would spend part of their migration in Hooksett Pool while moving to and from marine waters, once upstream fish passage was established at each of the four dams located downstream from the pool. Unfortunately, poor returns of these anadromous species have led to delays in the construction of upstream passage at these dams. As a result, only juvenile Atlantic salmon, American shad, and alewife, which are regularly stocked *upstream* of Hooksett Pool, spend time in the pool during their downstream migration to the sea. EPA supports the long-term commitment by USFWS and NHFGD to restore access to the important upstream spawning and rearing habitat that these migratory species require. These agencies' efforts began in 1969. EPA reviewed anadromous and catadromous species separate from resident species since they do not spend each stage of their lifecycles in Hooksett Pool. Catadromous species, such as American eel, mature in freshwater and migrate to sea to spawn. Potential thermal impacts to the migration of diadromous species were assessed by EPA, and are discussed in Section 5.6.3.3 of this document.

Significant changes in fish abundance are most readily observed in numerically dominant species. However, species that are less abundant are at greater risk of being eliminated entirely from an ecosystem. Such species tend to disappear early on in a system subjected to new stressors. In addition, if these species are not considered "important" relative to their commercial or sporting value, their disappearance may largely go unnoticed. However, EPA recognizes the role that each species may play in maintaining a healthy ecosystem and the water body's balanced, indigenous community of fish. Therefore, to the extent possible, EPA has assessed impacts to all fish species that made up the balanced, indigenous community before Merrimack Station's Unit 2 came on line, in 1968.

EPA also reviewed changes in the abundance of resident, non-indigenous fish species. This review includes species that were not collected during sampling in the 1960s, but appeared in subsequent years (*e.g.*, bluegill, spottail shiner). Assessing changes in the relative abundance for these species is important to understanding how their presence may have affected the balanced, indigenous community in Hooksett Pool, and to what extent, if any, elevated temperature may have contributed to their presence.

5.3.1.1 Representative Important Species

For purposes of predicting the effects on the balanced, indigenous community from thermal discharge associated with a CWA §316(a) variance request, EPA regulations and its Draft 1977 316(a) Technical Guidance, allow under certain circumstances for a detailed assessment to be limited to only a subset of the entire community. Such a subset is comprised of what are known as the "representative important species." The assumptions underlying the representative important species approach are described in the Draft 316(a) Technical Guidance as follows:

1. It is not possible to study in great detail every species at a site; there is not enough time, money or expertise.
2. Since all species cannot be studied in detail, some smaller number will have to be chosen.

3. The species of concern are those casually related to power plant impacts.
4. Some species will be economically important in their own right, *e.g.*, commercial and sport fishes or nuisance species, and thus "important."
5. Some species, termed "representative," will be particularly vulnerable or sensitive to power plant impacts or have sensitivities of most other species and, if protected, will reasonably assure protection of other species at the site.
6. Wide-ranging species at the extremes of their ranges would generally not be acceptable as "particularly vulnerable" or "sensitive" representative species, but they could be considered "important."
7. Often, all organisms that might be considered "important" or "representative" cannot be studied in detail, and a smaller list (*e.g.,* greater than 1 but less than 15) may have to be selected as the "representative" and "important" list.
8. Often, but not always, the most useful list would include mostly sensitive fish, shellfish, or other species of direct use to man or for structure or functioning of the ecosystem.
9. Officially listed "threatened or endangered species" are automatically "important."

Merrimack Station's Fisheries Analysis Report does not identify what species comprised Hooksett Pool's balanced, indigenous community. Instead, it focuses on seven fish species approved by the Technical Advisory Committee ("TAC") in 1992 as being "*resident* important species" (or "RIS") and two additional species mentioned during a meeting with EPA and the other agencies on October 5, 2006 (Table 5-2). The TAC consisted of state and federal agencies that recommended and reviewed environmental studies undertaken by Merrimack Station. While no longer formally identified as a TAC, the same agencies continue to assist EPA with environmental assessment related to Merrimack Station. These agencies are identified in Section 1.2 of this document. According to meeting minutes generated and provided by Merrimack Station for a meeting held August 31, 1992, Merrimack Station recommended four resident species that were "representative of the game and forage fish communities." The species recommended were largemouth bass, smallmouth bass, pumpkinseed, and yellow perch. In addition, Merrimack Station recommended three anadromous species (Atlantic salmon, American shad, and alewife), given the need of these species to migrate through Hooksett Pool en route to the sea.

Table 5-2. Species identified by Merrimack Station as being representative of the fish community in Hooksett Pool

1. Alewife (Alosa pseudoharengus)
2. American shad (Alosa sapidissima)
3. Atlantic salmon *(Salmo salar)*
4. Fallfish (Semotilus corporalis)
5. Largemouth bass (*Micropterus salmoides*)
6. Pumpkinseed (*Lepomis gibbosus*)
7. Smallmouth bass (*Micropterus dolomieu*)
8. White sucker (Catostomus commersoni)
9. Yellow perch (*Perca flavescens*)

EPA agrees that the species listed were part of the balanced, indigenous fish community in 1967. Merrimack Station's data and analyses of these species are an important component of EPA's assessment of thermal impacts. However, while it is appropriate to identify and focus on representative important species for "predictive" § 316(a) demonstrations, non-predictive (*i.e.*, retrospective, or "Type I") demonstrations, which are designed to assess prior appreciable harm, should not be restricted to assessing the status of representative important species. In fact, EPA's Draft 1977 316(a) Technical Guidance recommends that references to Representative Important Species be eliminated from Type I demonstrations (EPA 1977a). Merrimack Station's § 316(a) demonstration is largely retrospective (Type I). Therefore, EPA's assessment of the balanced, indigenous fish community of Hooksett Pool encompassed all species present in 1967. This does not mean that every species of fish present in 1967 requires an in-depth review, but when assessing community-wide impacts, there is no reason to exclude any resident species that was present prior to the increase in discharges of heated effluent to Hooksett Pool.

5.3.2 Other Aquatic Communities

Assessing changes in the resident fish community of a water body often provides the most conspicuous evidence of impacts to the overall aquatic community, but a complete §316(a) variance demonstration is not limited to fish. Planktonic organisms (*e.g.* phytoplankton, zooplankton, meroplankton), macroinvertebrates (*e.g.*, shellfish), habitat formers (*e.g.*, subaquatic vegetation), and wildlife are all supposed to be assessed at the level of detail appropriate to the facility's potential to impact these communities. EPA provides specific guidance for facilities developing demonstrations in its Draft 1977 316(a) Technical Guidance.

Merrimack Station does not assess impacts to aquatic communities other than fish in the Fisheries Analysis Report. However, it does state that the Station's past and current operations have resulted in no appreciable harm to the balanced, indigenous populations of fish and other aquatic organisms in the segment of the Merrimack River receiving the Station's thermal discharge. Merrimack Station bases this conclusion on all reports, past and present, prepared by its consultant, Normandeau Associates, Inc. According to EPA records, studies on non-fish aquatic organisms in Hooksett Pool were last conducted in the 1970s, and presented in the 1979 Summary Report. While historical studies are helpful in identifying the status of populations at the time of the studies, and could show any changes that may have occurred to these populations early on, data that were collected more than 30 years ago do not indicate the current status of these aquatic communities or whether they have been protected since then. In addition, many fish species in Hooksett Pool feed on plankton and aquatic insects, particularly during their early lifestages. As a result, population changes that occur in organisms at low trophic levels can affect populations at higher levels which are dependent on them.

5.4 Water Body Segment under Review

For purposes of assessing Merrimack Station's impacts to the balanced, indigenous community, EPA considers the entire length of Hooksett Pool to be the appropriate water body segment for evaluating this CWA § 316 (a) thermal variance request. The dams that define the boundaries of the pool effectively inhibit the movement of many organisms into and out of this area. Obviously, some fish and other organisms pass over the dams into and out of Hooksett Pool when water levels permit. Nevertheless, based on our review of species-specific life history information, EPA believes that all resident fish species identified as being part of the balanced, indigenous community historically had sufficient suitable habitat in Hooksett Pool to support them throughout every life stage. Suitable habitat is needed for various lifestage requirements, including gonadal development, spawning, egg and larva development, and foraging and refugia for juveniles and adults. The fish community found in Hooksett Pool during the 1960s reflected the suitability of the habitat at that time to support those species.

5.5 Capacity of Merrimack Station to Impact Hooksett Pool's Thermal Environment

Hooksett Pool is a relatively shallow, short, and slow-moving river impoundment, extending approximately 5.8 miles downstream from Garvin's Falls Dam to Hooksett Dam. These characteristics make the aquatic habitat in Hooksett Pool particularly vulnerable to the effects of Merrimack Station's thermal discharge, which is located at the approximate midpoint of the pool. One example of Merrimack Station's capacity to impact Hooksett Pool was described in the Merrimack River Monitoring Program Summary Report (Normandeau 1979b). According to the report:

> *Merrimack Generating Station Units I and II utilize 3.79 and 8.83 cms, respectively for once-through cooling water. Thus, during maximum power generation, the station withdraws 12.62 cms (199,000 gpm) from the Merrimack River. Because the river discharge in Hooksett Pond is sometimes less than the required 12.62 cms, the generating station may utilize more than 100% of the river volume during coincident periods of low flow and maximum power generation. During these periods, water from the discharge canal may*

recirculate and flow upstream towards the circulating water intakes. This situation occurs infrequently but was evident from the thermal profiles measured on September 2, 1977.

Water withdrawal at a rate significant enough to cause water from the discharge canal to flow upstream clearly has the potential to affect the Hooksett Pool environment. This large volume of water being withdrawn is then discharged back into Hooksett Pool, but at temperatures up to 104°F (40°C) under peak summer conditions. While the plant has not reported an incident recently where 100 percent of the pool's available flow was required for cooling water purposes, EPA calculated that the plant may have withdrawn approximately 95 percent of the available river flow on September 13, 2002. This rate is based on the plant's reported monthly maximum intake flow of 257.5 MGD (399.13 cfs) for September 2002, and a calculated river flow of 272.4 MGD (422 cfs) for that date.

Beyond the threat of extreme water withdrawal events such as those discussed above, Merrimack Station's current operations typically redirect up to 62 percent of the available flow under low-flow conditions. EPA regards this to be a large fraction of the available river flow. This figure is based on the plant's flow data from June 1–September 30 for the years 1993–2007, and the calculated 7Q10 of 587.75 cfs for this section of the Merrimack River.

PSNH collected continuous water temperature data in Amoskeag, Hooksett, and Garvins Falls impoundments during from May 2002–April 2003 in support of the company's FERC license renewal. Of the four dams monitored, the warmest waters were observed at Hooksett Dam. PSNH, in its draft water quality report states,

Water temperatures recorded in the Hooksett tailrace rise significantly compared with those observed at Garvins Falls. During the sampling period, the instantaneous differences in water temperature on average were over 2˚C [3.6˚F] warmer at Hooksett. The greatest difference in water temperature was over 5˚C [9.0˚F] warmer at Hooksett than at Garvins at the same time period. This occurred on September 16, 2002.

According to the water quality report (Gomez and Sullivan Engineers 2003), PSNH suggests that the heated discharge from Merrimack Station is the reason for elevated temperatures at Hooksett Dam. The report states,

The warmer water temperatures observed at Hooksett are likely due to the cooling water discharges into the river upstream of Hooksett at the Merrimack Station coal-fired power plant in Bow.

Thermal studies conducted by Merrimack Station since the 1960s have described Merrimack Station's thermal discharge under summer conditions as largely remaining a distinct buoyant plume, although the plume's configuration is affected by river flow. According to the 1979 Summary Report, the thermal plume extends as a lens of warm water one to two meters (3.3-6.6 feet) deep southward from the discharge canal. Further, the plume typically flows across the river under low-flow conditions, reaching the east bank between S-1 and S-3, and disperses throughout the river width as it approaches S-4 (Normandeau 1979b). The report also states that the plume often extends downstream to a point immediately upstream of Hooksett Dam. Based on these conclusions, and given that much of Hooksett Pool is 10 feet deep or less, Merrimack Station's thermal plume would affect one to two-thirds of the available habitat in the lower pool, including most if not all the near-shore shallows. Near-shore shallows are widely recognized as important habitat for juvenile fish.

EPA concludes that Merrimack Station has a significant capacity to thermally impact Hooksett Pool. This conclusion is based on the:

- short length and shallow depths of Hooksett Pool;
- significant fraction of shallow water habitat in the lower pool affected by the plume during summer months;
- quantity of water withdrawn, heated, and discharged by Merrimack Station;
- high and persistent temperatures above ambient associated with the plume under typical summer conditions;
- plume's tendency to extend across the entire width of the river,
- plume's demonstrated capacity to cause water column stratification, which can contribute to low dissolved oxygen events above Hooksett Dam
- low flows in Hooksett Pool typical during summer months (*i.e.*, July, August, September)

5.6 Review of Merrimack Station's § 316(a) Demonstration

EPA's review of Merrimack Station's § 316(a) Demonstration is structured to follow the format presented in Merrimack Station's Fisheries Analysis Report. The Fisheries Analysis Report is broken down into three major sections: (1) Results of the 2004-2005 Fish Sampling Program, (2) Inter-annual Abundance Trends from the 1967-2005 Sampling Program, and (3) Temperature Effects Assessment for Nine Representative Important Fish in Hooksett. For each Section, EPA provides a summary of Merrimack Station's analysis and conclusions. Following this, EPA presents its assessment of the plant's analysis. EPA also provides the results of its own analysis, where applicable.

5.6.1 Results of the 2004-2005 Fish Sampling Program

The first section of the Fisheries Analysis Report presents the results of fisheries sampling efforts performed during 2004 and 2005. Species with a two-year average relative abundance of five percent or more based on either trapnet or electrofishing sampling are listed in Tables 5-3 and 5-4.

Table 5-3 Relative abundance and mean catch per unit effort (*i.e.*, fish caught per 48 hours of sampling effort) in Hooksett Pool based on trapnet sampling conducted in 2004 and 2005 (Normandeau 2007a)

	Percent Relative Abundance			Catch per Unit Effort		
Species	2004	2005	Mean	2004	2005	Mean
Smallmouth bass	31.6	54.4	43.0	2.45	1.84	2.15
Spottail shiner	26.8	2.2	14.5	2.07	0.07	1.07
Redbreast sunfish	4.3	16.9	10.6	0.33	0.58	0.46
Rock bass	11.2	8.1	9.7	0.87	0.27	0.57
Bluegill	7. 7	9.6	8.7	0.59	0.32	0.46
Total	81.6	91.2	86.4	6.31	3.08	4.70

Table 5-4 Relative abundance and mean catch per unit effort (fish caught per 1,000-foot transect) in Hooksett Pool based on electrofishing sampling conducted in 2004 and 2005 (Normandeau 2007a)

	Percent Relative Abundance			Catch Per Unit Effort		
Species	2004	2005	Mean	2004	2005	Mean
Spottail shiner	62.1	17.2	39.7	27.17	2.25	14.71
Largemouth bass	9.6	13.3	11.5	4.21	1.73	2.97
Fallfish	2.4	14.9	8.7	1.04	1.95	1.50
Bluegill	3.5	12.8	8.2	1.55	1.67	1.61
White sucker	3.2	11.4	7.3	1.40	1.49	1.45
Smallmouth bass	4.5	6.6	5.6	1.96	0.86	1.41
Redbreast sunfish	3.1	8.0	5.6	1.38	1.05	1.22
Total	88.4	84.2	86.3	38.71	11.00	24.86

5.6.2 Interannual Abundance Trends from the 1967-2005 Sampling Program

The second section of the Fisheries Analysis Report presents the results of analyses that examined a time series of selected data for trends indicative of “appreciable harm” to the balanced, indigenous community. Merrimack Station presents its analyses based on electrofishing and trapnetting data, which are the two sampling methods consistently used since fish sampling was initiated in 1967. Merrimack Station selected the following analytical indices as being appropriate methods for assessing prior appreciable harm to the balanced, indigenous community:

- Catch Per Unit Effort
- Taxa Richness
- Rank Abundance
- Fish Community Similarity
- Length-Weight Relationships
- Species Guild Biomass

The trends analysis presented by Merrimack Station in the Fisheries Analysis Report is broken down by sampling method (*i.e.*, electrofishing and trapnetting) where each analytical index is discussed separately. After reviewing these analyses, EPA decided instead to format its discussion by the analytical index and compare, where possible, the results of the analyses for the two sampling methods used.

There are inherent biases or inefficiencies associated with any form of fish sampling which is why multiple methods are often used to develop a comprehensive understanding of the status of multiple fish populations. Electrofishing is typically conducted during daylight hours, and therefore misses fish that may visit sampling areas after dark. Trapnet (also known as fyke net) sampling, on the other hand, utilizes static gear that captures fish moving through the sampling area over the course of one or more days. Trapnets typically capture larger (and older) fish that reside and actively move in deeper water, although trap mesh size may affect sampling effectiveness for certain sizes of fish. As noted in the annual summary of monitoring at Merrimack Station for 1975, “Fyke netting was employed to illustrate the distribution of larger fishes within Hooksett Pond in relation to the Merrimack Station thermal discharge.” (Normandeau 1976a). In the 1975 Merrimack River Monitoring Program report, Merrimack Station refers to fyke-netting as “the most quantifiable sampling technique employed in the Merrimack River Program” (Normandeau 1976a). EPA carefully considered the effectiveness of both sampling types in its assessment of the Hooksett Pool fish community.

Sampling juvenile fish populations is important to understanding year class strength and potential recruitment into the adult population, as well as assessing available forage for piscivorous species. However, aggregations of juvenile fish alone are not good indicators of the fishery's status since many juveniles will not survive long enough to reach maturity and spawn. Therefore, combining the adult, breeding population with juveniles without adjusting for age differences tends to overestimate the population. Unfortunately, this appears to be the case for all of the trends analyses conducted by Merrimack Station.

5.6.2.1 Catch per Unit Effort ("CPUE") Trends Analysis

Merrimack Station analyzed selected historical electrofishing data, looking for the absence of a statistically significant decreasing trend for the species they identify as "Resident Important Species." According to Merrimack Station's decision criteria, if no statistically significant trend was calculated (*i.e.*, the null hypothesis was not rejected), then no appreciable harm occurred. If a significant decreasing trend was found, trends in what Merrimack Station considered to be the ambient and thermally-affected zones of Hooksett Pool were compared. If similar trends were found in both areas, Merrimack Station concluded that temperature was not the cause of the decline.

EPA does not agree with Merrimack Station's decision criteria. First, failing to reject the null hypothesis does not prove that there is no trend. Instead, it simply means that the data used in the analysis are not sufficient to conclude that there is a trend (Helsel and Hirsch 1992). Second, while EPA agrees that it is reasonable to consider the portion of Hooksett Pool upstream of the discharge represents ambient water quality conditions in the Pool (*i.e.*, temperatures not affected by the Station's thermal discharge), it cannot be considered a "control site" for purposes of assessing impacts to fish populations. It is reasonable to assume that each resident fish species in Hooksett Pool is comprised of a single population. Most fish are highly mobile and can move freely within the relatively slow moving waters of Hooksett Pool, so in EPA's view, significant declines observed throughout the entire pool (*i.e.*, above and below the thermal discharge) are indicative of a population-level effect. Given that the heated discharge from Merrimack Station can directly influence approximately 50 percent of the water in Hooksett Pool, it is also reasonable to expect that impacts to the lower half of Hooksett Pool could have pool-wide population effects.

5.6.2.1.1 CPUE Trends Analysis – All Species Combined

5.6.2.1.1a Electrofishing CPUE Trends Analysis – All Species Combined

In its Fisheries Analysis Report, Merrimack Station's trends analysis concludes the following:

Statistical analysis of the mean electrofishing CPUE among these seven years representing three decades of monitoring in Hooksett Pool revealed that the year to year variation exhibited no statistically significant negative (decreasing) trend in overall annual mean CPUE in Hooksett Pool (all species combined), supporting a finding of "no appreciable harm" due to Merrimack Station's thermal discharge over this period.

EPA reviewed this analysis within the context of its relevance to support a finding of "no prior appreciable harm" to the balanced, indigenous community of fish. Unfortunately, Merrimack Station did not include the most important decade in the equation, the 1960s, in this or its other statistical analyses. As discussed above, data from the 1960s, especially from 1967, best represent "pre-impact" conditions; that is the biological community before heated effluent from Merrimack Station became a more significant influence on the Hooksett Pool environment.[11] Merrimack Station states that it is unable to use electrofishing data collected prior to 1970 due to vagaries in sampling methods and locations in the 1960s. The Fisheries Analysis Report states that:

Due to the lack of documented electrofishing catch within the specific Hooksett Pool Monitoring Stations (e.g., N9 – N10), 1967 through 1969 electrofishing data from Hooksett Pool and Amoskeag Pool were not used for the multi-year, quantitative trend analysis of CPUE presented in this report.

Merrimack Station released a report in 1970, however, that provides the information necessary to use these data in a trends analysis. According to this report, electrofish sampling was conducted in 500-foot intervals from Station 0 to S-24 and 0 to N-6, and 1,000-foot intervals from N-6 to N-10 (Normandeau 1970). Merrimack Station's consultant, Normandeau Associates, Inc., used a sampling distance of 1,000 feet in establishing CPUE (*i.e.*, the number of fish caught per 1,000 feet sampled). Since this report lists the number of each species caught within the areas north and south of the discharge, as well as the total distance sampled in those areas, a CPUE can be computed using these data. For example, 216 yellow perch were caught in 1967 south of the discharge (S-0 to S-24), and 177 north of the discharge (0 to N-15). The sampling distance south of the discharge was 12,500 feet, and 7,500 feet north of the discharge, for a total of 20,000 feet sampled. Electrofishing sampling was conducted in September in the 1960s, and in September and August in 2004 and 2005. In 2004 and 2005, a distance of 10,000 feet was sampled each of the two months for a total of 20,000 feet (Normandeau 2007a). In 2004, August electrofishing

[11] As explained above, there is no data predating Unit I's operations, which began in 1960, but Unit 2 did not begin operations until 1968, when it increased the volume of the facility's water withdrawals and discharges by approximately 2.5 times. Therefore, the data from the 1960s that predates Unit 2's operation, when the facility's discharge to Hooksett Pool increased substantially, provides an important point of comparison.

took place on the last two days of the month. In 2005, sampling occurred on August 22. Given that the total sampling effort (20,000 feet) was the same during the 1960s and 2000s, and that sampling periods were similar (*i.e.*, late August–late September), EPA believes the electrofishing data collected during the 1960s are comparable to data collected in 2004 and 2005.

EPA nevertheless evaluated Merrimack Station's analyses which omitted data from the 1960s while recognizing that data from the 1970s (1972-1976) reflects the Hooksett Pool environment following four to eight years of thermal effects from the start-up and operation of Unit 2. Since Merrimack Station chose not to use electrofishing data from the 1960s, data from 1972 most closely represents the actual balanced, indigenous community in this analysis. The combined CPUE in 1972 for all resident species caught in 1972 was 63.2 fish (Normandeau 2007a). This excludes American eel which was caught, but is considered a migratory rather than a resident species. In 2005, the combined CPUE for the same species was only 15.60 fish (Table 5-5). According to the Fisheries Analysis Report, 2005 was the lowest CPUE for all species combined for the seven years evaluated (1972, 1973, 1974, 1976, 1995, 2004, 2005). But Merrimack Station based its fish community trends analyses on *all species* present at the time of sampling, instead of focusing on the species that were present in 1972, or preferably, the 1960s. Merrimack Station's analysis suggests an absence of a statistically significant negative trend, but it includes introduced species not among those present in the 1960s, and therefore not part of the balanced, indigenous community. The appearance and proliferation of two species in particular, bluegill (*Leponis macrochirus*) and spottail shiner (*Notropis hudsonius*), masks the declines in resident, indigenous species, such as yellow perch, white sucker, and pumpkinseed. Spottail shiners were not identified in sampling until 1974 when six individuals were collected. In 1995, 1,161 spottail were collected during sampling. Bluegills were not collected in Hooksett Pool electrofishing sampling prior to 1995. In 1995, however, 1,111 bluegills were caught. The combined CPUE of these two species represented 85.3 percent of all fish caught in 1995 sampling.

Table 5-5 Change in CPUE for selected species captured throughout the entire Hooksett Pool in 1972, based on electrofishing sampling in August and September for select years, as presented in Table 3-7 of the Fisheries Analysis Report

Electrofishing CPUE for the entire Hooksett Pool							
Species	1972	1973	1974	1976	1995	2004	2005
brown bullhead	2.15	0.55	0.6	0.2	0	0	0
chain pickerel	0.65	0.30	0.40	0.20	0.10	0.15	0.15
fallfish	1.7	0.5	0.05	0	0.45	1.45	1.3
golden shiner	0.3	0.25	0.45	0	0.2	1.35	0.4
largemouth bass	5.65	0.85	6.55	2.65	6.05	9.55	6.1
pumpkinseed	37.65	20.2	25.4	19.45	0.95	0.7	0.9
redbreast sunfish	4.50	2.80	5.50	8.00	5.90	2.65	1.85
smallmouth bass	0.8	4.15	3.1	4.9	1.4	5.35	1.9
white sucker	1.4	0.2	4.65	2	0.2	0.75	0.4
yellow bullhead	0.10	0.10	0.20	0.45	0.00	0.00	0.00
yellow perch	8.3	5.5	3.95	1.05	0.2	0.65	2.6
Total	**63.2**	**35.4**	**50.85**	**38.9**	**15.45**	**22.6**	**15.6**

EPA conducted a Kendall-Tau trends analysis for changes in the fish community that existed in Hooksett Pool in 1972, based on electrofishing sampling in the entire Hooksett Pool. The result of this trends analysis for the entire pool exceeded the significance test (p>.05) by only 0.0009, which is why the statistics software EPA used (Statistica®) flagged these correlations as being significant (Table 5-7). This result does not support an argument that the balanced, indigenous community as a whole has remained stable over time, nor does it demonstrate a dramatic decline. It should be noted that within the balanced, indigenous community, there may be some species that may suffer few or no adverse effects from the introduction of heated effluent, and may in fact benefit by the altered habitat.

The Fisheries Analysis Report also states:

> *Similarly, Merrimack Station finds no statistically significant decreasing trend for the total fish community in either of the two zones (i.e., ambient and thermally-*

influenced) supporting a finding of "no appreciable harm" due to Merrimack Station's thermal discharge over this period.

EPA again looked at Merrimack Station's data for changes in the balanced, indigenous community between 1972 and 2005. Fish species collected in 1972 were again used to best represent the balanced, indigenous community. According to these data, electrofishing CPUE's in the ambient zone for the species that comprised the balanced, indigenous community collectively dropped from 62.2 fish in 1972 to 21.9 fish in 2005 (Table 5-6). The decline in the thermally-influenced zone was even more pronounced, dropping from 64.2 fish in 1972 to 11.41 fish in 2005 (Table 5-6). Merrimack Station analyses, which included all species regardless of when they first appeared in the pool, concluded that no statistically significant decreasing trends were found in either zone. However, EPA's analyses concluded that there was a statistically significant declining trend during the period evaluated for the thermally-influenced zone (Table 5-7). A scatterplot of CPUE values for both zones and the entire pool illustrate the decline in abundance of the balanced, indigenous community over time (Figure 5-1).

Table 5-6 Changes in the CPUE between 1972 and 2005 for species caught in 1972, based on data provided in Table 3-7 of the Fisheries Analysis Report

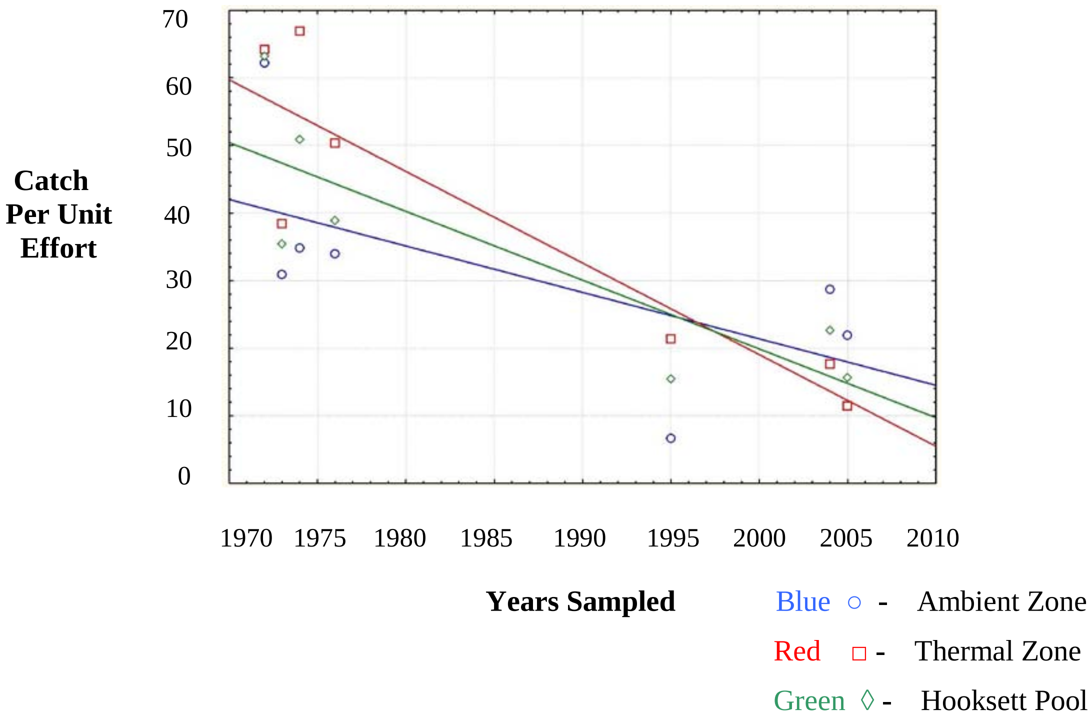
CPUE	1972	1973	1974	1976	1995	2004	2005
Ambient Zone	62.2	30.9	34.8	33.96	6.64	28.67	21.9
Thermally-Influenced Zone	64.2	38.41	66.9	50.32	21.33	17.63	11.41
Total Pool	63.2	35.4	50.85	38.9	15.45	22.6	15.6

Table 5-7 Results of Kendall-Tau trends analyses conducted by EPA based on electrofishing CPUE data between 1972 and 2005 provided in the Fisheries Analysis Report (Normandeau 2007a) for species caught in 1972

Analysis conducted by	Ambient Zone			Thermally-Influence Zone			Hooksett Pool		
	Kendall - Tau	P-Value	Trend	Kendall - Tau	P-Value	Trend	Kendall - Tau	P-Value	Trend
EPA	-0.6191	0.0509	Trend* Decline	-0.7143	0.0243	Trend Decline	-0.6191	0.0509	Trend* Decline

* Flagged as a significant correlation despite value exceeding p<.05

Figure 5-1 Scatterplot and best fit line of changes in combined electrofishing CPUE for all species collected in 1972 within ambient and thermally-influenced zones of Hooksett Pool, and pool-wide. Sampling conducted in 1972 – 1974, 1976, 1995, 2004, and 2005



The plant's conclusions were likely influenced by the presence and abundance of two species, bluegill and spottail shiner, which were not captured in Hooksett Pool in the 1960s and early 1970s. These species, and others that appeared later, should not have been included in an analysis of the balanced, indigenous community, except to explain how their presence may have affected the indigenous community. Therefore, EPA finds Merrimack Station's conclusion of "no appreciable harm" in this analysis to be unsupported by the data, as it applies to the balanced, indigenous community.

5.6.2.1.1b Trapnetting CPUE Trends Analysis – All Species Combined

EPA has considered the trapnetting data, as well as Merrimack Station's evaluation of that data, and concludes that this information indicates that the balanced, indigenous community has significantly declined since the facility's Unit 2 commenced operations. As a result, and in connection with other analyses discussed in this document, EPA concludes that the balanced, indigenous community has suffered appreciable harm from the facility's thermal discharge. EPA disagrees with Merrimack Station's contrary conclusion. In reaching its conclusion, Merrimack Station decided for various reasons to exclude various segments of the trapnetting data from its analysis. EPA also disagrees with certain of the Station's decisions in this regard. These issues are discussed in detail below.

Trapnetting Data from the Late 1960s

Merrimack Station analyzed fish sampling data dating back to 1967, prior to the start-up of Unit 2. These data were collected by NHFGD and presented in a 1971 report (Wightman 1971). They were also analyzed in a separate 1969 report completed by Merrimack Station's consultant, Normandeau Associates, Inc. (Normandeau 1969). In describing the earliest fish data collected in support of assessing thermal impacts related to Merrimack Station, Normandeau's current Fisheries Analysis Report (2007a) states:

> *While these 1967–1969 trapnet data could be useful in an evaluation of fish species presence and absence among years, the lack of documented effort and sampling location led to its being dropped from consideration for inclusion in the multi-year trends analysis of CPUE.*

The Fisheries Analysis Report further states that (p.28):

> *In addition to the lack of information regarding the number of net sets at specific locations, there is no raw fish catch data presented in the 1969 Normandeau report.*

EPA finds that these conclusions in the Fisheries Analysis Report are questionable. EPA also reviewed the 1971 NHFGD Report and the 1969 Merrimack Station Report and finds that while some details are omitted from the former, the latter appears to be based on a review of NHFGD's raw sampling data. In the 1969 Merrimack Station Report, Normandeau provided CPUE data for all species collected and calculated CPUE data down to two decimal places for nine abundant species at 3,000-foot intervals along the entire length of the Hooksett Pool. Given that no such detailed CPUE data were presented in the 1971 NHFGD Report, Normandeau must have had access to the state's raw data. The fact that Normandeau used the data collected by NHFGD from 1967–1969 in the 1969 Merrimack Station report, as well as in other analyses presented in reports as recently as 1997, weakens its current conclusion that the data should not be used for purposes of conducting a historical trends analysis.

In providing a basis for omitting these important early data, Merrimack Station also states in the Fisheries Analysis Report (p.27) that:

> *The 1971 NHFG (Wightman) Report did not provide information for Areas 1 and 2 that detailed whether nets were fished on the east, west, or both banks.*

Yet, based on EPA's review of the 1971 NHFGD Report, it appears that sampling locations *were* included. The 1971 NHFGD Report states that:

> *Netting sites were delineated by numbered marker posts in Sections 1 and 2 to insure similar net sets during the course of the study, while Area 3 net sites were plotted on aerial photographs to insure similar positioning in this area.*

Figures 5 and 6 in the 1971 NHFGD Report identify all the sites sampled. According to Figure 5, all Hooksett Pool trapnet sampling sites (Areas 1 and 2) were located on the east side of the river, except for samples collected in the discharge canal (Wightman 1971). In Amoskeag Pool, sampling was conducted on both sides of the river, as portrayed in Figure 6.

EPA concludes that the trapnet data collected by NHFGD between 1967 and 1969 includes important fish data from before Unit 2's thermal discharge and cooling water withdrawals that must be considered when evaluating the long-term effects of the plant's operations. With regard to these data, Merrimack Station states in the Fisheries Analysis Report that:

> *From the number of Monitoring Stations sampled in Areas 1,2 and 3, it is evident that considerably more trapnet sampling effort was expended during 1967–69 than in subsequent years of known and documented effort.*

EPA concludes that the trapnet data from 1967–1969 were usable in some analyses, including comparisons of species' relative abundance. EPA notes that trapnet sampling conducted in Hooksett Pool during the 1960s by NHFGD appears to have occurred in June and July, while data used by Merrimack Station in the Fisheries Analysis Report covered sampling conducted from May through September in the 1970s (1974–1976) and 2000s (2004–2005). EPA did not have the raw data from the 1970s to refine sampling periods to cover only June and July, but EPA did calculate the relative abundance of the five most abundant species collected only in June and July during trapnet sampling conducted in 2004 and 2005. This analysis is discussed further in Section 5.6.2.3.1b of this document (Table 5-16).

Post-1960s Trapnetting Data

Merrimack Station concluded that trapnet (also called "fyke net") data from four of the nine years of sampling – specifically, 1972, 1973, 1978, and 1995 – were unsuitable for use in a trends analysis due to discrepancies in sampling design, poor record keeping, and possible inconsistencies in set duration and frequency. In addition, data from 1977 was not used, but the Fisheries Analysis Report does not explain the omission. Deselecting almost half of the available historical data sets when conducting a retrospective trends analysis unavoidably raises questions and concerns about whether a reasonable and fair analysis was conducted.

According to the Fisheries Analysis Report, Merrimack Station concluded that trapnet data collected in 1994–1995 could not be used in the trends analysis because a 2.0-inch mesh size was used, whereas it believes that a 0.75-inch mesh was used throughout the 1970s. The facility bases the latter belief regarding the probable mesh size used in the 1970s on the recollections of one of its biologists. The Fisheries Analysis Report then indicates that the difference in mesh size would be a problem in a trends analysis because a 0.75-inch mesh would tend to capture more smaller-bodied fish that could pass through a two-inch mesh. While that seems a reasonable point about differences between 0.75-inch and 2.0-inch mesh nets, EPA finds it unlikely for several reasons that a 0.75-inch mesh was used during the 1970s.

First, the notion that the sampling regime was shifted from a 0.75-inch mesh to a 2.0-inch mesh is not supported by a letter from PSNH to EPA, dated March 1, 1993, which states,

> *The fyke netting program undertaken by NAI will be repeated in 1994 to provide fish community composition and target species abundance information. (PSNH 1993).*

This assurance is repeated in a proposal for environmental assessment services from Normandeau Associates, Inc., to PSNH, dated August 1994. This proposal states (p.7),

> *Fyke net samples will be collected with the same gear used by NAI during the 1972-1978 study. (Normandeau 1994)*

These statements, which were made closer in time to the actual sampling programs, suggest that the mesh sizes would have been kept constant and appear to contradict the recent recollections by the company's biologist.

Second, the purpose of fyke net (*i.e.*, trapnet) sampling in the 1970s was to sample the larger, adult segment of the fish population. This is stated in Merrimack Station's 1975 Merrimack River Monitoring Program Report (p.112) "[f]yke netting was employed to illustrate the distribution of larger fishes within Hooksett Pond in relation to the Merrimack Station thermal discharge." Similar reports from other years in the 1970s say the same thing. EPA regards it unlikely that a 0.75-inch mesh would have been used in a program targeting larger fish and no reason why this would have been the case as has been suggested.

Indeed, Merrimack Station conducted an analysis in 2004–2005 that found that a 2.0-inch mesh was more effective at catching larger fish than a 0.75-inch mesh. Specifically, in 2004 and 2005, Merrimack Station conducted a catch comparison study to assess the selectivity and catch efficiency of the two mesh sizes that were allegedly used in the 1970s and 1994–1995. Merrimack Station's hypothesis was that a 2.0-inch mesh, like that used in the 1994–1995 sampling, would not capture as many smaller bodied species and young-of-the-year juveniles as a 0.75-inch mesh, which was allegedly used throughout the 1970s. The study concluded that for small-bodied species, such as minnow species, the 0.75-inch mesh was indeed more effective than the two-inch mesh. However, for several of the larger-bodied species of particular concern in this case, such as yellow perch and white sucker, the 2.0-inch mesh caught *more* fish than the 0.75-inch mesh. Thus, Merrimack Station, in its draft report, concluded that, "[t]he weakness of the 0.75-inch mesh trap nets may be its capture of large-bodied individuals, which tended to under-represent catch of large-bodied individuals in 2005, relative to 2.00-inch trap nets" (Normandeau 2006a). While this study was conducted roughly thirty years after the sampling done in the 1970s, it tends to underscore the unlikelihood that a sampling program targeting larger fish would have chosen a 0.75-inch mesh.

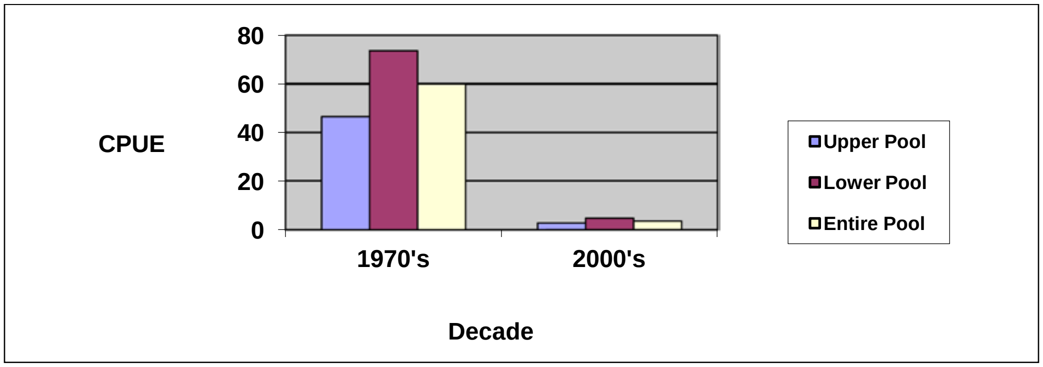
Moreover, Merrimack Station's comparison study demonstrated that the 2.0-inch mesh used in 1994–1995 would likely have been as or more effective at catching yellow perch and white sucker, among other species, than a 0.75-inch mesh. Therefore, if, as the facility suggests, a 0.75-inch mesh was used in the 1970s, the catch results for those species would have tended to be artificially low, not high. If such data were then used in a trends analysis, it would tend to mask or dilute any decline by producing an artificially lower baseline. In other words, the effect of using a smaller mesh size in the 1970s would cut in Merrimack Station's favor. Thus, if a 0.75-inch mesh size was actually used in the 1970s, including that data in a trends analysis would, if anything, tend to understate any decline, which would not be unfair to the facility.

Analyses Comparing Data Collected In Different Years

In light of the above discussion, EPA does not agree that use of the trapnet data collected in 1994–1995 should be completely abandoned, especially since it represents the only data of its type collected between 1978 and 2004 and, as Normandeau has stated in earlier reports, it targets adult fish (Normandeau 1976). Yellow perch data collected from June through September, 1994–1995, is presented in the Merrimack Station (Bow) Fisheries Study, dated 1997. This report presents the dramatic and largely steady decline of yellow perch from 1967, when 3,478 were caught (CPUE of 9.82 fish), to 1995, when 6 were caught (CPUE of 0.06 fish) during the study period (June – September).

Merrimack Station decided it could not complete a trends analysis for trapnet data similar to what it did for electrofish sampling. As described above, the facility decided it could not use a good deal of the trapnet data it had collected over the years in a trends analysis. Merrimack Station did, however, compile the data sets that it considered useable from the 1970s and the 2000s to provide a "then and now" analysis of changes in CPUE. This assessment by the facility concludes that trapnet CPUE is significantly lower in the 2000s than it was in the 1970s (Figure 5-2).

Figure 5-2 Comparison of total trapnet CPUE between 1970s and 2000s for all species identified as being part of the BIP in the 1960s, based on data provided in Table 3-17 of the Fisheries Analysis Report (Normandeau 2007a)



Specifically, using the data selected by Merrimack Station, CPUE for all species combined dropped by 89 percent between the 1970s and 2000s. Declines in the lower, or thermally-influenced, section of Hooksett Pool were even greater, dropping 91 percent. These data also provide a comparison of habitat use between both areas and decades. In the 1970s, the CPUE in the lower Hooksett Pool was 63 percent greater than in the upper Hooksett Pool. By the 2000s, however, they were both similarly depressed (Table 5-8).

Table 5-8 Comparison of total trapnet CPUE and 95% confidence limits between 1970s and 2000s for all species combined in Hooksett Pool based on data presented in the Fisheries Analysis Report (Normandeau 2007a)

Decade	Upper Pool			Lower Pool			Entire Pool		
CPUE and confidence limits	95% LCL	CPUE	95% UCL	95% LCL	CPUE	95% UCL	95% LCL	CPUE	95% UCL
1970s	21.6	46.7	71.8	33.8	74.0	114	35.9	60.2	84.5
2000s	0.5	6.6	12.8	2.3	6.5	10.7	2.5	6.4	10.2
Percent Change	-85.9			-91.4			-89.5		

As troubling as these results are, declines in total CPUE for the species that made up the balanced, indigenous community in the 1960s are even greater. Data provided in the Fisheries Analysis Report for the 2000s included (warmer water-favoring) species not present in Hooksett Pool in the 1960s and, therefore, not considered part of the balanced, indigenous community. The change in total CPUE for all species that comprised the balanced, indigenous community is illustrated in Table 5-9.

Table 5-9 Comparison of total trapnet CPUE and 95% confidence limits between 1970s and 2000s for all species identified as being part of the balanced, indigenous community in the 1960s, based on data presented in Table 3-17 of the Fisheries Analysis Report

Decade	Upper Pool			Lower Pool			Entire Pool		
CPUE and confidence limits	95% LCL	CPUE	95% UCL	95% LCL	CPUE	95% UCL	95% LCL	CPUE	95% UCL
1970s	21.6	46.6	71.6	34.0	73.6	113.2	35.9	60.1	84.1
2000s	1.1	2.8	4.6	1.9	4.8	7.6	2.0	3.6	4.7
Percent Change	-94.1			-93.5			-94.0		

Based on EPA's calculations, trapnet CPUE for the species that comprised the balanced, indigenous community in the 1960s declined 94.1 percent in the upper Hooksett Pool, 93.5 percent in the lower Hooksett Pool, and 94.0 percent in the entire Hooksett Pool between the 1970s and 2000s.

Merrimack Station argues that although the population declines between decades are statistically significant, they are observed in both the thermally-affected and ambient areas of Hooksett Pool. Merrimack Station concludes, therefore, that these data support a finding of "no appreciable harm." As previously discussed in Section 5.6.2.1.1a of this document, EPA rejects Merrimack Station's argument that a pool-wide fish population decline supports a finding of "no appreciable harm." Rather, given the significant amount of aquatic habitat that can be affected by Merrimack Station's thermal discharge, it provides substantive evidence to support a finding that appreciable harm to the balanced, indigenous fish community has indeed occurred.

5.6.2.1.2 CPUE Trends Analysis – Yellow Perch

In 1967, before Merrimack Station's Unit 2 commenced operation, the Hooksett Pool yellow perch population was second only to pumpkinseed in abundance, based on trapnet and electrofishing data collected by NHFGD (Wightman 1971).

5.6.2.1.2a Electrofishing CPUE Trends Analysis – Yellow perch

According to Merrimack Station's Fisheries Analysis Report:

> *No statistically significant negative (decreasing) trend was observed in yellow perch annual mean CPUE in Hooksett Pool (Ambient and Thermally-influenced zones combined), supporting a finding of 'no prior appreciable harm' due to Merrimack Station's thermal discharge during this four-decade period.*

Similarly, the report concludes that no decreasing trends were observed in either zone when analyzed individually.

Using data provided in the Fisheries Analysis Report, EPA also conducted a Kendall-Tau trends analysis for yellow perch in the ambient and thermally-influenced zones, and the entire Hooksett Pool. While the results of EPA's calculations for the Ambient Zone and Hooksett Pool are similar to those of Merrimack Station, EPA's finding differs significantly with that of Merrimack Station for the Thermally-Influenced Zone (Table 5-10). Merrimack Station's analysis calculates a P-value of 0.177 and, therefore, suggests, according to Merrimack Station, a "stable" trend. EPA's P-value is 0.014, however, which is indicative in this case of a declining trend. The P-value is the probability of getting a difference in the abundance data as big, or bigger, than if the null hypothesis is correct. In this case, the null hypothesis is that there is no statistically-significant interannual trend in abundance. With P-values less than 0.05 (*i.e.*, 5 percent) representing a statistically significant change, EPA finds a P-value of 0.014 to be compelling. By contrast, the P-value calculated by both Merrimack Station and EPA for yellow perch in the entire Hooksett Pool is not statistically significant (P-value = 0.0508), suggesting a "stable" trend. However, given that the difference between a finding of statistical significance here is only 0.0008 (*i.e.*, 0.08 percent), EPA does not find this result to be a compelling indication by itself that the yellow perch population in Hooksett Pool is stable, or that no prior appreciable harm has occurred.

Table 5-10 Results of Kendall-Tau trends analyses conducted by Merrimack Station and EPA based on electrofishing data provided in the Fisheries Analysis Report (Normandeau 2007b)

Analysis conducted by	Ambient Zone			Thermally-Influence Zone			Hooksett Pool		
	Kendall - Tau	P-Value	Trend	Kendall - Tau	P-Value	Trend	Kendall - Tau	P-Value	Trend
Merrimack Station	-0.429	0.177	No Trend	-0.429	0.177	No Trend	-0.619	0.051	No Trend
EPA	-0.524	0.099	No Trend	-0.781	0.014	Trend Decline	-0.619	0.051	Trend *

* Statistics program identified as a significant correlation since value is so close to threshold of < 0.05.

As with all other statistical analyses presented in the Fisheries Analysis Report, Merrimack Station did not include data from the 1960s, which EPA regards as the most important decade to consider when assessing changes in the balanced, indigenous community.

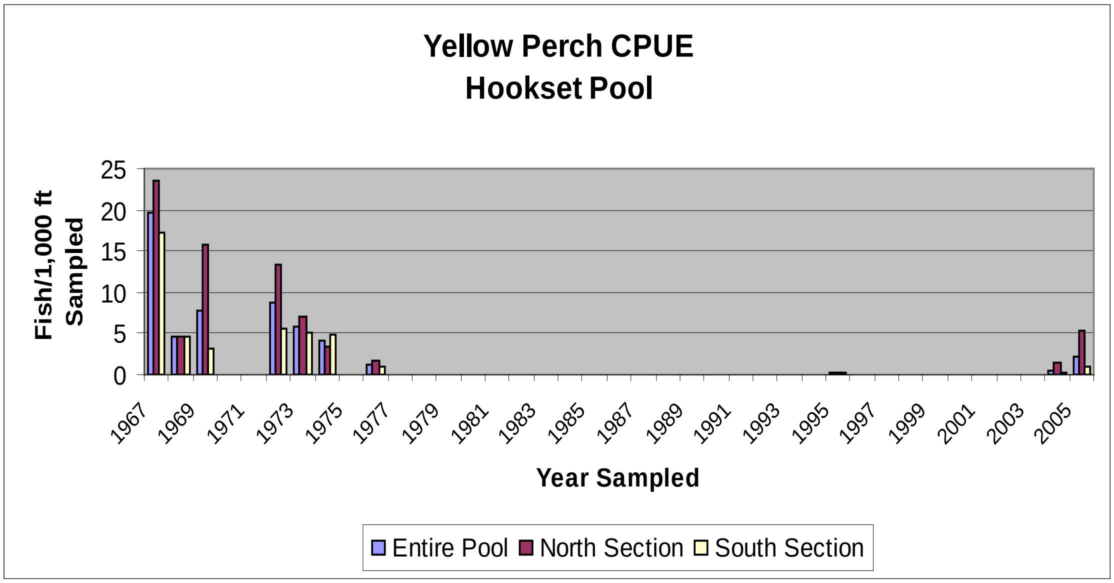
As previously discussed in Section 5.6.2.1.1a, EPA concluded that data from the 1960s was indeed usable for assessing long-term changes in CPUE. Therefore, using this information, EPA calculated yellow perch CPUE values for 1967, 1968, and 1969 (Table 5-11).

Table 5-11 Electrofishing CPUE data for yellow perch in Hooksett Pool, 1967-1969, based on data provided in Normandeau 1970a

Year	CPUE South of Discharge	CPUE North of Discharge	CPUE Total Pool
1967	216 fish = x fish 12,500 ft 1,000 ft	177 fish = x fish 7,500 ft 1,000 ft	393 fish = x fish 20,000 ft 1,000 ft
	x = 17.28	x = 23.6	x = 19.65
1968	59 fish = x fish12,500 ft 1,000 ft	34 fish = x fish 7,500 ft 1,000 ft	93 fish = x fish 20,000 ft 1,000 ft
	x = 4.72	x = 4.53	x = 4.65
1969	39 fish = x fish 12,500 ft 1,000 ft	118 fish = x fish 7,500 ft 1,000 ft	157 fish = x fish 20,000 ft 1,000 ft
	x = 3.12	x = 15.73	x = 7.85

Including these data points in Merrimack Station's fisheries analysis report graphic for yellow perch more fully describes, based on the best, reasonably available data, changes in yellow perch population since before Unit 2 came on line in 1968 (Figure 5-3).

Figure 5-3 Electrofishing CPUE data for yellow perch in Hooksett Pool based on information from selected years between 1967 – 2005 provided in two reports from Merrimack Station (Normandeau 1970a, Normandeau 2007b)



Note: Years that display no data represent gaps in data collection.

EPA included these data with the yellow perch data provided in the Fisheries Analysis Report, and conducted a Kendall-Tau trends analysis. The results of these analyses indicate that there has been a statistically significant decrease in yellow perch abundance within the Ambient Zone, Thermally-Influenced Zone, and the entire Hooksett Pool (Table 5-12).

Table 5-12 Results of Kendall-Tau trends analyses for yellow perch conducted by EPA based on electrofishing data provided in two reports from Merrimack Station (Normandeau 1970a, Normandeau 2007b)

Ambient Zone			Thermally-Influenced Zone			Hooksett Pool		
Kendall -Tau	P-Value	Trend	Kendall - Tau	P-Value	Trend	Kendall - Tau	P-Value	Trend
-0.600	0.016	Decline	-0.629	0.011	Decline	-0.644	0.009	Decline

Merrimack Station's analysis makes no distinction between juvenile and sexually mature adult fish. This blending of lifestages can obscure the true status of the fishery, especially when an adult, breeding population is depressed. EPA reviewed catch data provided in the Fisheries

Analysis Report to determine the approximate number of sexually mature yellow perch that were caught in August and September of 2005. Age-growth studies conducted by NHFGD each year from 1967 to 1969 provide a good estimate of age, based on length. These studies are discussed in the 1971 NHFGD Report. According to the USFWS (Krieger et al. 1983), female yellow perch in Canadian and northern United States waters mature at 3–4 years of age, one year later than males. Based on this information, the length-age data provided in the 1971 NHFGD Report, and the length-frequency data provided in the Fisheries Analysis Report, EPA conservatively calculated the age and sexual maturity of the fish collected in the 2005 sampling. Of the 52 yellow perch caught in 2005 during August and September, only two fish appear to be old enough to be considered sexually mature. Forty-five of the yellow perch caught were between 85 mm and 136 mm (3.35–5.35 inches), making them one- or two-year old fish. In general, many juvenile fish do not survive to maturity, so the capture of 45 juvenile yellow perch in the Ambient Zone is not indicative of a population rebound.

EPA has concluded that Merrimack Station's trends analysis conducted for yellow perch, which is based on electrofishing data collected between 1972 and 2005, does not support a finding of "no prior appreciable harm" to yellow perch from impacts related to Merrimack Station's thermal discharge. EPA's own assessment of all available data indicates that appreciable harm has occurred to the yellow perch population since Unit 2 came on line in 1968.

5.6.2.1.2b Trapnetting CPUE Trends Analysis – Yellow Perch

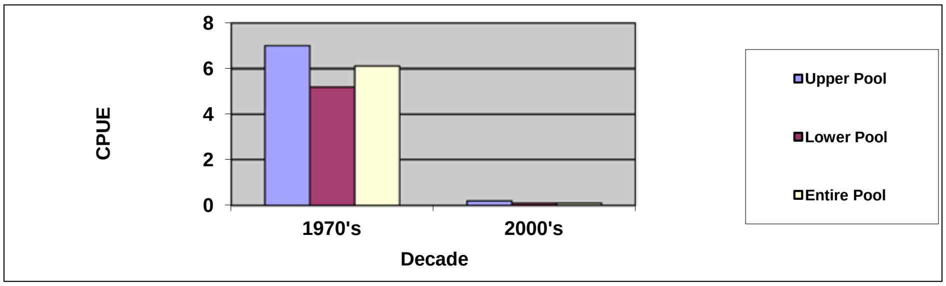
As previously mentioned, Merrimack Station did not provide a trends analysis in the Fisheries Analysis Report for any fish species based on trapnet data. Instead, the plant pooled trapnet data collected during selected years in the 1970s (1974, 1975, 1976) and compared them with data collected in 2004 and 2005, thereby providing a comparison between the two decades (Table 5-13).

Table 5-13 Change in yellow perch CPUE between 1970s and 2000s, based on data provided in Table 3-17 in the Fisheries Analysis Report

Decade	Upper Pool			Lower Pool			Entire Pool		
CPUE & confidence limits	95% LCL	CPUE	95% UCL	95% LCL	CPUE	95% UCL	95% LCL	CPUE	95%UCL
1970s	3.3	7.0	10.7	3.2	5.2	7.1	4.0	6.1	8.2
2000s	0.0	0.2	0.4	0.0	0.1	0.2	0.0	0.1	0.3
Change	-97.1%			-98.1%			-98.3%		

Based on the "then and now" analysis of yellow perch data collected in trapnet sampling, yellow perch CPUE declined by 98 percent throughout Hooksett Pool (Table 5-13, Figure 5-4).

Figure 5-4 Change in yellow perch CPUE between 1970s and 2000s, based on trapnet data provided in Table 3-17 of the Fisheries Analysis Report



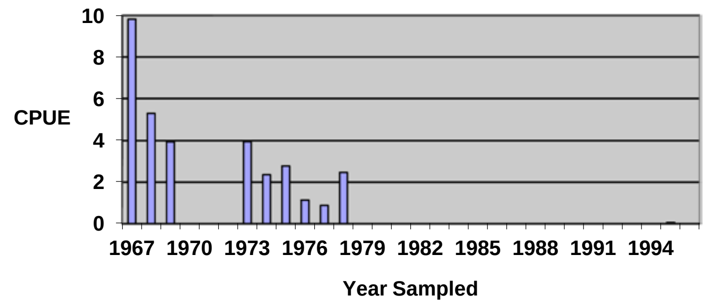
EPA also reviewed earlier yellow perch population studies conducted by Merrimack Station. On March 8, 1993, Merrimack Station submitted to EPA the Phase I Preliminary Report, Information Available Related to Effects of Thermal Discharge at Merrimack Station on Anadromous and Indigenous Fish of the Merrimack River. This study analyzed trapnet data collected from 1967 to 1978, which was normalized to cover a period from June through September. Merrimack Station's trends analysis revealed a statistically significant decline in yellow perch abundance during that time period (Table 5-14).

Table 5-14 Change in abundance of yellow perch in Hooksett Pool with analysis of abundance trend for data adjusted to a standard season (From Table 5-1, Saunders 1993)

Year	1967	1968	1969	1973	1974	1975	1976	1977	1978
Number of Fish	3478	2245	662	253	151	178	73	56	158
CPUE	9.82	5.28	3.94	3.95	2.36	2.78	1.14	0.88	2.47
Trend analysis: slope = -0.560, r = 0.839, significance = p < 0.01									

In January 1997, Merrimack Station released "Merrimack Station (Bow) Fisheries Study" (Normandeau 1997). Table 3-3 of the study provides the results of trapnet sampling for select species from 1967–1969, 1973–1978, and 1995. According to Merrimack Station's report, standardized CPUE of yellow perch in fyke nets decreased significantly during the 12-year period between 1967 and 1978, and the low 1994–1995 standardized CPUE data were consistent with a decreasing trend in CPUE (Figure 5-5).

Figure 5-5 Changes in yellow perch abundance based on trapnet sampling conducted from 1967-1969, 1973-1978, and 1995 (Normandeau 1997)



Note: Years that display no data represent gaps in data collection.

Based on our review of all trapnet information provided by Merrimack Station, EPA has concluded that the yellow perch population has declined significantly since 1967, with the steepest declines occurring in the years immediately following the start-up of the plant's Unit. EPA considers this decline in abundance indicative of appreciable harm to this species. This metric is particularly important since trapnet sampling is intended to target the adult segment of the population.

5.6.2.1.3 CPUE Trends Analysis – Pumpkinseed

Pumpkinseed sunfish (then referred to as "common sunfish") was the most abundant species in Hooksett Pool in 1967, according to data collected in both electrofishing and trapnetting studies conducted by NHFGD, and presented in a report by Merrimack Station (Normandeau 1970). Trapnet data for the years 2004 and 2005 ranked pumpkinseed fifteenth in abundance out of the seventeen species (Normandeau 2007a). Results from electrofishing in 2004 and 2005 were similar to trapnet sampling with both indicating that pumpkinseeds maintain little more than a remnant population in Hooksett Pool.

5.6.2.1.3a Electrofishing Trends Analysis – Pumpkinseed

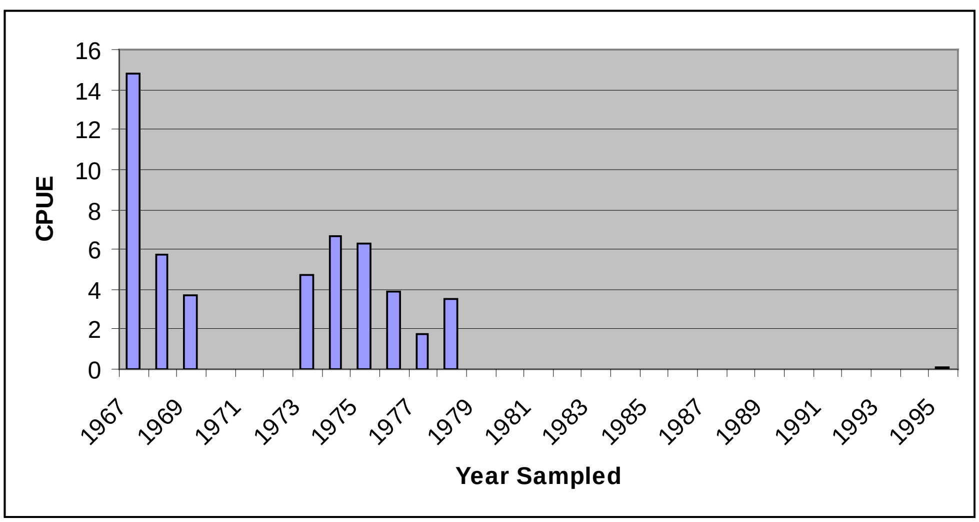
Statistically significant negative (decreasing) trends in annual mean CPUE were observed for pumpkinseed in the trends analysis conducted by Merrimack Station. Merrimack Station suggests, according to the Fisheries Analysis Report, that direct competition with bluegill, an introduced species not observed in Hooksett Pool until 1995, is the cause of the pumpkinseed decline rather than Merrimack Station's thermal discharge. Merrimack Station points out that bluegills spawn over a longer time period than pumpkinseeds, and that the "larger bodied" bluegill will also compete with pumpkinseed for spawning habitat in shallow gravelly habitat. What the Fisheries Analysis Report fails to mention, however, is that bluegill's heat tolerance is considerably higher than that of pumpkinseed. The Fisheries Analysis Reports lists 88°F

(31.1°C) as the avoidance temperature for pumpkinseed. Studies conducted by Beitinger (1977) identified 91.6°F (33.1°C) as the upper avoidance temperature for bluegill. Merrimack Station argues that the actual avoidance temperature for pumpkinseed should be 93°F (33.9°C) instead of 88°F because field observations of trapnet samples in the Station's canal indicate that pumpkinseeds were caught when temperatures were 93.2°F. Two problems exist with this argument. First, trapnet samples occur over a 48-hour period, so it is unclear how the temperature was determined specifically when the pumpkinseeds entered the trap, unless temperature data were recorded constantly at the trap entrance and the temperature never dropped below 93.2°F. Second, the mere presence of fish in water of a certain temperature does not prove that the temperature is desirable. Fish may be drawn into a thermally undesirable area to forage, or to escape predators. In addition, individual fish of a species may have varying levels of heat tolerance so the mere presence of one or more individuals at a given temperature does not necessarily demonstrate that the temperature is protective of the larger population. Where competition exists for limited forage, as well as spawning and juvenile-rearing habitat in areas exposed to a thermal discharge, it is reasonable to expect species with a greater preference for, and tolerance to, elevated temperatures to out-compete less tolerant species.

5.6.2.1.3b Trapnetting Trends Analysis – Pumpkinseed

Trapnet sampling results in 1967 for pumpkinseed were consistent with the electrofishing results showing that pumpkinseed was the most abundant species in Hooksett Pool that year. Merrimack Station's Fisheries Study (1997) presents trap net CPUE for the years 1967–1969, 1973–1978, and 1995. These data are illustrated in Figure 5-6.

Figure 5-6 Changes in pumpkinseed CPUE based on trapnet sampling conducted in the years 1967–1969, 1973–1978, and 1995 (Normandeau 1997)



According to the Fisheries Analysis Report (2007), Table 3-17, trapnet CPUE for pumpkinseed dropped from 11.7 fish caught per 48-hours in the 1970s to an average of 0.0 fish in the 2000s. Based on trapnet data, it appears that pumpkinseed, the most abundant fish species in Hooksett Pool prior to the start-up of Unit 2, has nearly disappeared from Hooksett Pool.

5.6.2.1.4 CPUE Trends Analysis – White Sucker

The common white sucker is native to New Hampshire. They are considered an important component of the aquatic system because they reproduce in great numbers, and form a large part of the total fish biomass in many areas (Hartel et al. 2002).

5.6.2.1.4a Electrofishing Trends Analysis

Based on electrofishing data, Merrimack Station concludes that:

> *[n]o statistically significant negative (decreasing) trend was observed in white sucker annual mean CPUE in Hooksett Pool (Ambient and Thermally-influenced zones combined), supporting a finding of 'no prior appreciable harm' due to Merrimack Station's thermal discharge during this four-decade period.*

The report also concludes that no decreasing trends were observed in either zone when analyzed individually. EPA reviewed the data, however, and found a significant disparity in abundance values for white sucker between trapnet and electrofishing data from the 1960s, suggesting a possible sampling bias for this species. While electrofishing sampling in 1967, 1968, and 1969 indicate the relative abundance of white sucker was low (1.7 percent averaged over the three-year period), trapnet samples suggest the opposite. According to data provided in the Merrimack River Thermal Study (Wightman 1971), trapnet relative abundance for white sucker averaged 16.2 percent over the same three-year period. It is possible that electrofish sampling may have under-represented bottom-feeding species such as white sucker. They tend to inhabit deeper areas during daylight hours, when electrofishing likely occurred, and forage in the shallows after dark (Moyle and Cech, Jr. 2004). Trapnets, which are typically deployed for periods up to or exceeding 24 hours are more likely to capture fish that actively feed along the shoreline at night. Given conflicting results from electrofishing and trapnet sampling, EPA is not convinced by the results of the electrofishing trends analysis alone that the white sucker population in Hooksett Pool has not declined significantly since either 1972 (the end point of Merrimack Station's analysis) or 1967

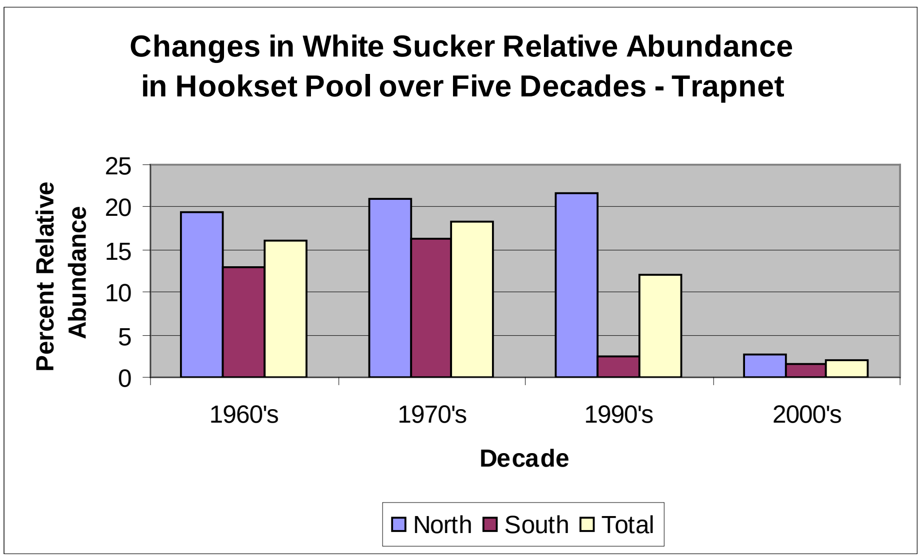
5.6.2.1.4b Trapnetting Trends Analysis

In 1967, the common white sucker was the fourth-most abundant species in Hooksett Pool, according to trapnet studies conducted by NHFGD (Wightman 1971). During the 1970s, white sucker was the second-most abundant species in upper Hooksett Pool (relative abundance 20.9 percent) and ranked third in the lower Hooksett Pool (relative abundance 16.4 percent)

(Normandeau 2007a). By the 2000s, white sucker relative abundance in the upper and lower Hooksett Pool had dropped to 2.7 and 2.1 percent, respectively (See Figure 5-7). Moreover, the mean CPUE dropped two orders of magnitude in Hooksett Pool between the 1970s and 2000s, from 11.0 fish to 0.1 fish.

Thus, the trapnetting data obviously provides evidence that white sucker have significantly declined since at least the 1970s. As with other species, Merrimack Station draws no conclusions regarding white sucker based on trapnet data.

Figure 5-7 Changes in white sucker relative abundance in Hooksett Pool over five decades (1960s–2000s) upstream (north), downstream (south) of Merrimack Station's discharge, and the entire pool (total) based on trapnet data presented in Normandeau (1969) and Normandeau (2007a)



5.6.2.1.4c Assessment of Trends In Light of Both Data Sets

EPA's review of the data reveals a significant disparity in relative abundance values for white sucker between trapnet and electrofishing data from the 1960s, suggesting a possible sampling bias for this species. While electrofishing sampling in 1967, 1968, and 1969 indicate the relative abundance of white sucker was low (1.7 percent averaged over the three-year period), trapnet samples suggest the opposite. According to data provided in the Merrimack River Thermal Study (Wightman 1971), trapnet relative abundance for white sucker averaged 16.2 percent over the same three-year period. Given conflicting results from electrofishing and trapnet sampling, EPA is not convinced by the results of the electrofishing trends analysis alone that the white sucker population in Hooksett Pool has not declined significantly since either 1972 (the end point of Merrimack Station's analysis) or 1967. The conclusion that there has been no decline based on the electrofishing data derives from the indication in this data that relative abundance was very low *to begin with*. Yet, the trapnetting data contradicts this suggestion of a low baseline condition and suggest that the electrofishing samples are not representative of the white sucker population. As a result, EPA is inclined to view the trapnet data as being more reliable. Therefore, EPA has concluded on the basis of the trapnet data that the white sucker population has indeed declined significantly since the 1970s. EPA disagrees with Merrimack Station's contrary conclusion.

5.6.2.1.5 CPUE Trends Analysis – Smallmouth and Largemouth Bass

Smallmouth bass and largemouth bass, collectively referred to as "black bass" in New Hampshire and elsewhere, are closely related species. EPA decided to discuss these two species together given that they are both introduced gamefish that feed primarily on other fish as adults (*i.e.*, piscivores). However, they do have some differing habitat preferences and temperature tolerances, which will be discussed in Section 5.6.3.3.d.

5.6.2.1.5a Electrofishing Trends Analysis – Smallmouth and Largemouth Bass

The trends analyses conducted by Merrimack Station for largemouth and smallmouth bass both concluded that there was no statistically significant negative (decreasing) trend in annual mean CPUEs in Hooksett Pool, supporting a finding of "no prior appreciable harm" due to Merrimack Station's thermal discharge during this four-decade period evaluated. Similarly, the report concludes that no decreasing trends were observed in either zone when analyzed individually.

The electrofishing data analyzed suggests that the populations of neither largemouth nor smallmouth bass have experienced a significant decrease in abundance over time. As with all other trends analyses performed by Merrimack Station utilizing electrofishing data, the plant does not clearly identify what fraction of the fish sampled are juveniles versus adults. A relatively large juvenile population is not necessarily indicative of a stable adult population if juvenile mortality is high. Young-of-year black bass are highly susceptible to predation and cannibalism by larger fish (Coutant and DeAngelis 1983).

5.6.2.1.5b Trapnetting Trends Analysis – Smallmouth and Largemouth Bass

EPA compared the results of electrofishing with those of trapnetting for studies conducted in the 1960s. While the two sampling methods yielded similar results for smallmouth bass, trapnetting for largemouth bass appeared to significantly under-represent the largemouth population compared to electrofishing samples. In this case, EPA concluded that electrofishing sampling was a more reliable indicator of the largemouth bass population, although recognizing the ambiguity associated with lumping juveniles and adults together to assess populations.

According to the Fisheries Analysis Report, smallmouth bass ranks first in the 2000s, with an average relative abundance of 42.8 percent. In the 1970s, the relative abundance was only 5.1 percent. While this appears to suggest that the population of smallmouth bass has increased dramatically over the past 30 years, sampling effort data indicates it has not. Drawing again from Merrimack Station's Fisheries Analysis Report (Table 3-17, p.74), smallmouth bass CPUE has actually declined slightly from 3.1 fish in the 1970s to 2.8 fish in the 2000s. Only because the populations of most resident, indigenous species have declined so dramatically does the smallmouth bass population appear robust by comparison.

5.6.2.1.6 CPUE Trends Analysis – Fallfish

Fallfish was not historically among the species studied by Merrimack Station in assessing thermal impacts to resident indigenous fish species. EPA recommended that it be reviewed for this thermal variance request due to its habitat requirements and thermal preferences, which are discussed in Section 5.6.3.3g.

5.6.2.1.6a Electrofishing Trends Analysis – Fallfish

The relative abundance of fallfish during the 1960s was low (under 5 percent), according to data provided in the Merrimack River Thermal Study (Wightman 1971). In 1967, the relative abundance in the ambient or "northern" section of Hooksett Pool was roughly the same as in the southern section, with 13 fish caught in the southern section and 5 in the northern section. In 1968 and 1969, after Unit 2 came online, no fallfish were caught in the southern section and 11 were caught in the northern section both years, according to Merrimack Station's Physical Studies – Fisheries Investigations Report (Normandeau 1970).

Fish sampling in 2004 and 2005 revealed the continued presence of fallfish in low abundance. Similar to the sampling in 1968 and 1969, fallfish were collected predominantly in the northern area of Hooksett Pool, upstream of the plant's thermal discharge. Of the 54 fallfish captured during August and September sampling (2004–2005), 49 fish (90.7 percent) were found in the ambient zone.

5.6.2.1.6b Trapnetting Trends Analysis – Fallfish

Trapnet sampling in the 1960s and 1970s are consistent with the electrofishing results with respect to both low overall abundance and a preference for habitat found in the northern section of Hooksett Pool, at least after 1967. According to the Fisheries Analysis Report (2007a), a total of 15 fish were caught during the analysis period for the 1970s. Of these, 11 were collected in the northern section. In the 2000s, only four fallfish were caught, all of them upstream of the plant's thermal discharge.

5.6.2.1.7 CPUE Trends Analysis – Alewife

Given that alewife is a regularly stocked anadromous species that spends a relatively short time period in Hooksett Pool during out-migration to the sea, a trends analysis is not likely to provide much useful information on the Station's thermal effects on the population of this species. Nevertheless, alewife is part of the balanced, indigenous community of fish, and sampling data that identifies the presence of alewife in Hooksett Pool, especially during August and September, is useful in establishing the period when alewife enter Hooksett Pool from upstream. A more detailed discussion of alewife, including its habitat requirements and thermal tolerances, can be found in Section 5.6.3.3.a.

5.6.2.1.7a Electrofishing Trends Analysis – Alewife

According to the Fisheries Analysis Report, of all the years evaluated between 1972 and 2005, alewives were only captured in 2004. This study does not shed much light on changes in the alewife population of the Merrimack River over time, but it does show how early juvenile alewives can descend into Hooksett Pool from rearing habitat in upstream tributaries, such as the Suncook River. While the 2004 Field Season Result of the Fisheries Analysis Report described juvenile alewives being present in the fall months, 19 of the 26 alewives captured were collected during August sampling.

5.6.2.1.7b Trapnetting Trends Analysis – Alewife

No alewives were collected during trapnet sampling in any year, according to information in the Fisheries Analysis Report.

5.6.2.2 Taxa Richness Analysis

Taxa richness is simply the number of species, or types of organisms identified to some other taxonomic level, that are collected during a given sampling period. "Species" is the level most commonly used for studying fish communities.

5.6.2.2a Taxa Richness Analysis – Electrofishing

According to the Fisheries Analysis Report, "Taxa richness of the fish community has increased throughout Hooksett Pool, including in both the Ambient Zone and in the Thermally-Influenced Zone of Hooksett Pool over the four decades of comparable electrofishing sampling (1972-2005)." The report further states,

> *Finding an increase and no significant decrease in the number of fish taxa present in Hooksett Pool supports a finding that the continued thermal discharge from Merrimack Station during this four-decade period has not reduced the species richness of the fish community, which in turn is indicative of 'no*

appreciable harm' to the fish community of Hooksett Pool from the Station's thermal discharge over the four-decade period examined.

Similar to the CPUE analysis, EPA reviewed the taxa richness analysis as it relates to the balanced, indigenous community. Taxa richness – in this case, "species" richness – is not in and of itself a useful indicator of "appreciable harm" to the balanced, indigenous fish community. Counting the number of species present in the 2000s does not address the question of whether those species are part of the balanced, indigenous community. In addition, while taxa richness is commonly used as an index for analyzing the effects of pollutants on aquatic organisms, it can be misleading when evaluating the effects of heat on the aquatic environment. Differences in mean temperature strongly influence species richness across sites, with a general increase in species richness from coldwater to warmwater categories (Wehrly et al. 2003). Therefore, an increase in species found in a thermally-influenced waterbody is not necessarily desirable. Such an increase in species richness in the fish community is likely associated with the intentional or accidental introduction of new species. If these species are more tolerant of heat, their presence may cause a shift away from the balanced, indigenous community. The more telling indices are those that compare the presence and abundance of those species that represent the balanced, indigenous community in the 1960s with the community that exists today. These indices, which include "rank abundance" and "community similarity," are discussed separately.

For the reasons expressed above, EPA does not agree with Merrimack Station's conclusion that an increase in taxa richness is indicative of "no appreciable harm" to the fish community of Hooksett Pool.

5.6.2.2b Taxa Richness Analysis – Trapnetting

According to the Fisheries Analysis Report (p.44), fish taxa richness varied slightly within Hooksett Pool, with 18 species observed in the 1970s and 17 species observed in the 2000s. Taxa richness in lower Hooksett Pool was more varied, ranging from 15 species observed in the 1970s to 12 species observed during the 2000s. The report goes on to note that of the seven species that were not represented in the 2000s lower Hooksett Pool trapnet catch but were recorded during the 1970s, five were represented by less than one percent of the overall 1970s fish community.

Merrimack Station does not suggest the results of this analysis support a finding of "no appreciable harm" to the fish community of Hooksett Pool. EPA would not conclude that, either. Merrimack Station emphasizes that the five species which were present in the 1970s but not in the 2000s were not numerically abundant in the 1970s. A few other notable observations can also be made based on these data, and will be addressed in the "rank abundance" analysis, which follows.

5.6.2.3 Rank Abundance Analysis

Rank-abundance builds on taxa richness as a measure of community structure by incorporating a weight to each species based on its relative abundance to the sampled catch as a whole. According to the Fisheries Analysis Report, rank-abundance is a useful index to assist in demonstrating "no prior appreciable harm" to a community by providing a comparable method to track the relative abundance of fish species over time and space. According to EPA's Draft 316(a) Technical Guidance: "Relative abundance can fluctuate seasonally and diurnally; however, it should not be significantly different from year to year. Significant shifts in relative abundance over a period of time are indicative of changes within the fish community."

Merrimack Station conducted rank-abundance analyses for both electrofishing and trapnet sampling data. A discussion of the analyses and data follows, as they apply to the balanced, indigenous community, and selected species of particular concern.

5.6.2.3.1 Rank Abundance – Balanced Indigenous Community

5.6.2.3.1a Rank Abundance – Balanced Indigenous Community – Electrofishing

Merrimack Station conducted a comparison of the abundance rankings for fish species captured by electrofishing in Hooksett Pool during August and September for the years 1972, 1973, 1974, 1976, 1995, 2004, and 2005. Merrimack Station states the following conclusion in the Fisheries Analysis Report:

> *As the RIS are considered to be representative of the total species community, the analysis of rank-abundance data for this time period supports a finding of "no appreciable harm" to the fish community of Hooksett Pool from the Station's thermal discharge over the four-decade period examined.*

EPA reviewed this analysis within the time period examined by Merrimack Station (*i.e.*, 1970s–2000s). In addition, EPA considered data collected by NHFGD during the 1960s since these data best represent the balanced, indigenous community prior to, and immediately following, the significant increase in heat load to the pool associated with the start-up of Unit 2.

While the species Merrimack Station used in its analysis are suitable as RIS, limiting the analysis of rank-abundance to seven species – of which three are anadromous and periodically stocked – unnecessarily narrows the assessment of whether or not changes to the entire balanced, indigenous community may have occurred over the past four or five decades. EPA considers "relative" and "rank" abundance useful to assess fish community impacts when used in combination with catch effort data. However, ranking by itself can be misinterpreted to mean a population is robust when it is not. Nevertheless, EPA evaluated changes in both rank and relative abundance, particularly for resident species that were numerically dominant in the 1960s and 1970s. EPA identified species as "numerically dominant" if their relative abundance was five percent or greater, which is consistent with the Draft 316 (a) Technical Guidance.

According to data presented in Merrimack Station's Supplemental Report Number 1, dated June 1970, 15 species were collected during electrofishing sampling conducted between 1967 and 1969 (Normandeau 1970). Among these species, four (pumpkinseed, largemouth bass, yellow perch, and redbreast sunfish) contributed five percent or greater to the total abundance of the fish community, averaged over this three-year period. Using electrofishing data provided in the NHFGD Thermal Study (1971) and the Fisheries Analysis Report (2007a), the relative abundance in the 1970s, 1990s, and 2000s for the four most-abundant species collected during the 1960s are included in Table 5-15.

Table 5-15 Changes in mean relative abundance over five decades for the four most-abundant species in Hooksett Pool in the 1960s, based on electrofishing sampling

Species	Relative Abundance (Percent)			
	1960s[1]	1970s[2]	1990s[3]	2000s[4]
1. pumpkinseed sunfish	37.2	51.6	0.4	2.8
2. yellow perch	17.1	9.8	0.2	6.6
3. redbreast sunfish	6.6	11.8	4.5	6.9
4. largemouth bass	22.4	7.4	4.0	23.7
Total	78.7	80.6	9.1	40.0

[1] Data collected during the years 1967–1969
[2] Data collected during the years 1972, 1973, 1974, 1976
[3] Data collected during the year 1995
[4] Data collected during the years 2004, 2005

As previously mentioned in Section 5.6.2.1.1a, electrofishing sampling was conducted in September in the 1960s, and in September and August in 2004 and 2005. In 2004 and 2005, a distance of 10,000 feet was sampled each of the two months for a total of 20,000 feet (Normandeau 2007a). In 2004, August electrofishing took place on the last two days of the month. In 2005, sampling occurred on August 22. Given that the total sampling effort (20,000 feet) was the same during the 1960s and 2000s, and that sampling periods were similar (*i.e.*, late August–late September), EPA believes the electrofishing data collected during the 1960s are comparable to data collected in 2004 and 2005 for purposes of measuring relative abundance.

These data illustrate the significant decline in relative abundance for some representatives of the balanced, indigenous community (*e.g.*, pumpkinseed and yellow perch) between the sampling periods in the 1960s and 1970s, compared to those of the 1990s and 2000s. For other representative species (*e.g.*, largemouth bass and redbreast sunfish) there is minimal change, or even a notable increase.

In addition to the shift in relative abundance among species, there was a significant decline in number of fish caught during comparable sampling. A total of 1,281 fish, representing 12 species, were collected in 1972 during electrofish sampling in August and September. By comparison, only 446 fish were caught in 2005, a 65-percent decline.

5.6.2.3.1b Rank Abundance – Balanced Indigenous Community – Trapnetting

EPA again reviewed trapnet data provided in the NHFGD Thermal Study (1971) to identify what species had a relative abundance of five percent or greater during sampling conducted in the 1960s (1967–1969). Trapnet relative abundance data for the 1970s (1974–1976, 1978) and 2000s (2004–2005) were provided in the Fisheries Analysis Report (Normandeau 2007a), and are included in Table 5-8. As previously mentioned in Section 5.6.2.1.1b, trapnet data were collected in Hooksett Pool during the months of June and July during the 1960s. According to the Fisheries Analysis Report, Merrimack Station used trapnet data collected from May through September during the 1970s and 2000s in its trapnet data analysis. EPA did not have the raw data from the 1970s to do a direct comparison of sampling data collected in the same months that were used in the 1960s. However, EPA did tease out trapnet data collected only in June and July of 2004 and 2005, as provided in the Fisheries Analysis Report. The differences are illustrated in Table 5-16.

Of the five most abundant species listed in the 1960s, none make the list today by contributing five percent or more to the total abundance. The top five dominant species in the 1960s accounted for 86.8 percent of the entire community. In 2004–2005, those five species represented only 4.5 percent of the fish community, a 94.8-percent decline in relative abundance.

Table 5-16 Changes in mean relative abundance of the five most-abundant species in Hooksett Pool in the 1960s, based on trapnet sampling data provided in NHFGD (1971) and Normandeau (2007a)

Species	Percent Relative Abundance			
	1960s*	1970s	2000s*	
1. pumpkinseed sunfish	26.2	19.5	0.4	0.0
2. yellow perch	23.0	10.1	2.1	1.9
3. brown bullhead	13.2	36.0	0.8	0.4
4. white sucker	16.2	18.2	2.1	2.2
5. golden shiner	8.2	0.9	0.0	0.0
Total	86.8	84.7	5.4	4.5

* Data used were collected May through September in the 1970s and 2000s (left column). In 1960s, data collected in June and July. Only June and July data used in 2000s (right column).

5.6.2.3.2 Rank Abundance – Pumpkinseed

5.6.2.3.2a Rank Abundance – Pumpkinseed – Electrofishing

According to the Fisheries Analysis Report, during the 1970s pumpkinseed was the first-ranked fish taxon during all four years of comparable sampling. Looking back further to the electrofish sampling data from the 1960s, pumpkinseed ranked first then as well. The Fisheries Analysis Report also states that pumpkinseed showed the largest downward movement from the first-ranked species in 1972, to the seventh in 2005. In fact, the decrease between 1972 and 2004 was even more extreme, dropping from first to eleventh place. Moving back up to seventh place in 2005 may seem like an improvement, but what it really shows is how much rank is affected by the total number of all fish caught. In 1972, pumpkinseed ranked first with 753 fish caught in August and September, and a CPUE of 37.65 fish. Although catches ranged from 753 in 1972 to 389 in 1976, it remained ranked first. However, in 2004, pumpkinseed ranked eleventh with 14 fish caught, but moved up to seventh in 2005 with only 18 fish caught. While the CPUE for pumpkinseed was 37.65 in 1972, it was 0.90 in 2005. Therefore, as the abundance of all fish species decline, changes in rank-abundance tend to become more variable, and in many cases less meaningful.

5.6.2.3.2b Rank Abundance – Pumpkinseed – Trapnetting

The rank-abundance analysis for pumpkinseed based on trapnet data depicts an even greater decline than electrofishing data collected in the 1970s and 2000s. Based on trapnet data, pumpkinseed ranked second only to brown bullhead catfish in 1972. The average relative abundance during the 1970s was 19.5 percent, with 1,208 fish being caught during the years selected for analysis. In 1967, before Unit 2 came on line, 772 pumpkinseeds were caught in September alone, representing 53.4 percent of the total fish caught. In 2005, pumpkinseed ranked fifteen, with an average relative abundance of 0.4 percent during the 2004–2005 sampling periods. According to Table 3-16 of the Fisheries Analysis Report (p.73), a total of two pumpkinseeds were caught in the 2000s. Based on both electrofish and trapnet sampling, it appears the pumpkinseed population in Hooksett Pool may no longer be self-sustaining.

5.6.2.3.3 Rank Abundance – Yellow Perch

5.6.2.3.3a Rank Abundance – Yellow Perch – Electrofishing

According to the Fisheries Analysis Report, yellow perch decreased in the abundance rankings during 1995 and 2004, but rebounded to be the third most abundant species during the 2005 sampling. Like pumpkinseed, a review of the historical data for yellow perch suggest that "rebounding" in rank-abundance reflects more on how poorly the overall fish community has fared in Hooksett Pool than it does on an increase in the yellow perch population. According to Normandeau's 1969 report, 393 yellow perch were caught during electrofish sampling in 1967. In 2004, 13 yellow perch were caught, and 52 perch were caught in 2005. Since a total of only 446 fish were caught for all species combined in 2005 (compared to 1,281 fish in 1972), the rank of yellow perch rose to third, but does not represent a recovery of the species.

5.6.2.3.3b Rank Abundance – Yellow Perch – Trapnetting

According to the Fisheries Analysis Report (p.44), yellow perch dropped in rank from fourth in the 1970s to sixth in the 2000s. Looking back further to 1967 data provided in Supplemental Report No. 1 (Normandeau 1969), yellow perch ranked second in the northern section of Hooksett Pool, and third in the southern section before Unit 2 came on line. Although trapnet CPUE dropped each year from 1967 to 1969, yellow perch relative abundance averaged approximately 23 percent, second only to pumpkinseed. However, by the end of the 1970s, yellow perch relative abundance had dropped to 10.1 percent. By the 2000s yellow perch relative abundance had sunk to 2.1 percent in Hooksett Pool, with 3.0 percent in the northern section and 1.2 percent in the southern section.

5.6.2.4 Fish Community Similarity Analysis

The Fisheries Analysis Report presents the results of a Bray-Curtis index of community similarity analysis, which it states was used to quantitatively compare the fish communities within Hooksett Pool among three decades of sampling (p.32). According to the report, the

Bray-Curtis index computes percent similarity among the fish taxa common in two sets of survey data, and negates the influence of uncommon species that may be present only within some years of comparison. Therefore, Merrimack Station considers the results significant for demonstrating "no prior appreciable harm." The closer the Bray-Curtis value is to 100%, the more similar the two communities are.

Species such as bluegill and spottail shiner, not collected during electrofishing and trap net sampling in the 1960s and 1970s, were numerically dominant in sampling conducted in the 1990s and 2,000's. The extent to which the presence and abundance of these two species affects the results of these analyses cannot be readily assessed by EPA with the information provided, although EPA agrees with Merrimack Station that analyzing community similarity is an effective tool for quantitatively comparing fish communities across decades. Contrary to Merrimack Station's conclusions, however, EPA finds the results of these analyses reveal more evidence of appreciable harm to the balanced, indigenous community.

5.6.2.4a Fish Community Similarity Analysis – Electrofishing

The Fisheries Analysis Report provides the results of the fish community sampled by electrofishing within Hooksett Pool during August and September in selected years, as computed by the Bray-Curtis Percent Similarity Index. According to the Fisheries Analysis Report (p.40), the Bray-Curtis similarity between the 1970s and 2000s fish communities was 51.3 percent. Between 1970s and 1995 it was only 40.8 percent, and between 1995 and the 2000s it was 61.1 percent. Despite a community dissimilarity of almost 60 percent between the 1970s and 1995, and approximately 49 percent between the 1970s and 2000s, Merrimack Station states:

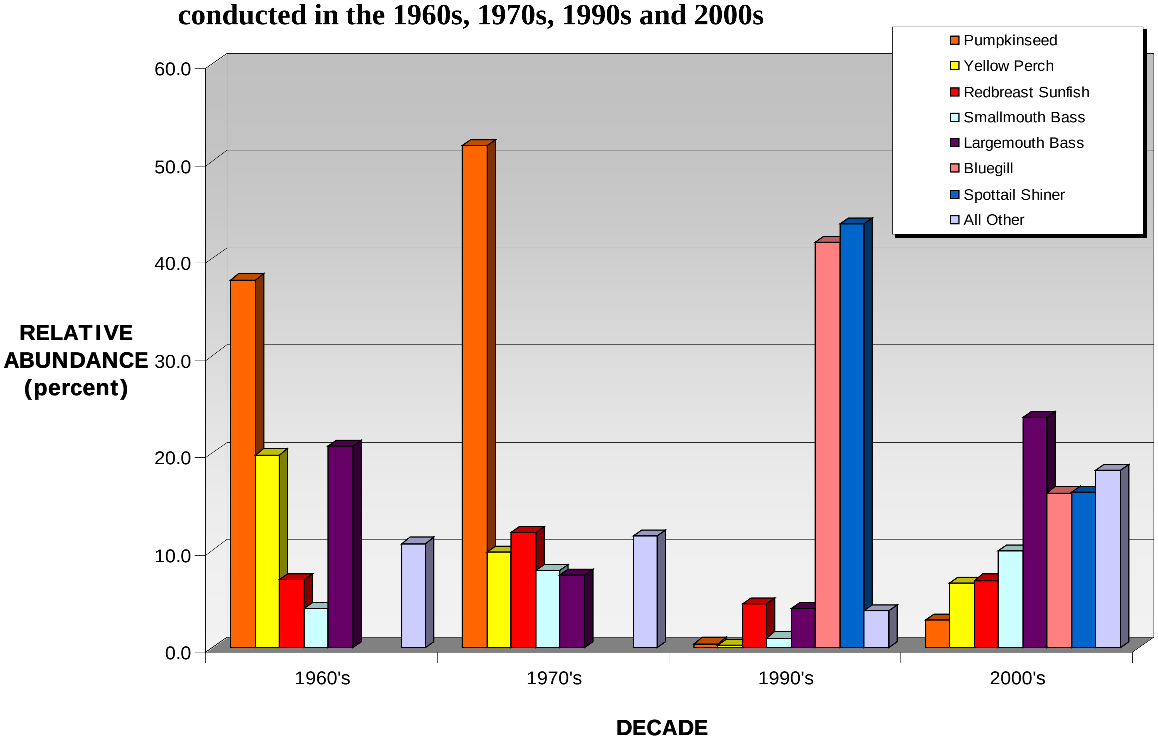
> *The analysis of the Bray-Curtis similarity supports a finding of "no prior appreciable harm" to the fish community of Hooksett Pool from Merrimack Station's thermal discharge over the four-decade period examined.*

According to the Fisheries Analysis Report, the basis for this determination is that:

> *Percent similarities between both the 1995 fish community and that sampled during the 2000s are greater for the Thermally-influenced portion of Hooksett Pool than that found in the Ambient zone of the upper Hooksett Pool. This suggests that factors other than potential thermal effects from the discharge of Merrimack Station, that would be limited to the Thermally-influenced portion of the lower Hooksett Pool, have caused changes in the community structure of Hooksett Pool.*

EPA reviewed this analysis as it relates to potential impacts to the receiving water's balanced, indigenous community from the facility's thermal discharge. Merrimack Station contends that greater similarities between fish communities in the thermally-influenced zone compared to the ambient zone during sampling conducted in 1995 and the 2000s supports a finding of "no appreciable harm." Yet, this argument fails to address impacts to the balanced, indigenous community since the balanced, indigenous community is most closely represented in this analysis by the 1970s fish community. It is obvious from the sampling data that significant adverse impacts to the Hooksett Pool's balanced, indigenous fish community had already occurred by 1995 (Figure 5-8).

Figure 5-8 Changes in the Hooksett Pool fish community based on electrofishing sampling conducted in the 1960s, 1970s, 1990s and 2000s



EPA disagrees with Merrimack Station's contention that this evidence suggests that "other factors" have caused changes in the community structure of Hooksett Pool fish community. While other factors, such as interspecies competition, may have contributed to changes in community structure, thermal impacts to the "thermally-influenced portion" of the pool likely affect the entire fish community of the pool. Studies have documented the importance of temperature-mediated competition on certain riverine fishes with results suggesting that the presence of competitively superior species may restrict the distributions of other species to thermally suboptimal habitats (Wehrly et al. 2003). Data from 1995, 2004, and 2005 show that bluegill, largemouth bass, smallmouth bass, and redbreast sunfish maintain numerical dominance in Hooksett Pool from 1995 to 2005 in the thermally-influenced zone. These species, all members of the sunfish family, have a comparatively high tolerance to heat. The greater similarity between 1995 and the 2000s in the thermally-influenced zone versus the ambient zone suggests to EPA that the most heat tolerant species are likely to remain numerically dominant in the thermally-influenced zone, and generally to fare better throughout Hooksett Pool than less heat-tolerant species. As heat is a regulated pollutant, and the focus of this 316(a) variance request, EPA considers the dominance of heat-tolerant species in Hooksett Pool to be indicative of appreciable harm to the balanced, indigenous community.

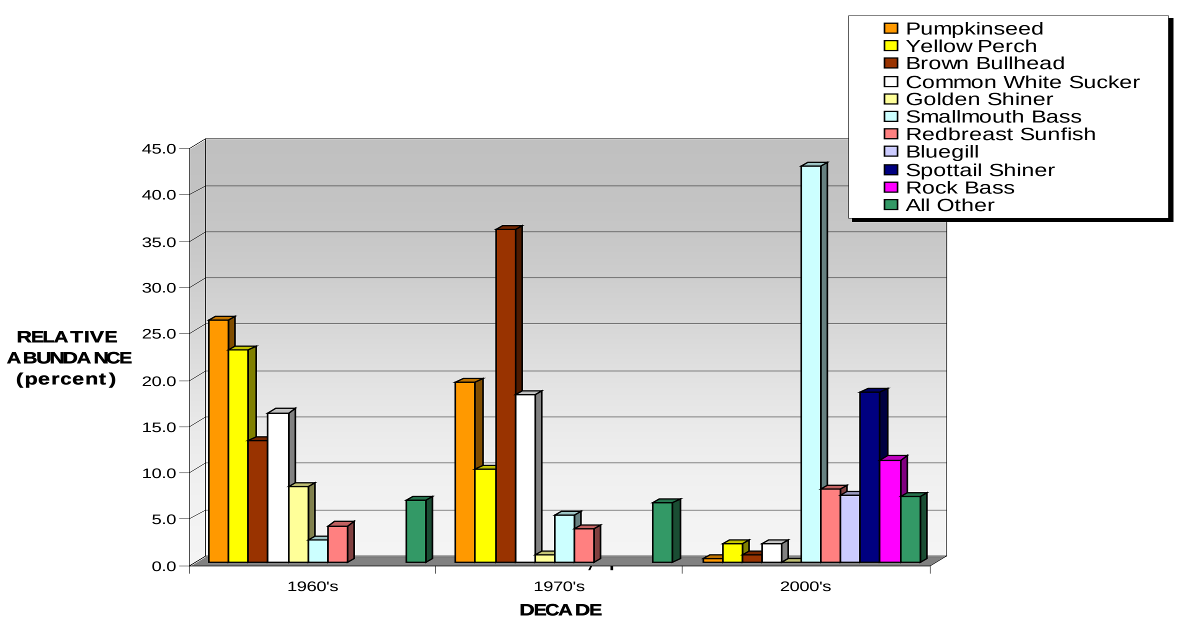
5.6.2.4b Fish Community Similarity Analysis – Trapnetting

While electrofish sampling indicates that Hooksett Pool fish community of the 1970s has changed by almost 50 percent compared to the current community (*i.e.*, 2000s), and over 60 percent between the 1970s and 1990s, trapnet data reveals even greater declines in similarity (Figure 5-9). According to the Fisheries Analysis Report (p.45), the fish community of the entire Hooksett Pool during the 1970s is only 23.2 percent similar to the current community. Yet despite a 76.8-percent change in similarity, Merrimack Station states,

> *. . . the analysis of the Bray-Curtis Similarity Index supports a finding of "no prior appreciable harm" from the Station's thermal discharge to the fish community of Hooksett Pool as sampled by trapnet.*

Merrimack Station argues that percent similarities between the fish community sampled during the 2000s are slightly greater for the lower Hooksett Pool than that found in the upper Hooksett Pool. This suggests that, according to Merrimack Station, factors other than potential thermal effects from the discharge of Merrimack Station (which the Station argues would be limited to the lower Hooksett Pool) have caused changes in the community structure of Hooksett Pool. Merrimack Station suggests that changes to the overall Hooksett Pool fish community can be best explained by the anthropogenic introduction of three centrarchid species, particularly bluegill, and are unrelated to Merrimack Station's thermal discharge.

Figure 5-9 Changes in the Hooksett Pool fish community based on trapnet sampling in the 1960s, 1970s, and 2000s



EPA finds Merrimack Station's explanation for a nearly 77-percent change in the balanced, indigenous community since the 1970s unpersuasive and unsupported. Fish species in Hooksett Pool utilize the entire pool. The heated discharge from Merrimack Station has a capacity to directly affect approximately half of the available habitat in Hooksett Pool. As such, impacts to a particular species south of the discharge are likely to affect the entire pool-wide population.

Merrimack Station suggests that introduced centrarchids (sunfish family), and bluegill in particular, caused the change in the Hooksett Pool fish community. As insectivores, bluegills likely compete with pumpkinseed sunfish and yellow perch for the same forage. However, Merrimack Station's suggestion that bluegill dominance and other species' decline are unrelated to the plant's thermal discharge is incorrect and overlooks the importance of the thermal preferences and tolerances of these species. Peterson and Schutsky (1976) determined that the avoidance temperature for bluegills acclimated to 80.6ºF (27ºC) is 92.3ºF (33.5ºC). The Fisheries Analysis Report identifies the avoidance temperatures for pumpkinseed and yellow perch as 88ºF (31.1ºC) and 83ºF (28.3ºF), respectively. Clearly, bluegills are more heat-tolerant than yellow perch or pumpkinseed. The ability not only to survive, but to function effectively in thermal conditions stressful to other species, gives bluegill a competitive advantage over those species. Thus, the facility's thermal discharge has created a habitat favoring bluegills.

The other species that currently dominate Hooksett Pool fish community also have comparatively high tolerances to heat. These include largemouth bass, smallmouth bass, and spottail shiner. According to the Fisheries Analysis Report, avoidance temperatures for largemouth bass range from 87–99ºF (30.6–37.2ºC). For smallmouth, the report identifies an avoidance temperature range of 95–100ºF (35.0–37.8ºC). Temperature data presented in Vermont Yankee's § 316(a) Demonstration, dated April 2004, identifies an avoidance temperature of 95ºF (35.0ºC) for spottail shiner (Normandeau 2004). Not only are these species more tolerant of heat, their reported maximum growth temperatures are higher, as well. As Table 5-17 illustrates, there has been an upward trend in the mean maximum growth temperature of the five most-abundant species, based on trapnet data collected in the 1960s, 1970s, and 2000s. Maximum growth temperature is a meaningful threshold because water temperatures above the maximum growth temperature affect fish adversely (Eaton et al. 1995b).

Table 5-17 Change in relative abundance of numerically dominant species caught by trapnet over four decades, and species-specific temperatures of maximum growth

Temp. Max. Growth F˚(C˚)	Species	Percent Relative Abundance		
		1960s[5]	1970s[3]	2000s[3]
86 (30) [1]	bluegill	0.0	0.0	7.3*
86 (30) [2]	spottail shiner	0.0	0.0	18.4*
86 (30) [3]	pumpkinseed	26.2*	19.5*	0.4
84.2 (29) [1]	largemouth bass	0.1	0.3	0.0
82.8 (28.2) [1]	smallmouth bass	2.5	5.1*	42.8*
82.0 (27.8) [1]	brown bullhead	13.2*	36.0*	0.8
81.5 (27.5) [4]	redbreast sunfish	4.0	3.7	7.9*
81.3 (27.4) [1]	rock bass	0.0	0.0	11.1*
80.2 (26.8) [1]	yellow perch	23.0*	10.1*	2.1
78.8 (26) [1]	white sucker	16.2*	18.2*	2.2
74.8 (23.8) [1]	golden shiner	8.2*	0.9	0.0
Total Relative Abundance		93.4	93.8	93.0
Mean Maximum Growth Temperature of Five Most – Abundant Species F˚(C˚) With 95% Confidence Intervals		80.4 (26.9) CI ± 4.1˚F	82.0 (27.8) CI ± 2.7˚F	83.5 (28.6) CI ± 2.3˚F

1 Eaton et al. 1995
2 Normandeau 2004
3 Normandeau 2007a
4 Aho et al. 1986
5 Wightman 1971
* Relative abundance exceeds five percent

5.6.2.5 Length – Weight Relationship Trends Analysis

Merrimack Station analyzed length-weight relationships for four species; bluegill, largemouth bass, smallmouth bass, and yellow perch. The analysis compared data collected in 1995 with data collected in 2004 and 2005. The results of this analysis suggest that the average body condition for yellow perch and largemouth bass has remained constant from 1995 to present, and that of smallmouth bass and bluegill has increased from 1995 to present. According to the Fisheries Analysis Report (p.41),

> *…the stability or increase in condition observed for yellow perch, largemouth bass, smallmouth bass, and bluegill from 1995 to 2004–2005 supports a finding of "no appreciable harm" to the fish community over the last 10 years from Merrimack Station's thermal discharge.*

As with other analyses in this report, EPA reviewed this analysis within the context of its relevance to support a finding of "no prior appreciable harm" to the balanced, indigenous community of fish. Length-weight data was collected from 1972 through 1978, and provided in the 1979 Summary Report, but was not used in this analysis. Yellow perch, smallmouth bass, and pumpkinseed were analyzed. It is unclear why Merrimack Station chose not to incorporate these important years of data into its analysis. Instead, Merrimack Station states in the Fisheries Analysis Report that it selected four numerically-abundant species for analysis (yellow perch, bluegill, smallmouth bass and largemouth bass) for the years 1995, 2004, and 2005. Yellow perch, however, was not abundant in 1995. In fact, its relative abundance in Hooksett Pool was at an historic low in 1995, at 0.2 percent. Only four perch were caught during August and September of that year. Fish surveys clearly indicate that significant impacts to the balanced, indigenous community in Hooksett Pool had already occurred by 1995. Comparing length-weight relationships between 1995 and 2005 does not address the question of "prior" appreciable harm to the balanced indigenous community. Without looking at data from the 1960s and 1970s, before Unit 2 began operations, Merrimack Station is simply comparing three sampling periods ranging from 27 to 37 years, all *after* the start-up of Unit 2.

5.6.2.6 Species Guild Biomass Trends Analysis

Merrimack Station compared the changes in biomass between the years 1995 and 2005 for the trophic guilds represented by the fish community of Hooksett Pool. These trophic guilds include filter feeder, generalist, herbivore, insectivore, and piscivore. Merrimack Station concludes that, over the past 10 years, insectivore guild biomass has remained relatively stable, there has been a reduction in the generalist guild, and an increase in the omnivorous and piscivorous guilds. Merrimack Station's conclusion is that these results support a finding of no prior appreciable harm to the balanced, indigenous population found in Hooksett Pool "during the evaluation period."

As with the length-weight relationship analysis, the "evaluation period" Merrimack Station selected is from years when the "balanced, indigenous populations" had already been impacted by Merrimack Station's increased thermal discharges, despite the availability of data from the 1970s. Therefore, this analysis also does not address the pertinent question of prior appreciable harm to the balanced, indigenous community. The data shows that by 1995 a significant change to Hooksett Pool fish community had already occurred. EPA finds, therefore, that Merrimack Station's analysis of trends in species guild biomass does not provide effective support for Merrimack Station's conclusion that its thermal discharge has had "no prior appreciable harm" on the fish community.

5.6.3 Temperature Effects Assessment for Nine RIS of Fish in Hooksett Pool

The third major section of the Fisheries Analysis Report (Sections 4 and 5 in the report) presents a retrospective analysis based on the distribution and life history of each of the nine "RIS" over the four-decade period examined. It also presents a predictive analysis of the effects of habitat changes resulting from Merrimack Station's historical and continued operations. Merrimack Station suggests that this combination of a retrospective and a predictive analysis is considered an alternative (Type III) demonstration by EPA, based on the Draft 1977 316(a) Technical Guidance.

As EPA's 1977 Draft 316(a) Technical Guidance indicates (p.71), Type I demonstrations are required for assessing the "absence of prior appreciable harm." The Guidance recommends excluding language concerning RIS for purposes of assessing "prior appreciable harm." Identifying RIS is primarily for the purpose of conducting predictive demonstrations (*i.e.*, Type II and III). While EPA has carefully reviewed the RIS analyses presented in the Fisheries Analysis Report, it has also assessed changes to the entire resident fish community. EPA considers changes to the entire community that historically comprised the balanced, indigenous community, as described in Section 5.3 of this document, to be most important for assessing prior appreciable harm. Nevertheless, Merrimack Station's detailed analyses on nine species have provided sufficient information for EPA to make a determination on whether prior appreciable harm has occurred to the balanced, indigenous community of Hooksett Pool.

5.6.3.1 Retrospective Analysis

Merrimack Station's retrospective analysis evaluated the occurrence and relative abundance of each RIS found in the vicinity of the Station during a period of "comparable and documented electrofish sampling in Hooksett Pool in each of several selected years (*i.e.*, 1972, 1973, 1974, 1975, 1976, 1994-95, 2004 and 2005) to determine if the interannual trends in RIS abundance in Hooksett Pool during this period substantiate a finding of 'no prior appreciable harm' from the Station's discharge." EPA finds Merrimack Station's arguments for a finding of "no prior appreciable harm" to the balanced, indigenous community unsupported by the data. The absence of any substantive analysis utilizing data collected in the 1960s – the period immediately prior to and following the start-up of Unit 2 – is probably this demonstration's greatest deficiency.

5.6.3.2 Predicted Thermal Effects Analysis

According to the Fisheries Analysis Report (p.81), temperature response data provided in the report fall into six categories: (1) upper incipient lethal temperature ("UILT"), (2) avoidance temperature, (3) optimum temperature for growth, (4) preferred temperature, (5) temperature of first spawning, and (6) temperature for egg incubation and larval development (collectively referred to as "early life history").

The report suggests that there exist two classes of thermal effects parameters among the six categories: exclusionary temperature limits and indicator temperature limits. UILT and avoidance temperatures are considered to be "exclusionary" parameters because the fish species will not be found in habitat where the water temperature is at or above the reported UILT or avoidance temperature values for any sustained period of time. The fish species is therefore excluded from using that portion of the habitat while thermal conditions are at or above those temperatures. The remaining four categories – optimum, preferred, spawning, and early life history – are considered by Merrimack Station to be "indicator" parameters because they are water temperature values that coincide with physiological or life history events represented by the thermal effects parameters.

The Fisheries Analysis Report states that ". . . a given fish species is not likely to change its distribution in response to the water temperature in the habitat occupied that is not at the optimum or preferred temperature." EPA disagrees. Sampling data collected in December and March in the plant's discharge canal clearly demonstrates the attractive force of the thermal plume during periods when ambient river temperatures are sub-optimal.

Other Thermal Impacts

The forage for all life stages of fish, but especially the larval and juvenile stages, can also be affected by Merrimack Station's thermal plume. Forage such as zooplankton, phytoplankton, and aquatic insects, come in contact with the thermal plume as it moves down the river, or they may avoid it, if able. Many plankters drifting down the river are pulled through the plant with the cooling water and discharged back into the river within the thermal plume. Merrimack Station has historically entrained a large fraction of the planktonic community passing the plant, given the plant's demonstrated capacity to withdraw 75–100 percent of the river's available flow under low-flow conditions. It continues to do so at its present capacity, which withdraws 62 percent of the flow under 7Q10 low-flow conditions, and up to 83 percent on a single day (e.g., August 14, 2001) (*See* Section 11.2.1b). Organisms entrained through the cooling system suffer mechanical and thermal stresses to such a degree that most are likely killed or impaired. For assessing entrainment impacts of cooling water intake structures, EPA typically assumes 100-percent mortality.

Data presented from one of the earliest studies of Hooksett Pool's plankton community was provided in NHFGD's report, "Merrimack River Thermal Study." According to this report, which covered the years 1967–1969, "[t]here appears to be a reduction in the frequency of occurrence of plankton in the surface waters south of the Bow Steam Plant." (Wightman 1971). It also states: "Zooplankton such as ciliates, rotifers, flagellates and cladocera appear to be adversely affected by the heated effluent while desmids, diatoms and blue green algae indicated similar effects among the phytoplankton."

Despite the importance of potential thermal impacts on the microscopic forage base for the early life stages of many fish species in Hooksett Pool, Merrimack Station's Fisheries Analysis Report provides no information on the subject. Where forage is limited, it is reasonable to expect competition between individuals and among species to be more intense. Elevated temperatures raise fish metabolism and increase the need for food, further intensifying inter-species competition. In such cases, species more tolerant to elevated temperatures would be expected to have a physiological advantage over species with lower tolerance. This phenomenon was observed in studies by Taniguchi et al. (1998), which demonstrated that, as temperatures increased, species having higher temperature tolerances competed more effectively for food than species less tolerant. This study also identified the loss of appetite of less heat-tolerant species contributing to a reduction in competitive success at higher temperatures.

EPA considers Merrimack Station's analysis of thermal affects on fish to be too limited in scope to adequately address all the potential significant effects heat can have on the fish community of Hooksett Pool. It focuses primarily on the avoidance response of the RIS (*i.e.*, their presence or absence at sampling locations). It does not address heat's effect on fish physiology, including a species' ability to compete with others for available forage and habitat, utilize available dissolved oxygen, and avoid predation. Additionally, there is no mention of heat's powerful influence on fish as an attractive force, and the potential implications on reproductive success for species such as yellow perch and white sucker that need prolonged exposure to cold temperatures to ensure proper gonadal development. Pumpkinseed subjected to elevated temperatures have been found to reproduce earlier, invest more in reproduction, and suffer higher adult mortality (Dembski et al. 2006). Detailed comments are provided in the Section 5.6.3.3.

5.6.3.2a Determination of Thermally-Influenced Habitat

Merrimack Station attempted to determine the volume of habitat potentially influenced by its thermal discharge using "reasonably available" Merrimack River water temperature data observed during nine separate survey dates from May through October (p.82). Of the nine survey dates used in this thermal analysis, only two dates occur in July or August when water temperatures tend to be at their highest, and flows lowest. Data collected on the other dates represent spring and fall temperature conditions (May 11, 24, June 9, 21, September 14, 24, and October 11, 1995). As explained in the Fisheries Analysis Report, these sampling dates were originally selected to examine the spring and fall migratory periods for anadromous fish, not mid-summer conditions.

EPA reviewed the permit file for thermal data collected and submitted by Merrimack Station over the years. Based on EPA records, water temperature data were collected throughout lower Hooksett Pool for several years in the 1970s, primarily during the summer months. Three annual Merrimack River Monitoring reports (1975, 1976, 1978) and the 1979 Summary Report, collectively provided temperature data for nine dates in July or August. Of these nine dates of comprehensive sampling, Merrimack Station chose to use data from only two dates in its temperature analysis (July 11, 1978 and August 8, 1978) to represent summer conditions. According to the 1978 Merrimack River Monitoring Report (Normandeau 1979), "Unit 2 was not operating from late June through early October; maximum river temperatures were 3º to 4º C lower during 1978 than in previous years." Merrimack Station suggests it has selected, as "somewhat conservative," conditions for its thermally-influenced habitat analysis. On the contrary, EPA finds the data Merrimack Station used were apparently collected during an unusually cool summer when Unit 2 was not even operating. Unit 2 generates roughly two-thirds of the plant's waste heat discharged into the river.

EPA has concluded that Merrimack Station's assessment of thermally influenced habitat is based on very limited data, and these data are neither conservative nor even representative of actual conditions in Hooksett Pool when the plant is under full operation, particularly during the summer months when thermal effects are most significant. As a result, Merrimack Station underestimates the amount of habitat affected by the thermal plume during the summer months. However, even these data indicate that habitats within the influence of the thermal discharge are unsuitable for certain species during summer months. EPA discusses species-specific thermal effects in greater detail in Section 5.6.3.3 of this document.

5.6.3.2b Temperature Data Not Discussed in Fisheries Analysis Report

EPA also reviewed additional temperature data previously submitted by Merrimack Station, but not utilized in the Fisheries Analysis Report. In one report, temperature data from three monitoring stations were compiled by Merrimack Station so that a 21-year (1984–2004) average minimum, mean, and maximum temperature were derived for each day from April 1 to October 31 (Normandeau 2007b). These temperature data are provided in Appendix A of this document. The three monitoring stations captured temperatures representing ambient river conditions (Station N-10), the confluence of the discharge canal and Hooksett Pool (Station S-0), and the downstream compliance point for meeting temperature objectives in the existing permit (Station S-4). Given its spatial and temporal coverage, EPA considered this data set to be representative of actual thermal conditions in Hooksett Pool, and used it to assess potential temperature effects on certain species and lifestages, which is discussed in this section, and sections 6, 8 and 9 of this document.

The first temperature data following the start-up of Unit 2 was presented in another report, "The Effects of Thermal Releases on the Ecology of the Merrimack River" (undated), developed for Merrimack Station by Donald A. Normandeau, Ph.D., of the Institute for Research Services at St. Anselm's College. According to this report, on July 18, 1968, when ambient temperatures in Hooksett Pool were 26.9ºC (80.4ºF), "Five degree Centigrade plus water is found all the way to S-24 and is restricted to upper 2-3 feet. Three degree Centigrade water also extends to S-24 but is only a foot deeper than five degree water." These early data indicate that temperatures at or above 31.9ºC (89.4ºF) extended downstream to just above Hooksett Dam (at S-24) to a depth of approximately three feet, and temperatures of 29.9ºC (85.8ºF) extended the same distance to a depth of approximately four feet.

This early thermal effects report describes Hooksett Pool as follows: "Much of the river is relatively shallow with most sections being less than ten feet in depth." Therefore, a thermal plume four feet deep can directly affect 40 percent or more of the water column. For juvenile fish that seek protection in the nearshore shallows, four feet can represent most, if not all, of their preferred habitat. Juvenile fish that avoid stressful or undesirable temperatures from the thermal plume may abandon the relative safety of the shallows, and move out into the deeper and cooler waters of the thalweg where larger predatory fish tend to reside. It should be noted that this report describes thermal conditions prior to the construction of a cooling canal in 1971, and the installation of 56 power spray modules in 1972.

Additional studies were conducted for at least five years during the 1970s. These studies suggest the configuration of the plume varies depending on river flow. During lower flows, the plume does not readily mix with the river, but instead becomes a lens of warm water one to two meters deep moving southward towards the Hooksett Dam. Under low-flow conditions, the plume typically flows across the river, reaching the east bank at Stations S-1 to S-3, and dispersing throughout the river width as it approaches S-4. Under low-flow conditions, thermal stratification is also evident as far south as S-24 which is immediately upstream of Hooksett Dam. Temperature data collected at S-22 and S-24 in July 1975 indicated that while stratification was still pronounced just above Hooksett Dam, bottom temperatures were approximately 3.6°C (6.5ºF) warmer than ambient temperatures collected at N-5, which is upstream from the discharge. Therefore, the thermal plume was not just affecting the upper layers of the water column; it was affecting the entire water column, including the bottom layers.

Temperature and dissolved oxygen ("DO") studies were conducted by PSNH during 2002 and 2003 as part of its hydroelectric licensing requirements for the Merrimack River Hydroelectric Project, which includes both Hooksett and Garvins Falls dams. Comprehensive diurnal studies conducted in July and August 2002 revealed considerable temperature and DO stratification just above Hooksett Dam, and periodic DO depressions at depth (Gomez and Sullivan Engineers 2003). PSNH, which also owns the hydroelectric plant at Hooksett Dam, attributed the elevated temperatures just above the dam to the thermal plume from Merrimack Station, according to the PSNH draft application to FERC, dated July, 2003.

5.6.3.2c Thermal Model

Merrimack Station submitted to EPA in April 2007 a document titled, "A Probabilistic Thermal Model of the Merrimack River Downstream of Merrimack Station" (Normandeau 2007b). This report attempts to make a case for monitoring in-river temperatures for permit compliance purposes at a location below Hooksett Dam. According to Merrimack Station, Monitoring Station A-0, which is not in Hooksett Pool, but located in the tailrace of Hooksett Dam, is the most representative of "mixed" in-river conditions. This may be true, but the most significant thermal impacts are occurring in Hooksett Pool, prior to full mixing. The thermal plume does not have to be thoroughly mixed to have an adverse effect on the fish community of Hooksett Pool. As previously discussed, the thermal plume can affect a third or more of the water column throughout the entire river south of the discharge, and reaches the opposite bank. This includes much of the shallow water habitat along the shorelines commonly used by juvenile fish. The thermal plume could force both juvenile and adult fish sensitive to elevated temperatures into the deeper, cooler waters of the river's thalweg, which may be poorly suited for purposes of foraging and refuge. In addition, the larvae of many fish species, including American shad, white sucker, and yellow perch, may not be able to readily avoid thermally-stressful surface temperatures. Since the highest water temperatures from the plant exist closest to the discharge point, the potential for the thermal plume to cause acute lethality or impairment to drifting organisms, such as fish larvae, is most likely to occur in the waters near the discharge. Therefore, EPA rejects Merrimack Station's proposed approach to monitoring compliance of in-river temperature limits at Station A-0 because it will not yield data representative of water temperatures in areas that need to be monitored to determine whether aquatic organisms are being adequately protected.

5.6.3.2d Revised Thermal Model

On January 10, 2011, EPA received another thermal plume modeling study from PSNH. This report, dated December 21, 2010, was prepared by Applied Science Associates, Inc. (ASA). The study is largely based on data collected in 2009. According to the report's cover letter, the model developed by ASA predicts the thermal plume generated by Merrimack Station to be largely confined to the western side of Hooksett Pool, and to tend to stratify in the upper half of the water column. This prediction is inconsistent, however, with a five-year study in the 1970's that revealed that the thermal plume initially flows across to the east side of the river under summer low flow conditions and then disperses throughout the river by the time it reaches Station S-4 (See Section 5.6.3.2b). The cover letter for the new report further states, "These results are consistent with those reported by Normandeau Associates, Inc. ("NAI") in their 2007 report, *A probabilistic Thermal Model of Merrimack River Downstream of Merrimack Station*." Yet, EPA rejected PSNH's 2007 model (See EPA's evaluation of the 2007 report in Section 5.6.3.2c, above).

According to the 2010 model predictions, the thermal plume is only significant in the immediate area where the cooling canal discharges into the river (Station S-0 West). PSNH defines "significant" as temperatures of 2°C (3.6°F) above ambient, or higher. EPA reviewed the temperature data collected during the periods in July and August 2009 that supported the modeling effort, and compared them to 20 years of temperature data collected by PSNH as part of the monitoring requirements under its NPDES permit. The ASA report only provided 2009 temperature data in graphic form so EPA had to pull the data points off the graph, but expects them to be within 0.2°C of the actual value. The ASA report refers to the study period from July 11-21, 2009, as the "validation" timeframe (ASA 2010). During this period, both units were operating, as were the power spray modules. The period from August 5-15 is referred to by the report as the "calibration" time frame. During this period, Unit 2 and the power spray modules were not operational; only Unit I was operating. Table 5-18 provides a comparison of the July 2009 data – the period when both units were operating - with data collected during the same period (July 11-21) from 1984-2004.

Table 5-18 Comparison of the July 11-21, 2009 mean temperature with data collected by PSNH on the same days from 1984-2004.

Monitoring Period	Station N-10[1]	Station S-0[1]	Station S-4[1]	Delta-T (N-10 > S-0)	Delta-T (N-10 > S-4)
July[2] (ASA)	21.5°C/70.7°F	27.3°C/81.1°F	22.3°C/72.1°F	5.8°C /10.4°F	0.8°C/1.4°F
July[3] (PSNH)	23.9°C/75.1°F	33.1°C/91.6°F	27.1°C/80.7°F	9.2°C/16.2°F	3.2°C/5.8°F

Notes:
[1]Temperatures reflect data collected on west-side, near-surface monitoring stations
[2] Temperatures collected from July 11-21, 2009
[3]Temperatures reflect the 11-day average (7/11-7/21) of mean temperatures reported by PSNH for the years 1984-2004.

The ASA report indicates that the model was calibrated and validated for summer conditions since this period corresponds with lower river flows, and higher air and water temperatures. Based on EPA's review of the two temperature data sets, it appears that ambient river temperatures, as represented by data collected at Station N-10, were significantly cooler (2.4°C/4.4°F) during the July 2009 study period than during the 21-year period from 1984-2004 for the same dates reviewed (July 11-21). This suggests that the ambient river temperatures used in the model did not reflect typical summer conditions in Hooksett Pool.

There were other notable differences in the data sets, as well. Based on the new model, PSNH predicts that "significant" temperatures would be restricted to the area of the river closest to the mouth of the cooling canal (as represented by Station S-0), but the 21-year data set for these periods in July and August indicates that temperature effects have been both more extreme and more extensive than the new model predicts. EPA's review of the two data sets revealed temperature differences between ambient (Station N-10) and Station S-0 to average 9.2°C (16.2°F) for July 11-21 period (21-year data set) compared to only 5.8°C (10.4°F) for the ASA data (Table 5-18). The differences were also notable in the two data sets when comparing ambient temperatures with temperatures recorded at Station S-4. The average delta-T for the July 11-21 period, based on the 21-year data set, was 3.2°C (5.8°F), while the average delta-T between Stations N-10 and S-4 was only 0.8°C(1.4°F) using the ASA data (Table 5-18).

Table 5-19 Comparison of mean monthly river flows (in cfs) in July and August 2009 with mean flows in July and August for the years 1993-2007, based on USGS flow data collected at Goffs Falls and corrected for Garvins Falls.

Flow Period	July	August
Monthly Mean (2009)	7,984.2 cfs	5,581.4 cfs
Monthly Mean (1993-2007)	2,347.2 cfs	1,522.9 cfs
Difference in Flow	5,637 cfs	4,058.5 cfs

EPA also reviewed river flow data in order to assess if flows in the summer of 2009 were comparable to typical summer flows. Using an existing 15-year river flow data set covering the years 1993 through 2007 for Garvins Falls Dam, EPA compared the mean river flow values of this data set with river flow data from the months of July and August in 2009. Based on this analysis, the mean river flow during July 2009 was more than three times (3.4) as high as the average flow in July, from 1993 to 2007 (see Table 5-19). The difference in mean flow during August 2009 was even higher (3.7 times higher) as compared to the August mean flow from 1993 to 2007. With river flows being more than three times greater in 2009 than the 15-year average (1993-2007), EPA cannot consider the flows in July and August 2009 used in ASA's model to be typical of summer flow conditions in Hooksett Pool.

Following its review of ASA's plume study, EPA has concluded that data collected in 2009 does not reflect typical thermal or flow conditions in Hooksett Pool during summer months, nor do they capture the magnitude of temperature change, or the spatial extent of the plume's influence that is reflected in 20 years of temperature data collected by PSNH. Therefore, ASA's report does not alter EPA's assessment of Merrimack Station's thermal impact on the Hooksett Pool.

5.6.3.3 Analyses of Nine "Representative Species" of Fish in Hooksett Pool

EPA reviewed this section of the Fisheries Analysis Report for evidence supporting Merrimack Station's contention that its thermal discharge as currently limited is sufficiently protective of the balanced, indigenous population of fish in Hooksett Pool. For each of the nine species discussed in detail, Merrimack Station attempts to predict how much available habitat in Hooksett Pool will be influenced by its thermal plume. Following some general comments on Merrimack Station's approach to this analysis, EPA presents an assessment of the plant's analysis for each species discussed in the Fisheries Analysis Report. Some species are discussed in greater detail than others, based on the results of EPA's assessment. As previously discussed in Section 5.6.3.2a, EPA finds that Merrimack Station's analyses are not supported with sufficient applicable temperature data. Therefore, EPA has supplemented its review with other relevant temperature data, as well as published scientific literature, in order to better assess the merits of Merrimack Station's arguments. All scientific literature used in this assessment is appropriately referenced.

The Fisheries Analysis Report lists pollution tolerance levels of all RIS and non-RIS species found in Hooksett Pool (Table 3-15, p.72). Merrimack Station states that conclusions about the interactions of RIS species with the Station's thermal discharge can be applied to other members of the same trophic guild and pollution tolerance classification (p.103). Although heat is identified in the CWA as a pollutant, it clearly was not considered when these pollution tolerance classifications were developed. The basis for how tolerance to pollution was derived for each species was not explained in the Fisheries Analysis Report. According to the report, Atlantic salmon and brown trout have the same pollution tolerance as largemouth bass (Table 3-15), and it suggests that largemouth can represent brown trout when assessing the Station's thermal discharge (p.102). EPA disagrees with this suggestion, however, given that the upper thermal tolerance limit for brown trout (*Salmo trutta*) is 75.4°F (24.1°C), while that for largemouth bass is 89.1°F (31.7°C) (Eaton et al. 1995). EPA rejects this approach to lumping many species together in one group where the temperature tolerances of the various species clearly have marked differences, unless the most thermally-sensitive lifestage of the most thermally-sensitive species is selected to represent the larger group. Without considering all aspects of temperature's influence on a given species, another species cannot accurately serve as its surrogate. In addition, the Fisheries Analysis Report cites the 1977 Draft 316(a) Technical Guidance to support its use of pollution tolerance classifications in this manner. EPA-New England has reviewed this guidance manual and does not agree that it supports Merrimack Station's approach.

Merrimack Station's analyses place considerable emphasis on the fraction of Hooksett Pool that reaches, by its calculations, the upper incipient lethal temperature ("UILT") for the species in question. The UILT is defined in the report as ". . . a lethal threshold temperature obtained from laboratory experiments in which fish are removed from a temperature to which they are acclimated, and placed in a range of other temperatures that typically result in a range of survival from 100% to 0%." EPA generally concurs with this definition, although the mortality threshold is typically 50 percent (Coutant 1970). By contrast, the Fisheries Analysis Report defines "maximum temperature for summer survival" as "the peak temperature during the warmest time of the year that can be tolerated by a species for brief periods, and is therefore considered exclusionary." (p.82). EPA also accepts this definition. Given the stated understanding of these two terms, it is confusing why Merrimack Station then goes on to repeatedly identify the UILT in the Fisheries Analysis Report as "representing the maximum temperature permissible for summer survival…" when describing temperatures for representative important species. The UILT represents the temperature that will kill a stated fraction of the population, generally 50 percent (Coutant 1970). Merrimack Station incorrectly suggests that the UILT is equivalent to the maximum temperature for summer survival, which erroneously diminishes the significance of what UILT represents.

Referring to the temperature at which a significant percentage (typically 50 percent but possibly even more; Merrimack Station suggests it could go as high as 100 percent) of the exposed fish died in a test as the "maximum permissible for summer survival" is inaccurate and misleading. It should also be noted that when such studies are conducted, some fraction of the sample are typically dying at lower temperatures (Coutant 1970). In addition, since significant effects to fish physiology and behavior are known to occur at temperatures well below the UILT, EPA finds discussions of how small a habitat area within Hooksett Pool will be subjected to temperatures reaching the UILT to be of minimal value except where the potential exists for eggs and larvae to be exposed to the thermal plume. In those cases, it is necessary to understand the potential acute and chronic effects associated with exposure to the thermal plume by life stages that have limited or no ability to avoid the stressful conditions it may create. EPA identified four species (alewife, American shad, yellow perch, and white sucker) with larval life stages that are particularly vulnerable to exposure to Merrimack Station's thermal plume. Thermal impacts to larval lifestages of these species are discussed in the following sections of this document: Alewife (5.6.3.3a), American shad (5.6.3.3b), yellow perch (5.6.3.3f), and white sucker (5.6.3.3h).

5.6.3.3a Alewife

Alewives, like other anadromous species, spend their early life stages in freshwater, then migrate to saltwater to grow and mature. Once sexually mature, they return to freshwater to spawn. Blueback herring is a similar species that, with alewife, are collectively referred to as "river herring." Like all anadromous species indigenous to New England, alewives typically survive after spawning, and return to the sea. The presence of hydroelectric dams downstream from Merrimack Station prevents most anadromous fish from reaching Hooksett Pool, or their natal spawning grounds farther upstream, however, adult alewives are routinely stocked in waters upstream of Hooksett Pool where spawning occurs, including Northwood Lake, which feeds into the Suncook River. In at least one case, alewives were stocked directly into Hooksett Pool (Normandeau 2007a).

The effects of Merrimack Station's thermal plume on the downstream migration of juvenile alewife were not discussed in Merrimack Station's Fisheries Analysis Report. Although upstream alewife migration is currently restricted by the lack of suitable fish passage at Hooksett Dam under most flow conditions, the potential for Merrimack Station's thermal plume to impede upstream alewife migration through the pool, and spawning success within it, also has not been addressed. Given that adult alewives are stocked in Hooksett Pool, or waters upstream, thermal effects on spawning, egg survival, and larva survival and growth must be considered. While river herring eggs are initially demersal and adhesive, they become pelagic after water-hardening and lose their adhesive properties (Pardue 1983). Therefore, both the egg and larval stages can drift downstream from spawning grounds into Hooksett Pool. Unless they were directly stocked into Hooksett Pool, the collection of river herring larvae by the plant during entrainment sampling in June 2007 (Normandeau 2007c) demonstrates that downstream movement of this early life stage does occur.

Merrimack Station suggests that ambient water temperatures in Hooksett Pool are suitable for spawning sometime prior to May 24. This is based on a mid-range spawning and larval survival temperature of 60ºF (15.6ºC), and four days of temperature data (Normandeau 2007). Unfortunately, Merrimack Station's analysis on temperature impacts on alewife larvae goes no further. Under Appendix C of the Fisheries Analysis Report, 79ºF (26.1ºC) is listed as the preferred temperature for alewife larvae, but there is no discussion on when larvae would be present in Hooksett Pool and how much habitat would be adversely affected by the thermal plume, if any. According to results from entrainment sampling conducted by Merrimack Station in 2007, approximately 25,000 "herring" larvae were caught at the plant's intake on or about June 11 (Normandeau 2007c). Merrimack Station's 21-year temperature data set (Appendix A) indicates that the temperature of the plant's discharge entering the Hooksett Pool at Station S-0 has reached as high as 94.1ºF (34.5ºC) on June 11, on or about the date river herring larvae were present. According to test data provided in Wismer and Christie (1987), alewife larvae exposed to this same temperature (94.1ºF) died after only 30 minutes. Alewife eggs exposed to 76.1ºF (24.5ºC) suffered lethality after one hour (Wismer and Christie 1987). EPA considers the stressful, and potentially lethal, temperatures created in Hooksett Pool by Merrimack Station's thermal discharge to create unsuitable habitat for alewife larvae.

Both adults and young-of-year juveniles pass through Hooksett Pool as they migrate downstream to the sea. Although the emigration of juveniles typically occurs in early fall during high flows associated with rain events, electrofishing sampling in late August of 2004 resulted in the capture of alewives in Hooksett Pool (Normandeau 2007a). According to the discussion on alewife in the Fisheries Analysis Report, juvenile alewife will potentially utilize habitat within Hooksett Pool from May through October. The report states that 80 juvenile alewives were caught in August and September of 2004.

Merrimack Station identifies 28.9ºC (84ºF) as being the "preferred" temperature for alewife. According to the Fisheries Analysis Report, Merrimack Station's rationale for this temperature is that it represents the midpoint of adult and young-of-year temperature ranges. EPA disagrees that this is the preferred temperature for alewife. Averaging the preferred temperatures of two distinct life stages is neither an established nor otherwise justifiable method of considering the effects on two distinct life stages given that it would not necessarily be protective of the more temperature-sensitive life stage. Indeed, the plant also identifies 84ºF (28.9ºC) as being the thermal "avoidance" temperature for alewife in the same report (p.92). Guidance developed by USFWS (Pardue 1983) found that "[j]uvenile alewives were collected from areas with water temperatures up to 77ºF (25ºC), but they avoided higher temperatures." In Hooksett Pool, none of the 80 juvenile alewives caught during sampling in August and September of 2004 were found in water temperatures above 78.8ºF (26.0ºC). Most (74 fish) were caught in water temperatures at 76.1ºF (24.5ºC), or lower. Based on 20 years of Hooksett Pool temperature data (1984–2004), the averaged mean (not maximum) water temperature at Station S-4 rose above 77ºF (25ºC) on June 25, and remained above 77ºF (25ºC) every day until September 4 (Appendix A). Even the temperature Merrimack Station selected as causing an avoidance response in alewives (84ºF [28.9ºC]) was exceeded at Station S-4 every day (averaged maximum) from June 25 to September 8.

Historical fish sampling data suggests that young-of-year and adult alewives generally are not common in Hooksett Pool except during periods of out-migration, which typically occur in September or October. Additional evidence of herring presence was provided in reports of "extraordinary impingement events" submitted by Merrimack Station. These reports documented the impingement of juvenile river herring in the plant's cooling water intake structures as early as September 3 (1998) to as late as October 30 (1997). Nevertheless, the capture of river herring larvae in June, and young-of-year juveniles in late August indicates that, at least in some years, larval and young-of-year alewives are present in Hooksett Pool before out-migration occurs. Based on our review of temperature data and the temperature requirements of alewife, EPA finds that the temperatures in Hooksett Pool associated with Merrimack Station's thermal discharge do not adequately protect alewives during the period when they may be present from June through mid-September. The thermal environment in Hooksett Pool after mid-September may be suitable for out-migrating juveniles under typical flow conditions.

5.6.3.3b American Shad

American shad represented an important part of the balanced, indigenous community of the Merrimack River before the construction of dams prevented their access to spawning grounds. Unfortunately, American shad restoration has thus far had only limited success in the Merrimack River, and the lack of upstream passage at Hooksett Dam prevents mature fish from accessing Hooksett Pool. However, a new plan was recently developed by the Technical Committee for Anadromous Fishery Management of the Merrimack River Basin ("Technical Committee") that seeks to "[r]estore a self-sustaining annual migration of American shad (*Alosa sapidissima*) to the Merrimack River watershed, with unrestricted access to all spawning and juvenile rearing habitat throughout the main stem river and its major tributaries." (TCAFMMRB 2010). The Technical Committee is comprised of USFWS, NHFGD, U.S. Forest Service, Massachusetts Division of Marine Fisheries, Massachusetts Division of Fisheries and Wildlife, and NOAA – National Marine Fisheries Service. According to the restoration plan, up to four million American shad fry (larvae), and five thousand adults are slated to be stocked annually in waters upstream from Hooksett Pool.

The stocking of larval American shad, in addition to pre-spawn adults, began in June 2010, mostly upstream of Hooksett Pool (pers. com. – J. McKeon, USFWS). Therefore, it is reasonable to expect that larval American shad will drift downstream into Hooksett Pool (pers. com. – J. McKeon, USFWS). Larvae that descend into Hooksett Pool could remain in the pool or continue drifting through it and drop down into Amoskeag Pool. If they remain in Hooksett Pool, they would mature into juveniles and likely stay in the pool until migrating downstream sometime between early September and late October.

EPA's assessment of potential thermal effects to American shad has focused primarily on the larval and juvenile forms since they are the lifestages most likely to be present in Hooksett Pool long enough to be impacted. Unless American shad actually spawn in Hooksett Pool, their eggs are not likely to be exposed to elevated temperatures associated with Merrimack Station's discharge, and most or all spawning would be expected to occur in waters upstream of the Hooksett Pool and Merrimack Station's discharge. Most adult shad will be stocked upstream from Hooksett Pool (pers. com. - J. McKeon, USFWS), and while suitable shad spawning habitat is available in Hooksett Pool (Normandeau 2007a), good habitat is limited due to the pond-like characteristics found throughout much of the pool. Moreover, following their fertilization, American shad eggs either sink to the bottom where they become lodged under rocks, or they are swept by currents downstream to nearby pools (ASMFC 2009). Therefore, most eggs should hatch in waters above Hooksett Pool. In addition, post-spawn adults should not reside in Hooksett Pool after spawning upstream. Adults move downstream soon after they spawn, returning to the sea until the next spawning season (Scott and Crossman 1973).

According to the Fisheries Analysis Report, 1,861 adult shad were stocked in Hooksett Pool in 2002, and up to 750 juvenile shad were captured after passing through the Amoskeag Dam fish bypass during the fall. Merrimack Station suggests these juvenile fish were a result of successful spawning and growth in Hooksett Pool. While the appearance of juvenile American shad emigrating out of Amoskeag Pool is encouraging, as it relates to successful spawning in the main stem of the Merrimack, there is insufficient information to know whether spawning actually occurred in Hooksett Pool or downstream in Amoskeag Pool. Even if spawning did occur in Hooksett Pool, the drifting surface-oriented shad larvae may have passed over Hooksett Dam and developed into juveniles in Amoskeag Pool. Similarly, larvae that developed into juveniles in Hooksett Pool could have dropped down into Amoskeag Pool if conditions in Hooksett Pool were unsuitable, and remained there until emigrating in the fall.

American Shad – Eggs and Larvae

According to the Fisheries Analysis Report, Merrimack Station estimates that American shad spawn in New Hampshire waters during May and June. Based on a 21-year temperature data set for Merrimack Station, the average, daily ambient temperatures for Hooksett Pool in May and June range from 50.6°F (10.3°C) to 72.9°F (22.7°C). At these temperatures, eggs would likely hatch within 3 to 17 days, according to information presented in Klauda, et al. (1991). The yolk sac is absorbed in four to seven days, and transformation to the juvenile stage is completed in 21–28 days (Klauda et al. 1991). Based on this information, American shad larvae could be present in Hooksett Pool through the end of July. Maximum survival of American shad larvae is reported by Klauda et al. (1991) to be between 59.9° and 79.7°F (15.5 and 26.5°C). However, a USFWS report identifies temperatures greater than 80.1°F (26.7°C) to be unsuitable for the hatching of American shad eggs and development of larvae (Stier and Crance 1985).

Since these larvae are photopositive (*i.e.*, attracted to light), they are likely to be most abundant near the surface (Klauda et al.1991). Temperature studies have repeatedly demonstrated that Merrimack Station's thermal plume has the greatest influence on surface waters in the southern portion of Hooksett Pool where drifting larvae would likely congregate. One of the earliest studies noted, "Most of the heated water with a significant temperature differential (3°C or better) is restricted to the upper three to four feet of the Hooksett Pond." (Normandeau, D.A. undated). Looking again at Merrimack Station's 21-year temperature data set, the averaged daily mean water temperature at Station S-4 reaches or exceeds 80.1°F (26.7°C) every day but one for the entire month of July (Normandeau 2007b).

While temperatures greater than 80.1°F (26.7°C) represent poor conditions for American shad larvae, shad larvae in Hooksett Pool may also be exposed to lethal temperatures. Fish larvae are generally weak swimmers, making it difficult or impossible for them to avoid or escape stressful thermal conditions. Therefore, in order to assess the potential for lethality to larvae from thermal stress, it is important to identify lethal temperatures and the duration of exposure to those temperatures that results in lethality. According to information provided in Klauda et al. (1991), American shad larvae acclimated to 68.9°F (20.5°C) survived a brief (15 minute) exposure to 88.7°F (31.5°C), but suffered significantly greater mortality when exposed to 92.3°F (33.5°C). According to Merrimack Station's 21-year data set, American shad larvae drifting past Station S-0 as early as May 26 could be exposed to temperatures exceeding 92.3°F (33.5°C). Maximum temperatures exceeding 92.3°F (33.5°C) at Station S-0 have been reported on all but nine dates in June and July (Appendix A).

Similar lethal temperatures were also identified by PSNH's consultant, Normandeau Associates, Inc. According to a 1992 draft report by PSNH, American shad larvae and juveniles small enough to have difficulty avoiding the thermal plume will be present through the month of July (Saunders 1993). This report refers to site-specific studies conducted by Normandeau Associates, Inc., that demonstrate significant mortality occurs at temperatures greater than 91.9ºF (33.3ºC) after only a 30-minute exposure to the plume. This temperature was reached or exceeded at Station S-0, where Merrimack Station's discharge plume enters the river, on all but six dates in the month of June, according to Merrimack Station's 21-year temperature data set (Appendix A). In July, 91.9ºF (33.3ºC) was exceeded on every date at Station S-0, with 13 dates reporting temperatures at or above 100ºF (37.8ºC). Results from similar laboratory bioassay studies conducted in 1975 by Normandeau Associates, Inc., indicated that temperature rises of 18º–20ºF (10º–11.1ºC) for 10 minutes followed by gradual cooling were lethal to larval shad (Normandeau 1976b). Historical temperature data in Hooksett Pool for June and July demonstrate that the difference between maximum ambient river temperatures (Station N-10) and temperatures recorded at the mouth of the discharge canal (Station S-0) routinely exceeded 18ºF (10ºC) (Appendix A). The PSNH report suggests that, based on these study results, restricting temperatures during June and July should be considered (Saunders 1993).

PSNH studied thermal impacts to larval American shad in 1975. The report on this study provided some information on flow rates in Hooksett Pool, but not for the months of June and July. Current speed data collected on August 15, 1975, the closest date to the June-July time period, indicates surface current speed in proximity to the discharge averaged 0.15 knots, or 0.27 feet/second (Normandeau 1976b). This is half the speed calculated by EPA for June (*see* Section 8.3.1.4b). If this accurately reflects typical current speeds when American shad larvae are present, then it could take approximately two hours for a drifting larva to travel the roughly 2,000 feet from Station S-0 to S-4. It is unclear from reviewing the report why Normandeau selected dates in August, October, and December to study thermal effects on drifting American shad larvae when this life stage is not present in Hooksett Pool during those months.

Still another study on the effects on American shad larvae from abrupt changes in temperature found quick rises in temperature from 20° to 25°C (68° to 77°F) and 20° to 30°C (68° to 86°F) were "clearly detrimental" to feeding-stage larvae (Leach and Houde 1999). Under current operations, similar acute temperature changes commonly occur in Hooksett Pool during the month of June at Station S-0.

In the Merrimack River Anadromous Fisheries Investigations: Annual Report for 1976, Merrimack Station identifies both shad eggs and larvae as being potentially entrainable, either directly in the Station's cooling water or in the thermal discharge plume (Normandeau 1976b). The report states,

> *Either form of entrainment may represent a potentially lethal condition depending on hydraulic and mechanical stresses and the time-temperature histories encountered.*

According to a draft report submitted by Merrimack Station to EPA in 1992, in situ and laboratory studies of larval shad temperature tolerances were conducted at the plant in 1975–1976 (Saunders 1993). Based on these studies, the report states,

> *Restrictions on maximum discharge temperatures and ΔT's at the point of discharge may be necessary in the future to protect larval shad.*

EPA has concluded that it is reasonable to expect shad larvae, when present in Hooksett Pool, to be subjected to stressful, and possibly lethal, surface temperatures related to the plant's thermal discharge. This conclusion takes into account the scientific literature on thermal effects described above, including studies conducted specifically for Merrimack Station. It also reflects the discharge temperatures documented at Station S-0 that have been demonstrated to cause lethality in larval American shad, and the larvae's duration of exposure in Hooksett Pool under these thermal conditions.

American Shad – Juveniles

The upper end of the optimal temperature range for juvenile shad is identified as 75ºF (23.9ºC) by both Klauda et al. (1991a) and a study published by the U.S. Fish and Wildlife Service (Stier and Crance 1985). Further, these studies both identify temperatures near 86ºF (30ºC) to be the maximum natural limit for juvenile shad, with 85ºF (29.4ºC) being "completely unsuitable," according to the Habitat Suitability Model developed by Stier and Crance (1985). Average maximum temperatures at Station S-4 exceed 29.4ºC (85ºF) on every date from June 25 to September 3, according to Merrimack Station's 21-year data set (Appendix A). Klauda et al. *(*1991) also noted that juvenile American shad acclimated to 75.2°F (24°C) experienced 50-percent mortality when exposed to 88.9°F (31.6°C). This temperature is reached or exceeded on all but 12 dates during the same summer time period (Appendix A). Marcy et al. (1972) reported that juvenile American shad experienced 100-percent mortality after 4–6 minutes of exposure to 90°F (32.2°C) when acclimated to 66.2°F (19°C). This temperature scenario is similar to conditions found in Hooksett Pool in mid-June when ambient temperatures (*e.g.*, on June 15 at

Station N-10) averaged 67.8°F (19.9°C) and the averaged maximum recorded temperatures at Station S-0 reached 92.9°F (33.8°C). Mortality dropped to only 12.5 percent when fish exposed to 91.2°F (32.9°C) had been acclimated at 72.9°F (22.7°C). This study also references work by Moss (1970) demonstrating that young American shad die rapidly when temperatures are suddenly raised from 75.2°–82.4°F (24°–28°C) to 90.5°F (32.5°C). In July, the mean ambient temperature in Hooksett Pool is 75.2°F (24°C) while the mean temperature where Merrimack Station's discharge plume enters the river at Station S-0 is 91.1°F (32.8°C).

EPA has concluded that water temperatures in lower Hooksett Pool that are affected by Merrimack Station's discharge, as represented by data collected at Station S-4, are poorly suited to provide juvenile American shad habitat during typical summer conditions. This conclusion is supported by Merrimack Station's 1976 report (Normandeau 1976b), which states,

> *After transformation from larvae to post-larvae, juvenile shad become surface-oriented in their feeding behavior, consuming mostly terrestrial insects (Massman, 1963). At this time they may be vulnerable to thermal stresses due to the surface warming caused by the Merrimack Station discharge.*

While out-migrating adult and juvenile shad may be able to avoid stressful temperatures by swimming below the thermal plume, juvenile shad that are residing in the pool could be precluded from feeding at their preferred depths due to the persistence of high temperatures in the upper water column of the lower pool throughout the summer.

5.6.3.3c Atlantic Salmon

Like American shad, anadromous Atlantic salmon were historically an important part of the balanced, indigenous community of the Merrimack River until the construction of dams prevented salmon from reaching natal spawning grounds in the upper reaches of the Merrimack River and its tributaries. And as with American shad restoration, Atlantic salmon restoration in the Merrimack River watershed was, in part, the basis for the temperature criteria in the existing discharge permit, according to written correspondence from NHFGD (1991) and USFWS (1991).

It is unlikely that Atlantic salmon would spawn in Hooksett Pool, or that juveniles would seek refuge there, given that the ambient flow and thermal conditions are largely unsuitable for salmon in this impoundment, especially during summer months. Nevertheless, Hooksett Pool is the only conduit between upstream spawning and juvenile rearing grounds and the ocean, where salmon migrate to grow and mature. Atlantic salmon parr, which are stocked as fry in suitable rearing habitat upstream from Hooksett Pool, undergo morphological and physiological changes known as smoltification in preparation for life in the marine environment (NOAA and USFWS 1999). During this period, salmon smolts begin their downstream migration to the sea. Temperature is strongly correlated with downstream migration (Handeland et al. 2003), and the commencement and cessation of smoltification is triggered by several factors, including water temperature (McCormick et al. 1999). According to biologists at USFWS and NHFGD, Atlantic salmon smolts typically migrate through Hooksett Pool between early April and late May.

Merrimack Station conducted studies in 2003 and 2005 to assess the potential for the plant's thermal plume to impede downstream migration of Atlantic salmon smolts. Merrimack Station concluded that the thermal plume did not create a barrier to the downstream migration of Atlantic salmon smolts, nor did it delay their downstream migration (Normandeau 2006b). EPA and the other reviewing agencies generally concurred with this assessment based on the data provided. Concerns remain, however, as to whether or not smolt exposure to the thermal plume may adversely affect their ability to adapt successfully to life in the marine environment. Studies conducted on migrating smolts in the Connecticut River suggest that temperature is a factor in the loss of smolt characteristics, with exposure to elevated temperatures accelerating the loss of some characteristics, such as seawater tolerance (McCormick et al. 1999). The presence of dams can further delay smolt migration. Smolt probably do not spend much time in Hooksett Pool during outmigration, but they may be foraging en route. The extent to which Merrimack Station's thermal plume affects their foraging behavior and success, if at all, has not been addressed. Higher flows typical of spring river conditions are likely to minimize potential adverse effects of the thermal plume on outmigrating smolts.

The study conducted by Merrimack Station also did not address the possible thermal effects on mature salmon migrating upstream to spawn. At present, poor returns of sea-run salmon and restricted upstream access prevent adult anadromous Atlantic salmon from reaching Hooksett Pool. In fact, most returning salmon are captured at Essex Dam in Lawrence, Massachusetts and transferred to a hatchery for egg production (Normandeau 2007a). Both NHFGD and USFWS are committed to restoring Atlantic salmon to the Merrimack River watershed. Therefore, thermal conditions in Hooksett Pool will have to be protective of in-migrating Atlantic salmon when NHFGD and USFWS determine that the salmon population has sufficiently recovered, and that upstream access to Hooksett Pool is warranted.

5.6.3.3d Smallmouth Bass and Largemouth Bass

As mentioned in the Fisheries Analysis Report, both smallmouth bass and largemouth bass, collectively known as black bass, were introduced into New Hampshire waters during the 1860s. It is unclear exactly when these gamefish species first appeared in Hooksett Pool, but they were present and fairly common in the 1960s. According to electrofishing data provided in the Fisheries Investigations Report (Normandeau 1970), smallmouth represented 4.0 percent of the fish community and largemouth represented 20.7 percent. Again, this information combines juvenile and adult fish caught, which does not provide clear insight into the status of these populations. Nevertheless, prior to the start-up of Merrimack Station's Unit 2, both of these species coexisted with other abundant species, such as yellow perch and pumpkinseed. While the relative abundance for largemouth and smallmouth bass in the 2000s is as high, or greater than those of the 1960s, relative abundance for other species that make up the balanced, indigenous community have declined dramatically. Yellow perch relative abundance, based on electrofishing sampling, dropped three-fold from 19.8 percent to 6.6 percent. Pumpkinseed dropped from 37.8 percent in the 1960s to 2.8 percent in the 2000s. There may be multiple reasons why some species have sustained their ranks within the fish community over the years while others have not. One significant factor that can influence virtually all others is the thermal environment to which these species are constantly exposed.

Black bass are members of the sunfish family (Centrarchidea). Centrarchids are most characteristic of warm-water lakes and sluggish streams (Moyle and Cech, Jr. 2004). Based on temperature requirements identified in the Fisheries Analysis Report, largemouth bass and smallmouth bass are among the most heat-tolerant species found in Hooksett Pool, with largemouth bass preferring warmer temperatures than smallmouth bass (Normandeau 2007a). According to Scott and Crossman (1973), the habitat of largemouth includes the upper levels of the warm water of small, shallow lakes and larger, slow rivers. Black bass are aggressive gamefish whose diets are highly varied, however, they increasingly forage on other fish as they increase in size (Hartel *et al*. 2002). The habitats of smallmouth and largemouth seldom overlap even though the two species often occur in the same lake (Scott and Crossman 1973).

The relatively stable population of largemouth bass in Hooksett Pool over the past 40 years is not surprising given their preference for warm water, and their appetite for a variety of forage, including other heat-tolerant fish species. Based on the information provided in the Fisheries Analysis Report, it appears that the high relative abundance of largemouth bass in the 2000s, particularly in the thermally-influenced portion of the pool, comes at the cost of other species less tolerant to heat. According to Merrimack Station, NHFGD expressed concern in the 1960s that the plant's thermal effects would result in an increase in the largemouth bass population at the expense of other gamefish species (Normandeau 1970). Based on trends data provided in the Fisheries Analysis Report (Table 3-6), the largemouth bass population has fared far better than all other species that were represented in electrofishing sampling in the 1970s.

EPA finds that evidence of stable or increasing largemouth bass and smallmouth bass populations does not, by itself, support Merrimack Station's conclusion that no prior appreciable harm has occurred to the balanced, indigenous population of fish in Hooksett Pool.

It should be noted that it is unknown whether smallmouth or largemouth bass have been stocked in Hooksett Pool over the past 40 years. According to the NHFGD, neither bass species has been stocked by the State during that time period, and the Department is not aware of any private effort to enhance bass stocks in Hooksett Pool (personal communication). Enhancing the bass populations through stocking efforts would confound the ability to accurately conduct a population trends analysis, and may obscure their true status.

5.6.3.3e Pumpkinseed

According to the Fisheries Analysis Report (p.106), the annual catch rate of pumpkinseed by electrofishing within the thermally-influenced zone of Hooksett Pool was highest in 1972 (43.4 fish) and lowest in 2004 (1.0 fish). In 1967, pumpkinseed was the most abundant species in Hooksett Pool. The trends analysis conducted by Merrimack Station for pumpkinseed resulted in a statistically significant negative (decreasing) trend for the years analyzed.

Merrimack Station attributes the dramatic decline in the pumpkinseed population primarily to the introduction of bluegill at some point in the early 1980s (Normandeau 2007a). In fact, however, according to the 1979 Summary Report, bluegills were being caught in seine net sampling as early as 1972. While competition with introduced species such as bluegill may be one factor contributing to the decline of pumpkinseeds, sampling data suggests the decline began before bluegills first appeared in electrofishing and trapnetting samples. According to electrofishing data presented in the Fisheries Analysis Report (p.64), pumpkinseed CPUE in Hooksett Pool declined from 37.65 fish in 1972 to 19.45 fish in 1976. Looking back further to 1967, before Unit 2 came on line, pumpkinseed CPUE was 42.5 fish in Hooksett Pool, based on data provided in Supplemental Report No. 1 (Normandeau 1970).

Pumpkinseed and bluegill are both centrarchids, and as such are generally more tolerant to warm water than coolwater species, such as white sucker and yellow perch. In fact, both species appear to be drawn to it, based on their presence in sampling areas influenced by the thermal discharge. According to a report submitted by Merrimack Station in 1992,

> *Because pumpkinseed are noticeably concentrated in the canal area, the population of pumpkinseed in the Hooksett Pool is most likely to be affected by any event that adversely affects that portion of the population present in the canal. (Saunders 1993).*

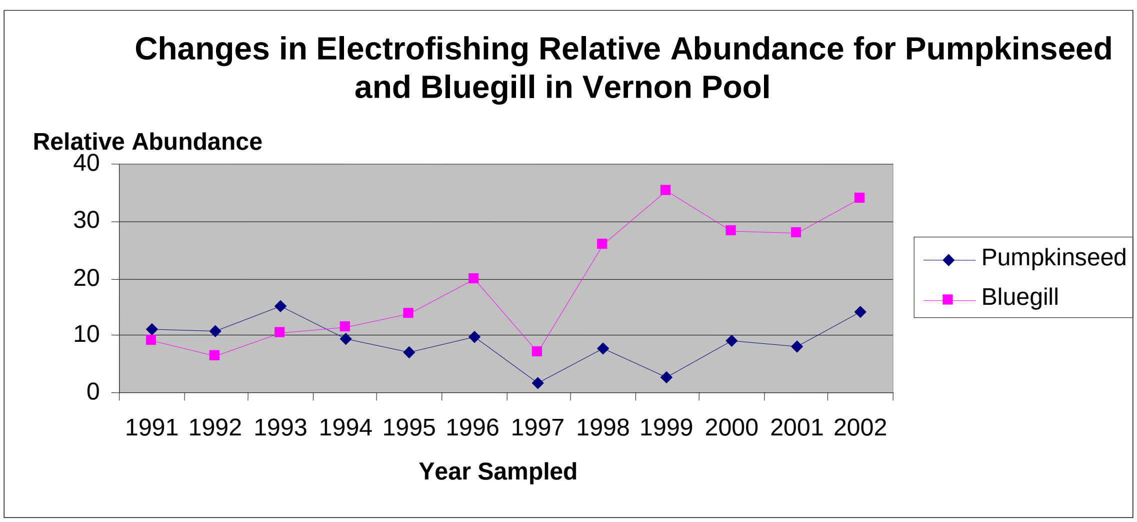
Based on an analysis of population densities throughout the entire pool for the five-year period 1972–1976, this report concluded that 22.4 percent of the pumpkinseed population resided in the discharge canal during summer months (Saunders 1993). Increased competition with bluegills within thermally-affected areas of Hooksett Pool, and possibly increased predation by bass species which are also attracted to the warmer water of the thermal discharge, may have contributed to the dramatic decline of pumpkinseed, however, this was never studied.

Long-term fish sampling in Vernon Pool of the Connecticut River provides an opportunity to review how bluegill and pumpkinseed have co-existed in a nearby river. Vernon Pool and Hooksett Pool are both major river impoundments in New Hampshire that largely share the same resident fish community. Both pools have been subjected to the effects of a thermal discharge from a power plant for approximately 40 years, which is why long-term fisheries data have been collected for these impoundments. Vermont Yankee NPS discharges heated cooling water into

Vernon Pool consistent with discharge limits established in its NPDES permit by Vermont DEC. One conspicuous difference between these pools is their dimensions. While Hooksett Pool is approximately 5.8 miles long with an average depth of 10 feet, Vernon Pool is 26 miles long with an average depth of 16 feet in the thalweg, and depths as great as 40 feet in the thermally-influenced area just above Vernon Dam (Normandeau 2004). In addition, and perhaps more important, is the fraction of available habitat that is subjected to thermal effects from these plants. Merrimack Station is located approximately halfway between the Garvins Falls and Hooksett dams, and its thermal plume has demonstrated its capacity to directly affect roughly 50 percent of the pool during summer months. Vermont Yankee, on the other hand, is located just a half-mile upstream of Vernon Dam, and therefore the thermal discharge can only directly affect approximately 13 percent of the available habitat in Vernon Pool, according to information provided in Vermont Yankee 316(a) Demonstration Document, dated April 2004. In addition, temperature limitations in Vermont Yankee's discharge permit prohibit elevations in water temperature during summer months from exceeding ambient conditions by more than 2°F at a monitoring station downstream of Vernon Dam. Whether or not this is adequately protective, it limits thermal discharges more than the limits in the currently effective Merrimack Station permit.

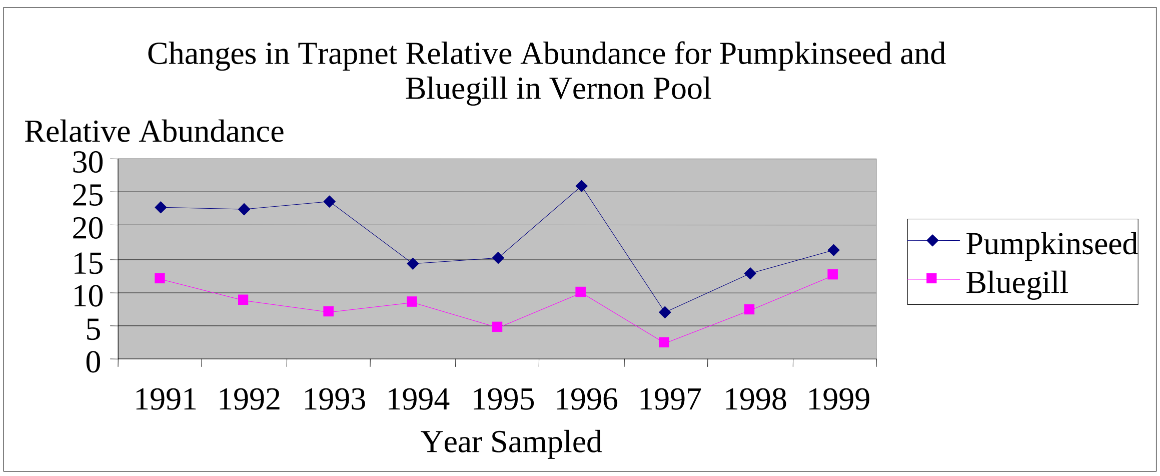
According to electrofishing data collected over a 12-year period (1991–2002) for Vermont Yankee Nuclear Power Station, bluegill relative abundance ranged from 9.0 percent in 1991, to 34.1 percent, in 2002 (Figure 5-10).

Figure 5-10 Changes in pumpkinseed and bluegill relative abundance in Vernon Pool from 1991–2002, based on electrofishing sampling (Normandeau 2004)



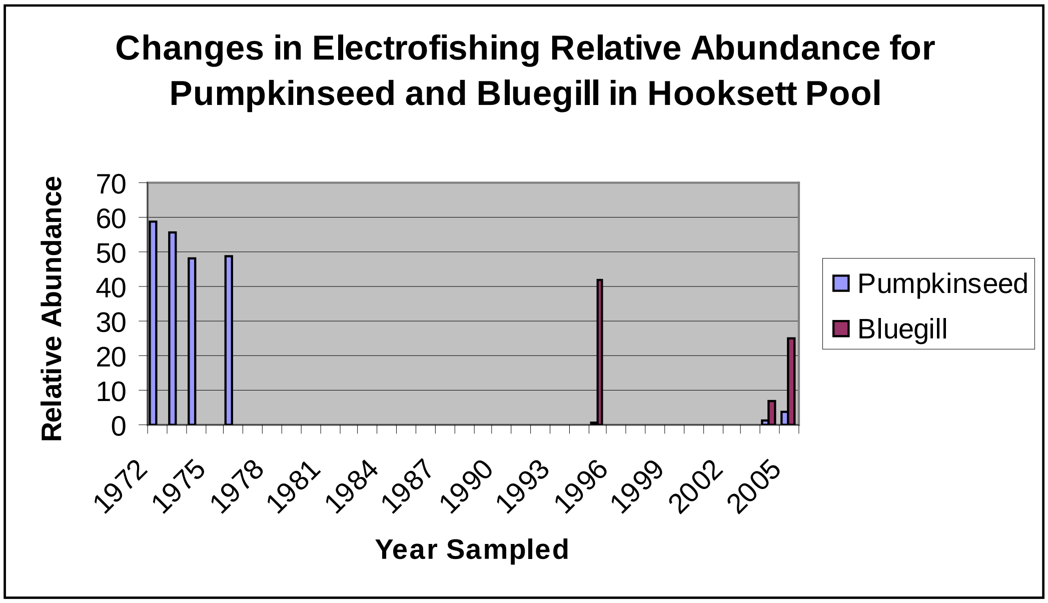
Pumpkinseed's relative abundance ranged from 11.0 percent in 1991 to 14.0 percent in 2002, although the trend varied (Figure 5-10). Trapnet data collected from 1991 to 1999 indicate a slight increase in relative abundance for bluegill (11.9 to 12.4 percent) during that time period. Pumpkinseed declined in abundance from 22.7 to 16.4 percent (Figure 5-11). These data suggest to EPA that while the bluegill population has increased over the periods sampled, the pumpkinseed population has maintained itself as well, and remains one of the numerically dominant species in Vernon Pool. Clearly, the changes in populations of blue gill and pumpkinseed in Vernon Pool are not consistent with the changes exhibited in Hooksett Pool (Figure 5-12). Therefore, it cannot be assumed that the collapse of the pumpkinseed population in Hooksett Pool is simply a result of the introduction of bluegill since both species appear to coexist successfully in Vernon Pool.

Figure 5-11 Changes in pumpkinseed and bluegill relative abundance in Vernon Pool from 1991-1999, based on trapnet sampling (Normandeau 2004)



Electrofish sampling conducted by NHFGD in Garvins Pool on August 6, 2007 provides a limited, but interesting assessment of how pumpkinseeds and bluegills are faring in the impoundment just upstream from Hooksett Pool. Bluegill was second-most abundant with 20.1 percent of all fish caught, while pumpkinseed was ranked third with a relative abundance of 18.9 percent (Table 5-20). This sampling is discussed further in the next section (5.6.3.3f) as it applies to yellow perch, which ranked first. If this sampling accurately represents the Garvins Pool fish community, then it would appear that the populations of these two species (bluegill and pumpkinseed) are similar.

Figure 5-12 Changes in pumpkinseed and bluegill relative abundance in Hooksett Pool for select years between 1972 and 2005, based on electrofishing sampling (Normandeau 2004)



Note: Years that display no data represent gaps in data collection.

The interactions of these fish species in response to changes in their thermal environment is complex. Nevertheless, under no reasonable interpretation of potential causes and effects can a persuasive argument be made that the decline of pumpkinseed, from being the most abundant fish species prior to the start-up of Unit 2 to one that has virtually disappeared in the mid-2000s, supports a finding of no prior appreciable harm to the balanced, indigenous population of fish in Hooksett Pool. To the contrary, a reasonable argument can be made that increased thermal discharges related to the operation of Unit 2 have contributed to the decline of pumpkinseed by altering the thermal environment in much of the Hooksett Pool, in combination with the introduction of heat-tolerant, non-native species, such as bluegill.

5.6.3.3f Yellow Perch

Thermal Effects on Reproduction

Yellow perch are uniquely adapted to seasonal variations associated with a temperate climate (Hokanson 1977). Gonadal development in yellow perch is dependent, among other factors, on the occurrence of a minimum overwintering water temperature that must be maintained for a specific duration, often referred to as a “chill period”. Adults must be exposed to this extended period of cold water temperatures to ensure the ripening of eggs (Krieger *et al.*, 1983). Based on studies conducted by Hokanson (1977), adult yellow perch must be exposed to water temperatures between 39.2 and 50ºF (4 and 10ºC) for 160–240 days (5.3–8 months) in order for eggs to fully develop.

Unfortunately, Merrimack Station's assessment of thermal effects for yellow perch is largely limited to predicting the amount of habitat that may be adversely affected by elevated temperatures that meet or exceed established "avoidance" temperatures. Temperature effects on gonadal development in yellow perch are not mentioned in the Fisheries Analysis Report. According to the report (p.110), "Spawning and life history thermal requirements need only be examined from April to early-May when yellow perch are known to be actively spawning (Scarola 1987)." Merrimack Station makes no mention of the potential impacts related to the attractive influence of the thermal discharge during winter periods. EPA discusses these potential impacts below.

Merrimack Station typically discharges approximately 256 million gallons of heated water per day into a 1,200 meter-long naturalized canal, which then flows past 54 power spray modules into Hooksett Pool. According to Merrimack Station's 21-year temperature data set, average daily mean ambient water temperatures dropped below 50.0ºF (10ºC) on October 26 and rose above 10ºC on May 1 (Normandeau 2007b). This period (188 days) is of minimally sufficient length to ensure full gonadal development in yellow perch (Hokanson 1977). Temperature data collected within the discharge canal in 1994–1995 averaged 57.6ºF (14.2ºC) in December and 60.6ºF (15.9ºC) in March. No temperature data was collected in January or February. While the spatial extent of Merrimack Station's thermal plume in Hooksett Pool appears to be reduced during winter months, fish sampling data suggest it has a strong attractive influence on yellow perch. Electrofishing sampling conducted by Merrimack Station in March 1995 revealed high catch rates in the canal compared to river sampling. The CPUE of yellow perch in the canal was 65.97 fish versus 0.00, 0.00, and 0.25 fish at three sites in the river. Electrofishing sampling within the canal in December 2005 provides similar results. The yellow perch CPUE in the canal (Station 18) was 70.0 fish. In contrast, yellow perch were caught at only one of ten river sampling stations in December 2005. At that location (Station 14W), one yellow perch was caught. On December 12, 2005, when 70 yellow perch were caught in the canal, temperatures in the canal ranged from 57.8ºF (14.3ºC) on the surface to 49.8ºF (9.9ºC) on the bottom. Temperatures at sampling stations in the river were approximately 34.9ºF (1.6ºC) throughout the entire water column.

While yellow perch reproduction strategies appear to have evolved in response to prolonged winter ambient temperatures of 10ºC or lower, the elevated temperatures in the discharge canal during winter months more closely correspond with otherwise preferred yellow perch temperatures of 64–77ºF (17.8–25.1ºC) (Krieger et al. 1983). According to Merrimack Station, the canal population of yellow perch sampled by electrofishing represented a significant portion of the overall Hooksett Pool population on an annual basis (Normandeau 1997). Yellow perch catches were highest within the "winter chill" period, with the highest CPUE in March. Even periodic excursions into elevated temperatures during the winter chill would reduce the required exposure to temperatures at or below 10ºC. This could result in incomplete gonadal development and reduced production of viable eggs if the minimum duration of exposure by yellow perch to temperatures at or below 10ºC is not reached. Studies to determine the extent of time that yellow perch or other species remain within the discharge canal during the winter chill period have never been conducted at Merrimack Station.

Thermal Effects on Spawning Success

Spawning activity of yellow perch is triggered by rising water temperatures, change in photoperiod, maturation of eggs, or some combination of the three (Hokanson 1977, Krieger et al. 1983), however, local environmental factors are a strong influence (Hokanson 1977). Yellow perch release gelatinous, semi-buoyant eggs, often onto submerged aquatic or inundated terrestrial vegetation (Krieger et al. 1983). Water temperature affects the progress and success of yellow perch early lifestage development, which includes two distinct embryonic stages and two larval stages (Hokanson 1977). Spawning temperatures appear to correspond closely with embryo thermal tolerances, ranging from 42.8–69.8ºF (6–21ºC), but the minimum temperature required for larvae to initiate feeding has been observed to be about 50.0ºF (10ºC) (Hokanson 1977). Since water in the discharge canal reach temperatures appropriate for spawning earlier than ambient water in Hooksett Pool, yellow perch attracted to the warmer waters of the discharge canal could be spawning early. If yellow perch are spawning prematurely in the discharge canal (*i.e.*, less than 160 days of gonadal development), egg viability would likely be adversely affected. Even if March water temperatures in the canal are appropriate for the survival of eggs and newly hatched larvae, once larvae develop the ability to swim they would likely be carried down current and out into the river. The average river temperature in March (41.9ºF [5.5ºC]) could kill larvae outright, or impair their ability to feed effectively, based on established temperature requirements for yellow perch larvae (Hokanson 1977).

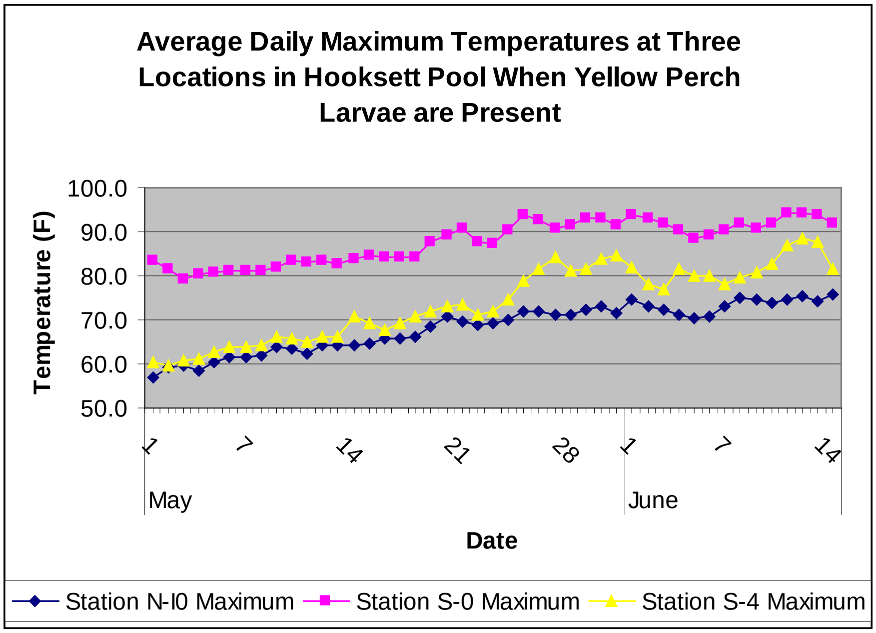
Merrimack Station conducted icthyoplankton sampling over an eight-week period from May 10 to June 27, 1995. Samples were collected upstream from the discharge, within the mixing zone in the thermal plume, and in the thermally-influenced area downstream. The reported findings suggest that yellow perch larvae could have been present before the sampling season started since yellow perch larvae were caught only during the first two sampling dates, and that larva densities were higher on the first date than the second (0.6 versus 0.2 per 50m^3) (Normandeau 1997). Given that the stated purpose of the icthyoplankton sampling was to assess the potential for entrainment of yellow perch larvae in the thermal plume at Merrimack Station, it appears that larvae may have been present earlier than expected. Ichthyoplankton entrainment studies conducted for Merrimack Station in 2006 and 2007 first captured yellow perch larvae during the first week in May, and every week thereafter until the second week in June (Normandeau 2007c). These samples were taken at the intake structure upstream from the discharge, and therefore would not reveal early spawning activity in the discharge canal.

Thermal Effects on Larva Survival

Icthyoplankton studies conducted by Merrimack Station in 1995 concluded that yellow perch larvae do become entrained in the plant's thermal plume (Normandeau 1997). Further, the report states the proportion of the Hooksett Pool population of yellow perch larvae subjected to the plume appears to be approximately the same as the proportion of Hooksett Pool water contained by the plume. According to this report (Normandeau 1997), although yellow perch larvae do occur in the Merrimack Station thermal plume, this does not occur at times when temperatures are potentially lethal. Merrimack Station refers to a compendium of temperature tolerance data compiled by Wismer and Christie (1987) to argue that yellow perch larvae tolerate temperatures as high as 92.7°F (33.7°C). That temperature, as presented by Wismer and Christie (1987), was the upper incipient lethal temperature (UILT) so the endpoint was mortality of some predetermined fraction of the sample. In that particular study, 50 percent of the fish tested died after only <u>ten minutes</u> of exposure (Wismer and Christie 1987). Further, Merrimack Station's report fails to mention that results from other studies presented in Wismer and Christie (1987) identify temperatures resulting in lethality as low as 79.7°F (26.5°C).

Koonce et al. (1977) reported larvae daily mortality rates at 3°C intervals from 37.4°F (3°C) through 86°F (30°C). According to this study, upper temperature lethal effects ranged from 45 percent mortality at 80.6°F (27°C) to 100 percent mortality at 86°F (30°C) (Koonce et al. 1977). Studies conducted by Hokanson and Kleiner (1974) studying the effects of temperature on the survival and developmental rates of embryonic and larval yellow perch found the upper median temperature tolerance limit ("TL50") for larvae in the swim-up phase to be 65.8°F (18.8°C) when embryos were exposed to constant temperatures soon after fertilization, and 72.5°F (22.5°C) when exposed to temperature extremes at an older stage of development. The TL50 is the maximum temperature for which survival is equal or greater than 50 percent of the optimum response, which for these studies were 67.8°F (19.9°C), and 73.2°F (22.9°C) for normal hatch (Hokanson and Kleiner 1974).

Figure 5-13 Comparison of the Measured Average Daily Maximum Water Temperature at Three Monitoring Stations in Hooksett Pool During Period When Yellow Perch Larvae are Present, Based on 21 Years of Temperature Monitoring Data (1984-2004)



According to the data on thermal tolerance of larval yellow perch presented in the peer-reviewed scientific literature discussed, adverse impacts leading to reduced survival to larval yellow perch have been observed at temperatures as low as 65.8°F (18.8°C) (Hokanson and Kleiner 1974). Temperatures as low as 79.7°F (26.5°C) have been identified as the upper incipient lethal temperature for larval yellow perch (Wismer and Christie 1987). Further, Wismer and Christie (1987) observed lethality of yellow perch larvae after 30 minutes of exposure to 88.3°F (31.3°C), and 10 minutes at 92.7°F (33.7°C), when acclimated to 59.0°F (15.0°C). This acclimation temperature is more consistent with May temperatures and those of June, for Hooksett Pool. Wismer and Christie (1987) also cite studies of yellow perch juveniles, a life stage that tends to be more tolerant than larvae or adults to elevated temperatures. Wismer and Christie (1987) identify 89.6°F (32.0°C) as the temperature causing lethality after 60 minutes, and 93.2°F (34.0°C) causing lethality after 15 minutes. These are based on an acclimation temperatures of 71.6–73.4°F (22–23°C), which are typically higher than average ambient conditions found in Hooksett Pool in June. Lower acclimation temperatures generally equate with lower tolerance to heat.

According to Merrimack Station's 21-year temperature data set, average daily maximum water temperatures at Station S-0 during the period when larval yellow perch were collected at Merrimack Station's intake structures (Station N-5) in 2006–2007 (May 1–June 14) ranged from a low of 79.2°F (26.2°C) on May 3 to a high of 94.3°F (34.6°C) on June 12. Based on yellow perch temperature tolerances provided in the scientific literature, and long-term temperature data collected by Merrimack Station, it appears likely that yellow perch larvae were exposed to potentially lethal temperatures within Merrimack Station's thermal plume. Average daily maximum temperature data provided by Merrimack Station indicates that temperatures at Station S-0 can exceed 88.3°F (31.3°C) as early as May 20, and can exceed 89.6°F (32.0°C) as early as May 22 (Normandeau 2007b). Temperatures well exceeding 89.6°F (32.0°C) at Station S-0 continue for the duration of the yellow perch larval period, which EPA estimates to be June 15 based on Merrimack Station's entrainment studies (Figure 5-13).

During the period when larval yellow perch are likely to be present, the conditions in Hooksett Pool resulting from Merrimack Station's thermal discharge are not protective of this lifestage. Consistent with this conclusion, Merrimack Station stated the following in a 1992 report (Saunders 1993), which states (p.5-2):

> *Because perch larvae may encounter the thermal plume at or near the surface during their pelagic phase, maximum discharge temperatures could potentially affect this species.*

The report goes on to conclude that (p.5-3):

> *Available information indicates that summer temperatures restrictions may be necessary to protect the most vulnerable resident species life stage (larval perch) from the warmest areas of the thermal plume during May and June.*

Thermal Effects on Juvenile and Adult Stages

The following is from Merrimack Station's thermal habitat analysis for yellow perch in the Fisheries Analysis Report (Normandeau 2007a):

> *Within lower Hooksett Pool, the avoidance temperature [83ºF/28.3ºC] was not exceeded during seven of the nine sampling events. On 21 June 1995, temperatures in excess of 83ºF were recorded at Monitoring Stations S0 and S4. River water temperatures that exceeded yellow perch avoidance limits occurred with 4.7% of the habitat available in the lower Hooksett Pool (also comprising 2.6% of the total Hooksett Pool habitat. This volume of water was limited to the upper four feet of the water column at S0 and the upper foot of the water column at S4. Temperatures greater than 83ºF on 14 September 1995 represented 1.8% of the habitat available in the lower Hooksett Pool (comprising 1.0% of the available Hooksett Pool habitat) and were limited to the upper 3 feet of the water column at S0.*

As previously explained, EPA concludes that Merrimack Station's thermal habitat analysis is based on insufficient temperature data and fails to accurately represent summer conditions in

Hooksett Pool. Therefore, Merrimack Station's thermal habitat analysis does not provide convincing evidence of the scope of thermal impacts to fish habitat in Hooksett Pool from the plant's discharge. To strengthen the analysis, EPA reviewed additional temperature monitoring data collected and submitted by Merrimack Station for the 21-year period from 1984 to 2004. According to these data, average daily maximum water temperatures on 30 of the 62 days in July and August reached or exceeded 100ºF (37.8ºC) at Station S-0, with the highest temperature reaching 104ºF (40.0ºC). Average daily maximum water temperatures exceeded 83.0ºF (28.3ºC) – the temperature Merrimack Station identified as an avoidance temperature for adult and juvenile yellow perch – every day at Station S-4 from June 15 to September 10. By comparison, average daily maximum temperatures in the ambient zone during the same period remained below 83ºF (28.3ºC) for 69 of the 88 days.

Length-weight relationships were studied by Merrimack Station in 1975 and 1976 for three species, including yellow perch. The Merrimack River Monitoring Program Report of 1976 stated that it had analyzed length-weight relationships, which reflect the condition, or "robustness," of the fish (Normandeau 1977). According to this report (p.108), data analysis for yellow perch collected at Station S-2-W may suggest deleterious conditions that worsened yellow perch condition. The report goes on, however, to suggest that there is no evidence of thermal effects (Normandeau 1977).

Merrimack Station identifies 77ºF (25ºC) as being the preferred temperature for yellow perch (Normandeau 2007a). According to Merrimack Station's 21-year water temperature data set, the averaged daily mean water temperature at Station S-4 exceeded 77ºF (25ºC) every day from June 25 to September 4 (72 days). Upstream from the discharge at Station N-10, it was exceeded on only two days during that time period. Of the 64 yellow perch captured during electrofishing sampling in July and August of 2004 and 2005, 80 percent (51 fish) were collected in the ambient zone upstream of the discharge. Of the 13 remaining fish, 11 were captured where bottom temperatures were reported to be 77ºF (25ºC), or lower. Trapnetting results for the same time period (*i.e.*, August and September of 2004 and 2005) resulted in the capture of only one yellow perch, a juvenile, which was caught in the ambient zone at Station 1E. Merrimack Station has estimated that 71.3 percent of available habitat in lower Hooksett Pool exceeded the preferred temperature for yellow perch during thermal studies conducted on 11 July 1978 (Normandeau 2007a). Seining studies conducted by Merrimack Station from 1973 to 1976 demonstrated that juvenile yellow perch and other non-centrarchid species (*e.g.*, white sucker) regularly abandoned Stations S-0 and S-2 during July and August (Normandeau 1977). Juvenile yellow perch were captured primarily from waters ranging from 69.8–77°F (21–25°C), according to Merrimack Station's 1976 Monitoring Program Report.

Interspecies Competition

Merrimack Station offered competition for food between yellow perch and bluegill as a possible explanation for the dramatic decrease in yellow perch abundance and increase in bluegill abundance (Normandeau 1997). According to the Merrimack Station Fisheries (Bow) Study, yellow perch and bluegill share a common preference for benthic food items, and if food items are limited, competition for benthic food resources may partially explain the reduction in yellow perch abundance (Normandeau 1997).

During summer months, when higher temperatures prevail, physiological rates, demand for resources, and the intensity of interspecific interactions are likely to be at a maximum (Brandt et al. 1980). Therefore, one plausible reason why bluegills can out-compete yellow perch in Hooksett Pool is that they prefer, and are more tolerant of, elevated temperatures. Studies conducted by Taniguchi et al. (1998) on competitive interaction of three species (brook trout, brown trout, and creek chub) demonstrated that, as temperature increased, the more thermally-tolerant species competed more successfully. In that study, both competitive interactions and loss of appetite were identified as reasons for changes in food consumption, with competition being responsible for initial changes when temperatures were increased (Taniguchi et al. 1998). Tidwell et al. (1999) looked at the effect temperature has on growth and survival of yellow perch under culture conditions, and found that 82.4°F (28°C) represents actual stress conditions. Survival was significantly lower in juvenile yellow perch raised at 82.4°F (28°C) than in perch raised at 68.0°F (20°C) or 75.2°F (24°C) (Tidwell et al. 1999). By comparison, preference and avoidance temperatures calculated for bluegill acclimated to 80.6°F (27°C) were 87.3°F (30.7°C) and 92.3°F (33.5°C), respectively (Peterson and Schutsky 1976). From 1984 to 2004, the averaged daily maximum temperature exceeded 28°C (82.4°F) at Station S-4 every day from June 10 to September 10 (93 days).

On August 7, 2006, NHFGD conducted electrofish sampling in the Garvins Pool of Merrimack River downstream of Concord. While the primary objective was to assess black bass populations, sampling for non-target species of the larger fish community was conducted, as well. Of the 51 fish collected, the three most abundant species were largemouth (10 fish), bluegill (10 fish), and yellow perch (9 fish) (NHFGD 2006). NHFGD returned a year later (August 6, 2007) and conducted more extensive electrofish sampling. Of the nine species captured including black bass, yellow perch was, by far, the most abundant (Table 5-20). In fact, in the impoundment just upstream from Hooksett Pool, yellow perch were nearly twice as abundant as bluegill, the next most-abundant species (NHFGD 2007).

In order to assess how populations of yellow perch have fared in another New Hampshire river where bluegills were also introduced, EPA again reviewed fisheries data collected in the Vernon Pool of the Connecticut River. According to the 316(a) Demonstration Document developed for Vermont Yankee Nuclear Power Station, dated April 2004, yellow perch is by far the most abundant species in Vernon Pool today, and has been at least since 1991. This is based on both electrofishing and fyke net sampling described in Vermont Yankee's 316(a) Demonstration Document (Normandeau 2004). The relative abundance of yellow perch has averaged 35.5 percent in Vernon Pool from 1991–2002, based on electrofishing data. Relative abundance of yellow perch was even higher when sampled with trapnets, representing 44.7 percent of the fish community from 1991–1999. Despite increased competition associated with the introduction of bluegill and other centrarchids (*e.g.*, rock bass), the yellow perch population in Vernon Pool remains robust. There are many variables that can affect interspecies competition. One reasonable explanation for the dramatic difference in yellow perch populations found in Vernon and Hooksett pools is the percentage of available habitat that is beyond the direct influence of the thermal discharges.

Table 5-20 Results from fish population assessments conducted by NHFGD (2008) in the Merrimack River above Garvins Falls, Concord, NH on August 6, 2007

Species	Mean Relative Abundance (fish/hour)	Percent of total	One Standard Deviation
Yellow perch	214.2	33.0	+120.8
Bluegill	111.6	17.2	+110.7
Pumpkinseed	102.6	15.8	+94.4
Largemouth bass	94.6	14.6	+74.1
Chain pickerel	34.2	5.3	+79.6
Black crappie	32.4	5.0	+41.3
Redbreast sunfish	25.2	3.9	+25.2
Golden shiner	12.6	1.9	+30.2
Smallmouth bass	12.4	1.9	+20.4
Common white sucker	5.4	0.8	+10.7
Brown bullhead	3.6	0.6	+6.7
Total	648.8	100	

Status of Yellow Perch in the Merrimack River

Prior to 2008, no "farfield" studies had been conducted by PSNH to assess differences in fish populations within and beyond the influence (*i.e.*, beyond Hooksett Pool impoundment) of Merrimack Station's thermal discharge. Fisheries data were collected in Amoskeag Pool, the impoundment directly below Hooksett Pool, from 1967–1969, but Amoskeag Pool does not represent a true far-field site because elevated temperatures associated with Merrimack Station's thermal discharge are also recorded in Amoskeag Pool, directly below Hooksett Dam (Normandeau 2007b). There are, however, three relatively current studies that provide useful information on fish populations just above Garvins Falls. This location, Garvins Pool, represents an ideal reference site for studying impacts to Hooksett Pool. Garvins Pool is close to Hooksett Pool, but is upstream from the plant's thermal plume, and maintains a distinct population of resident fish species due to the physical separation by Garvins Falls Dam. Some fish no doubt "drop down" into Hooksett Pool from Garvins Pool, particularly during their drifting larval stage; an early lifestage characteristic of some species such as yellow perch.

The first two studies, conducted by NHFGD, were discussed in the previous section (Interspecies Competition). The third was a study of yellow perch and white sucker populations conducted by PSNH, in 2008. The results of this study were presented to EPA in a report, dated June 2009 (Normandeau 2009a). Electrofish sampling was conducted on three dates between April 14 and May 2, and six dates between September 1 and October 10, 2008. Sampling occurred in waters above Garvins Falls Dam (Garvins Pool), in Hooksett Pool, and in Amoskeag Pool. EPA calculated the catch per unit effort for yellow perch caught in each impoundment, which are presented in Table 5-21. Based on these data, yellow perch appear to be considerably more abundant in Garvins Pool than in Hooksett or Amoskeag pools.

Table 5-21 Electrofishing catch per unit effort data for yellow perch based on sampling conducted for Merrimack Station in 2008 (Normandeau 2009a)

Catch per unit effort (fish/1,000 ft. sampled)	Garvins Pool	Hooksett Pool	Amoskeag Pool
	5.24	0.52	0.16

Looking more broadly to other rivers in New Hampshire, EPA considered again the status of yellow perch in Vernon Pool of Connecticut River, as discussed above (interspecies competition). Other sampling in the Connecticut River provides additional compelling evidence that yellow perch populations are robust compared to those of other species. For example, a 2008 study of the Connecticut River fish assemblage (Yoder and Hersha 2009) in New Hampshire found yellow perch to be among the top three most-abundant species in the four sampling areas where yellow perch would be expected to be found (*i.e.*, slower flowing, impounded sections). In two of these four sections, yellow perch abundance was more than three times greater than the next most-abundant species. Additionally, electrofish sampling conducted by NHFGD in 2007 found yellow perch to be, by far, the most abundant species in one location in the Connecticut River, and third-most abundant in another (NHFGD 2007). The thriving yellow perch populations in New Hampshire sections of the Connecticut River, and even in the Merrimack River, just above the influence of Merrimack Station's thermal plume, clearly indicate that the poor status of the yellow perch population in Hooksett Pool does not merely reflect a state- or region-wide phenomenon.

Cumulative Effects

Of all the resident species that comprise the balanced, indigenous community in Hooksett Pool, yellow perch appears to be the most vulnerable to the effects of Merrimack Station's thermal discharge. The thermal discharge has the capacity to adversely affect every life stage.

In addition to the thermal stress, yellow perch experiences mortality from the entrainment of larvae and the impingement of juveniles and adults by the plant's cooling water intake structure. According to entrainment sampling conducted in 2006 and 2007, Merrimack Station estimated that 49,671 and 443,750 yellow perch larvae were entrained by the plant during 2006 and 2007, respectively (Normandeau 2007c). By Merrimack Station's calculations, this early lifestage mortality is equivalent to the loss of 22 adult perch in 2006 and 195 perch in 2007. No yellow perch eggs were reported to have been entrained during sampling.

Merrimack Station estimates that 297 yellow perch were impinged in "Year 1" (June 2005–June 2006), and 39 were impinged in "Year 2" (July 2006–June 2007). If 100-percent mortality is assumed, which EPA does expect given the design of Merrimack Station's existing fish return system, the loss in adult equivalents is 110 yellow perch in Year 1 and 31 perch in Year 2. By combining 2006 entrainment data with Year 1 impingement data, and 2007 entrainment data with Year 2 impingement data, the total loss of adult yellow perch from entrainment and impingement in 2006/Year 1 is estimated to be 132 fish, and 226 fish in 2007/Year 2. These numbers of fish lost to entrainment and impingement are considerable given that the total number of yellow perch caught during electrofishing and trapnet sampling, conducted from April through December, was 101 fish in 2004, and 117 fish in 2005. In addition, many of the fish caught in 2004 and 2005 sampling were juveniles and, as such, the total number of yellow perch representing adult equivalents would be appreciably lower in both years sampled.

5.6.3.3g Fallfish

As Merrimack Station noted in the Fisheries Analysis Report (p.112), adult fallfish inhabit clear, flowing, gravel-bottomed streams and lakes, while the young prefer more rapid water upstream. This preference for higher flow is supported by the predominance of fallfish in the more lotic habitat upstream of Merrimack Station's discharge. However, prior to the start-up of Unit 2 in

1968, fallfish were more evenly distributed throughout Hooksett Pool, according to data provided by Merrimack Station (Normandeau 1970).

Fish sampling results indicate that the abundance of fallfish in Hooksett Pool has been relatively low since sampling commenced in 1967. While there is some evidence in the sampling data indicating a shift in habitat use away from the thermally-influenced areas south of the Merrimack Station's discharge during summer months, the more lotic flow conditions found in the northern portion of Hooksett Pool may generally be preferred by fallfish. Based on electrofishing data collected and analyzed by Merrimack Station, there does not appear to be a declining trend in the fallfish population over the period examined. While evidence of a stable, albeit small, fallfish population in Hooksett Pool is encouraging, it may reflect, to some degree, their preference for higher flows found predominantly upstream of the station's cooling water discharge. If so, then thermal impacts to fallfish from the plant's heated discharge would be less likely to occur. Regardless of the reason, it nevertheless appears from the information provided that the plant's thermal discharge has not had a detrimental impact on the Hooksett Pool's fallfish population.

5.6.3.3h White Sucker

Sampling conducted by NHFGD in 1967 identified common white sucker as the fourth-most abundant species in Hooksett Pool prior to the start-up in 1968 of Unit 2 (Wightman 1971). Based on its high abundance, white sucker was identified as a "representative finfish species" in the 1979 Summary Report. According to data presented in the Fisheries Investigations Report (Normandeau 1970), white suckers were evenly distributed north and south of the discharge canal in 1967 with trapnetting catch rates (CPUE) of 6.96 fish (northern stations) and 6.65 fish (southern stations). In the 1970s, according to the Fisheries Analysis Report (p.74), the average CPUE in the northern stations was 9.8 fish compared to 12.2 fish in the southern stations, for all years reviewed. By the 2000s, the average CPUE had plummeted to 0.2 fish in the northern stations and 0.1 in the southern stations.

In the 1976 Monitoring Program Report (Normandeau 1977), Merrimack Station described a similar decline of white sucker subjected to the thermal effects of a power plant. According to a study conducted in the Ohio River cited in the report, white sucker was the most deleteriously affected species by thermal addition to the Ohio River; prior to plant start-up, white suckers were distributed throughout the river. Merrimack Station's 1976 Monitoring Program Report provides the following additional information about white sucker:

> *Field observations have shown that adult white suckers prefer temperatures less than 27ºC although they have been observed in 31ºC waters. Stauffer et al. (1976) reported that 90% of the white suckers captured in the New River, VA, were inhabiting waters cooler than 23.3ºC. White suckers avoided thermal discharge areas when the water temperature was higher than 26.7ºC. Yoder and Gammon (1976) found that Ohio River white suckers near the J.M. Stuart power*

station were confined throughout the summer to backwater zones at temperatures of 25-27ºC. Trembley (1960; cited in Brown, 1974) reported white suckers in the Delaware River congregating at the cooler end of (23.9ºC) of a heated lagoon. When chased into 32.2ºC waters, some suckers died.

This 1976 report by Merrimack Station suggests that while white sucker is perhaps the least thermally-tolerant resident species in Hooksett Pool, their abundance both north and south of the discharge indicates successful growth and reproduction (Normandeau 1977). The report concludes that existing Merrimack Station discharges appear to have had no discernible deleterious effects on Hooksett Pool white suckers.

Thirty years later, Merrimack Station maintains the same conclusion despite significant reductions in both pool-wide trapnet CPUE, from 11.0 fish in the 1970s to 0.1 fish in the 2000s, and relative abundance, from 18.2 percent in the 1970s to 2.1 percent in the 2000s (Normandeau 2007a).

Thermal Effects on Larva Survival

According to Merrimack Station's Fisheries Analysis Report (p.116), a visual inspection of the thermal plume data from the 1995 and 1978 Thermal Studies revealed that the UILT for white sucker was not reached within the upper or lower Hooksett Pool during the April 1 – November 1 period. Additionally, Merrimack Station states (p.116) that in lower Hooksett Pool, under summer conditions of low flow and warm ambient conditions, water temperatures are predicted to exceed the UILT for white sucker during the extreme case on 16 days, with a probability of occurrence of one year out of every 100 years.

As EPA discussed in Section 5.6.3.2a of this document, the temperature data set used by Merrimack Station underestimates typical summer conditions in Hooksett Pool. Alternatively, there is long-term data collected at monitoring stations N-10, S-0, and S-4 that are representative of conditions in Hooksett Pool. EPA considers these data more reliable for assessing if and when white suckers may be exposed to temperatures that could cause lethality (*i.e.*, UILT).

Entrainment studies conducted for Merrimack Station in 2006 and 2007 indicate white sucker larvae are present in Hooksett Pool as early as the second week of April, peaked during the first week in June, and continued to be present through the first week of July (Normandeau 2007c). Published studies on heat tolerance of white sucker larvae, acclimated to temperatures similar to ambient conditions in Hooksett Pool during that time period, identify upper incipient lethal temperature ranging between 86.0–89.1ºF (30.0–31.7ºC), according to data compiled by Wismer and Christie (1987). EPA reviewed the temperatures that white sucker larvae could be exposed to in Hooksett Pool. Based on a 21-year temperature data set provided by Merrimack Station, the averaged daily maximum temperature at Station S-0 exceeds the UILT for white sucker larvae on June 4 when larva concentrations in Hooksett Pool were at peak abundance. On July 2, the last date when white sucker larvae were collected, the average daily maximum temperature exceeds the UILT for white sucker larvae at both stations S-0 and S-4 (Table 5-22).

Table 5-22 Measured average daily maximum and mean temperatures for stations N-10, S-0, and S-4 on three dates when white sucker larvae were collected in Hooksett Pool

Station		April 9[1]		June 4[2]		July 2[3]	
N-10 (ambient)	mean T	44.2F	6.8C	63.9F	17.7C	73.6F	23.1C
	max T	55.9F	13.3C	71.2F	21.8C	79.3F	26.3C
S-0	mean T	62.4F	16.9C	82.7F	28.2C	88.3F	31.3C
	max T	70.9F	21.6C	90.3F	32.4C	95.4F	35.2C
S-4	mean T	47.6F	8.7C	67.3F	17.6C	80.2F	26.8C
	max T	56.8F	13.8C	81.7F	27.3C	89.2F	31.8C

1 Earliest date white sucker larvae were collected during entrainment studies in 2007 (Normandeau 2007c)

2 Date of peak abundance for white sucker larvae during entrainment studies in 2007 (Normandeau 2007c)

3 Latest date white sucker larvae were collected during entrainment studies in 2006 (Normandeau 2007c)

Note: Data in bold denote temperatures within, or exceeding, the range of temperatures established as the UILT for white sucker larvae.

The averaged daily "mean" temperature at Station S-0 on July 2 is also within the range of temperatures identified as UILT for white sucker larvae (Table 5-22). These data indicate that white sucker larvae are routinely exposed to temperatures identified as the UILT for the species during the later portion of their larval period, not one year in a hundred, as Merrimack Station suggests.

The Fisheries Analysis Report also provides UILT exposure information for white sucker in the discharge canal. According to the report (p.116), temperatures exceeding the UILT for white sucker are predicted on 121 days (extreme case) and 95 days (median case). Although the plant's cooling water discharge canal is described by Merrimack Station as the "artificial habitat within the man-made structure," over a million white sucker larvae pass through the canal each year after having been drawn into the plant's cooling water intake structure, and exposed to temperatures 23.8ºF (13.1ºC) above ambient.

White sucker fry begin feeding near the surface on plankton until their yolk sac is completely absorbed (Twomey et al. 1984). According to Twomey et al. (1984), this typically occurs in 20 to 29 days, when fry have reached 14 to 18 mm in size. Twomey et al. (1984) notes that young suckers in the surface-feeding stage appear to congregate in eddies and backwaters in response to gentle currents. After the yolk sac is absorbed, a white sucker's mouth moves from a terminal to ventral position, and there is a shift to bottom feeding (Scott and Crossman 1973). While no recent sampling has been conducted in Hooksett Pool targeting post-larval juvenile white suckers, the presence of larvae in early April sampling (2007) indicates that young-of-year juveniles may be present in Hooksett Pool as early as the beginning of May, based on a 29-day maturation period (Twomey et al. 1984).

Thermal Effects on Juvenile and Adult Life Stages

Juvenile white sucker were commonly captured during immature fish seining studies conducted from 1973 to 1976 in nearshore shallows (Normandeau 1979). While white sucker was one of two predominant species caught during these surveys, they were absent at sampling stations S-0 and S-2 when temperatures reached their seasonal maximum (29.4 – 34.0ºC), as were other non-centrarchid species (*e.g.*, yellow perch), according to Merrimack Station's Monitoring Program report (Normandeau 1977). Modal temperature data recorded during seining events from 1974–1976 indicate white suckers were caught in a temperature range of 70.0–85.8ºF (21.1–29.9ºC) (Normandeau 1977).

Merrimack Station identifies 81.0ºF (27.2ºC) as the thermal preference for white sucker in the Fisheries Analysis Report (2007a). This may be appropriate for juveniles, which was the lifestage used in the study Merrimack Station cited, but adult white sucker typically prefer cooler temperatures. Studies conducted on adults, as compiled by Wismer and Christie (1987), identify 75.2–80.6ºF (24–27ºC) as the preferred temperature range for white sucker under summer conditions. Cincotta and Stauffer (1984) noted that white suckers in the New River, Glen Lyn, Virginia avoided discharge areas when temperature exceeded 80.1ºF (26.7ºC).

EPA reviewed white sucker electrofishing catch data in the Fisheries Analysis Report for the summer months (July, August, September) in 2004 and 2005, as well as surface and bottom temperatures collected during sampling. Of the 44 white suckers collected during this time period, 39 fish were caught upstream from Merrimack Station's thermal discharge in temperatures ranging from 74.7-77.2ºF (23.7-25.1ºC). The other five suckers were caught at downstream locations where temperatures ranged from 78.8–81.5ºF (26.0-27.5ºC) on the surface and 75.2–77.5ºF (24.0-25.3ºC) on the bottom. Based on these data collected in Hooksett Pool, the preferred summer temperature for adult white sucker appears to range from 74.7-77.2ºF (23.7-25.1ºC). This conclusion is consistent with the results from the literature.

Twomey et al. (1984) consider white suckers greater than 150 mm (total length) to be adults for purposes of their study. Based on this length threshold, only 3 of the 44 suckers caught in the summer months of 2004–2005 were juveniles. The data suggests that adult white sucker largely avoided the thermally-influenced portion of Hooksett Pool during summer months. It also suggests that the information provided in the Fisheries Analysis Report does not adequately address impacts to shallower areas where juvenile white sucker are likely to inhabit, as demonstrated during seining studies conducted in the 1970s. The thermal plume would be expected to occupy a greater percentage of the shoreline shallows given that it can extend three-feet deep or more below the surface.

The UILT for juvenile white sucker ranges from 84.2ºF (29.0ºC) to 87.8ºF (31.0ºC), based on data compiled by Wismer and Christie (1987). Since these temperatures represent stressful conditions leading to lethality for a fraction of a study sample (usually 50 percent), avoidance temperatures would be lower. Therefore, EPA estimates stressful temperatures leading to thermal avoidance for juvenile white sucker to range from 82.4–85.8ºF (28.0ºC–29.9ºC).

EPA reviewed the 21-year temperature data set provided by Merrimack Station in order to assess its ability to impair white sucker habitat downstream from the discharge. Average daily maximum water temperatures exceeded 85.8ºF (29.9ºC) every day at Station S-4 from June 25 to September 1 (Normandeau 2007b). This temperature represents the high end of the temperature avoidance range for juvenile white sucker. By comparison, average daily maximum temperatures in the ambient zone consistently remained below 85.8ºF (29.9ºC) during the same 69-day period (Normandeau 2007b).

Cumulative Effects

Most life stages of white sucker appear to be vulnerable to effects from Merrimack Station's thermal discharge. In addition, white sucker are particularly vulnerable to early life stage mortality associated with the entrainment of larvae and juveniles in the plant's cooling water intake structure. According to entrainment sampling conducted in 2006 and 2007, Merrimack Station identified white sucker as the species entrained the most in both years sampled (Normandeau 2007c). Study results provided by Merrimack Station estimate that 1.2 million white sucker larvae were entrained in 2006 and 1.1 million in 2007, representing 42 and 46 percent of the total larvae entrained for all species in 2006 and 2007, respectively. No white sucker eggs were collected, according to the report. Based on the number of larvae entrained and established mortality rates of white sucker for each life stage, Merrimack Station estimates that the larval equivalent of 14,426 white sucker adults were lost as a result of entrainment mortality over this two-year period.

Organisms small enough to pass through a power plant's cooling water intake structure's traveling screens are drawn, or entrained, into the system and ultimately discharged with the heated cooling water. Eggs and larvae are the life stages of fish typically small enough to become entrained. Larger life stages that are drawn to the intake structure, but are too large to pass through the traveling screens are "impinged' against the screen. While juvenile fish are typically impinged, being too large to be entrained, Merrimack Station estimates that 32,682 young-of-year juvenile white suckers were entrained in June 2007. This equates to an additional loss of 2,618 adult equivalents for a total two-year entrainment loss of 17,044 white sucker adults (Normandeau 2007c).

EPA finds that Merrimack Station's thermal discharge is not protective of white sucker habitat within the influence of the thermal plume during summer conditions. In addition, white sucker larvae either entrained into the plant's cooling water system during this period, or exposed to Merrimack Station's thermal plume, are likely to experience stressful thermal conditions leading to impairment or lethality.

6.0 § 316(A) VARIANCE REQUEST DETERMINATION

EPA reviewed all information provided by Merrimack Station pertaining to its request for a thermal variance to determine if the plant had demonstrated that:

- the plant's thermal discharge had not caused prior appreciable harm to the balanced, indigenous population in Hooksett Pool,
- thermal discharge limits based on applicable technology-based and water quality-based requirements (*see* Sections 7, 8 and 9, *supra*) would be more stringent than necessary to assure the protection and propagation of the balanced, indigenous population of shellfish, fish and wildlife in Hooksett Pool, and
- the alternative thermal discharge limits sought by the facility – namely, limits consistent with open-cycle cooling – would reasonably assure the protection and propagation of the balanced, indigenous population of shellfish, fish and wildlife in Hooksett Pool.

In assessing Merrimack Station's demonstration as it relates to prior appreciable harm, EPA reviewed each analytical index provided in the plant's Fisheries Analysis Report (Normandeau 2007a). As first discussed in Section 5.6.2 of this document, these indices are 1) catch per unit effort, 2) taxa richness, 3) rank abundance, 4) fish community similarity, 5) length-weight relationships, and 6) species guild biomass. EPA has concluded, and the other reviewing agencies have concurred, that Merrimack Station has failed to demonstrate that the plant's past and current thermal discharges have not resulted in prior appreciable harm to the balanced, indigenous population of shellfish, fish, and wildlife in Hooksett Pool of the Merrimack River. Instead, there is compelling evidence that the thermal discharge, possibly in combination with other impacts on the affected species, has appreciably harmed the balanced, indigenous community in Hooksett Pool.

6.1 Evidence of Appreciable Harm

Some of the more conspicuous pieces of evidence of appreciable harm are highlighted below. See referenced sections of this document for more detailed information.

1. Abundance for all species combined that comprised Hooksett Pool's balanced, indigenous community in the 1960s, has declined by 94 percent compared to the 2000s, based on trap net sampling. Moreover, combined CPUE dropped from 60.1 fish caught per 48 hours in the 1970s to 3.6 fish caught in the 2000s. *See* Section 5.6.2.1.1b & Table 5-9.

2. Abundance for all species combined that comprised the Hooksett Pool fish community in the 1970's has declined by 89.5 percent compared to community found in the 2000s, based on trap net sampling. *See* Section 5.6.2.1.1b & Table 5-8.

3. The combined relative abundance for the five most abundant fish species in the 1960s has declined by 94.8 percent based on trap net sampling. Combined relative abundance dropped from an average 86.8 percent (1967–1969) to 4.5 percent (2004–2005). *See* Section 5.6.2.3.1b & Table 5-16.

4. A calculated Bray-Curtis Percent Similarity Index of 23.2 percent when comparing Hooksett Pool fish community of the 1970s with that of the 2000s. The closer the Bray-Curtis value is to 100 percent, the greater the similarity of the two communities. Therefore, the fish communities of the 1970s and 2000s are dissimilar by 72.8 percent. *See* Section 5.6.2.4.

5. The Hooksett Pool fish community has shifted from a mix of warm and coolwater species that existed in the 1960s and early 1970s to a community dominated by thermally tolerant species, primarily centrarchids (*i.e.*, sunfish family), in the 1990s and 2000s. *See* Section 5.6.2.4.

6. Yellow perch abundance in Hooksett Pool significantly declined between 1967 and 2005, based on electrofishing CPUE data. *See* Section 5.6.2.1.2a and Table 5-15 and Figures 5-3 and 5-8. Yellow perch abundance also significantly declined during the same time period, based on trapnet sampling. *See* Section 5.6.2.1.2b.

7. Pumpkinseed abundance in Hooksett Pool significantly declined between 1972 and 2005, based on electrofishing CPUE data. Trapnet sampling data support the electrofishing data analysis. Pumpkinseed, the most abundant fish species in 1967 (53% relative abundance), has virtually disappeared from Hooksett Pool. *See* Sections 5.6.2.1.3 & 5.6.2.3.2a and b.

8. White sucker abundance in Hooksett Pool significantly declined between the 1970s and 2000s, based on trapnet CPUE data. White sucker trapnet CPUE dropped from 11 fish (caught per 48 hours) in the 1970s to 0.1 fish in the 2000s. Relative abundance dropped from 18.2 percent to 2.1 percent during the same during the same period. *See* Sections 5.6.2.1.4b.

9. Significant annual losses of yellow perch larvae, and of white sucker larvae and juveniles (among other species), from entrainment in Merrimack Station's cooling water intake structure exacerbate the effects of degraded habitat associated with the discharge of heated cooling water for these species. *See* Sections 5.6.3.3f & 5.6.3.3h.

6.2 Merrimack Station's Thermal Impact on Hooksett Pool

Given EPA's finding that there is compelling evidence of appreciable harm to the balanced, indigenous fish community of Hooksett Pool, EPA next considered whether or not Merrimack Station's thermal discharge has nevertheless been protective of this community. Fish communities may be subjected to multiple natural and anthropogenic stressors that individually, or in combination, appreciably harm the affected fish populations. Therefore, EPA assessed whether Merrimack Station adequately demonstrated that its thermal discharge did not cause, or contribute to, appreciable harm to the balanced, indigenous community.

EPA concludes that the capacity of the plant's thermal discharge to adversely impact the balanced, indigenous fish community of Hooksett Pool is significant. The weight of evidence provided in Merrimack Station's Fisheries Analysis Report and earlier reports points to a significant shift in the fish community away from what was the balanced, indigenous community of the 1960s and early1970s, to the more heat-tolerant community that exists today. In addition, not only has the fish community composition changed substantially, but sampling data suggests that overall fish abundance has dropped significantly, as well. Such a shift in community and in overall abundance indicates a degraded habitat no longer able to support the fish community that existed in the 1960s, or early 1970s. Changes in the fish community exceed those expected from natural variation alone. Introductions of fish species since the 1970s, whether intentional or accidental, have no doubt affected the resident, indigenous fish community. However, since virtually all are warmwater species, their ability to compete successfully with temperature-sensitive indigenous species may also be a consequence of Merrimack Station's thermal discharge.

Some of the more notable evidence of Merrimack Station's thermal effects, or the plant's capacity to affect, the balanced, indigenous community, is summarized below. *See* referenced sections for additional information.

1. During summer low-flow conditions, Merrimack Station's thermal plume can extend from the end of the Discharge Canal at Station S-0 downstream approximately 2.9 miles to Station S-24, just above Hooksett Dam. This represents approximately 50 percent of the surface area of Hooksett Pool. Elevated temperatures attributable to Merrimack Station's thermal discharge are

also recorded at Station A-O, immediately downstream of Hooksett Dam. *See* Section 5.5.

2. Given the relatively shallow depths of Hooksett Pool (generally 10 feet or less), the thermal plume can affect one- to two-thirds of the water column in the deepest areas during summer conditions. Most, if not all, of the shallower areas along the shorelines can be affected by the thermal plume downstream from the discharge. These shallow shoreline areas are important habitat for juvenile fish. *See* Sections 2.2 & 5.5.

3. Based on a 21-year data set provided by PSNH, the averaged daily maximum water temperature reached or exceeded 100ºF (37.8ºC) at Station S-0 on 30 days in July and August, with the highest temperature reaching 104ºF (40.0ºC). *See* Sections 3.2, 3.4, & 5.6.3.3f.

4. The thermal plume extends across the entire width of Hooksett Pool during typical summer conditions. As a result, surface-oriented organisms, including larval yellow perch, white sucker, and American shad, which have limited or no ability to avoid stressful thermal conditions, are exposed to plume temperatures while drifting past the discharge canal that have been demonstrated in controlled studies to cause acute lethality to these species. *See* Sections 5.5, 5.6.3.3b, 5.6.3.3f, & 5.6.3.3h.

5. Under extreme low-flow conditions, Merrimack Station presently redirects up to 83 percent of the Merrimack River flow through the plant. This water is heated and discharged back into Hooksett Pool at temperatures of up to 104°F (40°C). Under these conditions, the discharged water can be up to 23.8°F (13.1°C) warmer than ambient temperatures in the river. *See* Sections 3.4, 5.5, & 11.2.1b.

6. Following the start-up of Unit 2 in 1968, the plant's design withdrawal rate was 286 MGD (444 cfs) of river water (Institute for Research Services, undated). At that rate, and using the same calculated 7Q10 (587.75 cfs), the plant would have been withdrawing 75 percent of the total river flow under low-flow conditions. Shorter periods of extreme low flows have resulted in the withdrawal of even a greater percentage of the river's available flow for cooling. In some cases, the plant's withdrawal of water during such low-flow conditions has caused the heated water from the discharge canal to flow upstream in Hooksett Pool towards the cooling water intake structures. *See* Section 5.5.

7. Dissolved oxygen ("DO") studies revealed low-DO conditions immediately above Hooksett Dam. The study, conducted by PSNH, stated that the thermal plume from Merrimack Station caused stratification that contributed to low-DO conditions. *See* Section 2.4.

8. Once-abundant populations of coolwater species, such as yellow perch and white sucker, have significantly declined since the 1960s and 1970s. Heat-tolerant species such as bluegill, largemouth bass and smallmouth bass, now dominate. *See* Section 5.6.2.4, 5.6.3.3d, 5.6.3.3f, & 5.6.3.3h.

9. Yellow perch and white sucker largely avoided areas of the Hooksett Pool experiencing elevated temperatures associated with Merrimack Station's thermal discharge during August and September. The averaged daily maximum water temperature exceeded 83.0ºF (28.3ºC) – the temperature Merrimack Station identified as an avoidance temperature for yellow perch – every day at Station S-4 from June 15 to September 10. *See* Sections 5.6.3.3f & 5.6.3.3h.

10. Thermal conditions created by Merrimack Station's plume are not protective of juvenile alewife during August and early September. *See* Section 5.6.3.3a.

11. A comparison between the fish communities in Hooksett Pool and Vernon Pool (Connecticut River) demonstrates that temperature-sensitive species such as yellow perch have been competing successfully with introduced heat-tolerant species such as bluegill in the Vernon Pool, but not in the Hooksett Pool. Similarly, data collected by NHFGD in 2007 suggests that the yellow perch population just upstream of Hooksett Pool is robust relative to other species, including bluegill. *See* Section 5.6.3.3f.

12. The attraction of yellow perch to the thermal plume during colder months has been documented, which has potential implications for the species' ability to successfully reproduce following prolonged exposure to the warmer water. *See* Section 5.6.3.3f.

13. In addition to affecting fish directly, the rise in temperature of the cooling water has a significant effect on the plankton suspended in it downstream from the discharge, according to studies conducted in the 1960s for Merrimack Station. Zooplankton such as cladocerans and rotifers, which are important forage for larval and juvenile fish, were among the most susceptible. A significant fraction of the zooplankton forage base is likely exposed to high temperatures (often exceeding 100 degrees during the summer) and physical stressors, particularly under low-flow conditions when up to 83 percent of the river water is drawn into the plant, heated, and discharged back into the river. *See* Sections 5.6.3.2 & 11.2.1b.

6.3 § 316(a) Variance Request Determination – Conclusions

Based on a thorough review of all pertinent data and analyses, EPA has concluded that:

- PSNH has not demonstrated that Merrimack Station's thermal discharge has not caused prior appreciable harm to the Hooksett Pool's balanced, indigenous population of fish;
- To the contrary, the evidence as a whole indicates that Merrimack Station's thermal discharge has caused, or contributed to, appreciable harm to Hooksett Pool's balanced, indigenous community of fish;
- PSNH has not demonstrated that thermal discharge limits based on applicable technology-based and water quality-based requirements (*see* Sections 7, 8 and 9, *supra*) would be more stringent than necessary to assure the protection and propagation of the balanced, indigenous population of shellfish, fish and wildlife in and on Hooksett Pool; and
- PSNH has not demonstrated that its proposed alternative thermal discharge limits – namely, limits consistent with open-cycle cooling – would reasonably assure the protection and propagation of the balanced, indigenous population of shellfish, fish and wildlife in and on Hooksett Pool.

Therefore, EPA has determined that it must reject Merrimack Station's request for a CWA § 316(a) thermal discharge variance.

In the absence of a renewal of Merrimack Station's § 316(a) variance, EPA must establish appropriate thermal discharge limits for the facility that will satisfy both federal technology-based requirements and any more stringent requirements based on state water quality standards. The following sections present EPA's determination of technology-based requirements (Section 7) and water quality-based requirements (Section 8). The thermal discharge requirements ultimately selected for the permit based on these determinations are presented in Section 9.

7.0 TECHNOLOGY-BASED THERMAL DISCHARGE LIMITS

7.1 Introduction

This section presents the basis for EPA's determination of effluent limits for the discharge of heat by Merrimack Station based on application of the CWA's Best Available Technology Economically Achievable ("BAT") standard, in accordance with CWA §§ 301(b)(2) and 304(b)(2). *See also* 40 C.F.R. § 125.3(a)(2)(v). These sections of the CWA govern the development and application of BAT effluent limits for toxic and non-conventional pollutants. *See* 33 U.S.C. §§ 1311(b)(2)(A) & (F). Heat is defined as a "pollutant" by CWA § 502(6), 33 U.S.C. § 1362(6), and is considered a non-conventional pollutant under the statute. *See* 33 U.S.C. § 1314(a)(4).

In a letter dated July 3, 2007, EPA requested information from PSNH concerning, among other things, the feasibility of applying various technologies at Merrimack Station to reduce the facility's thermal discharge. In reply, PSNH submitted a document labeled, "Response to United States Environmental Protection Agency CWA § 308 Letter, PSNH Merrimack Station Units I & II, Bow, New Hampshire." According to information provided in this document, available technology – specifically, closed-cycle cooling technology – could reduce the thermal discharge from Merrimack Station into Hooksett Pool by approximately 99.5%.[12] Based on this and other information, as well as additional study and analysis discussed below, EPA concludes on a site-specific, Best Professional Judgment ("BPJ") basis that converting the current open-cycle cooling system to a closed-cycle cooling system using "wet" cooling towers is the BAT for Merrimack Station. As described below, EPA has also developed a set of thermal discharge limits consistent with using this BAT. These limits have been included in the Draft Permit because, as discussed farther below, EPA and NHDES conclude that water quality-based limits would be no more stringent.

It should be understood that while the Draft Permit's thermal discharge limits are based on closed-cycle cooling technology, the permit does not directly require the installation of closed-cycle cooling technology. The facility is free to meet the permit limits in any lawful means that it can develop. Alternative approaches to thermal discharge reduction are discussed farther below.

7.2 Legal Requirements and Context

As the United States Supreme Court has explained:

> *[t]he Federal Water Pollution Control Act, commonly known as the Clean Water Act, 86 Stat. 816, as amended, 33 U.S.C. § 1251 et seq., is a comprehensive water quality statute designed to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." § 1251(a). The Act also seeks to attain "water quality which provides for the protection and propagation of fish, shellfish, and wildlife." § 1251(a)(2).*

PUD No. 1 of Jefferson County v. Wash. Dept. of Ecology, 511 U.S. 700, 704 (1994). The CWA should be construed and interpreted with these overarching statutory purposes in mind.

To accomplish these purposes, the CWA prohibits point source discharges of pollutants to waters of the United States unless authorized by a NPDES permit (or a specific provision of the statute).

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[12] PSNH did not provide a numerical estimate of the reduction in thermal discharge achievable with closed-cycle cooling technology, but stated that using mechanical draft wet cooling towers in a closed-cycle configuration at both units "would effectively eliminate all thermal discharge to the Merrimack River." PSNH CWA § 308 Response at 100. Calculations based on other data provided by PSNH suggest that the resulting daily cooling water discharge volume (estimated as total intake for makeup and blowdown requirements, less evaporation losses) would be approximately 0.5% of the present daily maximum cooling water discharge volume. *See id.* at 18, 41, 54. Assuming for purposes of this calculation that the temperature parameters of the much smaller post-technology cooling water discharge match those of the much larger pre-technology discharges, a 99.5% reduction in cooling water discharge volume would result in a 99.5% reduction in the facility's total discharge of waste heat into Hooksett Pool.

The NPDES permit is the mechanism used to implement national effluent limitations and other requirements, such as monitoring and reporting, on a facility-specific basis. When developing pollutant discharge limits for a NPDES permit, permit writers consider limits based on the application of particular levels of technology for preventing or reducing pollutant discharges (technology-based limits), *and* limits based on what is needed to comply with state water quality standards applicable to the receiving water (water quality-based limits).

The CWA requires all discharges to meet, at a minimum, applicable technology-based requirements. The Act creates a number of different narrative technology standards that respectively apply to different types of pollutants as of particular dates. EPA applies these technology standards to entire industrial categories when it develops uniform national effluent limitation guidelines ("ELGs"). In the absence of applicable national ELGs, EPA applies technology standards on a facility-by-facility basis using BPJ to develop technology-based requirements for individual permits.

While technology-based effluent limitations are based on the pollution reduction capabilities of particular technologies or operational practices, the CWA does not dictate that dischargers within the pertinent industrial category must necessarily use those technologies or practices. Rather, dischargers are permitted to use any (otherwise lawful) means of meeting the limits that are set based upon the identified technologies or practices. Thus, where technology-based standards apply, the CWA allows facilities to take different and innovative approaches to satisfy them.[13]

As befits the "technology-forcing" scheme of the CWA, Congress also provided for the statute's technology-based requirements to become increasingly stringent over time. Of particular relevance here, industrial dischargers were required by March 31, 1989, to comply with effluent limits for non-conventional pollutants, as well as limits for toxic pollutants, that reflect the BAT "which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants."[14] 33 U.S.C. § 1311(b)(2)(A) & (F).

While EPA has developed certain national ELGs for the steam-electric power plant point source category – an industrial category that includes Merrimack Station – EPA has not promulgated

[13] Water quality-based requirements are not based on particular technologies or practices and, thus, also leave room for different approaches to achieving compliance with permit limits.

[14] In addition, CWA § 301(b)(1)(A) requires industrial dischargers, by July 1, 1977, to have satisfied limits based on the application of the Best Practicable Control Technology currently available ("BPT"), while Section 301(b)(2)(E) requires that limits based on the Best Conventional Pollutant Control Technology ("BCT") for conventional pollutants be met. *See* 33 U.S.C. §1311(b)(1) & (b)(2)(E). *See also* 40 C.F.R. § 125.3(a). Furthermore, CWA § 306, 33 U.S.C. § 1316, requires new sources to meet performance standards based on the Best Available Demonstrated Control Technology ("BADT").

ELGs for the discharge of heat by this category.[15] *See* 40 C.F.R. Part 423. As a result, and pursuant to CWA § 402(a)(1), 33 U.S.C. § 1342(a)(1), and 40 C.F.R. § 125.3(c)(2),[16] EPA develops BAT limits for thermal discharges by such facilities on a case-by-case, BPJ basis. Accordingly, EPA has developed technology-based BAT limits for Merrimack Station's thermal discharges on a BPJ basis.

7.2.1 Best Professional Judgment

As one court has explained, "BPJ limits constitute case-specific determinations of the appropriate technology-based limitations for a particular point source." *Natural Res. Def. Council v. U.S. Envtl. Prot. Agency,* 859 F.2d 156, 199 (D.C. Cir. 1988). The court further explained that:

> *[i]n what EPA characterizes as a "mini-guideline" process, the permit writer, after full consideration of the factors set forth in section 304(b), 33 U.S.C. § 1314(b), (which are the same factors used in establishing effluent guidelines), establishes the permit conditions "necessary to carry out the provisions of [the CWA]." § 1342(a)(1). These conditions include the appropriate . . . BAT effluent limitations for the particular point source. . . . [T]he resultant BPJ limitations are as correct and as statutorily supported as permit limits based upon an effluent limitations guideline.*

Id. See also Texas Oil & Gas Ass'n v. U.S. Envtl. Prot. Agency, 161 F.3d 923, 929 (5th Cir. 1998) ("Individual judgments thus take the place of uniform national guidelines, but the technology-based standard remains the same.") EPA's NPDES regulations at 40 C.F.R. §§ 125.3(c)(2) and (3), and (d)(3), list factors to be considered in setting BPJ limits and are consistent with the statute and the above explanations.

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[15] EPA issued regulations to establish national ELGs for the discharge of heat from steam-electric power plants in 1974, but those regulations were remanded to the Agency by the United States Court of Appeals for the Fourth Circuit in 1976. *See Appalachian Power Co. v. Train*, 545 F.2d 1351 (4th Cir. 1976) (EPA required to give further consideration to regulations concerning "thermal backfit requirements" and barring use of new and existing cooling lakes for closed-cycle cooling).

[16] *See Seabrook*, 1977 EPA App. LEXIS 16, at *19–*20 ("The effect of the remand of the steam-electric generating guidelines was . . . to require the Agency to determine what is [BAT] for existing sources on a case-by-case basis under Section 402(a)(1)."); *In re Central Hudson*, U.S. Environmental Protection Agency, Decision of the General Counsel No. 63, at 376 (after remand of effluent limitations and guidelines for steam-electric power plants by *Appalachian Power Co.*, permit issuing authority could use CWA § 402(a)(1) to impose effluent limitations in permits for four steam-electric generating stations discharging into Hudson River); *Status of Initial Decision of Reg'l Admin. Where Appeal is Pending,* U.S. Envtl. Prot. Agency, General Counsel Opinion No. 77-1, at 1 (Jan. 11, 1977) ("In the wake of *Appalachian Power*, the Agency has the option of either establishing heat limitations for Seabrook on an ad hoc basis under Section 402(a)(1) of the [CWA] or repromulgating the steam-electric regulations.").

7.2.2 Best Available Technology Economically Achievable (BAT)

For discharges of heat, the CWA requires achievement of:

> *effluent limitations . . . which . . . shall require application of the best available technology economically achievable . . ., which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants, as determined in accordance with regulations issued by the [EPA] Administrator pursuant to section 1314(b)(2) of this title, which such effluent limitations shall require the elimination of discharges of all pollutants if the Administrator finds, on the basis of information available to him . . . that such elimination is technologically and economically achievable . . . as determined in accordance with regulations issued by the [EPA] Administrator pursuant to section 1314(b)(2) of this title . . . .*

33 U.S.C. § 1311(b)(2)(A). In other words, EPA must set limits corresponding to the use of the best pollution control technologies that are technologically and economically achievable and will result in reasonable progress toward eliminating the discharge of the pollutant(s) in question.

In determining the BAT, CWA § 304(b)(2)(B) requires that EPA "take into account":

> *. . . the age of equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques, process changes, the cost of achieving such effluent reduction, non-water quality environmental impact (including energy requirements), and such other factors as the Administrator deems appropriate.*

33 U.S.C. § 1314(b)(2)(B). *See also* 40 C.F.R. § 125.3(d)(3). As elucidated by case law, the statute sets up a loose framework for assessing these factors in setting BAT limits. *See, e.g., BP Exploration & Oil, Inc. v. U.S. Environmental Protection. Agency*, 66 F.3d 784, 796 (6th Cir. 1995), *citing Weyerhauser v. Costle*, 590 F.2d 1011, 1045 (D.C. Cir. 1978) (citing Senator Muskie's remarks about CWA § 304(b)(1) during debate). Comparison of the factors is not required, merely their consideration. *Weyerhauser*, 590 F.2d at 1045 (explaining that CWA § 304(b)(2) lists factors for EPA "consideration" in setting BAT limits, in contrast to § 304(b)(1)'s requirement that EPA *compare* "total cost versus effluent reduction benefits" in setting BPT limits).[17] Moreover, "[i]n enacting the CWA, 'Congress did not mandate any particular structure or weight for the many consideration factors. Rather, it left EPA with discretion to decide how

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[17] *See also U.S. Envtl. Prot. Agency v. Nat'l Crushed Stone Ass'n*, 449 U.S. 64, 74 (1980) (noting with regard to BPT that "[s]imilar directions are given the Administrator for determining effluent reductions attainable from the BAT except that in assessing BAT total cost is no longer to be considered in comparison to effluent reduction benefits").

to account for the consideration factors, and how much weight to give each factor.'" *BP Exploration*, 66 F.3d at 796, *citing Weyerhauser*, 590 F.2d at 1045.

In sum, when EPA considers the required factors in setting BAT limits, it is governed by a standard of reasonableness. *BP Exploration*, 66 F.3d at 796, *citing Am. Iron & Steel Inst. v. Envtl. Prot. Agency*, 526 F.2d 1027, 1051 (3d Cir. 1975), *modified in other part*, 560 F.2d 589 (3d Cir. 1977), *cert. denied*, 435 U.S. 914 (1978). Each factor must be considered, but the Agency has "considerable discretion in evaluating the relevant factors and determining the weight to be accorded to each in reaching its ultimate BAT determination." *Texas Oil*, 161 F.3d at 928, *citing Natural Res. Def. Council*, 863 F.2d at 1426. *See also Weyerhauser*, 590 F.2d at 1045 (stating that in assessing BAT factors, "[s]o long as EPA pays some attention to the congressionally specified factors, [CWA § 304(b)(2),] on its face lets EPA relate the various factors as it deems necessary"). One court succinctly summarized the standard for reviewing EPA's consideration of the BAT factors in setting limits: "[s]o long as the required technology reduces the discharge of pollutants, our inquiry will be limited to whether the Agency considered the cost of technology, along with other statutory factors, and whether its conclusion is reasonable." *Ass'n of Pac. Fisheries v. U.S. Envtl. Prot. Agency*, 615 F.2d 794, 818 (9th Cir. 1980). *See also Chem. Mfrs. Ass'n v. U.S. Envtl. Prot. Agency*, 870 F.2d 177, 250 n.320 (5th Cir. 1989), *citing* 1972 Legislative History (in determining BAT, "'[t]he Administrator will be bound by a test of reasonableness.'").

Thus, when developing BAT limits using BPJ under CWA § 402(a)(1), the permit writer considers the BAT factors from CWA § 304(b)(2)(B) and 40 C.F.R. § 125.3. The regulations repeat the statutory factors, *see* 40 C.F.R. § 125.3(d), and specify that the permit writer must also consider the "appropriate technology for the category of point sources of which the applicant is a member, based on all available information" as well as "any unique factors relating to the applicant." 40 C.F.R. § 125.3(c)(2).

7.2.2.1 Technological Availability and Performance

According to the CWA's legislative history, "best available" technology refers to the "single best performing plant in an industrial field," in terms of its capacity to reduce discharges of pollutants. *Chem. Mfrs.*, 870 F.2d at 239, *citing* 1972 Legislative History at 170.[18] (As

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[18] *See also Texas Oil*, 161 F.3d at 928, *quoting Chem. Mfrs.*, 870 F.2d at 226; *Kennecott v. U.S. Envtl. Prot. Agency*, 780 F.2d 445, 448 (4th Cir. 1985) ("In setting BAT, EPA uses not the average plant, but the optimally operating plant, the pilot plant which acts as a beacon to show what is possible."); *Am. Meat*, 526 F.2d at 463 (BAT "should, at a minimum, be established with reference to the best performer in any industrial category"). According to one court:

> [t]he legislative history of the 1983 regulations indicates that regulations establishing BATEA [i.e., best available technology economically achievable, or BAT] can be based on statistics from a single plant. The House Report states:

discussed below, however, additional factors may also be considered in determining the BAT.) Thus, EPA may set BAT limits that are not technologically achievable by all of the dischargers in a particular point source category, as long as at least one discharger in the category demonstrates that the limits are achievable. *Chem. Mfrs.*, 870 F.2d at 239, 240. This comports with Congress's intent that EPA will "use the latest scientific research and technology in setting effluent limits, pushing industries toward the goal of zero discharge as quickly as possible." *Kennecott v. U.S. Envtl. Prot. Agency*, 780 F.2d 445, 448 (4th Cir. 1984), *citing* 1972 Legislative History at 798. *See also Natural Res. Def. Council*, 863 F.2d at 1431 ("The BAT standard must establish effluent limitations that utilize the latest technology").

Available technologies may also include viable "transfer technologies" – that is, a technology from another industry that could be transferred to the industry in question – as well as technologies that have been shown to be viable in research even if not yet implemented at a full-scale facility.[19] When EPA bases BAT limits on such "model" technologies, it is not required to "consider the temporal availability of the model technology to individual plants," because the BAT factors do not include consideration of an individual plant's lead time for obtaining and installing a technology. *See Chem. Mfrs.*, 870 F.2d at 243; *Am. Meat Inst. v. U.S. Envtl. Prot. Agency*, 526 F.2d 442, 451 (7th Cir. 1975).

While EPA must articulate the reasons for its determination that the technology it has identified as BAT is technologically achievable, courts have construed the CWA not to require EPA to identify the specific technology or technologies a plant must install to meet BAT limits. *See Chem. Mfrs.*, 870 F.2d at 241. The Agency must, however, demonstrate at least that the technology used to estimate BAT limit costs is a "reasonable approximation of the type and cost of technology that must be used to meet the limitations." *Id.* It may do this by several methods, including by relying on a study that demonstrates the effectiveness of the required technology. *BP Exploration*, 66 F.3d at 794 (upholding BAT limits because EPA relied on "empirical data" presented in studies demonstrating that improved gas flotation is effective technique for removing dissolved as well as dispersed oil from produced water). *Compare Pacific Fisheries*,

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> It will be sufficient for the purposes of setting the level of control under available technology, that there be one operating facility which demonstrates that the level can be achieved or that there is sufficient information and data from a relevant pilot plant or semi-works plant to provide the needed economic and technical justification for such new source.

Pac. Fisheries, 615 F.2d at 816–17, *quoting* 1972 Legislative History at 170.

[19] These determinations, arising out of the CWA's legislative history, have been upheld by the courts. *E.g., Am. Petroleum Inst. v. U.S. Envtl. Prot. Agency*, 858 F.2d 261, 264–65 (5th Cir. 1988); *Pacific.. Fisheries*, 615 F.2d at 816–17; *BASF Wyandotte Corp. v. Costle*, 614 F.2d 21, 22 (1st Cir. 1980); *Am. Iron*, 526 F.2d at 1061; *Am. Meat*, 526 F.2d at 462.

615 F.2d at 819 (regulations remanded because EPA based BAT limit on study that failed to demonstrate effectiveness of technology identified as BAT).

7.2.2.2 Engineering and Technical Considerations

In developing BAT limits, EPA also takes into account (1) the engineering aspects of the application of various types of control techniques process employed, (2) the process or processes employed by the point source category (or individual discharger) for which the BAT limits are being developed, (3) process changes that might be necessitated by using new technology, and (4) the extent to which the age of equipment and facilities involved might affect the introduction of new technology and its performance. As noted above, EPA has "considerable discretion in evaluating the relevant factors and determining the weight to be accorded to each in reaching its ultimate BAT determination." *Texas Oil*, 161 F.3d at 928, *citing Natural Resources Defense Council*, 863 F.2d at 1426. *See also Kennecott*, 780 F.2d at 448, *citing* 33 U.S.C. § 1314(b)(2).

In setting BAT-based thermal discharge limits on a BPJ basis for Merrimack Station, EPA considered the steam-electric power generation processes currently employed by Merrimack Station, the existing cooling processes used, engineering issues related to the possible application at the facility of the various treatment technology options under evaluation, and any process changes that would result from using these technologies. EPA also considered the age of the facilities at issue here in the context of assessing the feasibility of retrofitting new technology to the power plant and how it would likely perform.

7.2.2.3 Cost and Economic Achievability

EPA also considers the cost of implementing a technology when determining the best available technology that is economically achievable. CWA §§ 301(b)(2) and 304(b)(2) require "EPA to set discharge limits reflecting the amount of pollutant that would be discharged by a point source employing the best available technology that the EPA determines to be *economically feasible* . . . ." *Texas Oil*, 161 F.3d at 928 (emphasis added). *See* 33 U.S.C. § 1311(b)(2) (BAT limits "shall require the elimination of discharges of all pollutants if the Administrator finds, on the basis of information available to him . . . that such elimination is . . . economically achievable"); 33 U.S.C. § 1314(b)(2) (when assessing BAT for a particular point source category or individual discharger, EPA must take "cost of achieving such effluent reduction" into account); 40 C.F.R. § 125.3(d)(3) (same). The United States Supreme Court has concluded that treatment technology that satisfies the CWA's BAT standard must "represent 'a commitment of the maximum resources economically possible to the ultimate goal of eliminating all polluting discharges." *Nat'l Crushed Stone Ass'n*, 449 U.S. 64, 74 (1980). *See also BP Exploration*, 66 F.3d at 790 ("BAT represents, at a minimum, the best economically achievable performance in the industrial category or subcategory."), *citing Natural Res. Def. Council*, 863 F.2d at 1426.

The Act gives EPA "considerable discretion" in determining what is economically achievable. *Natural Res. Def. Council*, 863 F.2d at 1426, *citing Am. Iron*, 526 F.2d at 1052. It does not require a precise calculation of the costs of complying with BAT limits.[20] EPA "need make only a reasonable cost estimate in setting BAT," meaning that it must "develop no more than a rough idea of the costs the industry would incur." *Id. See also Rybachek v. U.S. Envtl. Prot. Agency*, 904 F.2d 1276, 1290–91 (9th Cir. 1990); *Chem. Mfrs.*, 870 F.2d at 237–38. Moreover, CWA § 301(b)(2) does not specify any particular method of evaluating the cost of compliance with BAT limits or state how those costs should be considered in relation to the other BAT factors; it only directs EPA to consider whether the costs associated with pollutant reduction are "economically achievable." *Chem. Mfrs.*, 870 F.2d at 250, *citing* 33 U.S.C. § 1311(b)(2)(A). Similarly, CWA § 304(b)(2)(B) requires only that EPA "take into account" cost along with the other BAT factors. *See Reynolds Metals Co. v. U.S. Envtl. Prot. Agency*, 760 F.2d 549, 565 (4th Cir. 1985) (in setting BAT limits, "no balancing is required – only that costs be considered along with the other factors discussed previously"), *citing Nat'l Ass'n Metal Finishers v. U.S. Envtl. Prot. Agency*, 719 F.2d 624, 662–63 (3rd Cir. 1983); *Pacific Fisheries*, 615 F.2d at 818 (in setting BAT limits, "the EPA must 'take into account . . . the cost of achieving such effluent reduction,' along with various other factors"), *citing* CWA § 304(b)(2)(B). EPA also considers the extent to which the age of the equipment and facilities involved may affect the cost of new technology.

In the context of considering cost, EPA may also consider the relative "cost-effectiveness" of the available technology options. The term "cost-effectiveness" is used in multiple ways. From one perspective, the most cost-effective option is the least expensive way of getting to the same (or nearly the same) performance goal. From another perspective, cost-effectiveness refers to a comparative assessment of the cost per unit of performance by different options. In its discretion, EPA might decide that either or both of these approaches to cost-effectiveness analysis would be useful in determining the BTA in a particular case. Alternatively, under some circumstances, EPA might reasonably decide that neither was useful. For example, the former approach would not be helpful in a case in which only one technology reaches (or comes close to) a particular performance goal. Moreover, the latter approach would not be helpful where a meaningful cost-per-unit-of-performance metric cannot be developed, or where there are wide disparities in the performance of alternative technologies and those with lower costs-per-unit-of-performance fail to reach some threshold of adequate performance.

The courts, including the United States Supreme Court, have consistently read the statute and its legislative history to indicate that while Congress intended EPA to consider costs in setting BAT

[20] In *BP Exploration*, the court stated that, "[a]ccording to EPA, the CWA not only gives the agency broad discretion in determining BAT, the Act merely requires the agency to consider whether the cost of the technology is reasonable. EPA is correct that the CWA does not require a precise calculation of BAT costs." 66 F.3d at 803, *citing Natural Res. Def. Council*, 863 F.2d at 1426.

limits, it did not require the Agency to perform a cost-benefit analysis or any other type of economic balancing test.[21] Following longstanding Agency practice, EPA has not relied upon comparative cost/benefit analysis in its BPJ, case-by-case determination of determine BAT-based thermal discharge limits for the Merrimack Station permit.

In setting the BPJ-based BAT limit for thermal discharges from Merrimack Station, EPA identified particular technologies that could be used to reduce the facility's discharge of heat to the Merrimack River and considered the cost of those technologies and whether those costs were achievable and reasonable.

7.2.2.4 Non-Water Quality Environmental (and Energy) Effects, and Other Factors EPA Deems Appropriate

In determining the BAT, EPA is not required to consider the extent of water quality improvements that will result from using a particular technology.[22] The Agency does, however, consider the non-water quality environmental effects (and energy effects) of using the technology in question. *See* 33 U.S.C. § 1314(b)(2)(B); 40 C.F.R. § 125.3(d)(3). In addition, the statute authorizes EPA to consider other factors that it deems appropriate. 33 U.S.C. § 1314(b)(2)(B). The CWA gives EPA broad discretion in deciding how to evaluate these non-water quality effects and weigh them against the other BAT factors. *Rybachek*, 904 F.2d at 1297 (discussing evaluation of non-water quality environmental impacts under CWA § 304 in context of challenge to EPA regulations establishing BAT limits for placer mining industry point sources), *citing Weyerhauser*, 590 F.2d at 1049–53 (discussing evaluation of non-water quality environmental impacts under CWA § 304 in context of challenge to EPA regulations establishing BPT limits for pulp and paper industry point sources).

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[21] *E.g., Nat'l Crushed Stone*, 449 U.S. at 71 ("Similar directions [to those for assessing BPT under CWA § 304(b)(1)(B)] are given the Administrator for determining effluent reductions attainable from the BAT except that in assessing BAT total cost is no longer to be considered in comparison to effluent reduction benefits.") (footnote omitted); *Texas Oil*, 161 F.3d at 936 n.9 (petitioners asked court "to reverse years of precedent and to hold that the clear language of the CWA (specifically, 33 U.S.C. § 1314(b)(2)(B)) requires the EPA to perform a cost-benefit analysis in determining BAT. We find nothing in the language or history of the CWA that compels such a result"); *Reynolds Metals*, 760 F.2d at 565. *See also Entergy Corp. v. Riverkeeper, Inc.*, 129 S.Ct. 1498, 1512–15 (2009) (in decision addressing technology standards under CWA § 316(b), dicta in majority and concurring opinion suggest that EPA may have discretionary authority to consider cost/benefit analysis in setting BAT standards, but is not required to do so).

[22] *See, e.g., Am. Petroleum*, 858 F.2d at 265–66 ("Because the basic requirement for BAT effluent limitations is only that they be technologically and economically achievable, the impact of a particular discharge upon the receiving water is not an issue to be considered in setting technology-based limitations.").

7.2.3 Data Sources and Analytic Methods

7.2.3.1 Data Sources and Analytic Methods Generally

In establishing BAT limits, EPA has broad discretion in selecting data for consideration and methods of analysis. *E.g., BP Exploration*, 66 F.3d at 804; *Reynolds Metals*, 760 F.2d at 565. Its conclusions with respect to data and analysis should "fall within a 'zone of reasonableness.'" *Reynolds Metals*, 760 F.2d at 559, *quoting Hercules, Inc. v. U.S. Envtl. Prot. Agency*, 598 F.2d 91, 107 (D.C.Cir. 1978). *See Chem. Mfrs.*, 870 F.2d at 228; *BASF Wyandotte Corp. v. Costle*, 598 F.2d 637, 656 (1st Cir. 1979).

7.2.3.2 Data Sources Relied on for This Determination

As part of its permit application, and in response to EPA information requests, PSNH has submitted a significant amount of information related to potential thermal load (and flow) reduction technologies. For purposes of this BAT determination, the most significant PSNH submission is its report entitled "Response to the United States Environmental Protection Agency CWA § 308 Letter, PSNH Merrimack Station Unit I & 2, Bow, New Hampshire" (Nov. 2007) [hereinafter, "PSNH November 2007 CWA § 308 Response"]. PSNH prepared and submitted the report in response to a CWA § 308 information request sent by EPA to PSNH in July 2007.[23] EPA's request sought, among other things, information related to alternative technologies that might be used at Merrimack Station to reduce the plant's thermal discharges to the Merrimack River and its entrainment and impingement of aquatic life as a result of water withdrawals by its cooling water intake structures.

In evaluating technological alternatives for reducing Merrimack Station's thermal discharge to the Merrimack River, EPA has considered the PSNH November 2007 CWA § 308 Response as well as other PSNH submissions. In addition, EPA has also considered other materials, such as relevant EPA guidance documents, information regarding experience at other power plants, and information from equipment manufacturers.

7.3 Processes and Technologies Currently Employed at Merrimack Station

7.3.1 Station Description

Merrimack Station is an electric generating plant located in Bow, New Hampshire. The facility has four generating units with a total nameplate capacity rating of approximately 520 MW.[24]

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[23] PSNH was assisted in preparing the report by its consultants Enercon Services, Inc., of Kennesaw, GA, and Normandeau Associates, Inc., of Bedford, NH.

[24] The production capability ratings PSNH reports to the regional grid operator are slightly less than the nameplate ratings. PSNH currently claims winter production capabilities of approximately 114 MW, 322 MW, and 43 MW for Unit I, Unit 2, and the combined smaller units, respectively, totaling 479 MW for the station. The corresponding claimed summer capabilities are 113 MW, 320 MW, and 34 MW,

Unit I, a coal-fired, steam-electric unit with a nameplate rating of 120 MW, was placed in service in 1960. Unit 2, a coal-fired, steam-electric unit with a nameplate rating of 350 MW, was placed in service in 1968. Units I and II are "baseload" generating units. Once connected to an electrical grid, a baseload unit's operating parameters are maintained to keep its electrical output as close as possible to its nameplate rating. The utility's objective is to operate the generating unit continuously at a constant electrical output, except when that unit undergoes a scheduled maintenance or experiences an unplanned outage. The station's remaining two units, Units CT1 and CT2, are oil-fired combustion turbines with a combined nameplate rating of 50 MW. These are "peaking" units that operate infrequently, generally at times when regional electricity demand is very high.[25] PSNH states that it currently has no plans to retire the station. PSNH November 2007 CWA § 308 Response at 25.

The Merrimack Station site encompasses approximately 230 acres on the west bank of the Merrimack River. The major operating components of the coal-fired units are contained in boiler and turbine houses near the river. The station's maintenance facilities, laboratories and administrative offices, as well as the switchyard and slag settling pond, are located to the west of the central boiler and turbine buildings. To the south of the central buildings are located assorted air emissions control equipment and the discharge canal that receives the station's cooling water discharges and conveys them to the river. To the north of the central buildings is a 25-acre coal storage area with capacity for 200,000 tons of coal, representing a 50-day coal supply. Unit I's existing smoke stack is 225 feet tall and Unit 2's existing stack is 317 feet tall. As part of the installation of a flue gas desulfurization ("FGD") system, a third stack has been constructed which is 445 feet tall.

The station site is at about the midpoint of a stretch of the Merrimack River known as the Hooksett Pool. Hooksett Pool is bounded downstream by the Hooksett Dam and upstream by the Garvin Falls Dam. The pool is about 5.8 miles long, ranges from six to ten feet deep, and has a surface area of about 350 acres and a volume of 130 million cubic feet at full pond elevation. Merrimack Station draws its cooling water from, and returns the heated discharge to, Hooksett Pool close by the plant.

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respectively, for a total station capability of 467 MW. ISO New England Seasonal Claimed Capability Report, Nov. 2009, available at www.iso-ne.com.

[25] Units CT1 and CT2 do not use cooling water from the Merrimack River or contribute to Merrimack Station's thermal discharges into the river. Consequently, these units have little relevance to the determinations that are the focus of this document. In general, references in this document to the "station," its technologies, and its usage of cooling water should be understood as referring solely to Units I and II and not encompassing Units CT1 and CT2 unless otherwise indicated.

7.3.2 Steam Production and Electricity Generation

Units I and II employ a conventional steam-electric generating process. The units produce electricity by combusting coal in boilers to create heat, using the heat to create steam by boiling treated process water running in tubes through the boilers, and then using the steam to spin turbines in order to generate electricity. After being exhausted from the generator turbines, the steam enters condensers where it is cooled and condensed back into process water that is recycled to the boilers to be heated into steam again. "Makeup water" to compensate for losses of process water is provided from groundwater wells.

7.3.3 Cooling Systems for Elimination of Waste Heat

To carry the waste heat away from the condensers, the station relies on cooling water taken from the Merrimack River. This "non-contact" cooling water runs through the condensers in tubes that maintain physical separation between the process steam and the cooling water. The cooling system currently operates in a "once-through" or "open-cycle" configuration in which the required cooling water is drawn from the river, run through the condensers to extract waste heat, and then returned to the river via the discharge canal. Cooling water drawn from the river is used in a similar fashion to carry waste heat away from certain pieces of station equipment that have individual cooling systems with heat exchangers, but this cooling water is discharged to the slag pond rather than directly to the discharge canal.

The station draws its cooling water through two cooling water intake structures, one for each of the two main generating units. The flow of the cooling water to the station is driven by pumps located at the intake structures. The Unit I intake structure has a design pumping capacity of 59,000 gallons per minute (gpm), split equally between two pumps, while the Unit 2 intake structure has a design pumping capacity of 140,000 gpm, again split equally between two pumps. Not all of the water drawn from Hooksett Pool is used for condenser cooling; some is used for other purposes such as equipment cooling or washing slag from the coal combustion process into the station's slag settling pond. However, condenser cooling is by far the largest water use: when the station is operating at full power, the maximum rates of condenser cooling water discharge are 48,000 gpm for Unit I and 130,000 gpm for Unit 2. Combined across the two units, the maximum condenser cooling water discharge rate of 178,000 gpm – or approximately 256 MGD – represents 89% of the maximum water intake rate of 199,000 gpm (or 286 MGD).

After exiting the condensers, the heated condenser cooling water is piped to the 3,900-foot long, C-shaped discharge canal at a point near the northern end of the canal. (The discharge from the slag settling pond enters the canal at roughly the same location.) PSNH states that at normal water levels the canal water velocity is approximately 0.3 ft/sec in most of the canal and approximately 1.1 ft/sec in the final leg, *see* PSNH November 2007 CWA § 308 Response at l9, suggesting that cooling water discharged from the plant is typically resident in the canal for roughly three hours before reaching the river.

The discharge canal contains 216 fountain-like power spray modules ("PSMs") that can be operated to spray water from the canal into the air. *See* PSNH November 20007 CWA § 308 Response at 18–20. After spraying by the PSMs, the water settles back down into the canal for discharge to Hooksett Pool. The PSMs are designed to increase evaporative cooling of the water in the canal and, thereby, to reduce the plant's ultimate thermal discharge to the river. Merrimack Station's present NPDES permit, issued in 1992, requires that:

> *[t]he power spray module system shall be operated, as necessary, to maintain either a mixing zone (Station S-4) river temperature not in excess of 69ºF, or an N-10 to S-4 change in temperature (Delta-T) of not more than 1ºF when the N-10 temperature exceeds 68ºF. [N-10 is a monitoring location upstream of the Merrimack Station discharge, while S-4 is a monitoring location downstream of the point of discharge.] All available PSMs must be operated when the S-4 river temperature exceeds both of the above criteria.*

The limited cooling capacity of the PSM system is illustrated by the hypothetical permit conditions that PSNH says Merrimack Station could meet. According to PSNH, if a new permit were written with an enforceable limit on the ΔT between Stations N-10 and S-4, the allowed temperature differential would have to be *at least 19°F* in order for the plant to be able to comply with the permit at bounding low river flow conditions with the existing canal and PSM configuration. PSNH November 2007 CWA § 308 Response at ix.

7.4 Evaluation of Alternative Technologies for Reducing Merrimack Station's Thermal Discharges

7.4.1 Overview

As stated above, the goal of this section is to establish thermal discharge limits based on the BAT for Merrimack Station in accordance with CWA §§ 301(b)(2), 304(b)(2) and 402 and 40 C.F.R. § 125.3(d)(3). This subsection evaluates alternative technologies for reducing thermal discharge. A range of generally available options for reducing thermal discharges from steam-electric generating facilities is evaluated, and several are screened out for various reasons. The remaining options are then evaluated in more detail. Finally, EPA presents its conclusions regarding the remaining options. Based on these conclusions, EPA presents its determination of the BAT and the resulting limits for the discharge of heat from Merrimack Station.

Because Merrimack Station is an existing plant, EPA must evaluate what constitutes BAT for reducing thermal discharges from the plant based on retrofitting technology to the facility. EPA recognizes that as compared to new facilities, existing plants like Merrimack Station may have less flexibility in designing and locating cooling system components, and may incur higher installation and operating costs. EPA also recognizes that installing retrofitted technologies at Merrimack Station may cause a marginal reduction in the facility's profits by requiring brief, otherwise unnecessary shutdown periods during which the plant would lose both production and revenue, and by decreasing the plant's thermal efficiency and electrical output. Finally, EPA recognizes that Merrimack Station may have site limitations, such as limited undeveloped space, which could make installation of certain technologies more difficult or infeasible. *See National Pollutant Discharge Elimination System–Regulations Addressing Cooling Water Intake Structures for New Facilities*, 65 Fed. Reg. 49,060, 49,064 (Aug. 10, 2000).

Nonetheless, it should also be clearly understood that technologies exist to generate electricity using a conventional steam-electric generating process with little or no discharge of heated cooling water. Indeed, these technologies, including both wet and dry cooling towers operated in closed-cycle configurations, have been in widespread use for many years.

At the same time, none of these technologies is automatically considered BAT for this case-by-case assessment. Rather, each technology's availability and economic achievability must be addressed on a site-specific basis. As explained above, this involves consideration of (1) each technology's availability for use at Merrimack Station; (2) the technology's performance at Merrimack Station in terms of heat removal, non-water quality environmental impacts, energy requirements), and any other impacts that EPA deems it appropriate to consider; and (3) the technology's cost if used at Merrimack Station, and the achievability and reasonableness of this cost in light of the progress to be made toward the CWA's goal of eliminating all pollutant discharges.

7.4.2 Alternative Cooling Technologies Generally Available for Use at Steam-Electric Generating Facilities

The first subsection below briefly describes three basic condenser cooling system configurations used by steam-electric generating plants – once-through water-based, closed-cycle water-based, and air-based – and discusses their general availability for steam-electric power plants, like Merrimack Station. The second subsection discusses cooling technologies generally and addresses which technologies merit more detailed evaluation for possible application at Merrimack Station.

7.4.2.1 Basic Cooling System Configurations

Generally, steam-electric power plants employ one or more of the following three basic cooling system configurations to remove waste heat from the condensers: (1) "once-through" or "open-cycle" water-based cooling systems, (2) "recirculating" or "closed-cycle" water-based cooling systems, and (3) dry, air-based cooling systems. As discussed below, EPA considers both once-through and closed-cycle cooling system configurations, as well as combinations of these systems, but not air-based cooling systems, to be available for Merrimack Station.

7.4.2.1.1 Open-Cycle, Water-Based Cooling Systems

A once-through cooling system withdraws water from a source water body for cooling purposes, runs the water through the condenser to extract waste heat, and discharges the heated water back to a water body (typically the source water body). After the heated cooling water leaves the condensers, various technologies may be applied to transfer waste heat to the atmosphere and, thereby, to reduce the thermal load discharged to the receiving water.

Merrimack Station's current cooling system with its discharge canal and PSMs is an example of a technology-assisted, once-through cooling system. Other cooling technologies generally available for this purpose include cooling towers (*i.e.*, "helper cooling towers") as well as cooling ponds with longer residence times. The magnitude of the thermal discharge by an open-cycle cooling system varies greatly depending on what cooling technologies, if any, are applied to the cooling water prior to ultimate discharge. As a category, open-cycle water-based (or "wet") cooling system configurations are clearly available for Merrimack Station.

7.4.2.1.2 Recirculating, Closed-Cycle Water-Based Cooling Systems

A closed-cycle cooling system runs cooling water in a loop between the condensers, where waste heat is transferred from process steam to the cooling water, and one or more cooling technologies, where waste heat is transferred from the heated cooling water to the atmosphere. As a result, the cooling water is chilled and may be reused for condensing steam. In a closed-cycle cooling system, however, the cooling technologies must be applied at a scale sufficient to chill the cooling water to a temperature allowing the water to be reused for condensing process steam. A closed-cycle cooling system will typically reduce a generating plant's thermal discharge (and cooling water withdrawals) by more than 90% of what the facility would discharge using an open-cycle cooling system. The specific reductions achieved will depend on the specific cooling technologies chosen and a variety of other factors.

Many steam-electric generating plants around the United States (and the world) use closed-cycle cooling systems,. In some cases, these closed-cycle systems have been retrofitted to existing steam-electric power plants. As a category, EPA considers water-based (or "wet") closed-cycle cooling system configurations to be generally available for the station.[26]

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[26] It is worth noting that between 1955 and 1997, the number of new steam-electric power plants using closed-cycle cooling water systems increased from 25 percent to 75 percent, with a corresponding decrease in plants using once-through systems. Between 1975 and 1984, the number of steam-electric power plants using closed-cycle recirculating systems increased 31 percent. For several reasons, including the CWA § 316(b) Phase I Rule, this trend toward the use of closed-cycle systems is projected to continue as new plants are built. *See National Pollutant Discharge Elimination System: Regulations*

7.4.2.1.3 Dry, Air-Based Cooling Systems

A dry cooling system uses air rather than cooling water to transfer waste heat to the atmosphere. In a "direct" dry cooling system, waste heat is extracted from the condensers directly by air flowing across the condensers. Dry cooling technologies can also be applied "indirectly" in a so-called "hybrid system." Hybrid systems use a water-based system to remove waste heat from the condensers and a dry cooling system to transfer a portion of the waste heat from the cooling water to the atmosphere. Technical Development Document for the Final Regulations Addressing Cooling Water Intake Structures for New Facilities (EPA-821-R-01-036), ch. 4, at 1 (Nov. 2001) (hereinafter "EPA TDD 2001 – New Facilities"). *See National Pollutant Discharge Elimination System: Regulations Addressing Cooling Water Intake Structures for New Facilities*, 66 Fed. Reg. 65,256, 65,282 (Dec. 18, 2001); U.S. Envtl. Prot. Agency, Off. of Water, Econ. and Eng'g, Analysis of the Proposed § 316(b) New Facility Rule (Aug. 2000), App. A at 14 (hereinafter "EPA Economic and Engineering Analysis"). The potential indirect applications of dry cooling technologies will be addressed below.

7.4.2.1.4 Combinations of Once-Through and Closed-Cycle Cooling Systems

Once-through and closed-cycle cooling systems can also be used together. For example, a facility could use a closed-cycle cooling system at one of its generating units and a once-through system at another of its units. PSNH has provided information on certain combined cooling system designs of this nature.

Another method of combining once-through and closed-cycle cooling systems would be to configure a closed-cycle system with bypass piping that would allow the cooling system to be operated in either a closed-cycle or once-through mode (subject to compliance with permit limits). PSNH has not provided information on the potential application of this type of multi-mode cooling system at Merrimack Station, but such systems are in use at other steam-electric generating plants. EPA considers this form of combined system to be generally available for steam-electric power plants.

7.4.2.2 Cooling Technologies Generally Available for Use in Either Open-Cycle or Closed-Cycle Water-Based Cooling Systems

Some cooling technologies used in closed-cycle cooling systems can also be used to reduce thermal discharges from open-cycle cooling systems. These technologies include cooling ponds and wet mechanical draft cooling towers.

Addressing Cooling Water Intake Structures for New Facilities, 66 Fed. Reg. 65,256, 65,266, 65,267, 65,269, 65,323–24 (Dec. 18, 2001).

7.4.2.2.1 Cooling Ponds

One technology used to reject waste heat from a water-based cooling system involves sending the heated cooling water to an artificial pond and then allowing the waste heat to be transferred to the atmosphere by evaporation. In a closed-cycle configuration, cooling water is drawn from the pond, used for condenser cooling, and then returned to the cooling pond where it is cooled through evaporation.

A cooling pond could also be used in conjunction with a once-through cooling system. Under this approach, water is taken from a natural source water body for condenser cooling and then fed into the cooling pond where the water is cooled prior to discharge. In this configuration, the pond's overall effectiveness at dissipating heat, and thereby reducing thermal discharges, depends on the pond's size in relation to the rate of cooling water inflow and outflow. In a sense, Merrimack Station's discharge canal can be understood to function like a limited-capacity cooling pond operated in a once-through configuration. Theoretically, devices like the PSMs could be used to increase evaporation from cooling ponds.

PSNH states that the Merrimack Station site includes insufficient real estate within which to construct a cooling pond of the size that would be required to use this technology in a closed-cycle configuration. PSNH November 2007 CWA § 308 Response at 32. Having considered the matter, EPA finds PSNH's view to be reasonable. Moreover, given the availability of alternative cooling technologies – specifically, cooling towers – that can almost completely eliminate thermal discharges from Merrimack Station, EPA finds it unnecessary to further investigate cooling pond technology as a potential BAT. Thus, EPA finds based on current information that cooling ponds are not technologically available for use at Merrimack Station. That said, PSNH is free to use any lawful technology, including cooling ponds, to meet final permit limits.

7.4.2.2.2 Wet Cooling Towers – Natural Draft and Mechanical Draft

In a "wet" or evaporative cooling tower, heated cooling water is pumped up to a level some distance above the base of the tower and is then allowed to fall through a rising column of air. *See* 65 Fed. Reg. at 49,081. *See also* Preliminary Regulatory Development Section 316(B) [sic] of the Clean Water Act, Background Paper Number 3: Cooling Water Intake Technologies (Apr. 4, 1994), at 2-3 to 2-5 (general discussion of cooling towers) (referred to hereafter as "EPA Background Paper No. 3"); 66 Fed. Reg. at 65,282. Heat transfer occurs largely through evaporation, and warmed, moistened air is emitted from the top of the tower. *See* 65 Fed. Reg. at 49,081. The cooling water exits from the bottom of the tower at a temperature approaching the wet bulb air temperature. *See* EPA Economic and Engineering Analysis, App. A at 14.

In a natural draft cooling tower the required air flow is produced by the natural "chimney effect" of heated air rising through the tower. *See* 1994 EPA Background Paper No. 3, at 2-4; EPA

Economic and Engineering Analysis at 11-2 to 11-3, App. A at 14. To produce the chimney effect, natural draft towers have to be quite tall. A typical natural draft wet cooling tower would be 450–550 feet tall. (The height of the existing Merrimack Station smoke stacks is of a similar order of magnitude, with the tallest stack standing 317 feet tall, but a natural draft tower would be still taller and larger around.) *See* PSNH November 2007 CWA § 308 Response at 33.[27]

Natural draft cooling towers are typically used in a closed-cycle configuration and would not be expected to be used with an open-cycle system, though it is theoretically possible that natural draft towers could be used solely for chilling thermal effluent prior to discharge, as opposed to being used for chilling heated cooling water prior to reuse. Natural draft towers tend to require a higher initial capital investment than mechanical draft cooling towers, which generate the required air flow by using fans. The absence of fans, however, makes natural draft towers cheaper to operate than mechanical draft towers. Natural draft wet cooling towers may impose a somewhat larger generating "efficiency penalty," but will have a smaller "auxiliary energy penalty" because they do not use fans. Without fans, natural draft towers will also run more quietly than mechanical draft towers. Moreover, the greater height of a natural draft cooling tower tends to eliminate or reduce icing or fogging concerns as it results in greater dispersion of any water vapor plumes. At the same time, the greater size of natural draft cooling towers may prompt greater concern about visual effects than is triggered by mechanical draft cooling towers.

Natural draft cooling tower technology is in use in the closed-cycle mode at steam-electric generating plants around the country and the world and is currently being retrofitted at the Brayton Point Station power plant in Somerset, Massachusetts.[28] Nevertheless, according to PSNH, natural draft cooling tower technology is infeasible at Merrimack Station. PSNH first states that "natural draft towers require adequate heat load provided by the circulating water system to fuel the thermal differential required to create and sustain the 'chimney effect.'" The company goes on to state that "[b]ecause of the relatively small capacity of cooling water (*i.e.*, circulating water) flow at Merrimack Station, particularly Unit I, implementation of natural draft towers at Merrimack Station is infeasible." PSNH November 2007 CWA § 308 Response at 33.

The precise meaning of these statements by PSNH is not entirely clear. PSNH may mean that Unit I, operating at times when Unit 2 is not operating, would produce insufficient waste heat to support the chimney effect in a single cooling tower sized to accommodate the waste heat from

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[27] PSNH has raised the issue that zoning regulations as a general matter can preclude construction of such tall structures but has provided no information to indicate that this would be the case at Merrimack Station. *Id.*

[28] *See, e.g.*, 65 Fed. Reg. at 49,080–81; Draft Supplement to Background Paper Number 3: Cooling Water Intake Technologies at A-3 (1996); EPA Background Paper No. 3, at 2-4; 41 Fed. Reg. 17,387, 17,388 (Apr. 26, 1976).

both units operating simultaneously. Alternatively, PSNH may mean that Unit I would produce insufficient waste heat to support the chimney effect even in a cooling tower sized only for Unit I. It is unclear whether PSNH might also be suggesting that the technology would be infeasible for a cooling tower sized for Unit 2 on a stand-alone basis. EPA has not independently verified any of these interpretations.

EPA is not prepared, based solely on the above statements by PSNH, to conclude that it would be infeasible to use natural draft towers in a closed-cycle configuration at Merrimack Station given the widespread use of this technology. Nevertheless, given PSNH's expressed position and given the undisputed availability of other cooling tower technologies equally effective at reducing thermal discharges, EPA considers it unnecessary to further investigate natural draft wet cooling tower technology as the potential BAT for Merrimack Station. At the same time, PSNH may use any lawful technology, including natural draft cooling towers, to meet the permit limits ultimately included in the final permit.

Mechanical draft wet cooling towers operate on the same physical principles described above for natural draft wet cooling towers, with the essential difference being that the required air flow is forced by fans rather than created by the natural chimney effect. *See* 1994 EPA Background Paper No. 3, at 2-4; EPA Economic and Engineering Analysis at 11-2 to 11-3, App. A at 14. *See also* 1994 EPA Background Paper No. 3, at 2-3 to 2-5 (general discussion of cooling towers); 66 Fed. Reg. at 65,282. As noted above, mechanical draft towers would be considerably shorter than natural draft towers sized for the same heat load, with a height of roughly 60 feet compared to the 450-550 foot height of a natural draft tower. As a result, they may have lesser visual impact. At the same time, mechanical draft cooling towers may require a number of cooling tower cells and, therefore, may occupy a larger ground area. The fans in a mechanical cooling tower may contribute to higher operating sound levels than from a natural draft tower, and will increase the plant's auxiliary electric load. The auxiliary energy penalty presents an operating cost that mechanical draft towers bear but natural draft towers do not. Mechanical draft wet cooling tower technology is in use at steam-electric generating plants around the country and the world and has been applied on a retrofitted basis.[29]

PSNH has not challenged the feasibility of using mechanical draft wet cooling tower technology at Merrimack Station and has provided preliminary design information for applying the technology in a closed-cycle configuration at the facility.[30] *See* PSNH November 2007 CWA §

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[29] *See, e.g.*, 65 Fed. Reg. at 49,080–81; 1996 EPA Supplement to Background Paper No. 3, at A-3; 41 Fed. Reg. at 17,388; 1976 Draft EPA CWA § 316(b) Guidance at 13; EPA 1976 Development Document at 149–57, 191; 39 Fed. Reg. at 36,192.

[30] EPA acknowledges that PSNH has pointed to a number of detriments from retrofitting mechanical draft wet (or hybrid wet-dry) cooling towers at Merrimack Station, and has reached the opinion that retrofitting such towers and converting the facility from once-through to closed-cycle cooling would be "unsuitable"

308 Response at 34–35. PSNH expresses serious concerns, however, regarding the possibility that the water vapor plume emitted by the towers could in certain weather conditions cause fogging and icing in areas near the plant that could cause traffic safety problems. *See id.* at 36, 51. Because of these concerns, PSNH asserts that hybrid wet-dry cooling tower technology, which is more expensive than wet cooling tower technology but produces an abated water vapor plume, would be a more technically appropriate choice for Merrimack Station.[31] *Id.* at 36. The relatively more detailed cost and performance estimates that PSNH has provided to EPA are therefore based on application of mechanical draft hybrid wet-dry cooling tower technology, rather than mechanical draft wet cooling tower technology. *See generally id.* at 36–63, 99–123. While EPA agrees with PSNH that potential consequences for traffic safety from icing and fogging must be assessed before any final decision is made on the application of mechanical draft cooling towers, EPA is not convinced based on the current information that mechanical draft wet cooling towers at Merrimack Station would cause safety problems.[32] Accordingly, EPA currently considers mechanical draft wet cooling tower technology to be available for application at the station, with or without the use of hybrid wet-dry components.

As noted, PSNH has not provided detailed cost estimates for applying "non-hybrid" mechanical draft wet cooling tower technology to Merrimack. However, it is possible to estimate the costs of applying wet technology by taking the cost estimates PSNH has provided for application of hybrid technology and reducing those costs by applying adjustment factors to certain cost items. EPA has performed calculations to produce such cost estimates.[33]

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for a variety of economic, engineering, and environmental reasons. *See* PSNH November 2007 CWA § 308 Response at iv–ix.

[31] EPA notes that PSNH does not view either wet cooling towers or hybrid towers as appropriate in the sense of having overall benefits sufficient to outweigh their costs.

[32] The potential plume-related safety issues are discussed at greater detail below in the detailed evaluation of the technology in the subsection on traffic safety.

[33] According to these calculations, if wet cooling towers were substituted for hybrid cooling towers in the cost estimate that PSNH provided for applying hybrid towers in a closed-cycle configuration for both units, the total capital budget for the project would decline by $9.7 million. This calculation is based on a $6.9 million difference in quoted cost from a vendor, adjusted upward to reflect a 25% contingency factor and a 12% overhead and construction financing factor. *See* PSNH November 2007 CWA § 308 Response, Att. 4 at 1–2 & Att. 1, at 7. Information provided by PSNH does not indicate that there would be any difference between wet and hybrid technology in terms of annually recurring costs. *But see* Clean Water Act NPDES Permitting Determinations for Thermal Discharge and Cooling Water Intake from Brayton Point Station in Somerset, MA (NPDES Permit No. MA0003654) (Draft Permit) at 7-49 (Jul. 22, 2002) (hybrid wet/dry cooling towers are somewhat less efficient and are estimated to increase overall project costs by 20 to 65 percent over the cost for a wet (only) cooling tower project).

On the basis of this evaluation, EPA concludes that although the costs of applying wet cooling tower technology to Merrimack Station would be lower than the costs of applying hybrid cooling tower technology to the station, it is unnecessary to evaluate the two technologies separately for this BAT determination. This is because the two technologies would achieve similar reductions in thermal discharges and EPA has concluded that the more expensive hybrid technology would be economically achievable and would perform satisfactorily on all other dimensions considered as part of the BAT determination. Accordingly, given PSNH's expressed preference for hybrid cooling tower technology, EPA considers it unnecessary to perform a more detailed evaluation of the non-hybrid mechanical draft wet cooling tower technology for Merrimack Station. That said, PSNH may use any lawful technology, including non-hybrid mechanical draft wet cooling towers, to meet the ultimate final permit requirements.

7.4.2.2.3 Dry Cooling Towers

Dry cooling towers use a different method of transferring waste heat from heated cooling water to the atmosphere. With dry cooling towers, the cooling water does not come in direct contact with the air but instead travels in closed pipes through the tower. Air going through the tower flows along the outside of the pipes and absorbs heat from the pipe walls, which have previously absorbed heat from the water. Because the cooling water remains inside pipes, there is no evaporation and the warmed air emitted at the top of the tower is dried, rather than moistened as in a wet cooling tower, with the result that there is no water vapor plume. However, because of the absence of evaporation the water exiting at the bottom of the tower for reuse as cooling water approaches the dry bulb air temperature rather than the cooler wet bulb air temperature approached by the water in a wet cooling tower. *See* EPA TDD 2001 – New Facilities § 4.2.2; EPA Economic and Engineering Analysis, App. A at 14. In other words, dry cooling achieves somewhat less cooling and, as a result, has a somewhat larger "efficiency penalty" than a wet cooling tower. Also, dry cooling tower installations tend to have greater area requirements and to be more costly than wet towers of equivalent capacity because the sensible heat transfer process used in dry cooling is less efficient and thus requires a larger area to accommodate a given quantity of heat transfer. *See* EPA Economic and Engineering Analysis, App. A, at 14; 66 Fed. Reg. at 65,282–84, 65,304–06 (various estimates put costs of dry cooling as from 1.75 to three times more than cost of wet cooling).

Despite their lower efficiency and higher cost, dry cooling towers have several advantages over wet cooling towers: they do not consume water through evaporation or drift; they do not produce cooling tower blow down discharges that could adversely affect water quality; and they do not require cooling water makeup withdrawals that can result in the entrainment and impingement of aquatic organisms. In addition, dry cooling towers do not raise concerns about fogging, icing, or mineral deposits from vapor or drift because they emit neither water vapor nor salt drift. Use of dry cooling towers at Merrimack Station would also entirely eliminate thermal discharges to the Merrimack River related to condenser cooling water.

PSNH concludes that dry cooling tower technology is infeasible for Merrimack Station for two reasons. First, PSNH believes that the station site has inadequate space to accommodate dry cooling towers large enough to handle the plant's full waste heat load. *See* PSNH November 2007 CWA § 308 Response at 32. Second, PSNH concludes that, because of the design of the plant's condensers, the cooling water that dry cooling towers would return to the condensers would be too warm to allow the condensers to function properly. *See id.* at 32–33.

EPA has not independently verified either of these conclusions but has decided that it is not necessary to investigate them further in this instance.[34] Although dry cooling is clearly an established technology that has been widely used for *new* power plants, especially in arid areas with limited supplies of water, EPA has not identified a single case of an existing power plant converting from open-cycle cooling to closed-cycle cooling using dry cooling. Therefore, EPA does not have the requisite confidence that a retrofit of dry cooling is an available technology for Merrimack Station. PSNH's site-specific concerns about feasibility at Merrimack Station contribute to this lack of confidence. In addition, given the undisputed availability of other cooling tower technologies likely to have substantially lower cost, and nearly the same effectiveness at reducing thermal discharges to the Merrimack River, even if EPA was able to determine that dry cooling is an available technology for Merrimack Station, the Agency would presently be unable to determine it to be the BAT. EPA notes that it does not see a theoretical reason that retrofitting dry cooling to an existing open-cycle facility would necessarily be impossible, but the Agency must proceed with caution in the absence of any examples of such a conversion. Of course, PSNH may use any lawful technology, including dry cooling, to comply with the ultimate final permit limits.

7.4.2.2.4 Hybrid Wet-Dry Cooling Towers

Hybrid (wet-dry) cooling tower technology adds a dry cooling technology component to a wet cooling tower. EPA TDD 2001 – New Facilities, ch. 4, at 1. The purpose of the dry section is to abate the water vapor plume that the wet cooling tower would otherwise produce. (Hybrid wet-dry towers are sometimes referred to as plume-abated wet cooling towers. *See* PSNH November 2007 CWA § 308 Response at 36.) Transfer of waste heat from the cooling water to the atmosphere is accomplished through a combination of evaporation and sensible heat transfer. Mechanical draft hybrid towers are slightly taller than equivalent mechanical draft wet towers (e.g., 70 feet versus 60 feet). *See id.* Their initial capital investment costs are likely to be higher than those of wet towers, but lower than those of dry towers. *See* 65 Fed. Reg. at 49,081

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[34] EPA notes that dry cooling is generally thought to require more space than a wet tower installation would for the same facility and, therefore, space constraints may be more likely to pose problems in a retrofit context. In addition, whereas PSNH states that dry cooling would not be compatible with Merrimack Station's condensers, if that was the case, it might be possible to replace the condensers. Such replacement, however, would add additional cost.

(discussion of wet/dry towers). They are also expected to have somewhat higher operating and maintenance costs than wet towers. *See* PSNH November 2007 CWA § 308 Response at 36. Mechanical draft hybrid wet-dry cooling towers are established technology in common use at steam-electric generating plants around the country and the world. [35]

PSNH does not contest the availability of mechanical draft hybrid wet-dry cooling tower technology for Merrimack Station, but does express concerns regarding the residual water vapor plume. *See* PSNH November 2007 CWA § 308 Response at 51. EPA considers this technology available for Merrimack Station and deserving of detailed evaluation as a potential basis for setting BAT limits. (As stated above, EPA has not concluded that hybrid towers are needed to the exclusion of non-hybrid mechanical draft cooling towers, but EPA will nonetheless evaluate hybrid towers given PSNH's stated preference for them.) EPA discusses concerns regarding vapor plume issues in the section below on Fogging and Icing.

PSNH has provided information on the estimated cost and performance of mechanical draft hybrid wet-dry cooling tower technology installed in a variety of configurations at Merrimack Station: closed-cycle for both Units I and II; closed-cycle for Units I and II individually; and once-through configurations for both Units I and II at two different levels of heat removal capability. EPA has evaluated mechanical draft hybrid wet-dry cooling tower technology applied in each of these configurations as a potential basis for setting BAT limits.

7.4.2.2.5 Expansion of Merrimack Station's Existing Discharge Canal and PSM Cooling System

PSNH has evaluated the potential reduction in Merrimack Station's thermal discharges that could be achieved by doubling both the length of the existing discharge canal and the number of PSMs. PSNH's conclusion from this evaluation is that "[o]verall, current thermal performance of the PSMs is not distinctly improved." *See id.* at 117–18. EPA agrees with PSNH's generally negative assessment of this option and concludes that expansion of the station's existing canal/PSM cooling system does not merit further evaluation as a potential BAT.

7.4.2.2.6 Reduction of Plant Operations

Another method of reducing thermal discharges that is theoretically available to every steam-electric generating plant is simply to curtail the generation of electricity, thereby reducing condenser cooling water requirements and any associated thermal discharges. Obviously, generation curtailment would have major energy effects and, assuming a profitable power plant,

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[35] *See, e.g.*, 65 Fed. Reg. at 49,080–81; EPA Economic and Engineering Analysis, App. A at 14–15; 39 Fed. Reg. at 36,192; Pub. Serv. Comm'n of Wis./Wisc. Dep't of Natural Res., Final Environmental Impact Statement, Badger Generating Company, LLC, Electric Generation and Transmission Facilities (Jun. 2000, 9340-CE-100), Exec. Sum.

could have very substantial opportunity costs. Such substantial energy and cost effects would be expected from significant generation curtailment at Merrimack Station given that the facility is currently a baseload, coal-burning plant. At the same time, generation curtailment would not only reduce thermal discharges, but would also reduce adverse environmental effects associated with withdrawals of water from the river for cooling and emissions of air pollutants as a result of coal combustion.

Ultimately, EPA concludes that curtailing generation is not the BAT for Merrimack Station given that there are other available methods of reducing Merrimack Station's thermal loading to the Merrimack River without major energy effects. Meanwhile, other regulatory efforts are addressing the air emissions from the facility. That said, PSNH is free to use any lawful option, including generation curtailment, to meet the permit's ultimate thermal discharge limits.

7.4.3 Evaluation of Availability of Alternate Cooling Technologies Specifically for Merrimack Station

As discussed earlier, to establish BPJ-based BAT limits on thermal discharges from Merrimack Station, EPA must determine not only which cooling technologies are generally available for reducing thermal discharges from steam-electric generating plants, but also which ones are available for retrofitting specifically at Merrimack Station. In doing so, EPA must evaluate whether the technology is technologically and economically feasible for use at Merrimack Station. Moreover, to determine the BAT, EPA must also consider the factors discussed above, such as cost and non-water quality environmental and energy effects, as they are implicated by use of the technology at Merrimack Station.

EPA previously discussed and compared cooling system technologies at a general level, with consideration given to specific application of technologies at Merrimack Station, in order to determine which configurations and technologies merited more detailed evaluation. In this section, the application at Merrimack Station of specific mechanical draft hybrid wet-dry cooling tower technologies in a variety of closed-cycle, once-through and combined configurations is evaluated in greater detail.

7.4.3.1 Mechanical Draft Wet or Hybrid Wet-Dry Cooling Towers in Closed-Cycle Configuration for Units 1 & 2

Of the various alternative configurations of cooling technologies evaluated in this section, installation of mechanical draft wet or hybrid wet-dry cooling towers in closed-cycle configuration for both Units I and II would produce the greatest reduction in Merrimack Station's thermal discharges to the Merrimack River. *See* Table 7.1 below.

In other words, this approach would be the best performing available technology for the facility in terms of reducing its discharges of waste heat to the Merrimack River. As such, it would make the most progress toward the CWA's goal of eliminating the discharge of pollutants.[36] Consequently, this option will be discussed at length. Where appropriate, discussions of other technologies in later subsections will be shorter and will reference the discussions in this subsection.

Table 7-1: Comparison of Maximum Thermal Discharge for Generating Units Cooling Combinations

	Unit 1 & II Once-Through	Unit 1 Closed-Loop, Unit 2 Pass Through	Unit 1 Pass Through, Unit 2 Closed-Loop	Unit 1 & II Closed-Loop
Thermal Discharge (MBtu/year)	26,301,024	17,803,867	8,591,860	94,703
Thermal Discharge Reduction (Percent)	0	32.3	67.3	99.6

7.4.3.1.1 Potential Thermal Effluent Reduction

According to information provided by PSNH, installation of mechanical draft hybrid wet-dry cooling towers in closed-cycle configuration for both Units I and II at Merrimack Station would reduce the thermal discharge from Merrimack Station into the Merrimack River by approximately 99.5%.[37] (Wet (as opposed to hybrid wet-dry) mechanical draft towers would

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[36] As discussed above, air (or dry) cooling would theoretically achieve the greatest reduction by eliminating thermal discharges entirely, but EPA is unable presently to conclude that dry cooling is an available (or feasible) technology for retrofitting at Merrimack Station. PSNH's submissions conclude that dry cooling is not feasible for retrofitting at Merrimack Station and EPA has not found any cases of an open-cycle plant converting to closed-cycle cooling using dry cooling towers. In addition, dry cooling would be far more expensive despite the small margin of additional thermal reduction it offers over wet cooling towers.

[37] PSNH has not provided a numerical estimate of the reduction in thermal discharge but has stated that the installation and use of mechanical draft hybrid wet-dry cooling towers in a closed-cycle configuration at both units "would effectively eliminate all thermal discharge to the Merrimack River." PSNH November 2007 CWA § 308 Response at 100. Calculations based on other data provided by PSNH regarding this option suggest that the resulting daily cooling water discharge volume (estimated as total intake for makeup and blowdown requirements less evaporation losses) would be approximately 0.5% of the present daily maximum cooling water discharge volume. *See id.* at 18, 41, 54. Assuming for purposes of this calculation that the temperature parameters of the much smaller post-conversion cooling water discharges would match those of the much larger pre-conversion discharges, a 99.5% reduction in

achieve roughly equivalent reductions in thermal discharge.) Converting only one unit to closed-cycle cooling would achieve lesser thermal discharge reductions as indicated in Table 7-1 above.

7.4.3.1.2 Technological Availability

Mechanical draft wet and hybrid wet-dry cooling tower technologies are widely used at steam-electric power plants. These technologies are often used in closed-cycle configurations and have been retrofitted in closed-cycle configurations at a number of plants. *See* Clean Water Act NPDES Permitting Determinations for Thermal Discharge and Cooling Water Intake from Brayton Point Station in Somerset, MA (NPDES Permit No. MA0003654) (Draft Permit) at 7-37 to 7-38 (Jul. 22, 2002); Responses to Comments, Public Review of Brayton Point Station NPDES Permit No. MA0003654, at IV-114 to 115 (Oct. 3, 2003). PSNH agrees that either technology could be retrofitted at Merrimack Station in closed-cycle configuration and has provided estimates of the costs and performance consequences of doing so. EPA concludes that retrofitting mechanical draft wet and hybrid wet-dry cooling tower technologies in a closed-cycle configuration for both Units I and II (or for either unit alone) are available technologies for Merrimack Station.

7.4.3.1.3 Cost and Economic Achievability

As previously discussed, for purposes of making BAT determinations under the CWA, EPA evaluates economic achievability in terms of affordability. PSNH has submitted substantial, albeit initial, information regarding its estimates of the capital, operation and maintenance (O&M), and other direct and indirect costs of retrofitting mechanical draft hybrid wet-dry cooling tower technology in a closed-cycle configuration at Merrimack Station. Installation of cooling towers, regardless of the type of tower and the specific cooling system configuration, would involve both one-time costs and annually recurring costs. One-time costs include the initial capital investment to procure equipment and construct the facilities, as well as lost profits from any otherwise unnecessary outage period in which one or both units must cease generation in order to allow construction to proceed. Annually recurring costs include incremental costs to operate and maintain the new facilities and costs associated with any reduction in generation efficiency.

In this subsection, EPA begins by summarizing PSNH's estimates of one-time costs and annually recurring costs related to installation and use of mechanical draft hybrid cooling tower technology and by assessing the likely accuracy of the estimates. EPA also calculates an estimated equivalent annualized cost for the total one-time cost and combines it with the estimated annually recurring costs to obtain an estimate of total annualized costs. Finally, EPA

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cooling water discharge volume would translate to a 99.5% reduction in total thermal discharge from the station into the Merrimack River. *See* PSNH July 2010 CWA § 308 Response at 22.

evaluates the affordability of the technologies to PSNH based on an assessment of PSNH's ability to finance the necessary outlays. EPA also considers the potential impact on the electric bills for typical residential customers that could result from upgrading Merrimack Station's cooling system.

Based on this analysis, EPA concludes that retrofitting mechanical draft wet or hybrid wet-dry cooling tower technology in closed-cycle configuration at both Units 1 and 2 at Merrimack Station (or at either one of the units) is economically achievable. PSNH has not demonstrated otherwise.

7.4.3.1.3.1 One-Time Costs

PSNH initially estimates the capital expenditure required to retrofit mechanical draft hybrid wet-dry cooling tower technology in a closed-cycle configuration at both Units I and II of Merrimack Station to be $42.3 million. To this initial estimate PSNH adds a 25 percent contingency factor and a 12 percent factor for corporate overhead and construction financing to reach a total recommended project budget of $59.2 million.[38] The major components of PSNH's capital budget estimate for the project are summarized in Table 7-2 below.

As indicated in Table 7-2, the cost for the cooling towers themselves represents less than half of the total project budget. Other major elements include the addition of a booster pumping station to pump the heated cooling water to the cooling towers and additional piping to carry the cooling water from the existing cooling water outfall to the towers and back from the towers to the existing pumps at the cooling water intake structures. EPA views PSNH's proposed initial project scope as reasonable in light of our experience reviewing power plant cooling systems, but EPA has not independently verified PSNH's capital budget estimate. (Again, EPA notes that approximately 28.5 percent of the estimated project cost is for unknown contingencies and overhead and construction financing ($16.9 million/$59.2 million = 28.5%), but understands that PSNH included these values to address potential unknowns inherent in preparing an initial cost estimate for a project of this magnitude.)

[38] PSNH's cost estimates are presented in 2007 dollars.

Table 7-2: PSNH's Recommended Engineering and Construction Budget for Installation of Mechanical Draft Hybrid Wet-Dry Cooling Tower Technology in Closed-Cycle Configuration at Merrimack Station Units I and II ($MM)[39]

Cooling tower delivery and erection	$16.3
New cooling water discharge and supply piping	5.7
New booster pumping station, valves, and tie-ins	4.5
New electrical substation, tower work, and tie-ins	2.3
Cooling tower basin installation	2.2
Modifications to existing intake pumping station	1.6
Design engineering	1.3
Other (including administration and support craft costs)	8.4
Total before contingency, overhead, and financing factors	$42.3
Recommended minimum contingency (25%)	10.6
Overhead and construction financing (12%)	6.3
Total recommended engineering and construction budget	$59.2

PSNH's cost estimates are based on 2007 cost structures. EPA has updated PSNH's estimates to reflect reasonable values as of 2010 based on estimated changes in the costs for the various account components since 2007. As of late 2010, the updated estimate of the cost for installing closed-cycle cooling for both units at Merrimack Station is $65.4M (capital costs plus contingency and overhead costs).[40]

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[39] *See* PSNH November 2007 CWA § 308 Response at 59.

[40] Memorandum by Abt Associates, Inc., "Cost and Affordability Analysis of Cooling Water System Technology Options at Merrimack Station, Bow, NH" (September 14, 2011) (*see* Table 1-1 and Table 1-4, column 4). It should be understood that the costs for upgrading the intake system (e.g., screening and fish return upgrades) are not included here because this analysis is concerned with thermal discharge controls only, and not cooling water intake effects.

Besides project construction, the other potentially significant one-time cost is lost profits (electricity market revenues less Merrimack Station's variable generation costs) associated with the generation foregone during any construction outage periods when the units would otherwise be operating and generating profits. PSNH estimates that construction would require a concurrent seven-week outage for both units, which exceeds by three weeks the outages that would otherwise be scheduled for regular maintenance. Assuming that both units would otherwise have run at 100% capacity factors during the extra three-week outage period, and assuming a cost of $37 per MWh for projected replacement power costs, PSNH calculates the estimated lost pre-tax profit from the extra three weeks of outage to be $8.8 million. PSNH November 2007 CWA § 308 Response at 45–46. EPA brought this value forward to 2010 based on changes in electricity rates in New England since 2007, which results in a figure of $9.1 million.[41] Memorandum by Abt Associates, Inc., "Cost and Affordability Analysis of Cooling Water System Technology Options at Merrimack Station, Bow, NH" (September 14, 2011) (*see* Table 1-1).

EPA notes two reasons why PSNH's estimate of lost profits may err to the high-side: first, PSNH has used the units' nameplate ratings rather than the lower production capability ratings that PSNH currently claims in its reports to the regional system operator; and second, PSNH has assumed that the units would have been operating at 100 percent capacity[42] rather than a lower figure reflecting the facility's recent actual capacity factors. As shown in the Table 7-3 below, Merrimack Station's actual capacity factor has been closer to about 80 percent over the last ten years.

EPA further notes that PSNH has provided little information to support its assertion that converting to closed-cycle cooling would require three weeks of otherwise unnecessary outage. At the same time, EPA recognizes that there is considerable uncertainty in any estimate of lost profits, particularly with respect to the future market price of electricity. Given the inherent uncertainty and the relatively small proportion of total estimated project costs that the lost profits represent, EPA considers PSNH's $8.8 million estimate adequate for purposes of this BAT determination. As previously discussed, EPA brought this value forward to 2010, resulting in a figure of $9.1 million.

PSNH's total estimate, in 2007 dollars, of one-time costs for this option is $68.0 million, representing the sum of the $59.2 million estimated construction budget and the $8.8 million

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[41] Based on electricity price information from the Department of Energy, Energy Information Administration, electricity prices declined slightly in New England from 2007 to 2010.

[42] Capacity Factor data obtained from EPA Web Site: http://camddataandmaps.epa.gov/gdm. Merrimack Station's average capacity factor for 2001–2009 is 79.8%.

estimated lost profits amount discussed above. Brought forward to 2010, and prior to tax adjustments, the cost of closed-cycle cooling installation is $65.4, with $9.1million in outage-caused lost profits, for a total initial cost of $74.6 million. *See id.* at Tables 1-2, 1-4. Tax adjustments, such as for depreciation, reduce this total figure to $52.9 million, on an after-tax, present value basis. *See id.* at Table 1.4.

Table 7-3 Capacity Factors for Merrimack Station Units I and II (2001-2009).

	UNIT 1		UNIT 2	
Year	MWh Produced	Capacity Factor	MWh Produced	Capacity Factor
2001	915517.52	87.03%[43]	2164877.82	70.56%
2002	810636.33	77.06%	2208430.61	71.98%
2003	1001553.52	95.21%	2152545.96	70.16%
2004	932942.05	88.69%	2355514.26	76.78%
2005	972074.1	92.41%	2310644.84	75.31%
2006	865132.69	82.25%	2474713.61	80.66%
2007	1028114.7	97.74%	2435894.26	79.40%
2008	859953.64	81.75%	2148482.75	70.03%
2009	901288.7	85.68%	1646268.43	53.66%
AVE		87.54%		72.06%
Average Capacity Factor			79.8%	

In order to facilitate consideration of the affordability of this total one-time cost, EPA believes that it is useful to reframe it in terms of an equivalent annualized cost.

[43] Capacity Factor = Actual Electrical Production (MWe)/Unit's Nameplate Capacity (MWe) x Hours per Year (8765.8). Example; In 2001 for Unit I; (915517.52 MWe produced)/(120 MWe - Unit I Nameplate Capacity)(8765.8 - Hours/Year) = 87.03%

7.4.3.1.3.2 Annually Recurring Costs

PSNH estimates that implementation of mechanical draft hybrid wet-dry cooling tower technology in a closed-cycle configuration for both Units I and II at Merrimack Station would result in additional annually recurring costs of $6.5 million in the first five years, rising to $6.6 million and then $6.9 million in subsequent years. These costs fall into five categories and are summarized in Table 7-4 below.

EPA has not independently verified PSNH's estimates of incremental annual costs, but uses them for purposes of this analysis.[44] EPA notes that the largest of PSNH's estimated costs – the cost of electricity required to run the booster pumps and tower fans – appears to be somewhat overstated because PSNH has assumed that the fans and pumps would run and consume electricity in all hours of each year, which overstates the electricity requirements.

Neither the fans nor the pumps would operate at times when the respective generating units experience outages; and required fan usage would likely be reduced during cooler months of the year.[45] Moreover, as stated above, even apart from outages, Merrimack Station's two main generating units do not run at full capacity 24 hours per day, 7 days per week. As a result, there are likely to be additional times when all the fans and pumps are not needed. EPA further notes that the second largest of the annual recurring costs – the value of generation output lost due to reductions in condenser cooling efficiency – may also be overstated for similar reasons.[46] Changing the assumed capacity factor used in PSNH's estimates of these two costs from 100 percent to Merrimack Station's actual capacity factor for 2001 – 2009 of 79.8 percent would reduce PSNH's estimate of total annually recurring costs by approximately $850,000 per year, and making an adjustment for reduced fan usage in the cooler months would reduce the cost estimate still further.

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[44] *See* EPA TDD 2001 - New Facilities, §§ 3.3.2, 3.3.3.

[45] PSNH's discussion of the tower design states that "the need to operate all the tower fans during the cooler seasons would be totally dependent on ambient conditions" and notes that a programmable logic control system would be included in the design to minimize costs of unnecessary fan operation. *See* PSNH November 2007 CWA § 308 Response at 39.

[46] PSNH has calculated the value of the lost capacity using the assumption that the units operate in all hours of every year, which is clearly an upward-biased assumption. However, because the information PSNH has provided does not make clear how PSNH determined the annualized lost capacity quantities used in the value calculations, it is impossible for EPA to be certain that the upward bias is not offset elsewhere in the value calculation.

Table 7-4: PSNH's Estimated Annually Recurring Costs Associated with Installation and Operation of Mechanical Draft Hybrid Wet-Dry Cooling Tower Technology in Closed-Cycle Configuration at Merrimack Station Units I and II ($ million)[47]

Cost of electricity to run booster pumps and tower fans[48]	$4.2
Value of generation output lost due to reduction in condenser efficiency[49]	1.9
Cost for intensified chemical and biocidal treatment of cooling water	0.2
Labor cost to operate cooling towers	0.1
Maintenance cost for cooling towers and booster pumps – years 1–5	0.1
Maintenance cost for cooling towers and booster pumps – years 6–15	0.2
Maintenance cost for cooling towers and booster pumps – years 16–30	0.5
Total estimated annually recurring costs – years 1–5	$6.5
Total estimated annually recurring costs – years 6–15	$6.6
Total estimated annually recurring costs – years 16–20	$6.9

Nevertheless, EPA recognizes that such estimates are inherently subject to considerable uncertainty with respect to elements such as the future market price of electricity and weather conditions. Accordingly, EPA has decided not to alter PSNH's $6.5–$6.9 million estimate of annually recurring pre-tax costs for purposes of this BAT determination, except that, as in the previous section, EPA brought these values forward from 2007 to 2010, and then projected these values into the future on a nominal dollar (i.e., including the effects of inflation) basis. This conversion yields a cost of $6.8 – 7.2 million per year.

7.4.3.1.3.3 Affordability

As discussed above, EPA has concluded that for purposes of this BAT determination, it is reasonable to use as the starting point PSNH's estimates of one-time and annually recurring pre-

[47] *See* PSNH November 2007 CWA § 308 Response at 43–50.

[48] Calculated by PSNH as $72/MWh * 8760 hours/year * 6.70 MW, where 6.70 MW is the total power required to operate the new equipment (0.96 MW for Unit I booster pumps, 3.65 MW for Unit 2 booster pumps, 0.60 MW for Unit I tower fans, and 1.49 MW for Unit 2 tower fans).

[49] Calculated by PSNH as $72/MWh * 8760 hours/year * 2.98 MW, where 2.98 MW is the estimated annualized generating capacity lost from reductions in condenser efficiency due to warmer input cooling water (0.16 MW for Unit I and 2.82 MW for Unit 2).

tax costs for a retrofit installation of mechanical draft hybrid wet-dry cooling tower technology in a closed-cycle configuration at Merrimack Station. (Non-hybrid wet cooling towers would be somewhat less expensive.) Those estimates, as of 2007, are $68.0 million in one-time costs and $6.5 - $6.9 million in annually recurring costs. EPA brought these estimates to 2010, resulting in a one-time pre-tax cost of $74.6 million and annual recurring costs of $6.8 – 7.2 million. On an after-tax basis, present value basis, these values translate into a total initial cost of $52.9 million (including outage expenses), and total annual costs (including "energy penalties") of $58.9 million, for a total present value (at 5.3%) after-tax, cash cost of $111.8 million. This is equivalent to an annualized cost to PSNH on an after-tax, nominal dollar (*i.e.*, including the effects of inflation) basis of $8.98 million per year over 21 years at 5.3 percent. Memorandum by Abt Associates, Inc., "Cost and Affordability Analysis of Cooling Water System Technology Options at Merrimack Station, Bow, NH" (September 14, 2011) (*see* Table 1-4, column 3).

EPA currently expects that PSNH will recover the costs of cooling tower installation and operation through increased electricity rates, as authorized under the New Hampshire Public Utilities Commission's rate regulation framework. As such, PSNH's electricity consumers, and not the company's shareholders, will "pay for" technology needed for Merrimack Station to comply with CWA requirements. Nevertheless, technology installation will require that PSNH finance the capital outlays, which could pose an affordability challenge to the company depending on its financial circumstances. In the discussion below, EPA assesses the affordability of the cooling system improvements being considered for Merrimack Station in terms of the financial challenge to PSNH and the rate impact to electricity consumers.

EPA assessed whether installing and operating cooling tower technology at Merrimack Station could pose a financial challenge to PSNH by considering (a) the increase in the company's assets needed for technology installation, (b) the capital outlay that would be required relative to PSNH's recent capital expenditure levels, and (c) the potential interest charges that would be needed to finance technology installation, assuming that the outlay is financed completely through debt. Memorandum by Abt Associates, Inc., "Cost and Affordability Analysis of Cooling Water System Technology Options at Merrimack Station, Bow, NH" (September 14, 2011) (*see* Section 3.1). .

From each perspective, EPA concluded that cooling tower technology installation would be affordable by the company. Specifically, EPA estimated that the total capital outlay for technology installation would amount to only 3.4 percent of the current Property, Plant and Equipment value for PSNH at the end of 2010. *Id.* at Section 3.1.1. For the second measure, EPA reviewed the total capital outlay in relation to PSNH's capital expenditure values for the past three years. The technology outlay for Merrimack Station would be approximately 26 percent of the average capital expenditure value over this period. *Id.* at Section 3.1.2. For the third measure, EPA reviewed potential interest charges for the technology capital outlay, assuming the installation was financed fully from debt, and compared this value to interest expenses recorded in PSNH's income statements for the past 3 years. The estimated interest charge in this case would be less than 2 percent of the interest expense during this period. *Id.* at Section 3.1.3.

Finally, EPA notes that PSNH's current debt rating, BBB/Baa2, falls within the range of *Investment Grade* debt, as conventionally assessed by organizations such as Standard and Poor's and Moody's. *Id.* at Section 3.1.1. For these reasons, EPA concludes that PSNH can afford to install cooling towers for year-round closed-cycle cooling operations by Units I and II at Merrimack Station. PSNH has not suggested otherwise.

With the expectation that PSNH will pass the costs of cooling tower installation and operation through to electricity customers under conventional ratemaking practices, EPA also considered whether the resulting increase in electricity rates, specifically to residential consumers, could pose an affordability challenge. Memorandum by Abt Associates, Inc., "Cost and Affordability Analysis of Cooling Water System Technology Options at Merrimack Station, Bow, NH" (September 14, 2011) (*see* Section 3.2). For this analysis, EPA estimated the annual revenue requirement that would result from cooling tower installation and operation over the assumed 20 years of equipment life, and then assigned a share of this amount to residential customers based on the composition of PSNH electricity revenue. EPA used two different approaches to allocating the total annual revenue requirement to PSNH's residential customers. Based on these two approaches, EPA estimated that the potential increase in electricity rates per kWh to residential customers would range from approximately $0.0018 or 0.18¢ per kWh to $0.0022 or 0.22¢ per kWh as an annual average over the 20-year rate recovery period. Over the past five years, electricity sales per residential customer have averaged 7,492 kWh annually, or 624 kWh monthly. Using these values, and the estimated range of increases in electricity rates stated above, the estimated increase per household customer in electricity costs over the 20-year period would range from approximately $13.83 annually or $1.15 monthly, to approximately $16.19 annually or $1.35 monthly. These values translate into an estimated increase in the average residential customer bill for 2010 ranging from approximately 1.1 percent to approximately 1.3 percent. EPA does not take any resulting increase in electric rates lightly, but judges this increase, both as a dollar amount and as a percentage increase in the current bill, to be affordable and reasonable in light of the thermal discharge reductions to the Merrimack River that would result.

In summary, while not specifically endorsing PSNH's cost estimates (and having identified certain reasons why PSNH's cost estimates may be biased high), EPA agrees with PSNH that retrofitting mechanical draft wet or hybrid wet-dry cooling towers at Merrimack Station in a closed-cycle configuration for both units would entail significant one-time and annually recurring costs. Nevertheless, using PSNH's cost estimates for purposes of this evaluation, EPA concludes for the purpose of determining the BAT under the CWA, that the costs for these options are reasonable and economically achievable.[50]

7.4.3.1.4 Non-Water Quality Environmental Impacts

EPA has considered a variety of non-water quality environmental effects that could arise from applying mechanical draft wet-dry cooling tower technology in a closed cycle configuration at Merrimack Station. The potential effects considered include increased air pollutant emissions from other generating plants, sound emissions from cooling tower operation, reduced water quantity in the river, and visual effects from the cooling towers and any visible water vapor plume. From this consideration, EPA concludes that none of these potential environmental impacts should prevent this option from being selected as the BAT for reducing the facility's thermal discharge to the Merrimack River.

7.4.3.1.4.1 Air Pollutant Emissions

Any direct air emissions from cooling towers installed at Merrimack Station would be subject to separate air permitting requirements under federal and state air pollution control laws (*e.g.*, standards for particulate emissions). The preliminary cooling tower design PSNH has submitted to EPA includes highly efficient drift elimination equipment to minimize emissions of entrained water droplets. *See* PSNH November 2007 CWA § 308 Response at 48. Moreover, salt-based particulate matter emissions should not be a major issue given that the cooling water at issue here is fresh water. In sum, EPA does not anticipate significant air pollutant emissions from the cooling towers. That said, any cooling towers would be subject to federal and state air pollution control laws that will ensure that any air emissions are properly controlled.

Beyond air emissions from the cooling towers themselves, cooling system modifications at Merrimack Station have the potential to affect air pollutant emissions indirectly. Pumps and fans associated with mechanical draft cooling tower technology create an incremental electricity demand. Assuming that this "auxiliary energy" demand is answered by the power plant in question means that in order to continue to meet market demand, either the power plant must increase its generation accordingly or another plant must do so.[51] PSNH has estimated the total

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[50] Obviously, if year-round closed-cycle cooling for both units is economically achievable, then lower cost options, such as the options for seasonal closed-cycle cooling or closed-cycle for only one unit, are also economically achievable.

[51] EPA notes that Merrimack Station Units I and II, as baseload units, might already be operating at full capacity and be unable to increase their own generation to meet the new demand. EPA assumes that, in that case, the regional grid operator would likely find it cheaper to obtain the necessary generation by requesting increased output from other generating plants than by instructing PSNH to start Merrimack Station Units CT1 or CT2.

amount of incremental demand from the booster pumps and tower fans as 6.7 MW for both units combined. *See id.* at 45. PSNH refers to the electricity requirements of the booster pumps and tower fans as "parasitic losses." In general, this estimate represents the maximum amount of power that would be required when both units are operating. The incremental demand would be less when either unit experiences a planned or unscheduled outage and in cooler weather conditions when tower fan operation could be reduced. *See id.* at 39.

Beyond the auxiliary energy demand, cooling system modifications also have the potential to affect air emissions because changing from open-cycle to closed-cycle cooling reduces condenser efficiency. This reduces the maximum electrical output of the generating units in warm weather and decreases the overall efficiency with which the units can convert coal into electricity. PSNH has estimated the reduction in electricity output as 2.98 MW for both units combined on an annualized average basis, with a maximum in hot and humid weather conditions of approximately 15 MW, *see id.* at vii;[52] to compensate for this reduced output by Merrimack Station, other generators in the region would have to increase output by the same amount (assuming a given level of demand). For purposes of this BAT determination, EPA has assumed that Merrimack Station's coal consumption and consequent air pollutant emissions would remain constant despite the decline in electricity output.[53] This is the same assumption PSNH has implicitly made in its estimate of the annually recurring costs associated with lost output. (EPA notes that the reduction in condenser efficiency and the resulting output losses would be somewhat less if wet cooling towers were used instead of hybrid wet-dry towers.)

Based on the estimates and assumptions just described, the overall indirect effect on air pollutant emissions from applying mechanical draft hybrid wet-dry cooling tower technology in a closed-cycle configuration at Merrimack Station can be understood as whatever air pollutant emissions would result from increased output at other generation plants to supply approximately 10 MW on average (or approximately 22 MW at peak conditions).[54] The actual air pollutant emissions

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[52] PSNH reports total estimated peak-period capability reductions of 22 MW, of which EPA understands 6.7 MW to be the electricity demand created by the booster pumps and fans, leaving an estimated peak-period capability reduction of approximately 15 MW due to reductions in condenser efficiency at the two units.

[53] An output reduction of 2.98 MW represents a 0.6% reduction in the combined nameplate rating of Units I and II (2.98 MW / 470 MW = 0.6%). Thus, an assumption that coal consumption remains constant while output declines by 2.98 MW is essentially equivalent to an assumption that average heat rates increase by 0.6%. EPA has not independently verified this assumption but views it as plausible and sufficiently accurate for purposes of this BAT determination. EPA notes that even if Merrimack Station's coal consumption were to increase slightly, the incremental SO_2, NO_x, and particulate emissions would be substantially mitigated by the station's existing and planned new air pollution control equipment.

[54] These figures represents the total of the incremental electricity demand from the new booster pumps and fans (6.7 MW at peak and slightly less on average) plus replacement power for the average 3 MW (or

associated with this incremental generation obviously would depend on the emission rates of the particular generating plants that would supply the electricity.

Predicting the specific generating plants in an integrated regional electric system whose output would increase to meet an increase in regional electricity demand would demand a complex modeling exercise. Neither EPA nor PSNH have undertaken to provide such predictions, which is entirely reasonable in the context of this BAT analysis. EPA can adequately consider this issue for the purpose of this BAT determination without generating a more specific estimate of the indirect air emissions. Based on a general understanding of the types of generating units operating in the New England region and their relative operating costs, EPA believes it is reasonable to assume that in the near term the increased output would come from a mix of plants burning natural gas and fuel oil, with most of the output coming from natural gas-fueled combined cycle units.[55] Because these combined cycle units tend to have relatively low emission rates of air pollutants, and also because in any event the incremental generation would represent an increase in total electrical generation in the region of less than 0.1%,[56] EPA believes that any increase in air pollutant emissions over the near term due to an estimated increase in regional generation of 10 MW is likely to be very modest.

In addition, it should be understood that any emissions increases would be limited by applicable air pollution standards, and that the State of New Hampshire has mandated that Merrimack Station install new scrubbers to substantially reduce the facility's air pollutant emissions. Therefore, whether Merrimack Station or some other facility produces a small amount of additional electricity due to a conversion to closed-cycle cooling, this would be more than offset by the substantial reductions in overall air emissions that are expected from this plant (and others). Further, EPA believes that the long-term impact on air pollutant emissions from installing this cooling system option at Merrimack Station is likely to be less than the near-term impact and may be close to zero. The reason is that cap-and-trade regulations in place for SO_2,

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up to 15 MW at peak times) of Merrimack Station output lost due to the reduction in condenser efficiency.

[55] EPA notes that the few coal-fired units in the New England region tend to run as baseload units, along with the region's nuclear units, and that their output therefore generally would not increase to meet any increase in regional demand. EPA also notes that many of the region's natural gas-fueled combined cycle units run as intermediate rather than as baseload units, suggesting the ability to increase output to meet incremental demand, and that capacity factors of the region's fuel-oil fired units has decreased over time as more gas-fired combined cycle units have been built, suggesting that the gas-fueled units typically would be chosen to meet incremental demand before the oil-fired units would.

[56] A constant load of 10 MW across the year would require generation of 87,600 MWh of electricity (10 MW * 8760 hours/year). This represents approximately 0.07% of the total 2008 net electricity consumption in New England of 131.7 million MWh. *See* ISO New England, 2009-2018 Forecast Report of Capacity, Energy, Loads, and Transmission at 5.

NO_x, and, in New England, CO_2 as well, limit cumulative emissions over time because the total number of emission permits issued is fixed. These regulations therefore have the general effect of requiring any temporary near-term increase in air emissions to be offset by a subsequent reduction in emissions. While it is not possible to be certain that the offsetting future reductions would take place specifically in New England for types of pollutants whose permits are traded over a region broader than New England, even if the reductions took place in other regions of the United States, New England would likely be a downwind beneficiary.

For the reasons just discussed, and given the very substantial potential reductions in thermal discharge available from the possible application of mechanical draft wet or hybrid wet-dry cooling tower technology in a closed-cycle configuration, EPA concludes that the possibility of very modest increases in air pollutant emissions does not disqualify the option from serving as the basis for setting BAT limits at Merrimack Station.

7.4.3.1.4.2 Sound Emissions

The operation of mechanical draft cooling towers produces a degree of constant sound emissions, from falling water and from operation of the tower fans. Cooling towers can include equipment to reduce and/or attenuate both sources of noise, and the cooling tower design submitted by PSNH includes such equipment and its costs are reflected in the project budget. *See* PSNH November 2007 CWA § 308 Response, Att. 1, at 7. PSNH has stated that with the sound attenuation devices, the expected sound levels produced by the towers would be in the range of 45-50 dBA at a distance of 350 feet from the towers and less than 30dB(A) at a distance of one-half mile, which "corresponds to the typical late-night noise levels in a small town." *See id.* at 52. PSNH states that sound levels would increase on the river close to the station but that "adjacent residential areas would be mostly unaffected by the noise generated from the cooling tower assuming a noise-abated tower design is chosen ." *Id.*

The eastern border of Merrimack Station is the Merrimack River. The opposite bank of the river is tree-lined. The remainder of Merrimack Station's property is bordered by patches of woods, open fields, gravel pits, light industrial buildings, warehouses and scattered residences. PSNH indicates that it would site any cooling towers in the area located to the south of the plant inside the elongated C-shape of the present cooling canal. *See id.* at Drawing PSNH001-SK-001. The most sensitive category of potential sound receptors is residences, and the nearest residences to this proposed tower area are approximately 1500–2900 feet east of the plant, across the river in the towns of Pembroke and Allenstown. Before installing and operating any mechanical draft cooling towers, PSNH would be required to conduct an appropriate noise analysis to ensure compliance with any applicable local noise standards. (While there are no applicable noise requirements under either federal or state law,[57] New Hampshire municipalities may have local noise prevention ordinances.)

EPA agrees with PSNH's assessment that any concerns regarding sound emissions from operation of cooling towers at Merrimack Station can be adequately addressed by including sound attenuation devices in the tower design. *See* Nuclear Regulatory Comm'n, Generic Environmental Impact Statement for License Renewal of Nuclear Plants (NUREG-1437 Vol. 1) § 4.3.7 (Dec. 14, 2001); EPA TDD 2001 – New Facilities at 3-35. Given that such devices have been included in all the potential cooling tower applications being evaluated in this document, EPA concludes that sound emissions are not a reason to reject mechanical draft wet cooling towers or wet-dry hybrid cooling towers from potentially being selected as the BAT at Merrimack Station.

7.4.3.1.4.3 Visual/Aesthetic Effects

PSNH notes two categories of visual and aesthetic effects that would be caused by construction of cooling towers at Merrimack Station: (1) the presence of the towers themselves; and (2) the occasional presence of a transient visible water vapor plume (*i.e.*, steam). *See* PSNH November 2007 CWA § 308 Response at 51, 54.

With respect to the visual impact of the cooling tower structures, the information provided by PSNH indicates that the mechanical draft hybrid wet-dry cooling tower structures for a closed-cycle configuration would be approximately 350 feet long and 65 feet high, and that an area around the towers 500 feet long and 150 feet wide close to the river would have to be cleared of trees to maximize airflow to the towers, removing an existing visual buffer. *Id.* at 54. As a

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[57] While EPA has not promulgated enforceable federal noise standards, the Agency published a document in March 1974 entitled, "Information On Levels Of Environmental Noise Requisite To Protect Public Health And Welfare With An Adequate Margin Of Safety" (EPA 550/9-74-004). In this document, EPA attempted to collect and summarize, as the title indicates, "information on the levels of noise requisite to protect public health and welfare with an adequate margin of safety. " *Id.* at Foreword - 1. In providing information regarding such protective sound levels, EPA stated clearly and repeatedly that the identified levels should not be regarded or used as federal noise standards or regulations. Nevertheless, the levels identified in EPA=s 1974 document are still often used as reference points in noise assessments. EPA states, *id.* at 4, that "undue interference with activity and annoyance will not occur if outdoor [sound] levels are maintained at an energy equivalent of 55 dB. " *See also id.* at 3, Table 1 (A sound level of L_{DN}=< 55 dB will prevent undue annoyance or interference with activities "outdoors in residential areas and farms and other outdoor areas where people spend widely varying amounts of time and other places in which quiet is a basis for use.") An L_{DN} of 55 dBA is equivalent to a level of 49 dBA at night for a steady sound. *See* Determination on Remand from the EPA Environmental Appeals Board Brayton Point Station, NPDES Permit No. MA0003654, at 69 (Nov. 30, 2006). Based on the above assessment of cooling tower sound emissions and local receptors, EPA concludes that these emissions will not exceed the relevant levels identified EPA's information document.

result, the structure would be visible up and down the river for some distance. While it remains to be seen whether all of this tree removal is necessary, EPA acknowledges some negative visual effect from the installation of cooling towers, especially if trees that would have otherwise hidden the cooling towers must be taken down. Still, EPA does not regard these visual/aesthetic effects, even assuming the tree removal predicted by PSNH, as sufficient justification not to determine that closed-cycle cooling with mechanical draft towers is the BAT at Merrimack Station for controlling thermal discharges.

To begin with, the cooling towers would not be out of character with the existing site, which already has large industrial buildings, tall smokestacks, a coal pile, and electrical transmission lines. *See* Pub. Serv. Comm'n of Wis./Wis. Dep't of Natural Res., Final Environmental Impact Statement, Badger Generating Company, LLC, Electric Generation and Transmission Facilities, Exec. Sum. at 6 (Jun. 2000, 9340-CE-100) (hereinafter "Badger Power EIS"). Moreover, the towers would be significantly shorter than the plant's existing smoke stacks and their bulk would be consistent with that of the plant's existing central boiler and generator buildings. (EPA notes that the visual effects would be greater if PSNH were to consider natural draft rather than mechanical draft cooling towers.) In addition, while the towers might be visible from the river, PSNH itself states that "the station is an industrial facility already visible from these vantage points." *See* PSNH November 2007 CWA § 308 Response at 54. Finally, given that the visual effect of the cooling towers would be greatest from locations on the river, PSNH singles out recreational boaters on the river as an affected population of particular concern with respect to aesthetic impacts. *Id.* Yet, any such boaters would already be affected by the existing power plant and EPA notes that these individuals seem likely to be among those who will most appreciate the reduction in pollutant discharges to the river (and attendant environmental benefits) that the cooling towers would yield.

With respect to the visibility and aesthetic impacts of a water vapor plume, PSNH urges that there would be an aesthetic issue but has provided little information to support that contention. PSNH indicates a preference for hybrid wet-dry cooling tower technology over wet cooling tower technology precisely because of the ability of the hybrid technology to mitigate water vapor plumes. Based on the design "plume point" of the hybrid towers, occurrence of a visible plume would be limited to times when the ambient temperature falls below 27°F. *Id.* at 51. PSNH notes that, based on prevailing wind conditions, the most likely direction of travel for the plume would be up or down the Merrimack River. *Id.* At one point in its report, PSNH states that depending on weather conditions, "the plume could extend skywards for hundreds of feet, or become inverted as a ground-level fog." *Id.* In another portion of its report, PSNH states that "the plume could potentially extend hundreds of feet into the sky, and travel for up to a few miles horizontally." *Id.* at 54. PSNH provides no data on the frequency or months and times of day when the air temperature at the Merrimack Station typically falls below 27°F – though such temperatures would not be unusual in New Hampshire in the winter – and no estimates of the likelihood of these various forms of plume behavior.

EPA does not view the mere occurrence of an intermittent visible water vapor plume from an industrial facility in itself to necessarily be a significant visual impact. Typically, any vapor plume would dissipate after traveling a short distance due to dispersion and evaporation. *See* EPA TDD 2001 – New Facilities at 3-33; Badger Power EIS at 54; AES, Inc., "AES Londonderry Highlights" at 6 (Jan. 18, 2002). In this instance, a visible cooling tower plume would have to rise 250 feet just to reach the height of the existing taller smokestack at Merrimack Station (not to mention any visible emissions from the stack); a rising water vapor plume thus is unlikely to appear as the most visually intrusive feature of the site. (The ground level fogging issue is discussed further in the subsection on fogging and icing, below, with respect to potential impacts on traffic safety.) Based on the information PSNH has provided to date, and based on EPA's experience in reviewing model data related to this issue at other locations, EPA believes that occasions when cooling towers at Merrimack Station would cause substantial ground-level fogging that would not otherwise have occurred due to meteorological conditions are likely to be relatively infrequent and limited to areas in relatively close proximity to the towers.

For the reasons discussed above, and given the very significant reductions in thermal discharge available from the application of mechanical draft or mechanical draft wet/dry hybrid cooling tower technology in a closed-cycle configuration, EPA concludes that the visual and aesthetic effects associated with the option do not disqualify it from being the BAT for thermal discharge reduction at Merrimack Station.

7.4.3.1.5 Other Factors EPA Deems Appropriate

PSNH has raised three additional concerns that EPA believes are worthy of particular consideration. First, PSNH raises concern about water losses from the Merrimack River as a result of using evaporative cooling towers. Second, PSNH states concern over whether the imposition of BAT limits based on closed-cycle cooling using mechanical draft wet or wet-dry hybrid cooling towers would endanger the reliability of the regional electric system. Third, PSNH questions whether application of this option would cause adverse impacts (other than the visual and aesthetic impacts already discussed) due to fogging or icing. In addition, EPA has considered the environmental benefit of reduced entrainment and impingement that will result from using a closed-cycle cooling technology at Merrimack Station.

7.4.3.1.5.1 Loss of River Water

Hybrid wet-dry (and wet) cooling towers rely on evaporation to transfer waste heat from the cooling water to the atmosphere. Therefore, application of hybrid (or wet) cooling tower technology at Merrimack Station would cause some amount of the water taken from the

Merrimack River by PSNH for cooling to be lost to evaporation instead of being conveyed (along with heat and other pollutants) back to the river. For hybrid cooling towers in a closed-cycle configuration at both units, PSNH has estimated this water loss as 4.79 MGD (4.79mgd)/(587.75cfs-7Q10 Flow)(0.646-conv cfs to mgd) = 1.3%).

Assuming for the sake of argument that this estimate is otherwise correct, EPA notes that it does not account for the evaporation that occurs with the station's current open-cycle/discharge canal/PSM cooling system and therefore errs to the high side to an unknown extent. Indeed, by increasing water temperatures, the thermal discharge probably increases evaporation rates from the Hooksett Pool itself. In other words, under the current system, Merrimack Station withdraws a larger volume of water from the river, heats it up substantially, and then discharges it through its lengthy discharge canal while periodically using the PSMs. This contributes a thermal plume to the river. With a closed-cycle system, water withdrawals and thermal loadings would be reduced by more than 95 percent. In light of these considerations, it is unclear which cooling system would ultimately result in greater overall evaporative losses.

Given the very substantial reductions in thermal discharge available from the possible application of mechanical draft hybrid cooling tower technology in a closed-cycle configuration, EPA concludes that the possible loss of river water to evaporation does not disqualify the option from serving as the basis for setting BAT limits at Merrimack Station.

7.4.3.1.5.2 Reliability of Regional Electric System

PSNH has expressed concern that during the permitting process EPA "provide appropriate consideration to the critical importance of Merrimack Station in the electric grid and the potential implications and effects of any new permit limitations on electric system reliability." PSNH November 2007 CWA § 308 Response, Transmittal Letter at 3. EPA has considered this issue carefully and sees no credible threat to electric system reliability from application at Merrimack Station of any of the cooling system options evaluated in this document as a potential basis for setting BAT limits. Nevertheless, because EPA agrees that electric system reliability is a vital public concern, and because PSNH has raised the issue, EPA will further address the issue as part of this BAT determination.

PSNH has stated that it has no retirement plans for Merrimack Station, *id*. at 25, and has not suggested that the station would be retired if faced with required expenditures for modification of its cooling systems. Indeed, PSNH has already been willing to spend larger amounts on air pollution controls at the station. PSNH has not challenged the technical feasibility of applying wet mechanical draft or hybrid wet-dry cooling tower technology in a closed-cycle configuration at the station and has not asserted that such modifications would cause the units to experience more frequent outages, either planned or unplanned. PSNH has stated that the station is especially important to the region because some of the station's units have "blackstart" capability, meaning that they can begin to generate power without an external source of start-up electricity. *See id.*, Transmittal Letter at 3. Yet, since there does not seem to be any prospect of the Merrimack Station units being retired because of the cooling system modifications under consideration, their blackstart capability would still be available to the region.

The only way in which the potential cooling system modifications could possibly affect system reliability appears to be the additional amount of electrical demand that would have to be met by other generating resources in the region due to the modifications. As discussed above with respect to air pollutant emissions, PSNH has estimated that application of hybrid cooling tower technology in a closed-cycle configuration at Merrimack Station Units I and II would create a need for additional electric generation in the region of approximately 10 MW on average across the year and 22 MW in peak summer conditions. *See also id.* at vii. From a system reliability perspective, the larger of these two figures is the relevant one, yet even this figure represents less than 0.1% of the region's 2008 total electric generating capacity of 27,765 MW. ISO New England, Inc., 2009–2018 Forecast Report of Capacity, Energy, Loads, and Transmission at 1. The regional system operator has projected total regional electricity demand and capacity resources through 2018, and those projections show resources exceeding demand by a margin of more than 3700 MW across the entire period. *Id.* It is clear that there is no reason to question the region's ability to reliably supply an incremental peak demand of 22 MW.

In addition, the regional electric supply could be affected by any outages of the Merrimack Station generating units that were needed to implement a conversion to closed-cycle cooling. Yet, this should not threaten electric system reliability because any such outages can be planned and managed and will be relatively short in duration. Merrimack Station, like other power plants, already has regular, planned unit outages for maintenance which are managed without threatening overall electric system reliability. Any outages for installing cooling towers would be managed in the same way.

EPA concludes that there are no issues related to reliability of the regional electric system that would disqualify mechanical draft wet or hybrid wet-dry cooling tower technology in a closed-cycle configuration from being the BAT for reducing thermal discharges at Merrimack Station.

7.4.3.1.5.3 Fogging and Icing

As noted in the earlier discussion on aesthetic impacts, PSNH has expressed concern that the water vapor plume emitted by mechanical draft hybrid cooling towers could cause a traffic safety issue by contributing to ground-level fogging or icing under certain weather conditions. This is a separate, though related, issue from the possible visual/aesthetic effects associated with the visible water vapor plume that may be emitted by a cooling tower under some conditions.

EPA regards public safety issues to be of the utmost importance and has considered this issue carefully. Based on current information, EPA finds an insufficient basis to conclude that there is a significant threat of a traffic safety problem posed by the possibility of fogging or icing being caused by cooling towers at Merrimack Station. In addition, EPA also finds that if fogging or icing seems likely, it would likely be relatively infrequent and limited in geographic extent to areas quite close to the plant. Moreover, any such effects could be mitigated by reasonable traffic safety measures, as needed. The following paragraphs discuss EPA's consideration of this issue.

At the outset, it should be emphasized that using hybrid wet-dry cooling towers (as opposed to simple wet towers) is considered to be an effective technique for mitigating concern about water vapor plumes, whether that concern is driven by visual effects, fogging, icing or some combination of these factors. Moreover, PSNH has indicated that if it had to install cooling towers, hybrid wet-dry cooling towers would be its preferred approach. Therefore, to the extent that fogging and icing is a concern, an effective technology for addressing the issue has been identified and evaluated.

Of course, PSNH correctly points out that even hybrid wet-dry cooling towers create a (reduced) water vapor plume that could become visible under certain circumstances. PSNH November 2007 CWA § 308 Response at 51. Moreover, in certain weather conditions, a visible plume could become inverted as ground-level fog. If there is fog, it is possible that it could impair visibility on any nearby roads and that, under certain conditions, a water vapor plume (visible or invisible) could become inverted and freeze on any nearby road surfaces. To the extent that these threats exist with wet mechanical draft cooling towers, the chance of a problem is much reduced by using hybrid wet/dry towers. Models exist for attempting to predict the likelihood that such fogging or icing problems might occur based on tower characteristics and local weather data, but PSNH has not, to EPA's knowledge, conducted such a modeling analysis. PSNH does note that, based on prevailing wind patterns, the likely route of travel for any plume would be up or down the Merrimack River, but also notes that it is possible that fogging and icing could affect nearby roadways. *Id*. PSNH has not provided an estimate of the likely timing, frequency, location, or geographic extent of any such roadway effects.

In the absence of site-specific data, EPA has evaluated this issue based upon experience from other plants as discerned from general research and analyses conducted for other permits. This research has included discussions with operators of other electric generating plants that use either hybrid wet-dry or wet cooling towers. EPA spoke with representatives of two power plants that use wet mechanical draft cooling towers, and learned that any icing concerns that do exist at these plants are limited to areas very close to the cooling towers (within a few hundred feet) and have not affected roadways or bridges within relatively short distances from the towers (in one case, within approximately a half-mile, and in another case, within about 700 feet). Telephone Memorandum, Sharon Zaya, U.S. Envtl. Prot. Agency (Jan. 4, 2002) (regarding Call with Ken Daledda, Bergen Station, New Jersey); Memorandum from Mark Stein, U.S. Envtl. Prot. Agency, to Brayton Point NPDES Permit File (Dec. 12, 2001) ("Brief Notes on an Issue Discussed During Conference Call with John Gulvas of Consumers Energy and the Palisades

Nuclear power station in Covert, Michigan"); 39 Fed. Reg. at 36,192. Neither icing nor fogging appeared to create an actual safety problem in any of the situations referenced above. Presumably, if these plants used hybrid wet/dry cooling towers, there would even less icing and fogging. Another plant did install a hybrid wet/dry cooling tower system to enable it to mitigate a visible plume due to initial concerns over potential highway icing or fogging, but this plant reported to EPA that, in practice, the plume did not turn out to pose a fogging/icing hazard. This plant reported that it now only uses the "dry components" of the hybrid towers to mitigate any potential visual effects related to a periodically visible plume of fog during humid conditions. Telephone Memorandum, Sharon Zaya, U.S. Envtl. Prot. Agency (Jan. 4, 2002). Other EPA research has supported the conclusion that icing problems, if any, tend to occur close to the cooling towers, typically on-site. *See* EPA TDD 2001 – New Facilities at 3-33; Badger Power EIS, Exec. Sum. at xvii, xviii, 18–19, 72–75, 137–39; AES Londonderry Highlights at 6; Nuclear Regulatory Comm'n, Generic Environmental Impact Statement for License Renewal of Nuclear Plants (NUREG-1437 Vol. 1) §§ 4.3.4.2, 4.3.5.1.1, 4.3.5.1.3; 39 Fed. Reg. at 36,192. *See also* Draft Permit Determinations Document for Brayton Point Station NPDES Permit at 7-51.

In modeling analysis performed for other locations, EPA has seen that under most weather conditions when it is predicted that local fogging or icing may be caused by a water vapor plume, such local fogging or icing would be probable due to prevailing meteorological conditions even without the water vapor plume from the cooling towers, though the plume could add to the risk of a problem. *See* Response to Comments Document, Public review of Brayton Point Station NPDES Permit No. MA 003654 (Oct. 2, 2003), App. M (evaluation of possible water vapor plumes from mechanical draft wet cooling towers (not hybrid towers) installed at a power plant). *See also* Pub. Serv. Comm'n of Wis./Wis. Dep't of Natural Res., Final Environmental Impact Statement, Badger Generating Company, LLC, Electric Generation and Transmission Facilities at 73. In sum, EPA believes it is possible to infer from these model results that any incremental occurrences of fogging and icing due to cooling tower water vapor plumes are likely to be infrequent, especially if hybrid wet-dry towers are used.

Applying these findings to Merrimack Station, EPA concludes that, in the absence of site-specific data to the contrary, it is likely that any possible plume-related fogging or icing issues would be limited to the station site and possibly to the nearby portion of River Road, the two-lane town road in Bow, New Hampshire that provides access to Merrimack Station. River Road runs roughly north and south along the western property line of the station, and its closest segment lies 400 to 500 feet from the location where any cooling towers would be located according to the preliminary design PSNH has submitted to EPA. The closest major roads to the west, New Hampshire Route 3A and Interstate 93, are a mile or more from the potential cooling tower location, and the closest major road to the east, New Hampshire Route 3, is across the river roughly three-quarters of a mile away. At these distances, these major roads would likely be unaffected by any plume from the station. With respect to River Road, EPA believes that infrequent fogging and icing issues, if any, that are limited to a single road, could be mitigated by traffic safety measures. For example, PSNH could monitor predicted weather conditions and, when fogging or icing appears possible, could notify the Bow Highway Department in order to initiate icing controls (*e.g.*, salting or sanding of the road) or activate lighted cautionary signs warning of potential fog conditions. (Indeed, River Road and other roads in the area no doubt already experiences occasional ice, snow and fog – given their location along the Merrimack River corridor in New Hampshire – and, to the extent needed, steps to ensure traffic safety are likely already in place.)

For the reasons described, EPA concludes that the limited potential for traffic safety problems resulting from the fogging and icing of local roadways as a result of the application of mechanical draft wet or wet-dry hybrid cooling tower technology in a closed-cycle configuration at Merrimack Station is not adequate justification to disqualify the option from being selected as the BAT for limiting thermal discharges at Merrimack Station.

7.4.3.1.5.4 Reduced Entrainment and Impingement

Converting both generating units to closed-cycle cooling will have the substantial added environmental benefit of maximizing reductions in the entrainment and impingement of aquatic organisms by Merrimack Station's cooling water intake structures. Converting these units to closed-cycle cooling using wet or wet-dry hybrid mechanical draft cooling towers would result in a reduction in water withdrawals of approximately 95% or more, and would reduce entrainment and impingement by the same proportion. These benefits are discussed in substantial detail in Sections 11 and 12 of this document, which discuss EPA's determination of the Best Technology Available for cooling water intake structures to minimize adverse environmental impacts under CWA § 316(b). EPA notes that while there are other technologies that could yield similar impingement reduction benefits, there is no other technology that can achieve similar entrainment reductions while allowing the facility to continue generating essentially the same amount of electricity.

7.4.3.2 Other Options

Immediately above, EPA presents a detailed evaluation of wet and wet-dry hybrid mechanical draft cooling towers in a closed-cycle configuration. Farther above, EPA evaluates a variety of other technologies, albeit in less detail. Two of those technological approaches – both of which utilize closed-cycle cooling in different ways – warrant further discussion here.

7.4.3.2.1 Partial Closed-Cycle Cooling

As mentioned above, another option for thermal discharge reduction at Merrimack Station would be to apply wet or wet-dry hybrid mechanical draft cooling towers for only one of the facility's two generating units, rather than for both of them, or for both units on a seasonal basis rather than year-round. These partial closed-cycle cooling options would cost less and pose lesser adverse secondary effects (*e.g.*, energy penalties), but they would achieve lesser secondary benefits (*e.g.*, reduced entrainment and impingement) and, most importantly, would achieve substantially lesser reductions in thermal discharges.[58] *See* Memorandum by Abt Associates, Inc., "Cost and Affordability Analysis of Cooling Water System Technology Options at Merrimack Station, Bow, NH" (September 14, 2011), at Table 1-4; *See also* Table 7-1, *infra*, and Table 12-3, *supra*. As a result, they are not the best performing available technologies and are not the BAT unless the better performing technologies are ruled out. Therefore, these approaches will only be assessed further if the option for providing closed-cycle cooling for both units on a year-round basis is ruled out.

7.4.3.2.2 Helper Towers

Not only can wet or wet/dry hybrid mechanical draft cooling towers be used in a closed-cycle system, but they can also be used in an open-cycle configuration. Cooling towers used in an open-cycle configuration are called "helper towers." Under this approach, the facility operates in the open-cycle mode except that cooling towers are used to remove waste heat from the water *after* it has been used for cooling – emitting the heat to the atmosphere – but *before* the water is discharged back to the river.

Under this approach, thermal discharges are reduced, but cooling water withdrawals are not. Therefore, this approach does not yield the secondary benefit of reducing entrainment and impingement. Furthermore, helper towers would probably impose the same or larger auxiliary energy penalties, but a lesser efficiency penalty because cooling water would come from the river at colder ambient temperatures. As a result of these small differences, there would likely also be small differences in air emission and energy effects, whereas other effects such as visual effects, fogging, or icing effects would likely be the same or similar.

Helper towers provide less efficient heat removal than cooling towers used in a closed-cycle configuration. Thus, helper towers would remove less heat with the same number of cooling tower cells. Put differently, more cells would be needed to try to achieve the same level of thermal discharge control. How much heat this option removed, and how much the option cost, would depend on how many cooling tower cells were used. Ultimately, this option would likely remove less heat, and could not remove any more heat, than the options involving wet or wet-dry hybrid mechanical draft cooling towers in a closed-cycle configuration. *See* Table 7.1. Therefore, this option will only be assessed further if the option for closed-cycle cooling for both units is ruled out.

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[58] While EPA considered the question of these options' cost-effectiveness, the Agency decided that cost-effectiveness would not be a useful criterion for choosing between the options given the wide disparity in thermal discharge reduction achievable by each. *See* Table 7-1, *supra*.

7.5 Determination of Technology-Based Thermal Discharge Limits for Merrimack Station

Section 7.5 discusses the analyses detailed above and presents EPA's determination regarding NPDES permit requirements for the control of thermal discharges from Merrimack Station under the BAT standard of CWA §§ 301(b)(2) and 304(b)(2). To the extent that this section reiterates matters discussed and documented above, supporting references will not be repeated here.

EPA evaluated numerous cooling system options to determine which might constitute the BAT for reducing thermal discharges from Merrimack Station. Based on its own research and analysis, as well as on information submitted by PSNH, EPA has concluded that retrofitting mechanical draft wet or hybrid wet-dry cooling towers in a closed-cycle configuration for both Units I and II constitutes the BAT for the control of thermal discharges by Merrimack Station. Therefore, the facility's NPDES permit should include thermal discharge limits based on the reduced thermal discharges that would be possible using that technology. Retrofitting Merrimack Station to meet such thermal discharge limits would eliminate more than 95% of the facility's current discharge of heat to the Merrimack River.

7.5.1 Summary of Legal Standards

Under the CWA, EPA establishes technology-based standards for thermal discharges based on the degree of control attainable by the "best available technology economically achievable" (*i.e.*, BAT). For facilities in the steam-electric power generating point source category, such as Merrimack Station, EPA develops technology-based thermal discharge limits based on BAT using Best Professional Judgment under CWA § 402(a)(1) and 40 C.F.R. § 125.3, because there is no national effluent limitation guideline governing thermal discharge from this category.

For heat and other non-conventional pollutants, as well as for toxic pollutants, the CWA requires discharges to achieve:

> *effluent limitations for categories and classes of point sources, other than publicly owned treatment works, which . . . shall require application of the <u>best available technology economically achievable</u> for such category or class, <u>which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants</u>, as determined in accordance with regulations issued by the [EPA] Administrator pursuant to [CWA § 304(b)(2),] section 1314(b)(2) of this title, which such effluent limitations shall require the elimination of discharges of all pollutants if the Administrator finds, on the basis of information available to him . . . that such elimination is <u>technologically and economically achievable</u> for a category or class of point sources as determined in accordance with regulations issued by the [EPA] Administrator pursuant to [CWA § 304(b)(2),] section 1314(b)(2) of this title . . . .*

33 U.S.C. § 1311(b)(2)(A) (emphasis added). This means that EPA must set BAT limits that represent a level of treatment based on technologies that (1) are technologically and economically achievable, and (2) will result in reasonable progress toward the elimination of the discharge of such pollutants.

CWA § 304(b)(2)(B) requires EPA to take into account the following factors when it sets BAT limits: the age of the equipment and facilities involved; the manufacturing processes used; the engineering aspects of the application of recommended control technologies, including process changes and in-plant controls; non-water quality environmental impacts (including energy requirements); cost; and any other factors that EPA deems appropriate. *See* 33 U.S.C. § 1314(b)(2)(B). *See also* 40 C.F.R. § 125.3(d)(3). The statute and regulations set up a loose framework for EPA's consideration of the BAT factors. EPA is not required to compare the factors, only to consider them. Moreover, neither the statute nor regulations specify a particular process by which the Agency must consider the BAT factors or dictate that a particular weight be assigned to any of the factors. Instead, EPA is given broad discretion to decide how to account for and weigh the relevant factors subject to a reasonableness standard. One court summarized the standard for measuring EPA's consideration of the BAT factors as follows: "[s]o long as the required technology reduces the discharge of pollutants, our inquiry will be limited to whether the Agency considered the cost of technology, along with other statutory factors, and whether its conclusion is reasonable." *Pacific Fisheries*, 615 F.2d at 818.

Technological Availability. The starting point for determining the BAT is the best performing plant in a given industry (in terms of reducing discharges of a particular pollutant), including viable transfer technologies (*i.e.*, technology from another industry that could be transferred to the industry in question) and technologies shown to be viable in research even if not yet implemented at a full-scale facility. Courts have construed the CWA not to require EPA to identify the specific technologies that a plant must install to meet BAT limits and, instead, only to require the Agency to demonstrate that the technology it uses to estimate BAT costs reasonably approximates the type and cost of technology available for use to meet the effluent limits.

BAT factors bearing on technological availability may include the age of the equipment and facility involved. The type of treatment technology to be applied is primarily a function of the type of operation the facility is engaged in and the nature of the pollutants in its effluent, but age may bear on the feasibility of retrofitting technologies to an existing plant to meet BAT limits. Therefore, to set a BPJ-based BAT limit for thermal discharges from Merrimack Station, EPA considered the age of the facility's electric power generation units and cooling system components in the context of assessing the feasibility of retrofitting the facility with the treatment technologies being evaluated by the Agency.

Other factors considered by EPA in developing BAT limits that also bear on technological availability include (1) the process or processes employed by the facility or category of facilities, (2) the engineering aspects of the application of the application of various types of control techniques, and (3) any changes to the facility's processes that would result from application of the treatment technology in question. In setting the BPJ-based BAT limit for thermal discharges from Merrimack Station, EPA considered (1) the steam-electric power generation and cooling processes currently employed by Merrimack Station; (2) engineering factors relating to the application of alternative treatment technologies; and (3) any process changes that would result.

Cost and Economic Achievability. The CWA and EPA regulations call upon the Agency to consider the cost of the options, but give the Agency considerable discretion in considering cost and determining what is economically achievable. Neither the statute nor regulations specify a particular method of evaluating the cost of complying with BAT limits or dictate how cost should be considered in relation to the other BAT factors. EPA is directed only to consider whether the costs are "economically achievable" and to "take [cost] into account" when assessing the BAT. A facility's age may also have a bearing on the cost of the options. Moreover, EPA is not required to undertake a precise calculation of cost; only a reasonable cost estimate is needed. In addition, EPA may, but is not required to, consider the relative cost-effectiveness of the available technological alternatives for reducing pollutant discharges.

The courts, including the United States Supreme Court, have also consistently read the CWA and its legislative history to indicate that Congress intended EPA to consider costs in setting BAT limits, but did not intend to require the Agency to perform a cost-benefit analysis or any other kind of cost/benefit balancing test. Furthermore, the courts have also indicated that Congress did not intend cost to be a factor of primary importance in determining the BAT, as compared to achieving pollutant discharge reductions consistent with the CWA's goals and requirements. That said, EPA could in a given case decide that a technology is not the BAT because its costs are unreasonable when considered in conjunction with other factors and the degree of pollutant discharge reduction that the technology would achieve. When a court reviews EPA's BAT determination for a specific point source category or individual discharger, as long as the required technology reduces the discharge of pollutants, the court's inquiry will be limited to whether the Agency considered the cost of technology, along with other statutory factors, and whether its conclusion is reasonable.

Non-Water Quality Environmental Impacts (and Energy Requirements). EPA is not required to consider the effect on water quality from reducing discharges of pollutants as result of compliance with BAT limits, but in determining the BAT, it must consider secondary non-water quality environmental effects that would result from using a particular technology (as well as the technology's energy requirements). The CWA gives EPA broad discretion in deciding how to evaluate non-water quality environmental (and energy) impacts and weigh them against the other BAT factors. The Agency applies its discretion and expertise to the relevant information regarding the relative impact of different environmental harms, and demonstrates on the record that it has considered the BAT factors in its determination.

Other Factors. CWA § 304(b)(2) also allows EPA to take into account such other factors as the Agency deems appropriate when setting BAT limits. For example, in this context EPA might deem it appropriate to consider potential effects on regional energy supply or the extent to which a thermal discharge reduction technology might also be able to reduce other adverse environmental impacts, such as those from cooling water withdrawals, such as entrainment and impingement of aquatic organisms.

7.5.2 Summary of Technology Evaluation and Determination of the BAT

EPA and PSNH evaluated a variety of options for reducing Merrimack Station's thermal discharges. These options ranged from operational measures, such as generation curtailment, to technological retrofit measures, such as using cooling towers in a "helper tower" configuration in conjunction with an overall open-cycle system, and using cooling towers in a closed-cycle cooling configuration for one or both of Merrimack Station's generating units on a year-round or seasonal basis. Furthermore, different types of cooling towers were evaluated, ranging from dry cooling towers, to natural draft cooling towers, to wet and wet-dry hybrid cooling towers. As presented above, many of these options were screened out for various reasons.

Ultimately, EPA decided to evaluate in more detail wet mechanical draft cooling towers and wet-dry hybrid mechanical draft cooling towers for year-round use for both of Merrimack Station's main generating units (Units 1 and 2). These technologies were the best performers in terms of thermal discharge reduction from among the available technologies, making them appropriate for detailed assessment in this BAT determination.[59] (As explained previously, the best performing technology in the industry is, at a minimum, the starting point for a BAT determination, though such technology could potentially be ruled out based on the consideration of other pertinent factors.) Moreover, in its presentations, PSNH indicated that if closed-cycle cooling was required, it favored wet-dry hybrid mechanical draft technology from among the cooling tower options (while also making clear it did not believe that closed-cycle cooling should be required).

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[59] EPA (and PSNH) also evaluated dry cooling, which would be capable of achieving a small additional margin of thermal discharge reduction (100% reduction vs. 98% for wet mechanical draft cooling towers), albeit at a substantial additional cost. Based on the record at hand, however, EPA explained that it could not with confidence deem the technology to be available for Merrimack Station. EPA has not identified a single case of dry cooling being retrofitted to an existing open-cycle power plant, and PSNH posited that retrofitting dry cooling would be infeasible at Merrimack Station due to space constraints and incompatibility with the existing condensers. In the face of these issues, EPA ruled out dry cooling for further, detailed evaluation, but indicated that PSNH was free to use the technology if it determined it to be feasible and preferred, and all necessary approvals could be obtained.

While PSNH suggests that retrofitting wet mechanical draft cooling towers in a closed-cycle cooling configuration for both Units 1 and 2 at Merrimack Station would pose design, engineering, and construction difficulties, it did not claim that it would be technologically infeasible (or "unavailable"). EPA agrees that retrofitting mechanical draft cooling towers in a closed-cycle configuration to Merrimack Station would present a complicated construction project, but the Agency concludes that it would be feasible.

EPA also considered the cost to PSNH of a mechanical draft cooling tower retrofit for year-round use for both Units 1 and 2 at Merrimack Station and found that such a retrofit would be economically achievable for PSNH. That said, EPA understands that the expenditures would be significant and could potentially reduce PSNH's profits. Nevertheless, Merrimack Station has long been a profitable plant, and EPA does not anticipate that converting to closed-cycle cooling would change that fact. Under New Hampshire's regulated energy market, PSNH may be able to pass all or much of the cost for converting to closed-cycle cooling along to its consumers. This would likely have only a relatively small effect on consumer electric rates, however. EPA concludes that the costs for the technology are both affordable and reasonable in relation to the substantial reduction in pollutant discharges that the technology could achieve (i.e., a 95% or greater reduction in thermal discharges).

EPA also considered all the other BAT factors specified in the statute and regulations, including some additional factors that the Agency deemed appropriate for consideration. These factors included the age of the facilities and equipment, the facility processes involved, engineering considerations, any process changes, non-water quality environmental effects (including air emissions, sound emissions, visual effects) and energy requirements and effects (*i.e.*, reduced energy available for sale by Merrimack Station). In addition, EPA considered effects on consumer electric rates, possible effects on the reliability of the electrical system, traffic safety as affected by water vapor plume-induced fogging or icing of roadways, reduced entrainment and impingement of aquatic organisms, and any reduction in water quantity in the river. EPA's consideration of these factors is presented in detail above. While EPA found that there would likely be some adverse effects with regard to some of these parameters (*e.g.*, reduced energy available for public sale due to the "efficiency and auxiliary energy penalties" associated with closed-cycle cooling), and certain beneficial effects associated with at least one other factor (*i.e.*, reduced entrainment and impingement), EPA did not find that any of the adverse effects, whether taken alone or in combination, were significant enough to disqualify the closed-cycle wet or wet-dry hybrid mechanical draft cooling tower option, which was, as stated above, from being the BAT for thermal discharge reduction.

Thus, having considered all of these factors, and taking into account the 95 percent (or greater) reduction in thermal discharges that year-round use of wet or wet-dry hybrid mechanical draft cooling towers in a closed-cycle configuration would achieve, EPA determines that this technology constitutes the BAT for Merrimack Station. Accordingly, EPA has specified thermal discharge limits to be included in the NPDES permit based on use of the specified technology. These limits are presented in Chapter 9 of this document. While EPA has determined that these limits could be met using the specified BAT, Merrimack Station is free to meet the permit limits using any other lawful technology that it chooses. For example, if PSNH found that dry cooling was feasible and decided for some reason that it preferred to use dry cooling, the permit would not prevent the company from taking that approach.

8.0 WATER QUALITY – BASED TEMPERATURE REQUIREMENTS

8.1 Introduction

As explained above, NPDES permit limits must, at a minimum, satisfy federal technology-based standards. Permit limits must also include any more stringent requirements necessary to satisfy state water quality requirements. *See* 33 U.S.C. §§ 1311(b)(1)(C), 1341(a), & (d). Therefore, EPA worked with NHDES, NHFGD, and USFWS to determine protective water temperatures in Hooksett Pool that would be required to satisfy New Hampshire water quality standards ("NHWQS"). A comparison was then made between water temperatures that could be achieved based on available technology, and those temperatures necessary to satisfy NHWQS. This comparison is discussed in Section 9.0.

8.2 New Hampshire Water Quality Standards – Temperature Requirements

New Hampshire's water quality requirements are set forth in state statute and regulation. Specifically, the requirements of the NHWQS are collectively spelled out in Chapter 485-A of the New Hampshire statutes, which governs water quality and the control of water pollution, and Chapter Env-Wq 1700 of the state's regulations (namely, the "Surface Water Quality Regulations").

Although these statutory and regulatory provisions do not specify *numeric* temperature criteria for the state's waters, they do specify *narrative* criteria for heat that are designed to be applied on a case-by-case basis to protect the existing and designated uses of each water body and restore and maintain the chemical, biological and physical integrity of the state's waters. Moreover, particular thermal discharge limits may also be needed to ensure compliance with a number of more generalized requirements specified in the NHWQS.

Chapter 485-A of New Hampshire's statutes governs water quality and the control of water pollution. N.H. Rev. Stat. Ann. § 485-A:1 states (in pertinent part) that:

> *[t]he purpose of this chapter is . . . to prevent pollution in the surface and groundwaters of the state and to prevent nuisances and potential health hazards. In exercising any and all powers conferred upon the department of environmental services under this chapter, the department shall be governed solely by criteria relevant to the declaration of purpose set forth in this section.*

Classification of the state's water bodies is addressed by N.H. Rev. Stat. Ann. § 485-A:8. The introductory language to this provision states that:

> *[i]t shall be the overall goal that all surface waters attain and maintain specified standards of water quality to achieve the purposes of the legislative classification.*

In addition, section N.H. Code R. Env-Wq 1701.01 of New Hampshire's regulations provides that:

> *[t]he purpose of these rules is to establish water quality standards for the state's surface water uses as set forth in RSA 485-A:8, I, II, III and V. These standards are intended to protect public health and welfare, enhance the quality of water and serve the purposes of the Clean Water Act and RSA 485-A. These standards provide for the protection and propagation of fish, shellfish, and wildlife, and provide for such uses as recreational activities in and on the surface waters, public water supplies, agricultural and industrial uses, and navigation in accord with RSA 485-A:8, I and II.*

The purposes of the CWA, of course, include restoring and maintaining the biological, chemical, and physical integrity of the Nation's waters, and, wherever attainable, ensuring water quality adequate for the protection and propagation of fish, shellfish, and wildlife, and for recreation, in and on such waters. *See* 33 U.S.C. §§ 1251(a) (introductory language) & (a)(2).

In addition to, and consistent with, the stated goals and purposes of New Hampshire's water quality requirements, the NHWQS also specify the uses of the state's water bodies that must be protected, and the numeric and narrative water quality criteria that must be satisfied, by any NPDES permit issued by EPA or the state. *See* 33 U.S.C. §§ 1311(b)(1)(C), 1401(a)(1) & (d). These uses and criteria address a variety of issues, including the protection of aquatic organisms.

The NHWQS regulations mandate that "[a]ll surface waters shall provide, wherever attainable, for the protection and propagation of fish, shellfish and wildlife, and for recreation in and on the surface waters." N.H. Code R. Env-Wq 1703.01(c). *See also* 33 U.S.C. § 1251(a)(2). The regulations also dictate that:

> *[a]ll surface waters shall be restored to meet the water quality criteria for their designated classification including existing and designated uses, and to maintain the chemical, physical, and biological integrity of surface waters.*

N.H. Code R. Env-Wq 1703.01(b). "Biological integrity" is defined to mean:

> *. . . the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition,*

> *diversity, and functional organization comparable to that of similar natural habitats of a region.*

Id. 1702(7). In addition, the WQS regulations specify a water quality criterion for "Biological and Aquatic Community Integrity" providing as follows:

> *(a) The surface waters shall support and maintain a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of similar natural habitats of a region.*
>
> *(b) Differences from naturally occurring conditions shall be limited to non-detrimental differences in community structure and function.*

Id. 1703.19(a) & (b). *See also id.* 1703.04 (criteria in N.H. Code R. Env-Wq 1703.05 through 1703.32 apply to all of the state's surface waters).

The NHWQS indicate that the Hooksett Pool segment of the Merrimack River has been designated as a "Class B" water body by the state. *See id.* 1703.01(a); N.H. Rev. Stat. Ann. § 485-A:8(II). For Class B waters, the state's statute dictates that:

> *[t]here shall be no disposal of sewage or waste into said waters . . . [where] such disposal of sewage or waste [would] be inimical to aquatic life or to the maintenance of aquatic life in said receiving waters.*

N.H. Rev. Stat. Ann. § 485-A:8(II).[60] Thus, in sum, pollutant discharges to a Class B water body, such as the Hooksett Pool, may not harm aquatic life (*i.e.*, "be inimical to" or contribute to "detrimental differences" from naturally occurring conditions) or undermine a water body's ability to support and maintain what would otherwise be the natural, balanced community of aquatic life in that water body.

In addition to these biologically-focused requirements, the NHWQS also address thermal discharges specifically. In N.H. Rev. Stat. Ann. § 485-A:8(II), the statute, in pertinent part, mandates that:

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[60] Under this provision, thermal effluent (*i.e.*, wastewater containing waste heat) constitutes a "waste." *See* N.H. Rev. Stat. Ann. § 485-A:2(VI) & (XVI); N.H. Code R. Env-Wq 1702.25 & 1702.51. In addition, *The American Heritage Dictionary* (2d College Ed.) (1982), defines "inimical" to mean, in pertinent part, "injurious or harmful in effect; adverse . . . ." *See also Merriam-Webster's Online Dictionary* (defining "inimical" as "1: being adverse often by reason of malevolence or hostility . . . 2 a: having the disposition of an enemy . . . 2 b: reflecting or indicating hostility . . . .), available at http://www.merriam-webster.com/dictionary/inimical (as of Jun. 29, 2009).

[a]ny stream temperature increase associated with the discharge of treated sewage, waste or cooling water . . . shall not be such as to appreciably interfere with the uses assigned to this class. The waters of this classification shall be considered as being acceptable for fishing, swimming and other recreational purposes and, after adequate treatment, for use as water supplies.

In other words, Merrimack Station's thermal discharges must not result in in-stream temperatures that "appreciably interfere" with fishing or other specified uses in the Hooksett Pool (*e.g.*, swimming or other recreational purposes, water supply after adequate treatment). In addition, N.H. Rev. Stat. Ann. § 485-A:8(VIII) provides that:

[i]n prescribing minimum treatment provisions for thermal wastes discharged to interstate waters, the department shall adhere to the water quality requirements and recommendations of the New Hampshire fish and game department, the New England Interstate Water Pollution Control Commission, or the United States Environmental Protection Agency, whichever requirements and recommendations provide the most effective level of thermal pollution control.

Given that Merrimack Station discharges to an interstate water – namely, the Merrimack River – this provision requires the NHDES to prescribe treatment requirements for thermal discharges that, at a minimum, adhere to the most effective of the water quality requirements and recommendations for thermal pollution control offered by EPA, NHFGD, and the New England Interstate Water Pollution Control Commission ("NEIWPCC").[61] Moreover, the NHWQS regulations incorporate these statutory requirements as water quality criteria for ambient temperature, dictating that "[t]emperature in class B waters shall be in accordance with N.H. Rev. Stat. Ann. § 485-A:8, II, and VIII." N.H. Code R. Env-Wq 1703.13(b).

From the state water quality requirements discussed above, EPA distilled the following criteria to guide its determination of water quality-based permit limits:

(a) thermal discharges may not be "inimical to aquatic life";

(b) thermal discharges must provide, wherever attainable for the protection and propagation of fish, shellfish, and wildlife, and for recreation, in and on the receiving water;

(c) thermal discharges may not contribute to the failure of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to, and with only non-

[61] NEIWPCC does not presently review and make recommendations for thermal discharge limits to be included in individual NPDES permits and, thus, is not relevant here.

detrimental differences in community structure and function from, that of similar natural habitats in the region; and

(d) [a]ny stream temperature increase associated with thermal discharge must not appreciably interfere with fishing, swimming and other recreational purposes.

After a lengthy assessment, EPA has concluded that the thermal discharge from Merrimack Station has indeed been inimical to aquatic life in the Hooksett Pool (Section 5). Therefore, EPA has worked to determine thermal discharge limits necessary to satisfy the NHWQS not only because of its obligations under CWA §§ 301(b)(1)(C) and 1341(a) and (d), but also in light of the above-discussed requirement in N.H. Rev. Stat. Ann. § 485-A:8(II) that NHDES must prescribe limits consistent with the water quality requirements and recommendations of EPA or NHFGD that yield the most effective thermal pollution control measures. Indeed, in light of the latter requirement, EPA has worked hard to coordinate with NHFGD, NHDES, and USFWS in developing these water quality-based requirements and recommendations for thermal pollution control.

8.3 Protective Temperatures for Fishes of Hooksett Pool

Because freshwater fishes cannot regulate their body temperature through physiological means, water temperature affects virtually all of their biochemical, physiological, and life history activities (Beitenger et al. 2000). Water temperature is so important to fish that it has been called the "abiotic master factor" (Smith and Hubert 2003). By adding heat to the lower half of the Hooksett Pool, Merrimack Station's thermal discharges have altered the habitat in ways that have caused, or contributed to, detrimental changes in the fish community.

An aquatic habitat degraded by elevated temperatures can increase the metabolism and decrease the overall health of individual fish, and can cause physiological effects that compromise successful reproduction. At certain temperatures, fish may avoid the heated habitat altogether and thereby be precluded from important areas for foraging or refuge. Fish, in their earliest life stages (*i.e.*, eggs and larvae) may not be able to avoid exposure to elevated temperatures of the plant's discharge, and, as a result suffer impairment or lethality. Elevated temperatures may also affect the abundance and variety of prey organisms available to foraging fish, as well as the abundance and variety of organisms that prey upon them. Finally, but perhaps most important, thermal alteration of a habitat can shift the competitive advantage toward those species more tolerant of elevated temperatures. A reduction in the forage base or other stressors, due either to natural or man-made causes (or both), will exacerbate this condition.

To determine the thermal discharge limits needed to satisfy the NHWQS, EPA has identified the species most sensitive to elevated temperatures from among those known to inhabit the Hooksett Pool. EPA has also identified protective temperatures for each lifestage of selected species, and the time periods when these life stages are expected to be present in Hooksett Pool. Obviously, temperatures vary from year to year on any given date. Therefore, EPA has established relevant time periods based on a 21-year temperature data set collected by Merrimack Station, which is attached as Appendix A.

In making this assessment, EPA divided fish species into two categories; resident and diadromous. Resident species are present in Hooksett Pool throughout their lives and reproduce there. Diadromous species only spend part of their lives in Hooksett Pool, however, exposure to elevated temperatures while in the pool can affect their survival, or migration success.

By protecting the most temperature-sensitive species, EPA expects that all species of interest would be protected and the NHWQS would be satisfied. As a result, the thermal discharges would not be expected to cause significant harm to the water body's community of aquatic organisms, and the protection and propagation of that community should be reasonably assured and the biological integrity of the water body maintained. This approach (*i.e.*, focusing on the most sensitive species as a way to protect the entire community) has been identified in the literature as one way to protect existing fish communities in a water body receiving thermal discharges (National Academy of Science/National Academy of Engineers 1972). It should also be noted that in this case when threshold temperatures were identified for the most sensitive fish species in Hooksett Pool, other species, or life stages of a species, were found to have temperature thresholds only slightly above the critical threshold temperature selected.

Following is a discussion of which species were identified as most temperature-sensitive and what temperatures were determined to be protective during the different time periods relevant for the different life stages. Section 8.3.1 discusses resident species present in Hooksett Pool, and Section 8.3.2 covers diadromous species (*e.g.*, American shad, American eel).

8.3.1 Resident Species

Since resident species are exposed to the Hooksett Pool environment during their entire life cycle, the quality and quantity of the habitat in the pool are central factors affecting the ability of these species to successfully forage, compete, and propagate. As previously discussed in Section 5, EPA considers each fish species found in Hooksett Pool to be represented by a single, pool-wide population of that species. Therefore, sufficient suitable habitat throughout the pool is essential for maintaining or, in the case of Hooksett Pool, re-establishing the balanced, indigenous fish community.

EPA reviewed scientific literature for the following resident species to determine which would be the most sensitive to elevated temperatures at various life stages: yellow perch, white sucker, pumpkinseed, fallfish, largemouth bass, smallmouth bass, bluegill, golden shiner, spottail shiner, and brown bullhead. These species had been previously selected for review based on their temperature tolerances and/or their sport fishing or forage value. Critical temperature values and time periods were identified for these species and compared to determine which species appeared to have the lowest threshold for effects from elevated water temperatures. The life stages considered for the purpose of establishing protective temperatures are as follows: (1) adult reproductive condition, (2) spawning stage, (3) egg stage, (4) larva stage, (5) juvenile stage, and (6) adult stage. The protective temperature limits and time periods developed from this analysis were based on a number of sources and are discussed in this section.

From this review, EPA determined that yellow perch was the resident fish species in Hooksett Pool most sensitive to temperature for each life stage evaluated. As a result, yellow perch was identified as an indicator species in this site-specific investigation of thermal effects. Put differently, this assessment relies on the fact that if thermal discharges are limited to protect the species most sensitive to temperature – in this case, yellow perch – then other species and life stages that are present in Hooksett Pool should also be protected. Thus restricted, the thermal discharges in question would not be expected to significantly harm the water body's community of aquatic organisms, the protection and propagation of the community should be reasonably assured, and the biological integrity of the water body would be maintained.

Yellow perch are native to New Hampshire waters (Normandeau 2007a) and have been present in Hooksett Pool since initial plant-related fish sampling commenced in 1967. Yellow perch was identified in an early Merrimack Station report as playing an important role in Hooksett Pool as an abundant game fish, and as a source of forage (as juveniles) for other gamefish species (Normandeau 1979b). The decline of yellow perch since Merrimack Station's Unit 2 began operations is one example of the deterioration of the balanced community that existed prior to the start-up of Unit 2, and it provides evidence of the inimical effects on aquatic life that have occurred from the facility's thermal discharge

8.3.1.1 Adult Reproductive Condition

EPA reviewed scientific literature that examined the temperature sensitivity of resident fish species found in Hooksett Pool during the adult-stage reproductive condition. EPA's literature review identified yellow perch as the species whose reproductive development is most sensitive to elevated water temperatures. A discussion of relevant yellow perch information follows.

8.3.1.1a Temperature – Adult Reproductive Condition

The gonadal development of adult yellow perch is dependent on, among other factors, the occurrence of a minimum overwintering water temperature that must be maintained for a specific duration, referred to as a "chill period." Adults must be exposed to this extended period of cold water temperatures to ensure the ripening of eggs (Krieger et al. 1983). Studies conducted on yellow perch demonstrated a reduction in spawning success when overwintering exposure temperatures were increased and chill period duration was decreased (Hokanson 1977). A review of yellow perch habitat requirements lists a temperature range of 4°–10ºC (39.2°-50°F) for between 145–175 days for the maturation of gonads (Krieger et al. 1983). According to

Hokanson (1977), a winter minimum temperature of 10ºC (50ºF) is near the upper limit for maturation of gonads in yellow perch.

Based on EPA's review of Merrimack Station's 21-year water temperature data set, the average daily mean water temperature in ambient portions of Hooksett Pool drops below 10ºC (50ºF) on October 26, and does not rise above 10ºC until May 1 (Normandeau 2007b). This indicates that the minimum temperatures needed for proper gonadal development exist in the ambient waters of Hooksett Pool for 185 days, on average. However, based on Hokanson's studies (1977), a chill period of 185 days at 10ºC (50ºF) equates to only 30-percent spawning success of all females exposed during the study. The spawning success rate increased to nearly 58 percent when females were exposed for a chill period of 170 days at 8.0ºC (46.4ºF). While EPA did not have a complete ambient water temperature data set for the entire winter period in Hooksett Pool, it appears, based on the data available, that daily mean ambient water temperatures typically drop below 8.0ºC (46.4ºF) within the first few days of November, and stay below 8.0ºC until April 20. This chill period would provide nearly 170 days (166 days) of exposure at 8.0ºC (46.4ºF), which would nearly double the spawning success rate, according to Hokanson (1977).

Based on the discussion above, the maximum temperature in Hooksett Pool that is protective for the maturation of yellow perch gonads and, ultimately, reproductive success, is 8.0ºC (46.4ºF). Therefore, a maximum temperature of 8.0ºC (46.4ºF) would apply at Station S-4 during the period when ambient temperatures are also at or below 8.0ºC. Since adult yellow perch are typically found relatively low in the water column during this period, the protective temperature would apply to depths three feet and greater at Station S-4.

8.3.1.1b Time Period – Adult Reproductive Condition

The winter chill period for adult yellow perch, defined as the period when ambient temperatures in Hooksett Pool are at or below 8.0ºC (46.4ºF), extends from approximately November 5 to April 20. Therefore, a weekly mean temperature limit of 8.0ºC (46.4ºF) would be in effect at Station S-4 from November 5 through April 20.

8.3.1.2 Adult Spawning Stage

In addition to being an important factor in proper gonadal development, water temperature is an important cue triggering the onset of spawning. Artificially high water temperatures may cause resident species to reach maturity earlier in the spawning season than they would otherwise, and even to spawn earlier than they would naturally, in the absence of elevated water temperatures. Spawning has been noted to take place earlier by fish in a discharge canal as compared to fish in nearby waters under ambient conditions (Marcy 1976). This disruption in the timing of spawning may severely decrease the survival rate of the early life stages of the affected species. Under normal conditions, spawning is timed to allow the emergence of newly hatched larvae and young-of-year fish to coincide with spring peaks in their favored prey. Early spawning may result in these life stages occurring in the lower basin before their prey is abundant. This could have a serious impact on the survival of the early lifestages of these species. Permit conditions that ensure a suitable thermal environment for the Hooksett Pool's balanced, indigenous population of aquatic organisms will help to restore conditions in the pool that will allow the recovery of its resident fish community.

Adult-stage resident fish from Hooksett Pool are adapted to the range of ambient temperature conditions typically found in the pool. Sampling data that documented the presence of adult-stage residence fish species in Hooksett Pool were available, although this information did not directly address the spawning condition. However, scientific literature was available that examined the adult stage spawning condition temperature sensitivity of fish expected to be "resident species" in Hooksett Pool. EPA's literature review identified yellow perch adults as the adult resident fish stage most sensitive to elevated water temperatures. A discussion of relevant adult yellow perch information follows.

8.3.1.2a Temperature – Adult Spawning Stage

Hartel et al. (2002) and Scott and Crossman (1973) both reported that yellow perch spawning occurs at night in shallow areas, when water temperatures are between 6.7º and 12.2ºC (44º–54ºF). Hokanson (1977) reported that successful reproduction of yellow perch depends on rising temperatures during spawning and early life stages. According to Krieger et al. (1983), temperatures from approximately 8.5º to 12ºC (47.3º–53.6ºF) represent a spawning Habitat Suitability Index of 1.0 (completely suitable), which are comparable to the conclusions of Hartel et al. (2002) and Scott and Crossman (1973).

Based on the scientific literature reviewed, EPA has selected 12.0ºC (53.6ºF) as the maximum temperature that is protective of yellow perch spawning habitat. Therefore, a maximum weekly mean temperature of 12.0ºC (53.6ºF) would apply at Station S-4 during the defined spawning period, as described below. The temperature would be measured one (1) foot below the surface at Station S-4 to approximate the shallow end of the spawning depth. This temperature limit and relevant time period may be replaced by a lower limit to protect a more sensitive life stage or species occurring in the basin at the same time.

8.3.1.2b Time Period – Adult Spawning Stage

Using the time period in spring when mean ambient temperatures in Hooksett Pool range from 6.7 ºC to12.0ºC (44º–53.6ºF), EPA estimated the spawning period for yellow perch to run from approximately April 10 to May 8 (Appendix A). During this period, EPA considers a weekly mean temperature of 12.0ºC (53.6ºF) at Station S-4 to be the maximum that is protective of yellow perch spawning in Hooksett Pool.

8.3.1.3 Egg Development Stage

Eggs from resident fish species in Hooksett Pool are adapted to the range of natural temperature conditions typically found in the pool. EPA reviewed available scientific literature that examined the egg-stage temperature sensitivity of fish identified as resident species in Hooksett Pool. Among Hooksett Pool resident species, yellow perch eggs were identified as most sensitive to elevated water temperatures. A discussion of relevant information for yellow perch eggs follows.

8.3.1.3a Temperature – Egg Development Stage

Koonce et al. (1977) examined the daily mortality rate for yellow perch eggs in the cleavage phase at 3ºC intervals from 3ºC through 30ºC (37.4º–86ºF). Mortality rates ranged from 5 percent at temperatures of 3ºC (37.4ºF) and 15ºC (59ºF) to 16-percent mortality, at a temperature of 18ºC (64.4ºF) (Table 8-1). A marked increase in temperature-induced mortality was observed in the interval between 18ºC (64.4ºF) and 21ºC (69.8ºF). At 18ºC, the mortality rate was 16 percent, but it climbed to 70 percent at 21ºC (Koonce et al. 1977). In this specific case, EPA considers this pronounced increase in mortality over a 3ºC temperature rise an important threshold of temperature sensitivity for yellow perch eggs. Unfortunately, the experiment did not publish egg mortality rates for temperatures between 18 ºC and 21ºC (64.4º–69.8ºF). In light of the absence of such data, EPA has reasonably concluded that the maximum temperature for the survival and proper development of yellow perch eggs in Hooksett Pool is 18ºC (64.4ºF).

Table 8-1 Daily mortality rates for the cleavage egg and swim-up larval phases of yellow perch development, from Koonce et al. (1977)

Temperature (ºC/ ºF)	Cleavage Egg Percent Mortality	Swim-up Larva Percent Mortality
3/37.4	5.0	100
6/42.8	0.5	85
9/48.2	0.3	42
12/53.6	0.0	12
15/59	5.0	2.0
18/64.4	16	0.0
21/69.8	70	8.0
24/75.2	100	20
27/80.6	100	45
30/86	100	100

8.3.1.3b Time Period – Egg Development Stage

Yellow perch spawning may begin as early as the latter part of February and continue through early July (Hokanson 1977), but is estimated by EPA to occur in Hooksett Pool in April and May when temperatures reach 6.7 ºC to 12.2ºC (44–53.9ºF). Icthyoplankton entrainment sampling conducted by Merrimack Station in 2006 and 2007 did not document the presence of any yellow perch eggs. Yellow perch egg masses normally do not drift in the water column, which should largely preclude them from being collected in plankton nets or entrained by cooling water intake structures. According to Krieger et al. (1983), female yellow perch broadcast egg strands in water depths of 1.0–3.7 m (3.3–12.1 ft). These gelatinous, semi-demersal, and adhesive egg masses are from 0.6–2.0 m (2.0–6.6 ft) long (Piavis 1991). Mansueti (1964) noted that yellow perch eggs are semi-demersal, usually becoming entangled with stream debris rather than sinking to the bottom. Therefore, eggs could remain at depths shallower than one meter (3.3 feet). A moderate amount of vegetation in littoral areas is important for spawning and cover, although rocks, sand, or gravel may be used if submerged vegetation is not available (Krieger et al. 1983).

Since yellow perch eggs were not collected during entrainment studies, it is difficult to determine the precise time period when they are present in Hooksett Pool. EPA consulted the scientific literature to estimate the beginning of the egg period. Based on preferred spawning temperatures of 6.7 ºC to12.2ºC (44º–53.9ºF) identified by Hartel et al. (2002) and the 21-year average daily mean water temperature recorded at the Hooksett Pool ambient monitoring station (N-10), yellow perch eggs could be present in Hooksett Pool from about April 10 when the mean temperature reaches 7ºC (44.6ºF), to May 8 when the mean temperature reached 12.2ºC (53.5ºF). (Appendix A). Using the high end of this temperature range (*i.e.*, 12.2ºC (53.5ºF), and a time-versus-temperature hatch rate developed by Hokanson (1977), EPA estimates the end of the egg development period to be approximately 19 days after spawning ceases. Therefore, the end of the egg development period is estimated to be May 27.

EPA has concluded that to satisfy NHWQS, a maximum mean weekly temperature of 18ºC (64.4ºF) must not be exceeded within all areas at, and downstream from, Station S-4 that may serve as yellow perch spawning habitat from April 10 through May 27, unless ambient water temperatures measured at Station N-10 are the same, or higher. This limit would be measured one (1) foot below the surface to ensure the shallow end of the spawning habitat is protected.

8.3.1.4 Larval Stage

Like eggs, larvae of resident fish species in Hooksett Pool are adapted to the range of ambient temperature conditions typically found in the pool. Fish larvae are generally weak swimmers, and may not be able to avoid stress-inducing, or even lethal, temperatures within a thermal plume. In addition, some larval stages of fish species are attracted to light, and stay close to the surface. This proximity to the surface can increase their exposure to thermal plumes, which also tend to be surface-oriented due to their positive buoyancy relative to the cooler ambient water.

EPA reviewed ichthyoplankton sampling data collected by Merrimack Station in 1995, 2006, and 2007 that documented the presence of larval fish in Hooksett Pool. In addition, EPA reviewed scientific literature that examines the larval stage temperature sensitivity of resident species in Hooksett Pool. From this literature review, EPA identified yellow perch larvae to be the most sensitive to elevated water temperatures. A discussion of relevant yellow perch larvae information follows.

Yellow perch larvae were identified in ichthyoplankton sampling performed in Hooksett Pool in 1995, and also during entrainment studies conducted in 2006 and 2007. Weekly entrainment sampling conducted by Merrimack Station in 2006 and 2007 identified yellow perch larvae at the Station's cooling water intake structure from the first week of May to the second week of June (Normandeau 2007c). Sampling at the intake structure is upstream of the thermal plume associated with the Station's cooling water discharge, at least during typical spring flow conditions. This sampling is limited to one location above the direct influence of the thermal discharge, and does not necessarily reflect the presence or abundance of larval yellow perch in other areas of the pool. Nevertheless, these data do provide at least a partial indication of the presence, abundance, and timing of yellow perch larvae in Hooksett Pool, which is relevant for establishing protective temperature limits for appropriate time periods.

8.3.1.4a Temperature (Chronic) – Larval Stage

Ambient water temperature data for the earliest date that yellow perch larvae were collected were not included in Merrimack Station's Entrainment and Impingement Report (Normandeau 2007c). Therefore, to estimate the water temperature on this date, EPA averaged the daily mean ambient temperatures for the first seven days of May using Merrimack Station's 21-year temperature data set (Appendix A). Based on this calculation, the first yellow perch larvae were collected in entrainment sampling at temperatures approximating 11.2ºC (52.1ºF). Similarly, Merrimack Station's 21-year temperature data set was used to establish a temperature that coincides with the end of the yellow perch larval period. Merrimack Station's entrainment data (Normandeau 2007c) indicates that yellow perch are present in larval form until mid-June. Therefore, EPA used temperature data on June 15 for purposes of estimating the end of the yellow perch larval period. Based on Merrimack Station's 21-year data set at Station N-10, the daily mean ambient water temperature associated with the end of the larval period (June 15) is 19.9ºC (67.8ºF).

In addition to the site-specific data collected to bracket the full range of temperatures that coincide with the presence of yellow perch larvae, EPA consulted literature sources to assist in determining a protective temperature for the proper development of the larval stage. Koonce et al. (1977) reported larva daily mortality rates at 3ºC intervals from 3ºC (37.4ºF) through 30ºC (86ºF). With a mortality rate of 1.0 representing 100-percent larva mortality, the mortality rate for upper lethal temperature effects rose from zero percent mortality at 18ºC (64.4ºF) to 100-percent mortality at 30ºC (86ºF) (Koonce et al. 1977). *See* Table 8.1. When these mortality rates are applied to Hooksett Pool, ambient temperatures in Hooksett Pool, during the period when yellow perch larvae are present, would correspond with mortality rates of approximately 12 percent on May 1 to approximately 3 percent on June 15, but with the mortalities at or below 2 percent for most of the period (Koonce et al. 1977).

EPA also considered internal guidance in establishing a water quality-based temperature limit for larvae. In its guidance document, "Quality Criteria for Water 1986," EPA recommends the following method for calculating maximum, long-term, protective temperatures. For warmer months (April through October), the "upper limiting temperature" is calculated by adding to the physiological optimum temperature (usually for growth) a factor that is one-third of the distance between the upper incipient lethal temperature and the optimum temperature for the most sensitive species and life stage that normally is found at that location and time (EPA 1987). Using the physiological optimum temperature of 18.0ºC (64.4ºF) for larval yellow perch, based on data provided in Koonce et al. (1977), and 28.0ºC (82.4ºF) as the upper incipient lethal temperature (Hokanson 1977), the upper limiting temperature for yellow perch larvae is:

$$18.0ºC + 1/3(28.0ºC – 18.0ºC) = 21.3ºC (70.3ºF)$$

EPA considered the poor status of the existing yellow perch population in Hooksett Pool, the range of ambient temperatures during the period when yellow perch larvae are likely to be present, published studies, and the particular vulnerability of surface-oriented yellow perch larvae to Merrimack Station's thermal discharge plume. Based on these factors, EPA concluded that water quality based requirements would call for 21.3ºC (70.3ºF) to be the maximum temperature permitted for the protection of yellow perch larvae in Hooksett Pool.

8.3.1.4b Temperature (Short-term) – Larval Stage

As discussed in Section 5.6.3.3f of this document, yellow perch larvae that come in contact with Merrimack Station's thermal plume are vulnerable to short-term thermal effects, possibly leading to lethality. While no site-specific survival studies have been conducted on yellow perch larvae in the area of Merrimack Station, temperatures demonstrated in studies to cause lethality to yellow perch larvae exist between Stations S-0 and S-4 for much of the period when yellow perch larvae are present. As previously mentioned, lethality has been demonstrated to occur in as little as 10 minutes when temperatures reach 33.7ºC (92.7ºF) and 30 minutes at 31.3ºC (88.3ºF), according to data presented in Wismer and Christie (1987). Hokanson (1977) observed 50-percent mortality of newly hatched larvae exposed to 28.0ºC (82ºF) for 24 hours. It should be noted that the studies referenced in Wismer and Christie (1987) used larvae that had been acclimated to a water temperature of 15ºC (59.0ºF). Mean ambient temperatures in Hooksett Pool during the months May and June averaged 14ºC (57.2ºF) and 20.1ºC (68.2ºF), respectively, according to Merrimack Station's historical temperature data (Appendix A). Higher acclimation temperatures typically correspond with higher temperature tolerances of fish species during controlled survival studies (Beitenger and Bennett 2000). For purposes of developing a protective temperature limit for short-term exposure, EPA considers the acclimation temperatures used in the referenced studies to be reasonably representative of "ambient" temperatures recorded at Station N-10 for the period May 1–June 15.

Since Merrimack Station's thermal plume extends across the entire river and is surface-oriented, it is highly likely that larval perch, which are also surface-oriented or pelagic during much of this life stage, are exposed to the plume. Therefore, in addition to a long-term temperature limit that is designed to be protective of larval yellow perch habitat, a temperature limit to prevent acute lethality of yellow perch larvae drifting past the plant is also necessary. Such a limit would be consistent with the NHWQS's (N.H. Code R. Env-Wq 1707.02) requirements for mixing zones, which call for maintenance of a zone of passage for swimming and drifting organisms, prohibit discharges from causing mortality to organisms within a mixing zone, and prohibit mixing zones from impinging upon the spawning grounds and/or nursery areas of any indigenous aquatic species.

EPA once again referred to internal guidance in establishing a water quality-based temperature limit for larvae, but this time for short-term exposure.

In its guidance document, "Quality Criteria for Water 1986," EPA recommends the following equation for calculating maximum, short-term, protective temperatures:

$$\text{Temperature (C}^\circ\text{)} = (1/b)(\log_{10} \text{time} - a) - 2^\circ\text{C}$$

Where: $\log_{10}$ = logarithm to base 10, in minutes

a = intercept on the "Y" or logarithmic axis of the line fitted to experimental temperature data and which is available for some species from Appendix II-C, National Academy of Sciences 1974 document

b = slope of the line fitted to experimental data and available for some species from Appendix II-C of the National Academy of Sciences 1974 document

2˚C = safety factor to assure no deaths occur

Because this equation, which is based on thermal tolerance research, predicts 50-percent mortality, a safety factor is needed to assure no mortality (NAS/NAE 1973). Several studies cited by the National Academy of Sciences (NAS/NAE 1973) indicated that a 2˚C (3.6˚F) reduction of an upper stress temperature results in no mortalities with an equivalent exposure duration.

In EPA's document, Temperature Criteria for Freshwater Fish: Protocol and Procedures (EPA 1977b), short-term maximum temperatures are calculated using a period of one day (1,440 minutes). According to the document, an appropriate time period for short exposure limitation, without risking violation of the weekly mean temperature, would be 24 hours since calculating a prolonged exposure period uses a weekly mean temperature.

Using the above equation, and yellow perch data provided in the NAS/NAE (1973) document, the maximum short-term temperature for the protection of juvenile yellow perch acclimated to a temperature of 19˚C (66.2˚F) is derived as follows:

$$\text{Max T (}^\circ\text{C)} = (1/-0.4126)(\log_{10} 1440 - 15.3601) - 2^\circ\text{C}$$

$$\text{Max T (}^\circ\text{C)} = (1/-0.4126)(3.1584 - 15.3601) - 2^\circ\text{C}$$

$$\text{Max T (}^\circ\text{C)} = (1/-0.4126)(-12.2017) - 2^\circ\text{C}$$

$$\text{Max T (}^\circ\text{C)} = 29.5727 - 2^\circ\text{C}$$

$$\text{Max T (}^\circ\text{C)} = 27.6\ (81.7^\circ\text{F})$$

EPA compared this temperature, derived from studies conducted on juvenile yellow perch, to results from 24-hour mortality studies conducted on larval yellow perch by Hokanson, described above. Hokanson (1977) reported 50-percent mortality of newly hatched larvae after being exposed to 28.0ºC (82.4ºF) for 24 hours. Hokanson's results suggest that using temperature tolerance derived for juvenile yellow perch is not adequately protective of larval yellow perch. On the other hand, the time period when larvae would be exposed to temperatures that may cause acute lethality is likely to be considerably shorter than 24 hours if the affected larvae are drifting with the river current. While a distinct thermal plume has been identified at points just above the Hooksett Dam, the plume temperature does gradually moderate as it moves downstream. Temperature data are routinely collected by Merrimack Station at Station S-0 where the thermal discharge enters the Hooksett Pool, and at Station S-4, which is approximately 2,000 feet downstream. EPA estimated the length of time larvae drifting downstream could be exposed to Merrimack Station's thermal plume from Station S-0 to Station S-4. While elevated temperatures related to the thermal plume have been documented to a point just above the Hooksett Dam, Station S-4 is the only long-term temperature monitoring station downstream of the discharge.

In order to calculate the velocity at which a yellow perch larvae drifts in Hooksett Pool, EPA divided the river flow by the approximate cross sectional area of the river in proximity to Stations S-0 and S-4. River flow data calculated for Garvins Falls for the month of June was presented in PSNH's FERC license application, Volume I (PSNH 2003). According to Figure B-7 in that document, the flow at Garvins Falls Dam is approximately 2,600 cfs or less 50 percent of the time during the month of June, based on flow data collected from 1937–2001. EPA considers this to be representative of average flow conditions during June when yellow perch larvae would most likely be exposed to potentially lethal temperatures within Merrimack Station's thermal discharge plume. In order to calculate the approximate flow velocity in the river segment between Stations S-0 and S-4, EPA determined the average river width and depth between Stations S-0 and S-4 using information provided in Figure 7 of the Merrimack River Monitoring Program 1976 report (Normandeau 1977). EPA calculated the average width and depth between Stations S-4 and S-0 to be 515 feet, and 9.2 feet, respectively. Based on this information, EPA calculated the approximate flow velocity, as follows:

$$\text{River Velocity (ft/sec) x River X-Sectional Volumeteric Area (ft}^2\text{) = Volumetric Velocity (cfs)}$$

$$\text{River Velocity (ft/sec) x 4,738 ft}^2 \text{ = 2,600 cfs}$$

$$\text{River Velocity = 0.55 ft/sec}$$

Therefore, the approximate time it takes a drifting larva to travel from Station S-0 to Station S-4 can be calculated using the following formula:

$$\text{Distance = Time x Speed}$$

$$2{,}000 \text{ ft} = \text{Time (T)} \times 0.55 \text{ ft/sec}$$

$$T = 3636.4 \text{ seconds, or } 60.6 \text{ minutes}$$

EPA reapplied the equation for calculating short-term exposure, but substituted the $\log_{10}$ of 1,440 minutes (24 hours) with that of 61 minutes.

$$\text{Max T (˚C)} = (1/\!-0.4126)(\log_{10} 61 - 15.3601) - 2˚\text{C}$$

$$\text{Max T (˚C)} = (1/\!-0.4126)(1.785 - 15.3601) - 2˚\text{C}$$

$$\text{Max T (˚C)} = (1/\!-0.4126)(-13.5751) - 2˚\text{C}$$

$$\text{Max T (˚C)} = 32.9 - 2˚\text{C}$$

$$\text{Max T} = 30.9˚\text{C (87.6˚F)}$$

Again, this temperature is based on studies conducted on juvenile yellow perch, not the more thermally-sensitive larval stage. Additionally, the thermal plume does extend beyond Station S-4, although heat loss occurs as the plume travels downstream. Looking back at results from studies conducted on yellow perch larvae, Wismer and Christie (1987) reported lethality of yellow perch larvae after only 30 minutes when exposed to 31.3ºC (88.3ºF). Therefore, EPA does not consider an hourly limit of 30.9ºC (87.6ºF) – just 0.4ºC lower – to be adequately protective of yellow perch larvae.

Recognizing that no single set of data is directly applicable for establishing a maximum short-term temperature for the protection of yellow perch larvae in Hooksett Pool, EPA has determined that a reasonable approach to establishing such a limit is simply to subtract 2ºC (3.6ºF) from the temperature identified above as causing yellow perch larval mortality after 30 minutes, which is 31.3ºC (88.3ºF). As previously mentioned, several studies cited in the National Academy of Science report (NAS/NAE 1973) indicate that a 2ºC (3.6ºF) reduction of an upper stress temperature results in no mortalities with an equivalent exposure duration. Therefore, the maximum short-term temperature (measured hourly) to prevent lethality or impairment to yellow perch larvae would be 31.3ºC – 2ºC, or 29.3ºC (84.7ºF). This limit would be enforced at Station S-0 (one-foot below the surface) since historical data demonstrates that temperatures at Station S-0 can exceed 33.7ºC (92.7ºF) prior to June 15. As previously mentioned, studies identified in Wismer and Christie (1987) documented larval yellow perch mortalities after only 10 minutes of exposure to 33.7ºC (92.7ºF). Enforcing this temperature limit at Station S-0 would also be warranted as a safety factor since the maximum hourly temperature is based on lethality that resulted after only 30 minutes, not one hour.

It should be noted that while the scientific literature indicates yellow perch is the most sensitive resident fish species in larval form, the thermal tolerance of white sucker larvae is similar.

Wismer and Christie (1987) identify upper incipient lethal temperatures for white sucker larvae ranging from 28.2º–31.7ºC (82.8º–89.1ºF), based on a 7-day exposure period. Therefore, temperature limits designed to be protective of yellow perch should also protect white sucker larvae, and other temperature sensitive species in their early lifestages. White sucker larvae were collected in Merrimack Station entrainment studies from April 9 to July 2 (Normandeau 2007c). Diadromous species, such as American shad, may be present in larval form during this time period, as well. These species are discussed in Section 8.3.2.4.

8.3.1.4c Time Period – Larval Stage

According to Merrimack Station's Entrainment and Impingement Report, yellow perch larvae first appeared in entrainment sampling at the plant's cooling water intake structure during the first week of May, and were last collected in the second week of June (Normandeau 2007c). While a single sampling point may not sufficiently represent the presence of larvae throughout the entire pool, early May appears to be reasonable for initial hatching, given ambient water temperatures and a time-versus-temperature hatch rate developed by Hokanson (1977). Seine sampling that targeted juvenile fish was conducted by Merrimack Station from 1973–1976. According to the 1975 Merrimack River Program Monitoring Report, dated September 1976, "Larval and post-larval fishes were observed at most stations during June. The larvae were large enough to be captured by seine and included in catch-per-effort statistics beginning in July. No larvae were observed after June at any station." (Normandeau 1976a). While these two statements seem contradictory, EPA suspects that "larvae large enough to be captured [ ] in July," were actually juveniles. It should be noted that this sampling effort was not targeting larvae, and the report did not identify what species were present in larval form. Based on Merrimack Station's entrainment sampling and larval development rates from Krieger et al. (1983), yellow perch larvae are likely to be present in Hooksett Pool from May 1 through June 15. Therefore, EPA has concluded that water quality-based temperature limits developed to protect yellow perch larvae are needed from May 1 through June 15, unless replaced by a lower temperature limit to protect a more sensitive life stage or species present in the basin at the same time.

8.3.1.5 Juvenile Stage

Sampling conducted between 1967 and 2007 has documented the presence of juvenile yellow perch in Hooksett Pool. Studies conducted by Merrimack Station in 2004 and 2005 provide the water temperature data associated with fish sampling in those years. In addition, EPA reviewed scientific literature that examined the juvenile stage temperature sensitivity of resident species found in Hooksett Pool. The literature review identified yellow perch as the species most sensitive to elevated water temperatures in this life stage. A discussion of relevant information for juvenile yellow perch follows.

8.3.1.5a Temperature – Juvenile Stage

The juvenile stage is probably the most thermally tolerant phase in the lifecycle of yellow perch, and other percids, with studies showing that juveniles selected temperatures 3ºC (5.4ºF) higher than adults when acclimated to 24ºC (75.2ºF) (Hokanson 1977). McCormick (1976) found maximum growth rates at 28ºC (82.4ºF) for juvenile yellow perch. On the other hand, Tidwell et al. (1999) found that yellow perch juveniles exposed to a temperature of 28ºC (82.4ºF) showed a marked reduction in survival when compared to those exposed to 24ºC (75.2ºF) or 20ºC (68ºF). The survival rate was only 75 percent at 28ºC (82.4ºF), as compared with 94 and 96 percent, for 24ºC (75.2ºF) and 20ºC (68ºF), respectively. In that study, however, stress levels leading to mortality may have been exacerbated by high stocking densities. Hokanson (1977) identifies 24.7ºC (76.5ºF) as the physiological optimum for yellow perch based on studies using juveniles.

The upper incipient lethal temperature limit for juvenile yellow perch, defined as the temperature where mortality is observed for 50 percent of the organisms tested, is given as a range between 29.2º–34ºC (84.6º–93.2ºF) (Hokanson 1977). Averaged daily mean summertime ambient temperatures in Hooksett Pool peak at 25.1ºC (77.2ºF). This temperature (25.0ºC) is one of the acclimation temperatures used in Hokanson's study. At an acclimation temperature of 25.0ºC (77.0ºF), the incipient lethal temperature for juvenile perch is 32.3ºC (90.1ºF) (Hokanson 1977). EPA again referred to its guidance document, "Quality Criteria for Water 1986," to calculate an upper limiting temperature for juvenile yellow perch. As previously described for larvae, the upper limiting temperature is calculated by adding to the physiological optimum temperature a factor that is one-third of the distance between the upper incipient lethal temperature and the optimum temperature for the most sensitive species and life stage that normally is found at that location and time (EPA 1987). Since temperatures identified as the physiological optimum varied from 24.7º to 28ºC (76.5º–82.4ºF), EPA averaged the two, resulting in a calculated physiological optimum temperature of 26.4ºC (79.5ºF). Using this value as the physiological optimum temperature and 32.3ºC (90.1ºF) as the upper incipient lethal temperature, the upper limiting temperature is calculated as follows:

$$26.4^{\circ}C + 1/3(32.3^{\circ}C - 26.4^{\circ}C) = 28.4^{\circ}C\ (83.1^{\circ}F)$$

Ambient temperatures in Hooksett Pool averaged 24.0ºC (75.2ºF) in July and August, based on daily mean temperatures measured at Station N-10 over the 21-year period 1984–2004 (Appendix A). Taking into consideration all the information provided above, as well as the poor status of the existing yellow perch population in Hooksett Pool, a temperature limit of 28.4ºC (83.1ºF) was judged by EPA to be protective for juvenile yellow perch. According to Piavis (1991), juvenile yellow perch migrate from the limnetic zone (*i.e.*, open water) to littoral (near-shore) waters in order to feed on richer near-shore food sources. In order to ensure that near-shore, shallow habitat utilized by juvenile yellow perch is protected, water quality-based requirements would call for a weekly mean temperature limit of 28.4ºC (83.1ºF), measured one foot below the surface at Station S-4.

EPA recognizes that compliance with this temperature limit as a weekly average (*i.e.*, the mean of multiple readings taken over a seven-day period) may still allow temperatures to periodically exceed 32.3ºC (90.1ºF), which is the upper incipient lethal temperature established for yellow perch during summer conditions. Additional study results presented in Hokanson (1979) indicate that, for juvenile yellow perch, 50-percent lethality occurred after 143 minutes at 32.0ºC (89.6ºF) when acclimated at 19ºC (66.2ºF), and after 12 hours at 30.9ºC (87.6ºF) when acclimated at 25–26ºC (77–78.8ºF). Studies referenced by Hokanson (1977) observed yellow perch invade water temperatures in excess of their upper incipient lethal temperature and die. All of these study results support the need to protect juvenile yellow perch against potential lethal effects from short-term, high temperature excursions.

In order to calculate a short-term maximum temperature, EPA again referred to its document, Temperature Criteria for Freshwater Fish: Protocol and Procedures (EPA 1977b). According to the calculation prescribed by the document to prevent short-term temperature effects, which is presented above in Section 8.3.1.4b, the maximum short-term (hourly) temperature for the protection of juvenile yellow perch and their nearshore habitat is 30.9ºC (87.6ºF). EPA also calculated the average daily temperature for juvenile yellow perch, as prescribed by the EPA's temperature criteria document, but the temperature derived by this method (27.6ºC/ 81.7ºF) is actually lower than the weekly temperature limit. This hourly maximum limit would be measured daily at Station S-0 within one-foot below the surface.

8.3.1.5b Time Period – Juvenile Stage

Sampling conducted by Merrimack Station has documented the presence of juvenile yellow perch in Hooksett Pool throughout the year. Therefore, a weekly mean temperature limit of 28.4ºC (83.1ºF) at Station S-4, and an hourly maximum temperature of 30.9ºC (87.6ºF) must not be exceeded (1 foot below surface). These limits would be in effect throughout the year, unless replaced by a lower temperature limit to protect a more sensitive life stage or species occurring in the basin at the same time.

8.3.1.6 Adult Stage

Adult-stage resident fish species in Hooksett Pool are adapted to the range of ambient temperature conditions typically found in the pool. Scientific literature that examined the adult-stage temperature sensitivities of fish expected to be resident species in Hooksett Pool were reviewed. The literature review identified yellow perch as the resident species most sensitive to elevated water temperatures, although white sucker had similar temperature tolerances in the adult stage. A discussion of relevant information regarding adult yellow perch follows.

8.3.1.6a Temperature – Adult Stage

Adult yellow perch generally prefer lower temperatures than juveniles (Hokanson 1977), and tend to move into deeper, cooler waters during the summer months. In the southern half of Hooksett Pool, very limited thermal refuge is available to yellow perch during the summer due to the shallow river depths (6 to 10 feet under most flow conditions) and Merrimack Station's thermal plume, which can span the entire width of the river, and affect up to one-third of the water column. Adult yellow perch must either move into the deepest waters of the river's thalweg, or upstream of the discharge canal. As discussed in section 5.6.3.3f of this document, fish sampling conducted in 2004 and 2005 by Merrimack Station indicates that adult yellow perch largely abandon the southern portion of Hooksett Pool during summer conditions. This suggests that adult yellow perch are being effectively precluded from habitat downstream of the discharge canal. As a result, considerably less area of the pool is available to support the population, which may reduce production (NAS/NAE 1972).

Mean daily temperature in ambient waters of Hooksett Pool during the months of July and August averaged 23.9ºC (75.1ºF) over the 21-year period, 1984 to 2004 (Appendix A). Additionally, surface temperatures taken at ambient stations upstream of the discharge canal during electrofishing sampling in July and August of 2004 and 2005 never exceeded 25.1ºC (77.2ºF), and the maximum difference in temperature between surface and bottom (*i.e.*, ΔT) was 0.5ºC (0.9ºF). By contrast, temperature data recorded during the same sampling periods at the station closest to Station S-4 (13W) documented surface temperatures up to 33.7ºC (92.7ºF). Maximum bottom temperature during sampling at this station was 30.3ºC (86.5ºF), and surface-to-bottom changes in temperature ranged from 3.0–6.0ºC (5.4–10.8ºF). Merrimack Station identifies 28.3ºC (83.0ºF) as the avoidance temperature for yellow perch (Normandeau 2007a).

In addition, temperatures below those that have been documented to elicit an avoidance response but above those identified as the thermal optimum have been demonstrated to impact a fish's physiology, including swimming performance, and metabolism (NAS/NAE 1973). This, in turn, can adversely affect a fish's ability to grow, compete for forage, and avoid predation. Scientific literature regarding adult yellow perch report a preferred temperature of between 17.6–25ºC (63.7–77ºF) (Krieger et al. 1983), while site-specific data reported above supports the preference of temperatures less than or equal to 25ºC (77ºF).

EPA once again calculated an upper limiting temperature using the formula described in "Quality Criteria for Water 1986" by adding to the physiological optimum temperature a factor that is one-third of the difference between the upper incipient lethal temperature and the optimum temperature for the most sensitive species and life stage that normally is found at that location and time (EPA 1987). Krieger et al. (1983) identifies 19–24ºC (66.2–75.2ºF) as the optimum temperature range for adult yellow perch. The scientific literature places the upper lethal limit for yellow perch adults at 32.2ºC (90ºF) (Krieger et al. 1983). This is supported by

Hokanson who reported that summer tests using an acclimation temperature of 25ºC (77.2ºF) resulted in an upper incipient lethal temperature of 32.3ºC (90.1ºF). Therefore, if 21.5ºC (70.7ºF), the mid-point of the optimum temperature range, is chosen as the optimum temperature, and 32.3ºC (90.1ºF) is chosen as the upper incipient lethal temperature, by following this method, the upper limiting temperature is calculated as follows:

$$21.5ºC + 1/3(32.3ºC – 21.5ºC) = 25.1ºC (77.2ºF).$$

Taking into consideration all the information provided above, as well as the poor status of the existing yellow perch population in Hooksett Pool, water quality-based requirements would call for a weekly mean temperature limit of 25.1ºC (77.2ºF). In addition, the hourly maximum temperature limit of 30.9ºC (87.6ºF) necessary to prevent acute thermal effects to juvenile yellow perch and their habitat would also be protective of adult yellow perch and their deeper water habitat.

8.3.1.6b Time Period – Adult Stage

Given that sampling conducted by Merrimack Station has documented the presence of adult yellow perch in Hooksett Pool throughout the year, the weekly mean temperature limit of 25.1ºC (77.2ºF) at Station S-4 would apply throughout the year, unless supplanted by a lower temperature limit to protect a more sensitive life stage or species occurring in the basin at the same time.

8.3.1.7 Summary of Temperature Limits and Time Periods for the Protection of Resident Species

All protective temperatures for yellow perch, the most temperature-sensitive resident species in Hooksett Pool, are presented in Table 8-2, below, organized by lifestage and time of year. Since several of the time periods overlap, a summary of the applicable temperatures and corresponding time periods throughout the calendar year is also presented (Table 8-3).

Table 8-2 Summary of protective temperatures for yellow perch at various lifestages, corresponding time periods, and applicable document section where discussed

Lifestage	Temp. °C (°F)	Time Period	Reference Section
Adult reproduction	8 (46.4)	Nov. 5 – April 20	8.3.1.1
Adult spawning	12 (53.6)	April 10 – May 8	8.3.1.2
Egg	18 (64.4)	April 10 – May 27	8.3.1.3
Larva	21.3 (70.3)	May 1 – June 15	8.3.1.4
Larva (acute)	29.3 (84.7)	May 1 – June 15	8.3.1.4b
Juvenile	28.4 (83.1)	All Year	8.3.1.5
Juvenile (acute)	30.9 (87.6)	All Year	8.3.1.5
Adult	25.1 (77.2)	All Year	8.3.1.6

Table 8-3 Summary of applicable protective temperatures and compliance point, schedule, and depth for yellow perch at various lifestages throughout the calendar year

Time Period	Temp. °C (°F)	Compliance	Station/Water Depth	Lifestage
Jan.1 – April 20	8 (46.4)	Weekly Avg.	S-4 / 3 ft	Adult reproduction
April 21 – May 8	12 (53.6)	Weekly Avg.	S-4 / 1 ft	Adult spawning
May 9 – May 27	18 (64.4)	Weekly Avg.	S-4 / 1 ft	Egg
May 28 – June 15	21.3 (70.3)	Weekly Avg.	S-4 / 1 ft	Larva
May 1 – June 15	29.3 (84.7)	Hourly Max.	S-0 / 1 ft	Larva (acute)
June 16 – Nov. 4	25.1 (77.2)	Weekly Avg.	S-4 / 3 ft	Adult
June 16 – Nov. 4*	28.4 (83.1)	Weekly Avg.	S-4 / 1 ft	Juvenile
June 16 – Nov. 4*	30.9 (87.6)	Hourly Max.	S-0 / 1 ft	Juvenile (acute)
Nov. 5 – Dec.31	8 (46.4)	Weekly Avg.	S-4 / 3 ft	Adult reproduction

* Limit would be applied to shoreline shallows (within 1 foot below surface) and therefore may be more restrictive than the lower temperature established for adults (3 feet below surface)

8.3.1.8 Thermal Effects in the Discharge Canal

Fish sampling conducted by the plant suggests that a significant segment of the Hooksett Pool yellow perch population may be attracted to the comparatively warm waters of the discharge canal during colder months. During electrofishing sampling conducted in both 1995 and 2005, high numbers of yellow perch were captured in the discharge canal compared to all other stations sampled. According to Merrimack Station's Fisheries Study Report, dated January 1997, "[t]he canal population of yellow perch comprised a significant portion of the total Hooksett Pool population as sampled by electrofishing, primarily due to a single high catch in March."

The attraction of relatively large numbers of yellow perch to the discharge canal raises the likelihood that yellow perch are residing in the canal during portions of what otherwise would be their winter chill period, which can adversely affect proper gonadal development. Studies reported by Hokanson (1977) demonstrated that the temperature preference in winter for yellow perch acclimated at 5ºC (41ºF) was 13ºC (55.4ºF), which is above the safe limit for gonadal maturation (<10ºC (50ºF)).

Further, exposure to elevated temperatures in the discharge canal could cause affected yellow perch to spawn earlier than they would if exposed only to ambient water temperatures. According to the Fisheries Analysis Report, the bottom water temperature in the canal collected during fish sampling on April 30, 2005, was 25.1ºC (77.2ºF), well above the 18ºC (64.4ºF) temperature considered protective of yellow perch egg development. No studies have been undertaken to assess to what extent, if any, yellow perch are actually spawning in the Merrimack Station's discharge canal, but there is a risk of such spawning occurring because yellow perch large enough to be sexually mature have been found in the discharge canal during the period when spawning would be expected. Moreover, yellow perch have also been found in the discharge canal in March when canal temperatures were conducive to yellow perch spawning (March 1995: 15.9ºC/60.6ºF). Such spawning would be problematic because although suitable spawning temperatures were prevailing in the discharge canal, ambient temperatures in Hooksett Pool recorded during the same time period were well below those considered protective of yellow perch egg or larva survival.

Studies conducted by Merrimack Station in 2009 included an assessment of sex ratios of yellow perch in the Garvin's Pool, Hooksett Pool, and Amoskeag Pool. The study showed that the male-to-female ratio (M:F) varied considerably, from 2.8:1 in Garvin's Pool to 0.9:1 in Hooksett Pool. Amoskeag Pool was similar to Hooksett at 1:1 (Normandeau 2009a). These results may be a manifestation of the sampling design, which targeted spawning aggregations. However, it should be noted that the intentional exposure of embryos to heat is an established practice in the culture of yellow perch where the use of all-female stocks is a significant advantage due to their faster growth (Madison et al. 1993). While there is presently no clear evidence that yellow perch spawning activity in the discharge canal, or elsewhere within the influence of the thermal plume, is affecting the ratio of males to females in Hooksett Pool, the significant sub-lethal effect that heat has on yellow perch eggs has been well-studied.

EPA has concluded that thermal conditions within the discharge canal are not protective of yellow perch during their winter period of gonadal development or their spring spawning period, nor are they protective of yellow perch eggs and larvae should spawning take place in the canal. Therefore, water quality-based requirements would call for a barrier capable of preventing adult yellow perch from entering into the discharge canal during the period when these previously identified critical life stages of yellow perch are occurring (Table 8-2).

8.3.2 Diadromous Species

Diadromy is the collective term used for fish species that spend part of their life cycle in fresh water and part in salt water. There are three forms of diadromy, two of which are represented by fish species found in the Merrimack River. Anadromous species are born in fresh water, mature in salt water, and return to fresh water to spawn. Conversely, fish that are born in salt water, mature in fresh water, and return to salt water to spawn are called catadromous species. As discussed in Section 5.3.1, anadromous species that commonly inhabit Hooksett Pool during part of their life cycle are Atlantic salmon, American shad, and alewife. Blueback herring and sea lamprey may occasionally be present, as well. Only one catadromous species, American eel, is at times present in the pool.

The populations of all diadromous species found in the Merrimack River are significantly below historical levels. For example, although landings data indicate that 365,000 adult shad were caught in the Merrimack as late as 1841, the annual run above the Essex Dam has likely been extirpated (TCAFMMRB 2010). However, as previously discussed in section 5.6.3.3b, a new plan was recently developed by the Technical Committee for Anadromous Fishery Management of the Merrimack River Basin that seeks to "[r]estore a self-sustaining annual migration of American shad (*Alosa sapidissima*) to the Merrimack River watershed, with unrestricted access to all spawning and juvenile rearing habitat throughout the main stem river and its major tributaries." (TCAFMMRB 2010). The technical committee is comprised of USFWS, NHFGD, U.S. Forest Service, Massachusetts Division of Marine Fisheries, Massachusetts Division of Fisheries and Wildlife, and NOAA – National Marine Fisheries Service. According to the plan, up to four million American shad fry (larvae) and five thousand adults are slated to be stocked annually in waters upstream from Hooksett Pool. Stocking may occur in Hooksett Pool, as well (pers. com. – J. McKeon, USFWS).

As part of the main stem of the Merrimack River, Hooksett Pool serves as a critical conduit between upstream spawning and juvenile-rearing habitats and the sea.

Although diadromous species only spend part of their lives in Hooksett Pool, exposure to the plant's thermal plume can potentially impede the progress of out-migrating fish, adversely affect larvae drifting past the plant, and impair the ability of larvae and juveniles to effectively forage and find suitable refuge while in the pool.

The periods of adult in-migration, spawning, larval development, and out-migration of juveniles and adults vary for each species, although alewife and blueback herring are similar in many respects. EPA has reviewed the available temperature data for all the diadromous species, and their applicable lifestages, that may be present in Hooksett Pool. Based on EPA's review, it appears that the temperatures identified as being protective of resident species, as described in Section 8.3.1, do not in all cases protect all diadromous species and lifestages expected to be found in Hooksett Pool. Therefore, some limits developed for the protection of diadromous species will supersede limits developed for resident species when those diadromous species are expected to be present in Hooksett Pool. EPA expects restoring Hooksett Pool's thermal habitat will not only immediately benefit the resident fish community, but will also ensure that suitable habitat exists for diadromous species when they are present. The following is a discussion of life stages, time periods, and temperature requirements when diadromous species are likely to be present in Hooksett Pool.

8.3.2.1 Adult In-Migration

Under most flow conditions, Hooksett Dam currently prevents access by in-migrating fish to Hooksett Pool and spawning habitat further upstream. However, a Fishway Prescription developed by the USFWS as part of the relicensing of the Merrimack River Hydroelectric Project, which includes Amoskeag, Hooksett, and Garvins Falls dams, requires construction of upstream fish passage at Hooksett Dam three years after the passage of 9,500 shad at Amoskeag, and at Garvins Falls Dam three years after the passage of 9,800 shad at Hooksett Dam (TCAFMMRB 2010).

Until fish passage is installed at Hooksett and Garvins Falls dams, adult American shad and larvae (fry), Atlantic salmon fry, and juvenile river herring will be trucked to suitable spawning habitat upstream of Hooksett Pool. While past stocking efforts have varied considerably from one year to the next, due in part to the availability of fish, the goal of the new American shad restoration plan is to stock up to four million shad larvae and five thousand adults annually. The technical committee intends to eventually develop restoration plans for other diadromous species, as well, including Atlantic salmon, river herring, American eel, and sea lamprey (pers. com. – J. McKeon, USFWS). Currently, American eels migrating upstream are trapped at the Amoskeag Dam and transported to head pond areas above Hooksett Pool where they grow and mature.

Since diadromous fish are not yet able to access Hooksett Pool from downstream, the protective temperatures required during in-migration are not discussed in detail. However, based on a review of available temperature data for all applicable diadromous species, EPA expects that the temperatures identified in this document to be protective of resident species will also be protective of in-migrating adult diadromous species when they are once again able to access Hooksett Pool.

8.3.2.2 Spawning

Spawning by anadromous species in Hooksett Pool has not routinely occurred since the Hooksett Dam and other downstream dams were constructed. The slow moving, restricted flows common to impoundments like Hooksett Pool are normally considered unsuitable spawning habitat for Atlantic salmon. There have been documented cases where alewives and American shad have successfully spawned in the pool (Normandeau 2007a). According to an anadromous fisheries report completed by Merrimack Station in 1976, many places in Hooksett Pool represent suitable spawning areas for American shad (Normandeau 1976b). Future stocking of shad in Hooksett Pool is possible, but the waters just above Garvins Falls Dam have higher priority, according to USFWS (pers. com. – J. McKeon, USFWS). However, even if American shad do not spawn within Hooksett Pool itself, spawning activity directly upstream, as well as the stocking of American shad fry, will allow for the recruitment of larvae and juveniles into the pool. These fish could remain in the Hooksett Pool until the fall out-migration to the sea. Additionally, adult river herring are routinely stocked in Northwood Lake, which feeds into the Suncook River, a tributary that enters the Merrimack in the lower Hooksett Pool (pers. com. – D. Smithwood, USFWS). While river herring eggs are initially demersal and adhesive, they become pelagic after water-hardening and lose their adhesive properties. Therefore, both the egg and larval stages can drift downstream from their spawning grounds and enter the Hooksett Pool (Pardue 1983). The collection of river herring larvae by the plant during entrainment sampling in June 2007 supports this possibility.

8.3.2.3 Out-Migration

The out-migration of anadromous fish through Hooksett Pool typically occurs from April through the end of June, and late August through October. During the spring period, Atlantic salmon smolts and adult American shad and alewife move downstream through Hooksett Pool, en route to the sea. In late summer-early fall, juvenile American shad and river herring emigrate from nursery habitats in the upper reaches of the Merrimack River and its tributaries. The movement of these fish often coincides with wet-weather or dam-controlled high flow events. These fish will also pass through Hooksett Pool heading to the sea, and will likely be feeding as they move. Sexually mature American eels, the only catadromous species in New England, descend rivers, such as the Merrimack, from September to December on their seaward migration (GMCME 2007).

8.3.2.4 Most Sensitive Diadromous Species Selected By Life Stage

EPA reviewed life history information on the diadromous species that reside in Hooksett Pool at some point in their lives. Based on this review, EPA has concluded that the following species and life stages are the most sensitive to the effects of elevated temperatures (Table 8-4). Temperature requirements for reproductive success, spawning, and egg survival are not discussed here in detail because adults are normally not stocked in Hooksett Pool, and are not able to pass the Hooksett Dam from downstream.

8.3.2.4a Atlantic Salmon – Smolt Out-Migration

The potential for Merrimack Station's thermal plume to impede the downstream migration of Atlantic salmon smolts was discussed in Section 5.6.3.3c. While studies conducted by Merrimack Station in 2003 and 2005 suggest that the plant's thermal plume does not impede the passage of smolts, exposure to elevated temperatures may adversely affect the ability of these fish to adapt to life in the marine environment. Smolts tend to travel near the water surface (NOAA and USFWS 1999) where they would likely come in contact with the plant's thermal plume. However, smolts may not pass under the plume, but remain within it if temperatures are not high enough in the plume to elicit an avoidance response. If smolts, already impeded by the presence of Hooksett Dam, linger to forage in the lower pool above the dam, their exposure to elevated temperatures may be extended. Delays in migration combined with exposure to increased temperatures may decrease smolt survival through loss of salinity tolerance (Zydlewski et al. 2005). Elliot (1991) identifies 22.5˚C (72.5˚F) as the upper temperature limit for feeding. As such EPA considers this to be the maximum protective temperature for migrating Atlantic salmon smolts. However, the maximum protective temperatures previously identified for early life stages of yellow perch, which cover the period when smolts would be migrating, are all below 22.5˚C (72.5˚F) (*See* Table 8-2). Therefore, the lower temperatures developed for yellow perch would apply.

8.4.2.4b American Shad – Adult Out-Migration

The planned annual stocking of approximately 5,000 adult American shad in waters upstream from Hooksett Pool warrants a review of how Merrimack Station's thermal plume may affect the out-migration of adult shad. Shad begin to head downstream to sea soon after they spawn (Klauda et al. 1991). Therefore, since spawning in the upper Merrimack River can occur anytime from early May to the end of June, based on peak spawning temperatures identified by Klauda et al. (1991) of 14–21ºC (57.2-69.8ºF), adult shad may move through Hooksett Pool during this same time period. This, of course, is based on the assumption that adult shad have been transferred beforehand. Out-migrating adult shad probably do not spend much time in Hooksett Pool, so water temperatures that would impede down-stream movement are the primary concern. EPA was not able to find published studies on avoidance temperatures for adult American shad, but studies conducted by Marcy et al. (1972) demonstrated that juvenile American shad avoided temperatures above 30ºC (86ºF). This temperature is above the limits developed for the protection of resident species so those lower limits would apply.

8.3.2.4c American Shad – Larva Rearing Habitat

As previously mentioned in Section 5.6.3.3b of this document, maximum survival of American shad larvae is reported to occur between 15.5° and 26.5°C (59.9°–79.7°F), according to Klauda et al. (1991). Five additional studies cited by Stier and Crance (1985) narrow the range slightly to 15.5°–26°C (59.9°–78.8°F). Further, studies by Leach and Houde (1999) found American shad larval survival to be significantly higher at 20° and 25°C (68°F and 77°F) than at 15°C (59°F). In addition, the USFWS identifies temperatures greater than 26.7°C (80.1°F) to be unsuitable for the hatching of American shad eggs and development of larvae (Stier and Crance 1985), and a report by the Atlantic States Marine Fisheries Commission cites studies indicating that water temperatures above 27°C (80.6°F) are capable of causing abnormalities or a total cessation of larval American shad development (Greene et al. 2009).

Since American shad larvae are photopositive (*i.e.*, attracted to light), they are likely to be most abundant near the surface (Klauda et al.1991). According to Merrimack Station's 21-year temperature data set (1984-2004), daily mean ambient water temperatures never exceeded 24.8°C (76.6°F) during May, June, and July, when shad larvae would likely be present in Hooksett Pool. This demonstrates that ambient conditions, such as exist in Hooksett Pool upstream of the plant's thermal discharge, provide suitable habitat for early lifestages of American shad.

EPA again calculated an upper limiting temperature using the formula described in "Quality Criteria for Water 1986" by adding to the physiological optimum temperature a factor that is one-third of the distance between the upper incipient lethal temperature and the optimum temperature for the most sensitive species and life stage that normally is found at that location and time (EPA 1987). As described above, the scientific literature supports 15.5º–26.5ºC (59.9°–79.7°F) as the optimum temperature range for American shad larvae, while study results by Leach and Houde indicate that survival is greater at 20° and 25°C (68°F and 77°F) than it is at 15°C (59°F). Therefore EPA calculated the optimum temperature for American shad larvae to be the mid-point of the range 20°–26.5°C (68°–79.7°F), which is 23.3°C (73.9°F). EPA did not find any studies that established an upper incipient lethal temperature for larval American shad. However, lethality studies identified by Klauda et al. (1991) place the upper lethal limit for *juvenile* American shad at 31.6ºC (88.9ºF) for fish acclimated at 24°C (75.2°F), which happens to be the mean ambient temperature in Hooksett Pool during the month of July (Appendix A). Klauda also cites work by Marcy et al. (1972) conducted near a power plant on the Connecticut River where the mortality of all juvenile American shad tested occurred within 4-6 minutes of exposure to 32.2°C (90.0°F). This demonstration of acute lethality further supports the selection of a lower temperature (i.e., 31.6ºC (88.9ºF)) as the upper incipient lethal temperature for juvenile American shad.

As previously discussed in section 5.6.3.3b of this document, Klauda et al. (1991) noted that American shad larvae survived 15-minute exposures to 31.5ºC (88.7ºF). With the upper incipient lethal temperature for the more robust juvenile lifestage being only 31.6ºC (88.9ºF), EPA has selected 31.5ºC (88.7ºF) as the upper incipient lethal temperature for larval American shad. This value could be revised if additional studies warranting a change are identified. Therefore, if 23.3ºC (73.9ºF) is chosen as the optimum temperature and 31.5ºC (88.7ºF) is chosen as the upper incipient lethal temperature, then following this method, the upper limiting temperature is calculated as follows:

$$23.3^{\circ}C + 1/3(31.5^{\circ}C - 23.3^{\circ}C) = 26.0^{\circ}C\ (78.8^{\circ}F).$$

Based on this calculation, EPA concludes that water quality-based requirements would call for 26ºC (78.8ºF) to be the maximum temperature permitted in order to protect American shad larvae in Hooksett Pool during the period when they are expected to be present.

Therefore, in order to ensure protective thermal conditions for the development of American shad larvae throughout Hooksett Pool, a mean weekly surface temperature of 26.1ºC (79ºF) should not be exceeded from May 1 through July 31. While this temperature is almost one degree Celsius above the protective temperature identified for yellow perch adults (25.1°C) for the same time period, it would be applied to surface waters (*i.e.*, one foot below the surface) because American shad larvae are most likely to be found near the surface. Therefore, the temperature limit for American shad larvae may be more restrictive than the limit for adult yellow perch, which would be applied three feet below the surface.

8.3.2.4d American Shad – Larva – Temperature (Short-Term)

As discussed in Section 8.3.1.4b of this document, yellow perch larvae that come in contact with Merrimack Station's thermal plume are vulnerable to acute (short-term) thermal effects, possibly leading to lethality. Similarly, temperatures demonstrated in studies to cause lethality to American shad larvae exist between Stations S-0 and S-4 for much of the period when larvae would be present. According to a 1992 draft report by PSNH, American shad larvae and juveniles small enough to have difficulty avoiding the thermal plume will be present through the month of July (Saunders 1993). This report refers to site-specific studies conducted by PSNH's consultant, Normandeau Associates, Inc., that demonstrate that significant mortality occurs at temperatures greater than 33.3ºC (91.9ºF) after only a 30-minute exposure to the plume. This temperature was reached or exceeded at Station S-0, where Merrimack Station's discharge plume enters the river, on all but six dates in the month of June, according to Merrimack Station's 21-year temperature data set (Appendix A). In July, 33.3ºC (91.9ºF) is exceeded on every date at Station S-0, with 13 dates reporting temperatures at or above 37.8ºC (100ºF).

PSNH studied thermal impacts to larval American shad in 1975, the report from which provided some information on flow rates in Hooksett Pool, but not for the months of June and July.

Results from similar laboratory bioassay studies conducted in 1975 by Normandeau Associates, Inc., indicated that a temperature rise of 18º–20ºF (10º–11.1ºC) for 10 minutes followed by gradual cooling was lethal to larval shad (Normandeau 1976b). Historical temperature data in Hooksett Pool for June and July demonstrate that the difference between maximum ambient river temperatures (Station N-10) and temperatures recorded at the mouth of the discharge canal (Station S-0) routinely exceeded 18ºF (Appendix A). The PSNH report suggests that, based on these study results, restricting temperatures during June and July should be considered (Saunders 1993).

As discussed in section 5.6.3.3b of this document, in order to assess the potential for lethality of larvae to occur from thermal stress, it is important to identify lethal temperatures and the duration of exposure to those temperatures that results in lethality. Current speed data collected on August 15, 1975, the closest date to the June-July time period, indicates surface current speed in proximity to the discharge averaged 0.15 knots, or 0.27 feet/second (Normandeau 1976b). This is half the speed calculated by EPA for June (0.55 feet/second), which is discussed in section 8.3.1.4b of this document. Based on this range of flow rates, it could take an American shad larva one to two hours to drift from Station S-0 to S-4, which is roughly 2,000 feet. Either flow rate provides sufficient exposure of drifting American shad larvae to plume temperatures that could cause lethality during most of June and July.

According to Klauda et al. (1991), American shad larvae acclimated to 20.5ºC (68.9ºF) survived a 15 minute exposure to 31.5ºC (88.7ºF), but suffered significantly greater mortality when exposed 33.5ºC (92.3ºF). Still another study on the effects on American shad larvae from abrupt changes in temperature found that quick rises in temperature from 20° to 25°C (68° to 77°F) and 20° to 30°C (68° to 86°F) were "clearly detrimental" to feeding-stage larvae (Leach and Houde 1999). Under current plant operations, similar acute temperature changes commonly occur in Hooksett Pool during the month of June at Station S-0. Since Merrimack Station's thermal plume extends across the entire river and is surface-oriented, it is highly likely that larval shad, which are also surface-oriented during much of this life stage, are exposed to the plume. Therefore, in addition to a weekly temperature limit that is designed to be protective of larval American shad habitat, a temperature limit to prevent acute lethality to shad larvae drifting past the plant is also necessary.

As with developing a protective short-term temperature limit for larval yellow perch, the lethality studies reviewed by EPA do not point to one specific temperature that is appropriate for the short-term protection of larval American shad. Therefore, consistent with the approach used to develop the short-term limit for yellow perch larvae (*see* Section 8.3.1.4b), EPA has selected a temperature identified in the scientific literature as causing lethality (31.5ºC/88.7ºF) and subtracted 2ºC to ensure protection of larval American shad from lethal exposure to extreme temperatures. Therefore, the short-term temperature limit for the protection of American shad larvae would be 31.5ºC – 2ºC, or 29.5ºC (85.1°F). As with the short-term temperature limit for yellow perch larvae, this limit would be measured hourly at Station S-0, one foot below the surface. Since the temperature developed to protect yellow perch larva from acute effects is slightly lower (29.3ºC/84.7°F), that temperature would prevail until June 15. From June 16 to July 31, a maximum temperature of 29.5ºC (85.1°F) would apply to protect American shad larvae.

8.3.2.4e American Shad – Juvenile Rearing Habitat

According to Klauda et al. (1991), juvenile American shad form schools, and prefer deep pools although they occasionally move into shallow riffles. Additionally, they undergo diel vertical migrations in summer nursery areas, moving to the surface at night and remaining closer to the bottom during the day. PSNH cites scientific literature that suggests juvenile shad become surface-oriented in their feeding behavior following transformation from the larval stage (Normandeau 1976b). The optimum temperature range for juvenile American shad is 15.6°C (60°F) to 23.9°C (75°F), according to the habitat suitability index developed by USFWS (Stier and Crance 1985). However, this range does not apply to juvenile American shad inhabiting a *riverine* environment, which the report suggests have a wide range of temperature tolerance. Laboratory studies described in a report by the Atlantic States Marine Fisheries Commission (Greene et al. 2009) found that juvenile American shad had higher initial growth rates at 28.5°C (83.3°F) than individuals at lower temperatures. Taking this information into account, EPA calculated the physiological optimum for juvenile American shad to be the mid-point between 15.6°C (60°F) and 28.5°C (83.3°F), which is 22.1°C (71.8°F). Therefore, if 22.1°C (71.8°F) is chosen as the optimum temperature and 31.6ºC (88.9ºF) is again chosen as the upper incipient lethal temperature (*See* Section 8.3.2.4c), then the upper limiting temperature is calculated as follows:

$$22.1°C + 1/3(31.6° – 22.1°C) = 25.3°C\ (77.5°F)$$

This temperature exceeds by 1.3 ºC the highest mean temperature found in ambient waters of Hooksett Pool during the summer months when juvenile shad would be present. According to PSNH’s 21-year data set (Appendix A), the mean ambient temperatures in Hooksett Pool during summer months are: 20.1ºC /68.2ºF (June), 24.0ºC/75.2ºF (July), 23.9ºC/75ºF (August), and 19.2ºC /66.6ºF (September). While Klauda et al. (1991) reported that juvenile shad can survive at higher temperatures, temperatures protective of juvenile shad habitat are appreciably lower.

EPA has selected 25.3ºC (77.5ºF) as being the maximum temperature for the protection of juvenile American shad from June 15 through September 30. This temperature is slightly higher than that selected for the protection of adult yellow perch (25.1ºC /77.2ºF), which covers the period when juvenile shad would likely be present in Hooksett Pool (*i.e.*, June 15 – September 30), so the temperature selected for the protection of adult yellow perch would prevail.

As previously stated relative to juvenile yellow perch, EPA recognizes from historical temperature monitoring data (Appendix A) that compliance with a weekly temperature limit may still allow daily maximum temperatures in Hooksett Pool under summer conditions to exceed the lethal temperature of 31.6ºC (88.9ºF) for juvenile American shad, even at Station S-4. Therefore, a short-term temperature for the protection of juvenile American shad is needed. EPA reviewed the scientific literature for additional lethality studies conducted on juvenile American shad, which was previously discussed in section 5.6.3.3b, but revisited here. Klauda et al. (1991) noted that juvenile American shad acclimated to 24°C (75.2°F) experienced 50-percent mortality of the test organisms when exposed to 31.6°C (88.9°F). Marcy et al. (1972) reported that juvenile American shad experienced 100-percent mortality after 4-6 minutes of exposure to 32.2°C (90°F) when acclimated to 19°C (66.2°F). This temperature scenario is similar to conditions found in Hooksett Pool in mid-June when temperatures (*e.g.*, on June 15) average 19.9°C (67.8°F) and averaged maximum recorded temperatures at Station S-0 reached 33.8°C (92.9°F). Mortality dropped to only 12.5 percent when exposed to 32.9°C (91.2°F) when fish were acclimated at 22.7°C (72.9°F). This study also references a study by Moss (1970) demonstrating that young American shad die rapidly when temperatures are suddenly raised from 24°–28°C (75.2°–82.4°F) to 32.5°C (90.5°F). In July, the mean ambient temperature in Hooksett Pool is 24°C (75.2°F), while the mean temperature where Merrimack Station's discharge plume enters the river Station S-0 is 32.8°C (91.1°F).

In order to calculate a short-term maximum temperature, EPA again referred to its document, Temperature Criteria for Freshwater Fish: Protocol and Procedures (EPA 1977b). Unfortunately, this document does not provide the necessary data to use the prescribed formula for developing a protective short-term temperature limit for American shad. Therefore, EPA instead calculated a protective short-term temperature by subtracting 2°C from an established upper incipient lethal temperature for juvenile American shad. As previously mentioned, the National Academy of Sciences (NAS/NAE 1973) cites several studies which indicate that a 2˚C (3.6˚F) reduction of an upper stress temperature results in no mortalities with an equivalent exposure duration. By subtracting 2°C from the upper incipient lethal temperature identified by Klauda et al. (1991), EPA calculated the maximum short-term temperature for juvenile American shad to be 31.6ºC – 2°C, or 29.6 ºC (85.3ºF). This limit is slightly higher than 29.5ºC (85.1ºF) , the maximum hourly limit developed for American shad larvae, so the lower temperature for larval shad would be applied within one (1) foot below the surface at Station S-0 until July 31. From August 1 through September 30, the maximum hourly temperature of 29.6 ºC (85.3ºF) would be in effect at Station S-0.

8.3.2.4f Alewife – Juvenile Out-Migration

For most Atlantic coast populations, juvenile alewives emigrate from nursery areas between June and November of their first year of life (Fay et al. 1983). In the Merrimack River, out-migration can begin as early as July, but typically begins with increased flows from dam releases in early

October, and is completed by the end of October (pers. com. – D. Smithwood, USFWS). Conditions that contribute to stimulating initiation of out-migration of alewives from nursery habitats include high flows related to intentional dam releases, heavy rainfall, and sharp declines in water temperature (Fay et al. 1983). While fish sampling in August and September by Merrimack Station captured no alewives prior to 2004, 80 fish were captured in Hooksett Pool in August 2004. According to information provided in the Fisheries Analysis Report (Normandeau 2007a), none of these fish were caught in water temperatures above 26.0ºC (78.8ºF), and most (74 fish) were caught in water temperatures of 24.5ºC (76.1ºF), or lower.

A habitat suitability index model developed by the USFWS (Pardue 1983) identifies temperatures between 15º–20ºC (59º–68ºF) to be optimal for juvenile alewives. Pardue (1983) collected juveniles in water temperatures up to 25ºC (77ºF), but noted they avoided higher temperatures. He also noted that both juvenile alewives and bluebacks were most abundant in surface waters during summer, but alewives were more abundant near the bottom in September and October, prior to emigration. Pardue's habitat suitability index depicts a linear decline in habitat suitability from 20ºC (68ºF) to 30ºC (86ºF), with 30ºC receiving a zero suitability value.

Once initiated, the movement of juvenile alewives away from nursery habitat is fairly rapid, with fish emigrating in "waves" that last two to three days (Fay et al. 1983). If these juveniles are not utilizing Hooksett Pool as juvenile rearing habitat, then the primary concern would be to ensure that temperatures in the pool provide alewives with unimpeded access downstream, and the opportunity to forage while en route. However, if juvenile alewives are spending some time in Hooksett Pool prior to their out-migration a temperature that fully protects their habitat should prevail. While the documented presence of alewives in Hooksett Pool in late August 2004, and herring larvae in June 2007 suggests they might utilize the pool as juvenile habitat, at least during some years, stocking efforts have and will largely focus on waters upstream (pers. com. – J. McKeon, USFWS). Therefore, EPA has focused on establishing a maximum temperature that ensures juvenile alewife have unimpeded downstream passage through Hooksett Pool. EPA reviewed available temperature studies, including information provided by PSNH (Normandeau 2007a). Finding scant information on temperatures that elicit an avoidance response in alewife, EPA concluded that the temperature selected by PSNH, 28.9ºC (84ºF), represented a reasonable estimate of such an avoidance temperature. Obviously, a temperature below 28.9ºC (84ºF) would need to be established to prevent impeding alewife migration. Given that the previously identified limits developed for juvenile shad, and juvenile and adult yellow perch would be in place during the entire period when alewife would be expected in Hooksett Pool, those lower temperatures would apply and would be expected to accomplish the goal of not impeding migration by alewives.

Table 8-4 Protective temperatures and related time periods for diadromous species and life stages in Hooksett Pool. These species are present only when stocked in Hooksett Pool, or waters upstream

Species	Life stage	Temp. ˚C (˚F)	Time Period	Section Reference
Atlantic salmon	smolt – out migration	22.5 (72.5)	May 1 – May 31	8.3.2.4a
American shad	larvae – habitat	26.0 (78.8)	May 1 – July 31	8.3.2.4c
American shad	larvae – acute	29.5 (85.1)	May 1 – July 31	8.3.2.4d
American shad	juvenile – habitat	25.3 (77.5)	June 15 – Sept. 30	8.3.2.4e
American shad	juvenile – acute	29.6 (85.3)	June 15 – Sept. 30	8.3.2.4e
Alewife	juvenile out-migration	< 28.9 (84)	Aug 30 – Oct 31	8.3.2.4f

8.3.3 Protective Temperatures for Fishes of Hooksett Pool – Conclusion

Some of the temperatures identified in this document as being protective of the resident fish community of Hooksett Pool (Tables 8-2, 8-3) are not expected to be sufficiently protective of the most sensitive diadromous species (Table 8-4) during summer months. The protection of American shad larvae and juveniles would require even lower temperatures than resident species require from June 1 through September 30, the period when American shad are expected to be present in Hooksett Pool. Table 8-5 summarizes temperature limits that would apply throughout the year should water quality-based limits govern this permit. While there appears to be overlap in the time periods and temperatures identified, there are differences in where limits would be applied (*i.e.*, Station S-0 vs. S-4), the applicable time period for the various limits (*e.g.*, averaged hourly, daily, or weekly), and compliance depth (*i.e.*, one-foot beneath the surface versus three-feet below the surface). The bases for these specific limits were described in this section.

Resident and diadromous species collectively define the larger indigenous community for which this effort to restore a suitable thermal habitat in Hooksett Pool is intended. As such, EPA considers these temperatures to be appropriate for establishing water quality-based limits if they were found to be more stringent than temperatures achievable through technology-based limits.

Table 8-5 Summary of applicable protective temperatures, and compliance schedule, location, and water depth for all resident and diadromous fish species throughout the calendar year

	Time Period	Relevant Species and Lifestage	Maximum Protective Temp. °C(°F)	Compliance Point/ Water Depth, Schedule
1	Jan.1–Apr. 20	Yellow Perch Adult – Reproduction	8.0 (46.4)[1]	S-4 / 3 ft Weekly Avg.
2	Apr.21–May 8	Yellow Perch Adult – Spawning	12.0 (53.6)	S-4 / 1 ft Weekly Avg.
3	May 9–May 27	Yellow Perch Egg	18.0 (64.4)	S-4 / 1 ft Weekly Avg.
4	May 28– June15	Yellow Perch Larva	21.3 (70.3)[2]	S-4 / 1 ft Weekly Avg.
5	June 16– July 31	American Shad Larva	26.0 (78.8)[2]	S-4 / 1 ft Weekly Avg.
6	May 1– June 15	Yellow Perch Larva (acute)	29.3 (84.7)[3]	S-0 / 1 ft Hourly Max.
7	June 16–July 31	American Shad Larva (acute)	29.5 (85.1)[3]	S-0 / 1 ft Hourly Max.
8	Aug. 1-Sept. 30	American Shad Juvenile (acute)	29.6 (85.3)[3]	S-0 / 1 ft Hourly Max.
9	Aug. 1–Nov. 4	Yellow Perch Juvenile (acute)	30.9 (87.6)[3]	S-0 / 1 ft Hourly Max.
10	June 16- Sept. 30	American Shad Juvenile	25.3 (77.5)[2]	S-4 / 1 ft Weekly Avg.

	Time Period	Relevant Species and Lifestage	Maximum Protective Temp. °C(°F)	Compliance Point/ Water Depth, Schedule
11	June 16–Nov. 4	Yellow Perch Adult	25.1 (77.2)[1]	S-4 / 3 ft Weekly Avg.
12	Oct 1–Nov.4	Yellow Perch Juvenile	27.2 (81.0)[2]	S-4 / 1 ft Weekly Avg.
13	Nov.5–Dec.31	Yellow Perch Adult – Reproduction	8.0 (46.4)[1]	S-4 / 3 ft Weekly Avg.

[1] The maximum mean protective temperature is based on a weekly average measured at Station S-4 at a depth of three feet below the surface, unless otherwise noted

[2] This maximum mean protective temperature is based on a weekly average measured at Station S-4 at a depth of one foot below the surface.

[3] Maximum acute temperatures are based on the maximum hourly temperature recorded at Station S-0 one foot below the surface during the time period specified.

[4] This maximum acute temperature is based on the maximum hourly average temperature recorded at Station S-4 one foot below the surface during the time period specified.

Shaded sections denote temperature limits and compliance schedules designed to prevent acute effects.

9.0 DETERMINATION OF THERMAL DISCHARGE LIMITS FOR DRAFT PERMIT (AND SOLICITATION OF PUBLIC REVIEW AND COMMENT ON A POSSIBLE ALTERNATIVE APPROACH)

9.1 Introduction

This section describes the thermal discharge limits specified in the Draft Permit and explains how they were derived from the analyses presented above. It also describes an alternative approach to deriving those limits that might potentially be applied in this case and solicits public review and comment on this alternative approach.

When determining effluent limits for an NPDES permit, EPA evaluates both technology-based requirements and water quality-based requirements (that is, conditions necessary to ensure compliance with state water quality standards). Once these requirements are identified, EPA applies the most stringent ones to ensure that both types of requirements will be satisfied. In certain limited circumstances, the Clean Water Act may provide for a “variance” from the otherwise applicable technology-based and/or water quality-based requirements.

In Section 7 of this document, EPA presented its determination of the Best Available Technology economically achievable (“BAT”) for the reduction of thermal discharges by Merrimack Station, as well as the effluent limits to be included in the new Draft NPDES permit based on that BAT. In Section 8, EPA presented its determination of the thermal requirements that must be satisfied to ensure compliance with state water quality standards. Section 6 presents EPA's determination in response to PSNH's request for thermal discharge limits for Merrimack Station based on a CWA § 316(a) variance from the otherwise applicable technology-based and water quality-based standards. As explained in Section 6, EPA determined after a thorough review that PSNH's variance request should be denied.

Accordingly, this section compares the technology-based and water quality-based requirements and identifies which are more stringent and therefore will be the source of the limits included in the new draft NPDES permit.

Finally, EPA also describes an alternative approach to deriving the permit's thermal discharge limits that might potentially be appropriate in this case, and solicits public review and comment on this alternative approach.

9.2 Technology-Based Thermal Discharge Limits

As discussed in Section 7, EPA has determined on a Best Professional Judgment ("BPJ") basis that mechanical draft wet or wet/dry hybrid cooling towers in a closed-cycle configuration for both generating Units I and II are the BAT for reducing thermal discharges from Merrimack Station under CWA §§ 301, 304 and 402 and 40 C.F.R. § 125.3. PSNH also evaluated options for reducing thermal discharges and concluded that closed-cycle cooling for both Units I and II using mechanical draft wet cooling towers would be the most effective technology for achieving such reductions.

In its March 2010 submission to EPA titled, "Response to Environmental Protection Agency's Information Request for NPDES Permit Re-issuance, PSNH Merrimack Station Units 1 &2, Bow, New Hampshire" (Enercon Services 2009), PSNH provided an estimate of the temperature increase (over ambient) of the cooling tower blowdown water before mixing with the Merrimack River, an estimate of the expected volume of such blowdown water and, based on these figures, an estimate of the maximum monthly heat load that Merrimack Station would discharge to the Merrimack River with closed-cycle cooling in place. This monthly heat load (presented in Millions of British thermal units per month (MBtus/month)) is presented in the third column in Table 9-1 and represents the best thermal discharge reduction performance that is achievable with the BAT in place at Merrimack Station. As such, these values constitute the technology-based thermal discharge reduction requirements reflecting the BAT for Merrimack Station.

EPA has also used this information to calculate the expected "in-stream" temperature increase that would result from the specified thermal discharge load. These estimated instream temperatures are presented in the sixth column of Table 9-1 below.

Table 9-1 Calculated increase in Merrimack River Water Temperature due to Cooling Tower Blowdown waste stream

Month	Hourly Maximum Temp. Increase (°F)[1]	Maximum Heat Load (MBtu/ Month)[1]	Mean of Monthly River Flow[2] (MGD)	Lowest Monthly Mean River Flow[2] (MGD)	Maximum River Temp. Increase (°F)[3]
January	22.2	6856	3767	816	0.033
February	20.1	5613	2928	1501	0.016
March	24.1	7428	4831	2552	0.011
April	24.1	7210	9288	2975	0.010
May	20	6164	5753	2683	0.009
June	13.6	4064	3509	1304	0.013
July	10.6	3264	1929	633	0.020
August	11.0	3393	1251	503	0.026
September	14.7	4396	1316	489	0.033
October	19.3	5950	3077	713	0.033
November	26.1	7795	4025	852	0.044
December	22.4	6920	4270	1244	0.022

1 Calculated by PSNH using five years (2002–2006) of meteorological data and river water temperatures.

2 1993–2007 USGS Surface-Water Monthly Statistics for New Hampshire, USGS gage 01092000 Merrimack River, Goffs Falls, below Manchester, NH.

3 Calculated assuming a constant blowdown flowrate of 1.2 MGD and using the lowest monthly river flow rate, and maximum hourly temperature increase from the Station. The mathematical relationship used to calculate the river temperature increase is: $\Delta T_{river} = \Delta T_{station} \times$ Blowdown flowrate ÷ River flowrate.

9.3 Water Quality-Based Thermal Discharge Limits

In Section 8 of this document, EPA determined the ambient temperatures that would need to be maintained in the river in order to meet New Hampshire water quality standards (NHWQS). (EPA coordinated with NHDES, NHFGD, and USFWS on this analysis.) More specifically, EPA determined protective temperatures for a variety of fish species (and life stages) for the time(s) of year when these organisms would be expected to be present in the Merrimack River in the vicinity of the station's thermal discharge. Table 9-2 below (and also presented as Table 8-5 in Section 8.3.3) displays these protective temperatures.

Table 9-2 Summary of applicable maximum protective temperatures, time periods, relevant species and lifestages , compliance points, schedules, and depths.

	Time Period	Relevant Species and Lifestage	Maximum Protective Temp. °C(°F)	Compliance Point/ Water Depth, Schedule
1	Jan.1–Apr. 20	Yellow Perch Adult – Reproduction	8.0 (46.4)[1]	S-4 / 3 ft Weekly Avg.
2	Apr.21–May 8	Yellow Perch Adult – Spawning	12.0 (53.6)	S-4 / 1 ft Weekly Avg.
3	May 9–May 27	Yellow Perch Egg	18.0 (64.4)	S-4 / 1 ft Weekly Avg.
4	May 28–June15	Yellow Perch Larva	21.3 (70.3)[2]	S-4 / 1 ft Weekly Avg.
5	June 16–July 31	American Shad Larva	26.0 (78.8)[2]	S-4 / 1 ft Weekly Avg.
6	May 1–June 15	Yellow Perch Larva (acute)	29.3 (84.7)[3]	S-0 / 1 ft Hourly Max.
7	June 16–July 31	American Shad Larva (acute)	29.5 (85.1)[3]	S-0 / 1 ft Hourly Max.
8	Aug. 1-Sept. 30	American Shad Juvenile (acute)	29.6 (85.3)[3]	S-0 / 1 ft Hourly Max.
9	Aug. 1–Nov. 4	Yellow Perch Juvenile (acute)	30.9 (87.6)[3]	S-0 / 1 ft Hourly Max.
10	June 16-Sept. 30	American Shad Juvenile	25.3 (77.5)[2]	S-4 / 1 ft Weekly Avg.
11	June 16–Nov. 4	Yellow Perch Adult	25.1 (77.2)[1]	S-4 / 3 ft Weekly Avg.

	Time Period	Relevant Species and Lifestage	Maximum Protective Temp. °C(°F)	Compliance Point/ Water Depth, Schedule
12	Oct 1–Nov.4	Yellow Perch Juvenile	27.2 (81.0)[2]	S-4 / 1 ft Weekly Avg.
13	Nov.5–Dec.31	Yellow Perch Adult – Reproduction	8.0 (46.4)[1]	S-4 / 3 ft Weekly Avg.

[1] The maximum mean protective temperature is based on a weekly average measured at Station S-4 at a depth of three feet below the surface, unless otherwise noted

[2] This maximum mean protective temperature is based on a weekly average measured at Station S-4 at a depth of one foot below the surface.

[3] Maximum acute temperatures are based on the maximum hourly temperature recorded at Station S-0 one foot below the surface during the time period specified.

[4] This maximum acute temperature is based on the maximum hourly average temperature recorded at Station S-4 one foot below the surface during the time period specified.

Shaded sections denote temperature limits and compliance schedules designed to prevent acute effects.

EPA concluded that maintaining protective temperatures in the river was necessary to satisfy the NHWQS. Accordingly, EPA also concluded that in order to satisfy the NHWQS, Merrimack Station's thermal discharges would need to be low enough not to cause river temperatures to exceed the stated values.

9.4 Determination of Limits for the Draft Permit

The calculations provided in Table 9-1, above, demonstrate that after conversion to closed-cycle cooling, the effect on river temperatures of Merrimack Station's thermal discharge will be small (in all cases, less than 0.05°F). This is so even under critical conditions (maximum hourly temperature, and lowest mean river flow).

Table 9-3, below, compares the water quality-based maximum mean protective temperature with the ambient temperature, assuming that the addition of heat from Merrimack Station, after conversion to closed-cycle cooling, would not be measurable. In all cases, these data indicate that the technology-based thermal limits would be more stringent than the water quality-based limits. This also demonstrates, of course, that compliance with the technology-based limits would also ensure satisfaction of the state's water quality standards. Therefore, EPA has included that technology-based thermal discharge limits in the Draft Permit, but these limits are also sufficiently stringent to satisfy state water quality standards.

Table 9-3 Summary of applicable maximum protective temperatures, and temperatures achievable with closed-cycle cooling (CCC) for both units

	Time Period	Relevant Species and Lifestage	Max. Mean Protective Temp. °C (°F) (WQ - Based)	Max. Mean Temp. CCC Both Units °C (°F)[1] (Tech-Based)	Max. Mean Temp. Current Operations °C(°F)[2]	Compliance Point/ Water Depth and Schedule
1	Jan.1– Apr. 20	Yellow Perch Adult – Reproduction	8.0 (46.4)	7.4 (45.2)	9.4 (49.0)	S-4/3 ft Weekly Avg.
2	Apr.21– May 8	Yellow Perch Adult – Spawning	12.0 (53.6)	11.4 (52.6)	12.9 (55.3)	S-4/1 ft Weekly Avg.
3	May 9– May 27	Yellow Perch Egg	18.0 (64.4)	15.9 (60.6)	17.1 (62.8)	S-4/1 ft Weekly Avg.
4	May 28– June15	Yellow Perch Larva	21.3 (70.3)	19.3 (66.8)	21.2 (70.2)	S-4/1 ft Weekly Avg.
	May 1– June 15	Yellow Perch Larva (acute)	29.3 (84.7)	24.2 (75.6)[3]	34.6 (94.3)[4]	S-0 Hourly Max.
7	June 16– July 31	American Shad Larva (acute)	29.5 (85.1)	29.5 (85.1)[3]	39.2 (102.6)[4]	S-0/ 1 ft Hourly Max.
8	Aug 1- Sept 30	American shad Juvenile (acute)	29.6 (85.3)	25.1 (77.1)[3]	40.1 (104.2)[4]	S-0/ 1 ft Hourly Maximum
12	Oct. 1– Nov.4	Yellow Perch Juvenile	28.4 (83.1)	14.6 (58.2)	18.8 (65.8)	S-4/1 ft Weekly Avg.
13	Nov.5– Dec.31	Yellow Perch Adult – Reproduction	8.0 (46.4)	8.0 (46.4)	XX[5]	S-4/ 3ft Weekly Avg.

Footnotes for Table 9-3

1 Maximum weekly mean temperature for closed-cycle cooling are expected to be the same as the highest 7-day average of the daily mean ambient temperatures recorded at Station N-10 during the time period specified. *See* Appendix A.

2 Maximum weekly mean temperatures under current operations are based on the highest 7-day average of the daily mean temperature recorded at S-4 during the time period specified. *See* Appendix A.

3 Maximum acute temperatures for closed-cycle cooling are expected to be the same as the highest average daily maximum ambient temperatures recorded at Station N-10 during the time period specified. *See* Appendix A.

4 Maximum acute temperatures under current operations is based on the highest average daily maximum temperature recorded at Station S-0 during the time period specified. *See* Appendix A.

5 Data not included in 21-year temperature information provided in Appendix A.

Shaded sections denote temperature limits and compliance schedules designed to prevent acute effects.

9.5 Alternative Approach to Determining Thermal Discharge Limits

As discussed immediately above and in Section 8 of this document, EPA has concluded that New Hampshire's water quality standards require thermal discharge limits that essentially would satisfy the following criteria:

(a) thermal discharges may not be "inimical to aquatic life";

(b) thermal discharges must provide, wherever attainable for the protection and propagation of fish, shellfish, and wildlife, and for recreation, in and on the receiving water;

(c) thermal discharges may not contribute to the failure of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to, and with only non-detrimental differences in community structure and function from, that of similar natural habitats in the region; and

(d) any stream temperature increase associated with thermal discharge must not appreciably interfere with fishing, swimming and other recreational purposes.

EPA believes that the discharge limits that it has determined satisfy these criteria – which have been drawn from water quality standards designed by the state to protect aquatic habitat, aquatic organisms, and recreational uses of its waters – may also satisfy the criteria of CWA § 316(a). (The criteria of § 316(a) are discussed in Section 6 (*i.e.*, thermal discharge limits must assure the protection and propagation of a balanced, indigenous population of fish, shellfish, and wildlife in and on the receiving water).)

If so, EPA would be legally authorized to include the above-discussed water quality-based limits in the permit, instead of the more stringent technology-based limits, on two grounds. First, the water quality-based limits would satisfy the NHWQS, and, second, they could be approved based on a variance from the technology-based limits under CWA § 316(a). These variance-based limits would not be the ones that PSNH requested in its variance application – which EPA has rejected – but they would be limits that EPA independently determined would satisfy the variance criteria of CWA § 316(a).

In *Dominion*, 12 E.A.D. at 500, n.13, EPA's Environmental Appeals Board discussed the issue of EPA independently determining thermal discharge limits under the CWA § 316(a) variance standard after rejecting the variance-based limits requested by the permit applicant. In its discussion, the Board characterized the variance evaluation process as entailing four possible steps. At the fourth step, the Board explained that EPA independently "*may* impose a variance it concludes does assure the protection and propagation of the BIP" in a case in which it determines that the otherwise applicable technology-based and/or water quality-based limits would be more stringent than necessary to assure the protection and propagation of the BIP, that the variance limits requested by the permittee would be insufficient, and EPA has identified alternative limits that it has determined will meet the standard of CWA § 316(a). *Id.* at 500. The Board emphasized, however, that it was not reaching the question of whether exploring this fourth step was *required* when the applicant had failed to carry its burden to demonstrate the sufficiency of the variance-based limits it had proposed. The Board stated that "[t]he language of the statute, which puts the burden of obtaining a variance on the applicant, leaves it far from clear that the Agency must undertake step 4 before denying a variance, though we recognize the Agency has generally followed this practice." *Id.* at 500 n.13. *See also id.* at 534 n.68, 552 n.97. *Cf. id.* at 537 n.73 ("baseline" thermal discharge limits based on water quality standards that are biologically driven may be "substantively related" to standards under CWA § 316(a)). Thus, the EAB held that EPA *may* develop its own independent variance under the circumstances described above.

EPA has considered making such an independent CWA § 316(a) variance determination in this case – *i.e.*, including the water quality-based thermal discharge limits to satisfy water quality requirements based on a variance from technology-based requirements under § 316(a). EPA ultimately decided, however, not to take this approach for the Draft Permit because it wants to further evaluate and consider public comment on, among other things, the following questions:

(1) Has EPA correctly rejected PSNH's variance request?
(2) Has EPA properly applied New Hampshire's water quality standards, including the biologically-driven standards?
(3) Will limits satisfying New Hampshire's water quality standards also satisfy CWA § 316(a)?

Thus, EPA affirmatively requests public comment on these questions and any other matters pertinent to these issues. Moreover, EPA hereby provides express notice that it plans to further consider this approach for the Final Permit, taking into account any public comments received. EPA will also, of course, be considering whether the technology-based limits included in the Draft Permit should be retained for the Final Permit.

10.0 COOLING WATER INTAKE REQUIREMENTS

10.1 Introduction

Cooling water intake structures ("CWISs") can cause or contribute to a variety of adverse environmental effects, including "entrainment" (the process by which fish larvae and eggs are killed or injured when they are pulled into and sent through a facility's cooling system along with water withdrawn from a water body for cooling) and "impingement" (the process by which fish and other organisms are killed or injured when they are trapped against the intake structure's screens). CWISs generally must comply with technology-based requirements under CWA § 316(b), 33 U.S.C. § 1326(b), and any applicable state water quality standards.

The following sections of this document present EPA's determination of the CWIS requirements for the new NPDES permit for Merrimack Station. To lay the foundation for this determination, this section explains the legal requirements applicable to CWISs.

CWA § 316(b) governs technology-based requirements for CWISs. It sets a technology standard that requires "that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact," and is referred to as the Best Technology Available ("BTA") standard.

EPA made its BTA determination for the Merrimack Station permit on a case-by-case, "Best Professional Judgment" ("BPJ") basis because there are no national, categorical CWIS requirements under CWA § 316(b) that apply to Merrimack Station. In addition, because states may apply their water quality standards to CWISs, EPA has considered whether New Hampshire's standards apply to the Facility's CWISs and, if so, what they require.

10.2 Legal Requirements Governing CWISs

10.2.1 CWA § 316(b) – Statutory Language

Section 316(b) is the CWA's only provision that directly requires regulation of the *withdrawal* of water from a water body, as opposed to the discharge of pollutants into water bodies. Rather than address all types of water withdrawal, however, this provision only governs CWISs.

Specifically, CWA § 316(b) provides that:

> *[a]ny standard established pursuant to [CWA sections 301 or 306] and applicable to a point source shall require that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact.*

33 U.S.C. § 1326(b). The plain meaning of this language is that Congress wanted EPA to ensure that the best technology available for minimizing adverse environmental impacts from CWISs

would be utilized by plants withdrawing water from the Nation's water bodies for their cooling processes. The legislative history related to CWA § 316(b) is relatively sparse, but what exists reinforces the plain meaning of the statutory language. In the House Consideration of the Report of the Conference Committee (Oct. 4, 1972) on the final version of the 1972 CWA Amendments, Representative Clausen stated that "[s]ection 316(b) requires the location, design, construction and capacity of cooling water intake structures of steam-electric generating plants to reflect the best technology available for minimizing any adverse environmental impact." 1972 Legislative History at 264. The impetus for enacting CWA § 316(b) seems to have been Congressional awareness of the problem of fish being harmed by power plant CWISs, as evidenced by the Senate Consideration of the Report of the Conference Committee (Oct. 4, 1972) for the final 1972 CWA Amendments. *Id*. at 196–99, 202.[62]

10.2.2 Regulations under CWA § 316(b)

EPA efforts to promulgate regulations setting national, categorical requirements for CWISs under CWA § 316(b) have a complicated history. This section describes important aspects of that history to provide the reader with relevant background information, but the bottom line is that there are no currently effective federal regulations that set categorical BTA requirements under CWA § 316(b) for *existing facilities* with CWISs. As mentioned above, and discussed in more detail below, in the absence of such categorical regulatory requirements, EPA applies § 316(b)'s BTA standard on a case-by-case, BPJ basis. This is required by 40 C.F.R. § 125.90(b) and is consistent with CWA §§ 402(a)(1)(B) and 402(a)(2), 40 C.F.R. §§ 122.43(a), 122.44(b)(3), 401.12(h) and 401.14, and longstanding EPA practice upheld by the courts.

EPA first promulgated § 316(b) regulations governing CWISs in 1976, see Best Technology Available for the Location, Design, Construction, and Capacity of Cooling Water Intake Structures for Minimizing Adverse Environmental Impact, 41 Fed. Reg. 17,387 (Apr. 26, 1976), but then withdrew the regulations three years later, after a federal court had remanded them to the Agency due to procedural error. See Appalachian Power Co. v. Train, 566 F. 2d 451 (4th Cir. 1977) (regulations remanded on procedural grounds without reaching their substantive merits); 44 Fed. Reg. at 32,956 (withdrawal of regulations). See also 66 Fed. Reg. at 65,261 (discussion of regulatory history). Over the following decades, EPA has applied the BTA standard of § 316(b) on a case-by-case, BPJ basis for both new and existing facilities with regulated CWISs. See, e.g., Entergy Corp. v. Riverkeeper, Inc., 129 S.Ct. 1498, 1503 (2009).

In 1995, EPA was sued for failing to promulgate regulations applying the BTA standard under CWA § 316(b). The parties to the case settled the litigation by entering into a consent decree in which EPA committed to developing new § 316(b) regulations in three phases. In general, Phase

[62] *Accord Seabrook*, 1977 EPA App. LEXIS 16, *19–*20; *In re Brunswick Steam Elec. Plant*, Decision of the Gen. Counsel No. 41, at 200–01 (1976) [hereinafter "*Brunswick*"].

I was to set BTA requirements for *new facilities* with CWISs, while Phase II was to set BTA standards for *large, existing power plants* with CWISs (defined as those with intake flows of 50 MGD or more). Given Merrimack Station's intake flow of more than 250 MGD, the facility was expected to be covered by the Phase II Rule. Phase III was to address all remaining existing facilities with CWISs, such as smaller power plants and manufacturing facilities.

The "Phase I Rule" was promulgated in 2001. *See generally* 66 Fed. Reg. 65,255. The regulations were challenged in federal court but were upheld with the exception of certain provisions that authorized compliance with the BTA standard by implementing environmental "restoration" measures. *See Riverkeeper, Inc. v. U.S. Envtl. Prot. Agency,* 358 F.3d 174, 189–91 (2d Cir. 2004) (hereinafter "*Riverkeeper I*"). The Phase I regulations for new facilities are currently in effect and are codified at 40 C.F.R. Part 125, Subpart I. They do not, however, apply to *existing* facilities such as Merrimack Station.

EPA next promulgated the "Phase II Rule" for large, existing power plants in September 2004. *See Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities*, 69 Fed. Reg. 41,576 (Jul. 9, 2004). The Phase II regulations were codified at 40 C.F.R. Part 125, Subpart J, and would have applied to Merrimack Station had they remained in effect. They were also challenged in federal court, however, and the reviewing court struck down or remanded to the Agency numerous provisions of the Phase II regulations. *Riverkeeper, Inc. v. U.S. Envtl. Prot. Agency*, 475 F.3d 83, 89, 130–31 (2d Cir. 2007) (hereinafter "*Riverkeeper II*"), *rev'd in part Entergy*, 129 S.Ct. at 1507 (reversing Second Circuit's holding that EPA did not have authority to consider a comparative cost/benefit analysis in determining the BTA). In response to *Riverkeeper II*, EPA formally suspended the Phase II Rule on July 9, 2007., with the exception that 40 C.F.R. § 125.90(b) was not suspended and remains in effect. *See National Pollutant Discharge Elimination System–Suspension of Regulations Establishing Requirements for Cooling Water Intake Structures at Phase II Existing Facilities*, 72 Fed. Reg. 37,107 (Jul. 9, 2007). This regulation provides that "[e]xisting facilities that are not subject to requirements under this [subpart J] or another subpart of this part [125] must meet requirements under section 316(b) of the CWA determined by the Director on a case-by-case, best professional judgment (BPJ) basis." 40 C.F.R. § 125.90(b).

Lastly, in 2006, EPA promulgated the "Phase III Rule." *See Final Regulations To Establish Requirements for Cooling Water Intake Structures at Phase III Facilities*, 71 Fed. Reg. 35,006 (Jun. 16, 2006). It was codified at 40 C.F.R. Part 125, Subpart N. The Phase III Rule addressed all existing facilities not addressed by the Phase II Rule (*i.e.*, smaller power plants and manufacturing facilities). It also addressed new offshore oil and gas extraction facilities because the Phase I Rule had not covered. As with the Phase I and II Rules, the Phase III Rule was challenged in federal court. EPA defended the Phase III Rule's provisions regarding new offshore oil and gas facilities but, following the Supreme Court's 2009 decision in *Entergy*, the Agency sought a voluntary remand of the Phase III Rule to the extent that it addressed existing facilities. EPA explained that it planned to reconsider the Phase III Rule decision with regard to existing facilities in conjunction with its reconsideration of the Phase II Rule. In other words, EPA planned to consider requirements for all existing facilities together. The Fifth Circuit granted EPA's motion, while at the same time affirming the Phase III Rule's provisions pertaining to new offshore oil and gas extraction facilities. *See ConocoPhillips Co. v. U.S. Envtl. Prot. Agency*, 612 F.3d 822, 842 (5th Cir. 2010).

On April 20, 2011, EPA published proposed regulations setting categorical standards applying CWA § 316(b) to CWISs at existing power plants and manufacturers, and new units at existing facilities. 76 FR 22174-22288 (April 20, 2011). The proposed rule addresses, among other things, existing facilities that were to have been addressed by the Phase II and Phase III rules. The new proposed rule is currently out for public review and comment. Once the comment period closes, EPA will at a minimum need to review, consider and respond to the comments before it can issue final regulations. EPA is planning to sign final regulations by July 27, 2011, but the Agency cannot be certain exactly when final regulations may be issued and go into effect. *See* 76 FR 22174-22288 (April 20, 2011).) Thus, there are currently no effective national categorical standards applying § 316(b) to the CWISs at Merrimack Station. As a result, EPA continues to apply CWA § 316(b) on a BPJ, site-specific basis.

10.2.3 State Water Quality Standards

10.2.3.a Application to Cooling Water Intake Structures

CWA § 316(b) requires CWISs to satisfy the BTA standard. This federal technology standard establishes the minimum requirements that all CWISs must meet. CWISs must also satisfy any more stringent state law requirements that may apply, including any applicable requirements of state water quality standards. *See* CWA §§ 301(b)(1)(C), 401(a)(1) & (d), & 510; 40 C.F.R. §§ 122.4(d), 122.44(d), & 125.84(e). *See also Dominion*, 12 E.A.D. at 626.

State water quality standards have three main operative components that must be satisfied: (1) the designated uses assigned to the state's water bodies, (2) narrative and numeric water quality criteria that the water bodies must attain, and (3) "anti-degradation" requirements designed, in essence, to protect the existing quality of the state's water bodies. *See* 40 C.F.R. § 131.6. NPDES permit conditions must be crafted to allow these three components of water quality standards to be satisfied or attained. Thus, if a state's water quality standards apply to the effects of CWIS operation, then permit conditions for CWISs must satisfy these water quality standards as well as the technology-based requirements of CWA § 316(b). *See, e.g.*, CWA § 301(b)(1)(C). *See also* 40 C.F.R. §§ 125.80(d) & 125.84(e) (provisions in Phase I regulations mandating that CWIS requirements in permit also must satisfy any more stringent state requirements) and 40 C.F.R. §§ 125.90(d) & 125.94(e) (parallel provisions in the now-suspended Phase II regulations). (Similarly, if a state duly adopts its own technology-based requirements for CWISs, then NPDES permits would also have to satisfy those requirements to the extent that they are more stringent than the federal requirements under CWA § 316(b). CWA § 301(b)(1)(C).) Under CWA § 510, states are clearly authorized to impose more stringent water pollution control standards than are dictated by the minimum federal requirements (at least in any case in which more stringent state standards are not otherwise expressly forbidden by the statute). *See* 40 C.F.R. § 131.4(a); *PUD No. 1*, 511 U.S. at 705.

NPDES permits issued by EPA are also subject to the State certification process under CWA § 401. CWA § 401(a)(1) provides, in pertinent part, that:

> *[a]ny applicant for a Federal license or permit to conduct any activity . . . which may result in any discharge into the navigable waters, shall provide the licensing or permitting agency a certification from the State in which the discharge originates . . . that any such discharge will comply with the applicable provisions of sections 1311, 1312, 1313, 1316, and 1317 of this title. . . . No license or permit shall be granted until the certification required by this section has been obtained or has been waived. . . . No license or permit shall be granted if certification has been denied by the State. . . .*

33 U.S.C. § 1341(a)(1). The plain language of § 401(a)(1) dictates that unless certification has been waived, no NPDES permit may be issued by EPA without certification by the State. *See PUD No. 1*, 511 U.S. at 707. This language also indicates that a denial of certification by the State bars issuance of the Federal permit or license. EPA regulations reiterate these commands. *See* 40 C.F.R. §§ 122.4(b), 124.53(a), & 124.55(a). Neither the statute nor the regulations identify any exceptions to the certification requirement. A State denial of certification could, of course, be challenged by the permittee through State legal proceedings. *See, e.g.*, 40 C.F.R. § 124.55(e); *Dubois v. U.S.D.A.*, 102 F.3d 1273 (1st Cir. 1996).

In addition, CWA § 401(d) provides, in pertinent part, that:

> *[a]ny certification provided under this section shall set forth any effluent limitations and other limitations, and monitoring requirements necessary to assure that any applicant for a Federal license or permit will comply with any applicable effluent limitations and other limitations, under section 1311 or 1312 of this title, . . . and with any other appropriate requirement of State law set forth in such certification, and shall become a condition on any Federal license or permit subject to the provisions of this section.*

33 U.S.C. § 1341(d). The plain language of § 401(d) makes clear that the State=s § 401 certification must contain any limitations needed to ensure compliance with CWA § 301, including § 301(b)(1)(C), and any appropriate requirement of State law, and that such limitations imposed in a certification must be included as conditions in the Federal permit. *See also PUD No. 1*, 511 U.S. at 707–08. EPA regulations repeat these commands from the statute. 40 C.F.R. §§ 121.2, 122.44(d)(3), 124.53(e)(1), & 124.55(a)(2). *See also* 40 C.F.R. § 122.4(d). Permit limitations based on State certification conditions can be challenged in State legal proceedings. 40 C.F.R. § 124.55(e). *See also Roosevelt Campobello Int=l Park Comm=n v. U.S. Envtl. Prot. Agency*, 684 F.2d 1041, 1055–56 (1st Cir. 1982).

The Supreme Court has also held that once the CWA § 401 State certification process has been triggered by the existence of a discharge, then the certification may impose conditions and limitations on *the activity as a whole* – not merely on the discharge – to the extent needed to ensure compliance with State water quality standards or other applicable requirements of State law. The Court explained that:

> *[t]he text [of CWA ' 401d)] refers to the compliance of the applicant, not the discharge. Section 401(d) thus allows the State to impose Aother limitations@ on the project in general to assure compliance with various provisions of the Clean Water Act and with Aany other appropriate requirement of State law.@ . . . Section 401(a)(1) identifies the category of activities subject to certification – namely, those with discharges. And ' 401(d) is most reasonably read as authorizing additional conditions and limitations on the activity as a whole once the threshold condition, the existence of a discharge, is satisfied.*

PUD No. 1, 511 U.S. at 711–12. Thus, for example, a State could impose certification conditions related to cooling water intake structures on a permit for a facility with a discharge if those conditions were necessary to assure compliance with a requirement of State law, such as State water quality standards. *See id.* at 713. This also helps to confirm that in setting *discharge* conditions to achieve water quality standards, a State can and should take account of the effects of *other aspects of the activity* that may influence the discharge conditions that will be needed to attain water quality standards.

10.2.3.b New Hampshire Water Quality Standards

Turning specifically to New Hampshire’s water quality standards, the state’s standards apply to the effects of cooling water withdrawals. That is, permit conditions on cooling water withdrawals must comply with (or not interfere with the attainment of) relevant water quality criteria, designated uses, and antidegradation requirements. New Hampshire's standards state as follows:

> *[t]hese rules shall apply to any person who causes point or nonpoint source discharge(s) of pollutants to surface waters, or who undertakes hydrologic modifications, such as dam construction or water withdrawals, or who undertakes any other activity that affects the beneficial uses or the level of water quality of surface waters.*

N.H. Code R. Env-Wq 1701.02(b) (Applicability). *See also id.* 1708.03 (Submittal of Data). This language clearly indicates the applicability of the standards to cooling water withdrawals from the state's waters.

Because cooling water withdrawals can result in the entrainment and/or impingement of aquatic organisms, and may affect water quantity in the source water, such withdrawals must comply with certain specific designated uses and water quality criteria. The state's standards dictate that:

> *(b) All surface waters shall be restored to meet the water quality criteria for their designated classification including existing and designated uses, and to maintain the chemical, physical, and biological integrity of surface waters.*
>
> *(c) All surface waters shall provide, wherever attainable, for the protection and propagation of fish, shellfish and wildlife, and for recreation in and on the surface waters.*
>
> *(d) Unless the flows are caused by naturally occurring conditions, surface water quantity shall be maintained at levels adequate to protect existing and designated uses.*

Id. 1701.03(b), (c), & (d) (Water Use Classifications). The state's standards also prescribe the following water quality criterion for "biological and aquatic community integrity":

> *(a) The surface waters shall support and maintain a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of similar natural habitats of a region.*
>
> *(b) Differences from naturally occurring conditions shall be limited to non-detrimental differences in community structure and function.*

Id. 1703.19. *See also id.* 1702.07 (definition of "biological integrity").

In sum, the limits in EPA-issued NPDES permits that address cooling water intake structures must satisfy both CWA § 316(b) and any more stringent requirements necessary to satisfy applicable state water quality standards. The NPDES permit that EPA expects to issue to Merrimack Station will be subject to state certification under CWA § 401(a)(1) and, therefore, will also need to satisfy any conditions of such a certification. The New Hampshire Department of Environmental Services (NHDES) administers the certification process for the state. EPA expects that NHDES will provide (or waive) its certification some time after it has reviewed the Draft Permit, but before EPA issues the Final Permit.

10.3 Determining the BTA under CWA § 316(b) on a Case-by-Case, BPJ Basis

As stated above, in the absence of regulations specifying national, categorical technology guidelines for CWISs, EPA develops permit conditions under CWA § 316(b) by determining the BTA for each facility on a case-by-case, BPJ basis. This approach is authorized by CWA §§ 402(a)(1)(B) and 402(a)(2) and required by 40 C.F.R. § 125.90(b). *See also* 40 C.F.R. § 122.44(b)(3).

Case law concerning the development of BPJ-based effluent limits is helpful to understanding the character of BPJ-based permit requirements. As one court stated, "BPJ limits constitute case-specific determinations of the appropriate technology-based limitations for a particular point source." *Natural Res. Def. Council*, 859 F.2d at 199. The court further explained that:

> *[i]n what EPA characterizes as a 'mini-guideline' process, the permit writer, after full consideration of the factors set forth in section 304(b), 33 U.S.C. § 1314(b) (which are the same factors used in establishing effluent guidelines), establishes the permit conditions 'necessary to carry out the provisions of [the CWA].' § 1342(a)(1). These conditions include the appropriate . . . BAT effluent limitations for the particular point source. . . . [T]he resultant BPJ limitations are as correct and as statutorily supported as permit limits based upon an effluent limitations guideline.*

Id. See also Texas Oil, 161 F.3d at 929 ("Individual judgments thus take the place of uniform national guidelines, but the technology-based standard remains the same.")

Neither the CWA nor EPA regulations dictate a specific methodology for developing permit limits based on a BPJ determination of the BTA under § 316(b). Nevertheless, the statute does identify a number of factors to be considered in the analysis. Specifically, the text of § 316(b) dictates that the permit limits must ensure that "the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact." 33 U.S.C. § 1326(b). None of the operative terms of § 316(b) are defined in the statute, but these terms have been interpreted by EPA over years of practice and, in some cases, by federal court decisions. The key terms are discussed below. In addition, EPA looks by analogy to Agency practice in the BPJ application of technology standards for the control of wastewater discharges.

10.3.1 Elements of a CWIS That Must Reflect the BTA

A CWIS's location, design, construction and capacity must reflect the BTA for minimizing adverse environmental impact. Each of these four elements of the CWIS are discussed immediately below.

10.3.1.a Location

The term "location" refers to the water body, or segment of the water body, in which the CWIS is located. The EPA 1976 Development Document (at p.15) states that "[t]he most important locational factor influencing the intake design is the nature of the water source from which the supply is taken." Location also refers to where the intake is located *within a particular water body*, such as its placement within the water column and its location relative to the shore line, the point of thermal discharges, the discharge of any fish return system, and any particularly sensitive resource areas (*e.g.*, migration routes, spawning areas, etc.). *See id.* at 15–26, 178–79. *See also* 1994 EPA Background Paper No. 3, at 2–3; 1977 Draft CWA § 316(b) Guidance at 6; *Seabrook*, 1977 EPA App. LEXIS 16, at *29–*30, *35–*36. At times, CWIS location has been referred to as the most important factor in minimizing adverse impacts because many adverse impacts can be avoided simply by siting the intake outside of particularly sensitive areas.[63]

Of course, adjusting the location of a CWIS to minimize adverse environmental impacts is typically far easier for a new facility than an existing facility. Nevertheless, CWIS location can be considered for existing facilities because in some cases it might be possible to reduce impacts by replacing an existing CWIS with a new one at a new location. Of course, the cost of such a "retrofit" would need to be considered, as well as any additional adverse environmental impacts that might result from constructing the new CWIS. *See* EPA 1976 Development Document at 169.

10.3.1.b Design

The "design" element of a CWIS refers to the various components that make up the CWIS itself. These components include screening systems intended to keep everything from aquatic organisms to debris from being drawn into the plant's cooling system. In

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[63] *See* EPA 1976 Development Document at 178.

addition, various types of fish bypass and return systems intended to minimize harm to aquatic organisms from impingement are also considered under the design element. Finally, consideration may also be given to various types of pumps and intake technologies, such as "velocity caps" and "variable speed pumps," which can influence the volume and/or velocity of water drawn into the plant. *See* EPA 1976 Development Document at 27–143. *See also* EPA 1996 Supplement to Background Paper No. 3. Design elements should be considered for both new and existing facilities. EPA 1976 Development Document at 142–43.

10.3.1.c Construction

The term "construction" refers to the physical aspects of installing the CWIS. When considering CWIS construction, EPA considers any adverse environmental impacts that might occur as a result of the process of installing or, for an existing facility, modifying the CWIS.

10.3.1.d Capacity

The term "capacity" as used in CWA § 316(b) refers to the volume of cooling water drawn through the intake. The velocity of the water drawn into the plant may also be considered under this factor (as well as under the design factor). In *Brunswick*, Decision of the Gen. Counsel No. 41, at 200–01, EPA's General Counsel stated the following:

> *. . . it seems clear to me that the term "capacity" in § 316(b) means the volume of water withdrawn through a cooling water intake structure. This conclusion is supported by the commonly understood meaning of the term "capacity" [footnote to dictionary definition of "capacity" referring to "cubic contents; volume" omitted], the definition of the term in the [later withdrawn] regulations [footnote omitted], and the legislative history of the Federal Water Pollution Control Act Amendments of 1972.*
>
> *In the course of debating the conference report of the Act on October 4, 1972, the Senate was well aware of the dangers posed to aquatic life by the withdrawal of large volumes of water through cooling water intake structures [footnote omitted].*

Accord Cent. Hudson, Decision of the Gen. Counsel No. 63, at 381, n.10; *Seabrook*, 1977 EPA App. LEXIS 16, at *22–*23. *See also* 1996 EPA Supplement to Background Paper No. 3, at A-3; 1994 EPA Background Paper No. 3, at 2–3; EPA 1976 Development Document at 153.

As with the other factors, "capacity" must be considered in making CWA § 316(b) determinations for both new and existing facilities. As EPA stated in *Central Hudson*, at 381, n.10:

> *Since the magnitude of entrainment damage is frequently a function of the amount of water withdrawn, the only way that massive entrainment damage can be minimized in many circumstances is by restricting the volume of water withdrawn or by relocating the intake structure away from the endangered larvae. The latter approach is often not feasible. Thus, in certain cases, the only means of minimizing serious entrainment damage is to restrict the volume of water withdrawn.*

See also Seabrook, 1977 EPA App. LEXIS 16, at *19–*20; 41 Fed. Reg. at 17,388–90; EPA 1976 Development Document at 178; 1977 Draft § 316(b) Guidance at 13 ("Reducing cooling water flow is generally an effective means for minimizing potential entrainment impact . . . [and i]n fact, . . . may be the only feasible means . . . where potentially involved organisms are in relatively large concentration and uniformly distributed in the water column").

10.3.2 The BTA Standard

CWA § 316(b) specifies that CWISs must reflect "the best technology available for minimizing adverse environmental impacts" (BTA). The elements of the BTA standard are discussed below.

10.3.2.a Availability of Technologies

To satisfy the BTA standard under CWA § 316(b), a technology must be "available." This term is not defined in the statute or current regulations. It has been well-accepted that "availability" in terms of the BTA technology standard refers, at a minimum, to *technological* feasibility. To determine whether a technology is available for a particular facility or industry, EPA will look to see whether a technology has actually been used at this type of facility or industry. EPA can also look at technologies that have been used for other types of facilities or application, or that have been used on a pilot or bench-scale basis, but could be "transferred" or "scaled up" for use at the type of facility under investigation.[64]

When determining the BTA for existing facilities, such as Merrimack Station, EPA must, of course, evaluate whether technologies may be available for *retrofitting* to existing

[64] These determinations, arising out of CWA legislative history, have been upheld by the courts. *See, e.g.*, *Am. Petroleum*, 858 F.2d at 264–65; *Pac. Fisheries*, 615 F.2d at 816–17; *BASF Wyandotte*, 614 F.2d at 22; *Am. Iron*, 526 F.2d at 1061; *Am. Meat*, 526 F.2d at 462–63.

plants. In this regard, EPA will look to technologies that have been retrofitted to existing facilities in the past. EPA could also look at technologies used at new facilities to the extent that their use was instructive about what could be retrofitted to existing plants.[65] In addition, when making a BTA determination under CWA § 316(b) on a case-by-case, BPJ basis, EPA ultimately must also consider whether a particular technology is feasible for use at the specific facility in question given the facts of that case. For example, while the fact that a technology works at a particular power plant might generally suggest that it could also work at Merrimack Station, the technology might not actually be feasible for Merrimack Station due to site-specific issues such as, for example, space limitations. A technology that is not actually feasible for a facility could not be the BTA for that facility.

Beyond technological feasibility, EPA has also read availability to connote *economic* feasibility. That is, a technology is deemed available on a case-by-case, BPJ basis only if it is both technologically and economically feasible for the facility in question.[66] There is strong support for this interpretation.

The Supreme Court has noted that the term "available" can be considered ambiguous in that it could be read to refer to either technological or economic feasibility, or both. *Entergy*, 129 S.Ct. at 1506 n.5. In addition, the Second Circuit stated that "a technology [with costs] that cannot [ ] be reasonably borne by the industry is not 'available' in any meaningful sense." *Riverkeeper II*, 475 F.3d at 99. Consideration of economic feasibility is also supported by the sparse legislative history of § 316(b). Specifically, in the House Consideration of the Report of the Conference Committee, Representative Clausen stated that:

> *[t]he reference here [in § 316(b)] to "best technology available" is intended to be interpreted to mean the best technology available commercially at an economically practicable cost.*

1972 Legislative History, p. 264 (emphasis added). Citing to Representative Clausen's remarks, EPA stated the following in the preamble to the Final CWA § 316(b) regulations issued in 1976, but later remanded to the Agency:

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[65] In one sense, one can think of a technology used at a *new* power plant as a potential "transfer technology" for use at *existing* plants.

[66] When determining the BTA on an industrial category-wide basis, however, the technology chosen as the BTA would have to be "available" to the industry as a whole, but might not be technologically or economically feasible for every facility within that industrial category.

> *[t]he brief legislative history of section 316(b) states that the term "best technology available" contemplates the best technology available commercially at an economically practicable cost. As with the statute, this language does not require a formal or informal "cost/benefit" assessment. Rather, the term "available commercially at an economically practicable cost" reflects a Congressional concern that the application of "best technology available" should not impose an impracticable and unbearable economic burden on the operation of any plant subject to section 316(b).*

41 Fed. Reg. at 17,388. Thus, EPA has long understood Congress to intend an economic practicability test to be applied as part of a BTA determination under § 316(b).

This is also consistent with the common understanding of the meaning of the words "available" and "practicable." For example, the *American Heritage Dictionary* (2d ed. 1982) defines "available" to mean "accessible for use; at hand." Moreover, the *American Heritage Dictionary* defines "practicable" as "capable of being effected, done or executed; feasible." Thus, although CWA § 316(b) does not mention considering *cost* in determining the BTA, EPA has reasonably interpreted the term "available" to include consideration of economic feasibility.

10.3.2.b "Adverse Environmental Impact"

The term "adverse environmental impact" ("AEI") as used in CWA § 316(b) is not defined in either the statute or existing regulations. As such, neither statute nor regulation expressly limits the extent of adverse environmental impact that may be considered. Stated differently, neither statute nor regulation specifies an impact threshold above which a CWIS's effects must rise before the BTA requirement is triggered.[67]

EPA has interpreted the entrainment and impingement of aquatic organisms to constitute AEI, without requiring a demonstration of broader-scale harm to populations of particular species or particular communities of organisms. As the Second Circuit explained in *Riverkeeper II*:

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[67] As mentioned above, the legislative history behind CWA § 316(b) is sparse, but in the House Consideration of the Report of the Conference Committee for the final 1972 CWA Amendments, Representative Clausen stated that "Section 316(b) requires the location, design, construction and capacity of cooling water intake structures of steam-electric generating plants to reflect the best technology available for minimizing any adverse environmental impact" (emphasis added). 1972 Legislative History at 264. This language suggests, if anything, that *all* AEI should be considered and minimized, perhaps with the exception of *de minimis* effects.

> *[i]n the Phase II Rule, as in the Phase I Rule, the EPA has interpreted the statutory directive of section 316(b) to minimize "adverse environmental impact" ("AEI") to require the reduction of "the number of aquatic organisms lost as a result of water withdrawals associated" with cooling water intake structures. 69 Fed. Reg. at 41,586.*

475 F.3d 83, 123–24, *rev'd on other grounds Entergy*, 129 S.Ct. 1498. The Second Circuit upheld EPA's interpretation in both *Riverkeeper I* and *Riverkeeper II*. In *Riverkeeper I*, the Second Circuit explained:

> *. . . the EPA's focus on the number of organisms killed or injured by cooling water intake structures is eminently reasonable. See Final Rule, 66 Fed. Reg. at 65,262-63, 65,292. As discussed above with respect to restoration measures, Congress rejected a regulatory approach that relies on water quality standards, which is essentially what UWAG urges here in focusing on fish populations and consequential environmental harm.*

358 F.3d at 196. In *Riverkeeper II*, the court reaffirmed its holding, stating, among other things, that "we are both persuaded and bound by our statements on this issue in *Riverkeeper I.*" 475 F.3d at 124–25 (footnote omitted). *See also id.* at 125 n.36 (presenting the "additional observation" that the "statutory structure thus indicates that Congress did not intend to limit 'adverse environmental impact' in section 316(b) to population-level effects").[68]

Consistent with this interpretation of the law, but long before promulgation of the Phase I and II Rules, EPA had explained in its May 1977 Draft § 316(b) Guidance, at p.15, that:

> *[a]dverse aquatic environmental impacts occur whenever there would be entrainment or impingement damage as a result of the operation of a specific cooling water intake structure.*

Similarly, EPA had also concluded based on the language and structure of CWA § 316(b), that CWISs must reflect the BTA for minimizing AEIs, whether or not those

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[68] *See also ConocoPhillips*, 612 F.3d at 840–42 (upholding BTA requirements based on likely AEI given presence of eggs and larvae in area of CWIS, without any necessity to evaluate AEI at the species population or biological community level); *Seabrook*, 1977 EPA App. LEXIS 16, at *20–*21 (CWA § 316(b) standard requiring that CWISs reflect BTA for minimizing adverse environmental impact differs from § 316(a) standard requiring that thermal discharge limitations protect balanced indigenous populations of fish, shellfish and wildlife, and § 316(b) may require further minimization of adverse impacts even if balanced indigenous populations would not be undermined). *Accord Cent. Hudson*, at 371, 382; *Brunswick*, at 197, 201–02.

adverse impacts were considered to be “significant.” *Brunswick*, at 203 (“The [cooling water intake] structures must reflect the best technology available for minimizing . . . adverse environmental impact – significant or otherwise.”) (emphasis in original); *Cent. Hudson*, Decision of the Gen. Counsel No. 63, at 381–82 (“Under Section 316(b), EPA may impose the best technology available . . . in order to minimize . . . adverse environmental impacts – significant or otherwise.”). In other words, once adverse impacts are beyond some *de minimis* level, there is no particular threshold of significance which must be crossed before the adverse impacts must be minimized by the application of BTA.[69]

10.3.2.c “Minimizing” Adverse Environmental Impacts

In past decisions, EPA determined that the term “minimize” should be understood to have its common meaning, which is, “reduce to the smallest possible amount, extent, size, or degree.” *American Heritage Dictionary*. *See also* 41 Fed. Reg. at 17,387–88; *Cent. Hudson*, Decision of the Gen. Counsel No. 63, at 371, 381; *Seabrook*, 1977 EPA App. LEXIS 16, at *21; *Brunswick*, at 197, 203. At the same time, EPA was clear in the May 1977 Draft § 316(b) Guidance that it did not regard CWA § 316(b) to require the complete elimination of all entrainment or impingement in all cases. The Guidance states (at p.3) that “[r]egulatory agencies should clearly recognize that some level of intake damage can be acceptable if that damage represents a minimization of environmental impact.”

In the Phase I Rule, however, EPA defined “minimize” to mean “reduce to the smallest amount, extent, or degree reasonably possible.” 40 C.F.R. § 125.83. Thus, EPA expressly included a reasonableness test within the concept of minimizing AEI. Although EPA did not include a similar definition in the Phase II Rule, *see* 40 C.F.R. § 125.93 (currently suspended), the majority opinion in *Entergy* discusses the meaning of the term “minimize” in the context of considering whether EPA has discretion to consider a comparison of the costs and benefits of alternative technologies in determining the BTA under CWA § 316(b). The Court essentially concluded that “minimizing” could reasonably be interpreted to include an implicit limitation of reasonableness. Specifically, the Court stated that the term minimize “admits of degree,” and so does not necessarily refer to the “greatest possible reduction.” 129 S.Ct. at 1506. Rather, EPA could interpret minimizing AEI to mean achieving the greatest possible *reasonable* reductions.

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[69] The significance or magnitude of the impacts may come into play, however, when considering whether the cost of undertaking particular actions to further reduce impacts is unreasonable.

The question then becomes what factors EPA can consider in determining whether a particular level of reduction is reasonable.

10.3.2.d Which Available Technology is "Best" for Minimizing AEI?

The BTA under CWA § 316(b) must constitute the "best" technology for minimizing AEI. There are a number of factors that EPA may consider in determining which technology is best for this purpose. These factors are discussed below.

10.3.2.d.i Technological Performance

In determining which of the available technologies is best for minimizing AEI, EPA must assess the performance of the available technological options (*i.e.*, the extent to which they are able to reduce AEI). In one respect, the *best* performing technology for minimizing AEI will be the one that achieves the greatest possible reductions in AEI. This is consistent with the common meaning of the term "best," which is defined by the *American Heritage Dictionary* as "surpassing all others in excellence, achievement, or quality . . . ." Similarly, in the 1976 preamble to the Proposed Final CWA § 316(b) regulations, EPA explained that in determining the BTA, EPA's "effort must be to select *the most effective means* of minimizing . . . adverse effects." 41 Fed. Reg. at 17,388 (emphasis added). Thus, as a starting point, EPA will look to see what the best performing technology in the industry (or from among any pertinent transfer or pilot-scale technologies).

This is not, however, EPA's stopping point. In *Entergy*, the majority opinion clearly states considerations beyond a technology's ability to reduce AEI may enter into the calculus that determines which of the available technologies is best. The Court explained:

> *[a]s we have described, § 1326(b) instructs the EPA to set standards for cooling water intake structures that reflect 'the best technology available for minimizing adverse environmental impact.' The Second Circuit [in Riverkeeper II] took that language to mean the technology that achieves the greatest reduction in adverse environmental impacts at a cost that can reasonably be borne by the industry. 475 F.3d at 99–100. That is certainly a plausible interpretation of the statute. The "best" technology -- that which is "most advantageous," Webster's New International Dictionary 258 (2d ed. 1953) -- may well be the one that produces the most of some good, here a reduction in adverse environmental impact. But 'best technology' may also describe the technology that most efficiently produces some good. In common parlance one could certainly use the*

> *phrase 'best technology' to refer to that which produces a good at the lowest per-unit cost, even if it produces a lesser quantity of that good than other available technologies.*

Entergy, 129 S.Ct. at 1505–06. The Court rejected the respondents' argument that the best technology *must* be the one that achieves the greatest reduction in AEI because § 316(b) calls for the best technology *for* minimizing AEI. The Court explained, as discussed above, that in its view, "'minimize' is a term that admits of degree and is not necessarily used to refer exclusively to the 'greatest possible reduction.'" *Id.* at 1506. The Court further opined that "[s]ection 1326(b)'s use of the less ambitious goal of 'minimizing adverse environmental impact' suggests, we think, that the agency retains some discretion to determine the extent of reduction that is warranted under the circumstances." *Id.*

Thus, the Court concluded that EPA has discretion to determine the extent of AEI reduction that is warranted in light of various circumstances.

10.3.2.d.ii Consideration of Relative Costs and Benefits

As discussed above, EPA may consider the cost of technological options to determine which technologies are available from a financial or economic perspective. In addition, the Supreme Court has confirmed that EPA may, in its discretion, also consider cost from other perspectives in deciding which technology is best for minimizing AEI.

Specifically, in *Entergy*, the Court held that EPA was permitted to consider a comparison of the relative costs and benefits of the technological options in its determination of which technology is "best" under CWA § 316(b)'s BTA standard. *See id.* at 1506 n.5 (determining which available technology is best "… may well involve consideration of the technology's relative costs and benefits"), *rev'g in part*, *Riverkeeper*, 475F.3d 83. *See also generally id.* at 1508–10. As quoted just above, the Court also reasoned that:

> . . ."*best technology" may also describe the technology that most efficiently produces some good [(in this case, a reduction in AEI)]. In common parlance one could certainly use the phrase "best technology" to refer to that which produces a good at the lowest per-unit cost, even if it produces a lesser quantity of that good than other available technologies.*

Id. at 1506. Furthermore, the Court found that the requirement that AEI be minimized leaves EPA with "some discretion to determine the extent of reduction that is warranted under the circumstances . . .," and that such a "determination could plausibly involve a consideration of the benefits derived from reductions and the costs of achieving them."

Id. In addition, the Court opined that if the BTA standards only mandated technologies that could "'be reasonably borne by the industry . . . [,]' 475 F.3d at 99[,] . . . [then] whether it is 'reasonable' to bear a particular cost may well depend on the resulting benefits; if the only relevant factor was the feasibility of the costs, their reasonableness would be irrelevant." *Id.* at 1510.

While the *Entergy* court clearly held that EPA is *authorized* to consider a comparison of the costs and benefits of technological options in determining the BTA under CWA § 316(b), it was also clear that EPA did not have to do so. Indeed, the Court repeatedly explained that EPA's authority to consider comparative costs and benefits was discretionary. Specifically, the Court held that § 316(b)'s silence with regard to whether or not cost/benefit considerations were to be a factor in determining the BTA should be interpreted "to convey nothing more than a refusal to tie the agency's hands as to whether cost-benefit analysis should be used, and if so to what degree." *Id.* at 1508. The Court also stated that the fact that the BTA standard is:

> *. . . unencumbered by specified statutory factors of the sort provided for [certain technology standards applicable to discharges of pollutants], … can reasonably be interpreted to suggest that the EPA is accorded greater discretion in determining its precise content [than it is with regard to the other standards]*.

Id. The Court further explained that ". . . under *Chevron*, that an agency is not *required* to do so [(*i.e.*, to compare costs and benefits)] does not mean that an agency is not *permitted* to do so." *Id.* Finally, the Court held that "it was well within the bounds of reasonable interpretation for the EPA to conclude that cost-benefit analysis is not categorically forbidden." *Id.* *See also id.* at 1509 (identifying the "principle" of the "permissibility of at least some cost-benefit analysis" in determining the BTA under § 316(b)).

In the litigation over the Phase III Rule under CWA § 316(b), the Fifth Circuit applied the *Entergy* decision and stated that it:

> *. . . lucidly establishes that the EPA may employ cost-benefit analysis when effecting regulations that reflect the "best technology available for minimizing adverse environmental impact." The Entergy Corp. Court also endorsed the idea, however, that, although it may employ cost-benefits analysis in rule making, the EPA is not required to do so, and is afforded discretion to consider to what degree, if any, costs and benefits should be weighed in determining the "best technology available to minimizing adverse environmental impact."*

ConocoPhillips, 612 F.3d at 828. *See also id.* at 827, 837 ("the Supreme Court has now made pellucid that the EPA *may* but is not *required* to engage in cost-benefit analyses for CWIS rule making . . ."). Moreover, the court upheld EPA's determination of the BTA for new offshore oil and gas "rigs" *without* considering a comparison of costs and benefits. *Id.* at 840, 842. The court held both that EPA could, but was not legally mandated to, consider a comparison of costs and benefits, *id.* at 837–38, and that it was rational for EPA to determine the BTA without a cost/benefit comparison in light of the absence of benefits information and the difficulty of obtaining it. *Id.* at 840–41 (". . . when an agency is faced with such informational lacunae, the agency is well within its discretion to regulation on the basis of available information rather than to await the development of information in the future").

Given that EPA may, in its discretion, consider comparative cost/benefit analysis in determining the BTA under CWA § 316(b), a question arises as to what test EPA uses in this regard. In *Entergy*, the Supreme Court explained that in determining the BTA for the Phase II Rule, EPA had used a "significantly greater than" test (*i.e.*, costs should not be significantly greater than the benefits). *See* 129 S.Ct. at 1509. The Court also explained that, more broadly, "EPA sought only to avoid extreme disparities between costs and benefits." *Id.* The Court found this to be both a reasonable exercise of the Agency's discretion as well as consistent with the Agency's decades-long general practice of applying a "wholly disproportionate" test (*i.e.*, to qualify as the BTA, an option's costs should not be wholly disproportionate to its benefits) when using a cost/benefit test.[70] *Id.*, *citing Seabrook*, 1 E.A.D. at 340; *Cent. Hudson*, Decision of the Gen. Counsel No. 63, at 371, 381.[71] The Court also held that both of the two stated tests were permissible under the statute. *Id.*

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[70] To the best of our knowledge, the now-suspended Phase II Rule was the first and only time that EPA ever used the "significantly greater than" test. In all other cases of rulemaking or BPJ permitting, EPA has used either the "wholly disproportionate test" or it has not compared costs and benefits at all.

[71] In *Seabrook*, the Administrator stated that:

> *. . . the Agency's position, that cost/benefit analysis is not required under Section 316(b), is correct. Section 316(b) provides flatly that cooling water intakes shall "reflect the best technology available for minimizing adverse environmental impact.". . . Indeed, but for one bit of legislative history [citation to Representative Clausen's previously quoted remarks omitted], there would be no indication that Congress intended costs to be considered under Section 316(b) at all. I find, therefore, that insofar as the RA's [(i.e., the Regional Administrator's)] decision may have implied*

In evaluating costs and benefits under CWA § 316(b), EPA considers total project costs and total project benefits to the extent they can be estimated. Consistent with principles of natural resource economics, and as recognized by the courts, EPA may consider both use (*e.g.*, commercial and recreational fishing values) and non-use (*e.g.*, existence value, bequest value) benefits. *See, e.g.*, *id.* (noting consideration of use and non-use values for Phase II Rule); *ConocoPhillips*, 612 F.3d at 828–29 (same for Phase III Rule). Where reasonably possible, EPA may develop monetized estimates of the benefits and, as appropriate, augment them with qualitative benefits assessments.[72] Where monetized benefits estimates cannot reasonably be developed due to problems such as information gaps or cost and time constraints, EPA may rely entirely on qualitative benefits assessments or, depending on the circumstances, may eschew any comparison of costs and benefits. *See Entergy*, 129 S.Ct. at 1509 (noting that EPA's benefits assessment included a monetary value for use benefits and "non-use benefits of indeterminate value"); *ConocoPhillips*, 612 F.3d at 840, 842 (upholding EPA determination of BTA for new offshore oil and gas rigs without comparing costs and benefits); *Dominion*, 12 E.A.D. at 679–84 (discussing qualitative consideration of benefits and non-use benefits).

> *the requirement of a cost/benefit analysis under Section 316(b), it was incorrect. However, the RA may have meant only that some consideration ought to be given to costs in determining the degree of minimization to be required. I agree that this is so – otherwise the effect would be to require cooling towers at every plant that could afford to install them, regardless of whether any significant degree or entrainment or entrapment was anticipated. I do not believe that it is reasonable to interpret Section 316(b) as requiring use of technology whose cost is wholly disproportionate to the environmental benefit to be gained.*

1977 EPA App. LEXIS 16, at *17–*19.

[72] In *Central Hudson*, an EPA decision cited by the Supreme Court in *Entergy*, 129 S.Ct. at 1509, EPA's then-General Counsel presented an approach melding the wholly disproportionate test with the qualitative consideration of the benefits of AEI reduction, stating that ". . . EPA must ultimately demonstrate that the present value of the cumulative annual cost of modifications to cooling water intake structures is not wholly out of proportion to the magnitude of the estimated environmental gains (including attainment of the objectives of the Act and § 316(b)) to be derived from the modifications." The relevant "objectives of the Act and § 316(b)" include the following: minimizing adverse environmental impacts from cooling water intake structures; restoring and maintaining the physical and biological integrity of the Nation's waters; and achieving, wherever attainable, water quality that provides for the protection and propagation of fish, shellfish and wildlife, and provides for recreation, in and on the water. *See* 33 U.S.C. §§ 1251(a)(1), (2), & 1326(b). Obviously, considering benefits in these terms yields a qualitative assessment, rather than a monetized one.

See also Entergy, 129 S.Ct. at 1513, 1515 (Breyer, J., concurring). One of the reasons, of course, that qualitative consideration of benefits may be appropriate is that all relevant benefits may not be subject to monetization. *See, e.g.*, *id.* (Breyer, J., concurring); *Dominion,* 12 E.A.D. at 681–82 (citing cases).

Finally, beyond considering costs in terms of feasibility or cost/benefit comparison, EPA may also consider the relative "cost-effectiveness" of the available technology options. The term "cost-effectiveness" has been used in multiple ways. From one perspective, the most cost-effective option is the least expensive way of getting to the same (or nearly the same) performance goal. *See Entergy,* 129 S.Ct. at 1509–10 (characterizing this as a type of cost/benefit analysis, and citing *Riverkeeper I*, 358 F.3d at 194, n. 22); *Riverkeeper II*, 475 F.3d at 99–100. From another perspective, cost-effectiveness refers to a comparative assessment of the cost per unit of performance by different options. *See Entergy*, 129 S.Ct. at 1506 (". . . '[B]est technology' may also describe the technology that *most efficiently* produces some good. In common parlance one could certainly use the phrase 'best technology' to refer to that which produces a good at the lowest per-unit cost, even if it produces a lesser quantity of that good than other available technologies."). In its discretion, EPA might find either or both of these approaches to cost-effectiveness analysis to be useful in determining the BTA in a particular case. Alternatively, under some circumstances, EPA might reasonably decide that neither was useful. For example, the former approach would not be particularly helpful in a case in which only one technology reaches (or comes close to) performance goals. Moreover, the latter approach would not be helpful where a meaningful cost-per-unit-of-performance metric cannot be developed, or where there are wide disparities in the performance of alternative technologies and those with lower costs-per-unit-of-performance fail to perform adequately.

10.3.2.d.iii Consideration of Additional Factors

In determining the BTA, EPA may also, in its discretion, consider additional factors relevant to assessing the benefits and detriments of the available technological options. For example, EPA may decide that beyond a technology's ability to reduce AEI from the CWIS, it is also appropriate to consider the technology's "secondary environmental effects" (*e.g.*, air pollution effects or energy supply effects) in determining the BTA. The Supreme Court was clear in ruling that in determining the BTA, EPA is not bound to consider the factors set forth in CWA §§ 301, 304, and 306 for the technology standards governing pollutant discharge limitations, but at the same time the Court found that § 316(b)'s silence with regard to the factors for consideration indicates that Congress delegated broader authority to EPA to use its discretion to decide which factors should be considered. *See Entergy,* 129 S.Ct. at 1508. Consistent with this line of reasoning, in *Riverkeeper I,* the Second Circuit earlier stated:

> *. . . [b]ecause section 316(b) refers to sections 301 and 306 but provides a different standard ("best technology available for minimizing adverse environmental impact" instead of, for example, "best available demonstrated control technology") and does not explicitly provide that regulations pursuant to section 316(b) are subject to the requirements of sections 301 and 306, we think it is permissible for the EPA to look to those sections for guidance but to decide that not every statutory directive contained therein is applicable to the Rule.*

358 F.3d at 187. Thus, EPA can look by analogy to CWA §§ 301, 304, and 306, as well as 40 C.F.R. § 125.3, for guidance in identifying relevant factors to consider in determining the BTA under § 316(b) basis, but EPA is not legally *required* to consider the factors in those provisions. At the same time, of course, EPA must exercise its discretion in a reasonable way in light of the circumstances of the case at hand.

10.3.2.e Interaction of CWA §§ 316(b) and 316(a) Analyses

CWA §§ 316(a) and (b) impose different standards and address different, though related, concerns. While § 316(a) addresses thermal discharges, § 316(b) addresses the adverse effects of CWISs. Section 316(a) authorizes EPA (or the State) to issue a permit with thermal discharge effluent limitations less stringent than otherwise required under §§ 301 and 306, as long as the alternative limits will be sufficient to ensure the protection and propagation of a balanced indigenous population of fish, shellfish, and wildlife in and on the receiving water ("BIP"). (The application of CWA § 316(a) to the Merrimack Station permit is discussed in detail in Section 6 of this document.) Section 316(b), on the other hand, requires that the design, location, construction, and capacity of CWISs reflect the BTA for minimizing AEI, subject to the economic tests discussed above. Section 316(b) BTA requirements are not excused even if the AEI from the CWIS would not preclude the protection and propagation of the source water body's BIP. Of course, whether or not CWIS operation harms or threatens the BIP will weigh into an assessment of the magnitude of the CWIS's adverse effects.

In addition, in assessing the impact from the CWIS, EPA must consider the impacts from the operation of the CWIS alone, as well as its impacts considered *in conjunction with* other environmental stressors. In some cases, "other environmental stressors" might include a facility's thermal discharge.

EPA has long held these views on the interaction of CWA §§ 316(a) and (b). For example, in the preamble to the 1976 Proposed Final CWA § 316(b) Regulations, EPA stated:

. . . the conclusion in a 316(a) hearing should not necessarily govern the outcome of 316(b). Certainly, the Agency would not deny a request for less stringent thermal effluent limitations under 316(a) where the necessary statutory showing had been made because of entrainment effects of the plant's intake structure. Similarly, the Agency should not be precluded from addressing evident entrainment problems simply because the plant's thermal effluent is not itself environmentally unacceptable. The concerns of the two sections are different and the legal standards by which compliance with their requirements is to be judged are similarly distinct.

41 Fed. Reg. at 17,389. The Administrator reached a similar conclusion in deciding a permit appeal related to the Seabrook nuclear power plant, but also provided the following more detailed explanation of how sections 316(a) and (b) interact:

Interdependence of Sections 316(a) and (b). The RA ruled that a determination of the effect of the thermal discharge cannot be made without considering all other effects on the environment, including the effects of the intake (i.e., entrainment and entrapment); the applicant must persuade the RA that the incremental effects of the thermal discharge will not cause the aggregate of all relevant stresses (including entrainment and entrapment by the intake structure) to exceed the Section 316(a) threshold. I believe this is the correct interpretation of Section 316(a). The effect of the discharge must be determined not by considering its impact on some hypothetical unstressed environment, but by considering its impact on the environment into which the discharge will be made; this environment will necessarily by impacted by the intake. When Congress has so clearly set the requirement that the discharge not interfere with a balanced indigenous population, it would be wrong for the Agency to put blinders on and ignore the effect of the intake in determining whether the discharge would comply with that requirement.

The Utilities argue that the Agency recognized the independence of Section 316(a) and (b) in the preamble to the regulations, which states that the "concerns of the two sections are different and the legal standards by which compliance with their requirements is to be judged are similarly distinct" (41 F.R. 17389). As SAPL [i.e., the Seacoast Anti-Pollution League] points out, the fact that the legal standards of the two sections are different does not mean that factual aspects of the intake may not be considered in making a legal conclusion about the discharge.

> *   *   *
>
> *Finally, the RA ruled that even if entrainment and entrapment effects would not cause an "imbalance" [in the indigenous population of organisms in the water body] they must be "minimized." This is in accord with Agency policy that "the conclusion in a 316(a) hearing should not necessarily govern the outcome of 316(b)" (41 F.R. 17389). Thus, the RA concluded, even if the Section 316(a) burden were met, an applicant could face restrictions on intake capacity which could only be met by use of closed-cycle cooling. I believe this conclusion is also correct. As mentioned above, some considerations of cost relative to the environmental benefits to be obtained through further minimization would be appropriate.*

Seabrook, 1977 EPA App. LEXIS 16, at *19–*21. *Cent. Hudson*, Decision of the Gen. Counsel No. 63, at 381–83 ("Simply because cooling water could be discharged at a temperature which does not unduly disrupt the aquatic ecosystem does not mean that the withdrawal of the cooling water therefore will not also have an adverse environmental impact.").

10.3.2.f Cumulative Impacts

To the extent that it is necessary to assess the magnitude of the adverse effects from a CWIS's operation, EPA must consider the impacts from the operation of the CWIS alone *and* its impacts considered *in conjunction with* other environmental stressors. In other words, BTA determinations under § 316(b) must consider any adverse cumulative effects of the operation of the CWIS. EPA cannot determine the adverse effects of the CWIS in isolation from other stresses on the same environment. For example, the loss to a CWIS of a certain number of organisms, or a certain percentage of a population of organisms, might be a more serious adverse impact in an environment already suffering from other adverse impacts than it would be in an otherwise healthy ecosystem. As EPA has concluded, "it would be wrong for the Agency to put blinders on." *Seabrook*, 1977 EPA App. LEXIS 16, at *19. In the end, any such cumulative effects must be considered on a case-by-case basis to assess the magnitude of the adverse effects of CWIS operation and the appropriateness of requiring certain expenditures to minimize those impacts.

10.4 Conclusion

The permit requirements in Merrimack Station's new NPDES permit must satisfy the federal technology-based BTA standard of CWA § 316(b) as well as any more stringent requirements necessary to achieve compliance with New Hampshire's water quality standards. The BTA for Merrimack Station, and the permit requirements associated with the BTA, must be determined on a case-by-case, site-specific BPJ basis. Permit requirements needed to satisfy New Hampshire water quality standards must also be determined on a site-specific basis. EPA's determination of permit requirements for CWISs is set forth in the following chapters and, as stated above, these requirements will be subject to the CWA § 401(a)(1) water quality certification process.

11.0 ASSESSMENT OF AVAILABLE COOLING WATER INTAKE STRUCTURE TECHNOLOGIES

11.1 Introduction

This section evaluates Merrimack Station's existing CWISs and their biological impacts. This section also discusses potentially available technological alternatives for ensuring that the design, construction, location, and capacity of the plant's CWISs reflect the best technology available (BTA) for minimizing adverse environmental impacts, as required by CWA ' 316(b). EPA's review considers engineering, environmental, and economic issues related to these alternatives, and identifies technologies that the agency has rejected as well as those warranting further review. EPA's analyses and conclusions regarding which technologies constitute the BTA for Merrimack Station's new permit are presented in Section 12.

11.2 Biological Impacts Associated with Merrimack Station's Cooling Water Intake Structures

Cooling water intake structures (CWISs) cause adverse environmental impacts by (1) killing fish eggs and larvae, and other small forms of aquatic life, as a result of entraining them in water withdrawn from the source water body and sent through the plant's cooling system, and (2) killing or injuring fish and other larger forms of aquatic life as a result of impinging them on CWIS screens. Entrainment and impingement not only kill large numbers of individual organisms, but they also potentially cause or contribute to broader adverse environmental effects. For example, entrainment and impingement can cause or contribute (in combination with other stressors) to the depletion of populations of particular species in the affected source water body. Entrainment and impingement can potentially reduce the abundance of species of commercial and/or recreational importance, species listed as threatened or endangered, and species that provide locally important forage. Indeed, the early life stages of fish (i.e., egg, larva, and juvenile) that are subject to entrainment generally represent an important component of the available forage for much of the aquatic community of the Hooksett Pool. Entrainment and impingement losses can also cause or contribute to a decline in the health of a water body's overall community or assemblage of aquatic organisms.

Inserting a physical structure, such as a CWIS, into a water body that is a major anthropogenic source of mortality for that water body's aquatic organisms necessarily degrades the quality of the habitat provided by that water body. Moreover, entrainment and impingement losses may combine with other natural and man-made stressors to accelerate or worsen the overall deterioration of the aquatic environment in a particular water body, or to prevent or delay its recovery from a degraded state. In Hooksett Pool, much of the available habitat has been, and continues to be, altered by the discharge of heated cooling water from the plant. This stressor alone has the capacity to alter the Pool's fish populations, so additional mortality related to the operation of Merrimack Station's CWIS must be regarded to exacerbate adverse conditions of an aquatic habitat already compromised by heat.

The fish community of Hooksett Pool has been studied at various times for over 40 years, and is described in detail in previous sections of this document (*See* Section 5.3), as well as in numerous reports generated by PSNH (*See* Reference List, Section 13). Other biological communities (*e.g.*, invertebrates) have not been studied as extensively and, consequently, are not as well understood. Therefore, EPA has focused primarily on impacts to the fish community in this review, while recognizing that the adverse effect of the CWIS on aquatic organisms in the Hooksett Pool is not limited to harm to fish.

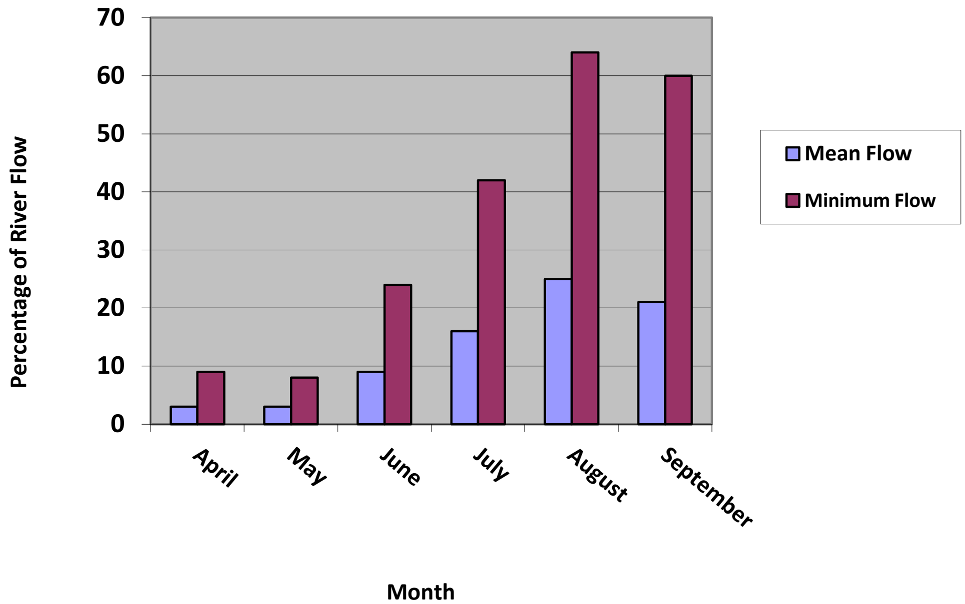
EPA analyzed impingement and entrainment data collected by Merrimack Station as part of the Agency's assessment of the adverse environmental impact of the existing CWISs on resident and migratory fish. The following is a discussion of entrainment and impingement impacts at Merrimack Station.

11.2.1 Entrainment at Merrimack Station

The plankton community generally consists of all microscopic plant and animals present in the water column. For this analysis, however, EPA primarily evaluated impacts to fish eggs and larvae, also known as "icthyoplankton."

Merrimack Station currently utilizes a once-through (or open-cycle) cooling system designed to withdraw up to 286 million gallons per day (MGD) of water from the Hooksett Pool portion of the Merrimack River (85 MGD for Unit 1 and 201.6 MGD for Unit 2), and then to discharge the heated water back to the river. The fraction of the river that runs through the plant, and the corresponding fraction of the plankton community that is entrained with it, varies with the river flow. Under minimum flow conditions, and based on mean monthly flow rates calculated for Garvins Falls Dam, the fraction of the river flow withdrawn by the plant ranges from approximately 9 percent in April to as high as 64 percent in August (Figure 11-1). In June, the month when fish larvae are most abundant in Hooksett Pool, the monthly flow withdrawn for cooling has reached 24 percent of the available river flow under minimum flow conditions and 9 percent under mean flow conditions, based on flow data provided by PSNH for those months. Larvae are still present in July when the intake withdrawal flow rises to 16 percent of the river under mean flow conditions, and up to 42 percent under minimum flow. These represent sizable fractions of the river flow during these months and, by extension, represent the entrainment of sizable fractions of the larva community.

Figure 11-1 Monthly flow withdrawal rates from Merrimack Station as a fraction of minimum and mean river flows based on plant and river data from 1993–2007.



* **Mean flow reflects the average of all years reviewed. Minimum flow reflects the single year with the lowest monthly mean river flow and the mean plant flow for that month and year.**

11.2.1a Entrainment Studies

In order to assess entrainment impacts at Merrimack Station, the plant conducted entrainment sampling in 2006 at both Units I and II from late May through mid-September. Sampling was started again in early April 2007, and continued through June 2007. Entrainment samples were collected using a 0.300 mm mesh plankton net suspended over a barrel sampler located outside the pumphouses of both units. Water was supplied through a three-inch raw water tap drawn from the condenser supply line. Both daytime and nighttime samples were collected. Flow was calculated for each sample using a timed volumetric method to insure that a sample volume of at least 100 m^3 was filtered and collected. A total of 48 valid samples were collected at Unit 1 and 47 at Unit 2 from May 2006 to June 2007. Additional information regarding the sampling method is provided in Merrimack Station's report (Normandeau 2007c).

Merrimack Station attempted to conduct entrainment survival studies in 2007, however, no larvae were collected after eight hours of sampling at both units on the date selected for the study. Therefore, absent convincing site-specific information to the contrary, EPA assumes 100 percent mortality of eggs and larvae entrained at Merrimack Station.

No direct assessment can be made of the fraction of the total number of eggs and larvae present in Hooksett Pool that are lost to entrainment through Merrimack Station's CWISs because no in-river ichthyoplankton sampling was conducted during PSNH's entrainment study. If eggs and larvae are assumed to be equally distributed throughout the river, however, then the fraction of available water that is withdrawn for cooling can provide the basis for an estimate of the percentage of the Pool's eggs and larvae that are lost to entrainment. Based on current information, this is a reasonable approach and it is discussed in more detail in Section 12.

Total entrainment of fish larvae was estimated by Merrimack Station based on sampling conducted during the 2006–2007 study period (Table 11-1). According to the study, total entrainment was estimated to be 2,786,283 larvae from both units in 2006 for the period sampled, and 2,449,268 larvae in 2007. Of the species entrained, white sucker was dominant in both 2006 and 2007, representing 41.6 percent and 45.8 percent, respectively. Other species that were numerically dominant over this two-year period were carp and minnow species (30%), members of the sunfish family (10.8%), and yellow perch (10%) (Table 11-2).

Table 11-1 Estimated total entrainment abundance of fish larvae by species at Merrimack Station, May 2006 through June 2007, data from Normandeau (2007c).

Species or Family	2006			2007		
	Unit 1	Unit 2	Both Units	Unit 1	Unit 2	Both Units
Brown bullhead	18,311	49,461	67,772	0	0	0
Carp and minnow family	165,914	839,808	1,005,722	343,337	241,396	584,733
Herring family	0	0	0	0	25,009	25,009
Margined madtom	9,140	24,794	33,934	0	0	0
Rock bass	57,729	0	57,729	0	0	0
Spottail shiner	0	0	0	4,762	0	4,762
Sunfish family	240,268	148,208	388,476	94,325	93,772	188,097
Tessellated darter	22,944	0	22,944	32,387	49,602	81,989
Unidentified	0	0	0	0	0	0
White sucker	171,333	988,703	1,160,036	665,804	455,125	1,120,929
Yellow perch	0	49,671	49,671	418,741	25,009	443,750
Total	685,637	2,100,646	2,786,283	1,559,356	889,912	2,449,268

Table 11-2 Percent relative abundance of fish larvae by species entrained in both units at Merrimack Station, May 2006 through June 2007, data from Normandeau (2007c).

Species or Family	Larvae - Percent Relative Abundance		
	2006	2007	Mean
Brown bullhead	2.4	0	1.2
Carp and minnow family	36.1	23.9	30.0
Herring family	0	0.1	0.1
Margined madtom	1.2	0	0.6
Rock bass	2.1	0	1.1
Spottail shiner	0	0.2	0.1
Sunfish family	13.9	7.7	10.8
Tessellated darter	0.8	3.3	2.1
Unidentified	0	0	0
White sucker	41.6	45.8	43.7
Yellow perch	1.8	18.1	10.0
Total	99.9	99.1	99.7

During sampling in 2006 and 2007, fish larvae were collected from April to August. None were collected in September. Since sampling was not attempted in March of either year, it is unknown whether larvae were present during that month.

The sampling results indicate that Merrimack Station entrains far fewer fish eggs than fish larvae. This is expected since most species residing in Hooksett Pool, like many freshwater species in general, lay negatively buoyant eggs. This and other characteristics help ensure that these eggs remain on or near the bottom of the river, which reduces their vulnerability to entrainment. According to Merrimack Station's entrainment and impingement report (Normandeau 2007c), an estimated 33,989 eggs were entrained in 2006, while 15,797 eggs were entrained in 2007. Of the eggs collected in 2006, none were identified. In 2007, half of the eggs were from species in the carp and minnow family, and the other half were not identified (Table 11-3).

In addition to entrainment of eggs and larvae, sampling conducted by Merrimack Station in 2007 revealed significant entrainment of post-larval, young-of-year white suckers. According to the plant's report (Normandeau 2007c), an estimated 32,682 post-larval white suckers were entrained in both units during the month of June 2007.

Merrimack Station's entrainment sampling indicates highly variable entrainment rates from one year to the next (Table 11-1). For example, Merrimack Station estimated that Unit 2 entrained 742,481 larvae in May 2006, but only 65,726 larvae in May 2007.

Table 11-3 Estimated total entrainment abundance of fish eggs by species at Merrimack Station, May 2006 through June 2007, data from Normandeau (2007c).

Species or Family	2006			2007		
	Unit 1	Unit 2	Both Units	Unit 1	Unit 2	Both Units
Brown bullhead	0	0	0	0	0	0
Carp and minnow family	0	0	0	7,899	0	7,899
Herring family	0	0	0	0	0	0
Margined madtom	0	0	0	0	0	0
Rock bass	0	0	0	0	0	0
Spottail shiner	0	0	0	0	0	0
Sunfish family	0	0	0	0	0	0
Tessellated darter	0	0	0	0	0	0
Unidentified	9,141	24,848	33,989	7,899	0	7,899
White sucker	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0
Total	9,141	24,848	33,989	15,797	0	15,797

As another way of considering the effect of Merrimack Station's entrainment, Merrimack Station conducted an "Adult Equivalent Loss" analysis. This analysis utilized life stage-specific survival rates to convert projected estimates of loss by life stage to an equivalent number lost at succeeding life stages. Stage-specific survival values used for the adult equivalent analysis were applied for these calculations. The adult stage was defined for selected species based on the number of years required for those species to reach sexual maturity. Based on this analysis, Merrimack Station calculated the loss of 13,298 adult equivalents from entrainment in 2006, and 13,204 adult equivalents in 2007 (Table 11-4). Full details of the adult equivalent loss analysis are presented in Merrimack Station's entrainment and impingement report (Normandeau 2007c).

Table 11-4 Estimated monthly and annual entrainment, and calculated adult equivalent loss, based on entrainment sampling conducted at both units for the months sampled (Normandeau 2007c).

		2006		2007	
Month	Species or Family	Monthly Entrainment Estimate*	Adult Equivalent Estimate	Monthly Entrainment Estimate	Adult Equivalen t Estimate
April	Carp and Minnow family	**		0	0
	Sunfish family	**		42,083	174
	White sucker	**		17,641	112
	Yellow perch	**		0	0
May	Carp and Minnow family	0	0	19,478	84
	Sunfish family	24,773	102	2,122	9
	White sucker	692,860	4,382	181,560	1,148
	Yellow perch	24,848	11	409,742	180
June	Carp and Minnow family	893,945	3,853	573,154	2,441
	Sunfish family	194,503	803	143,892	594
	White sucker	442,444	2,798	954,410	8,448
	Yellow perch	24,823	11	34,008	15

July	Carp and Minnow family	102,635	442	**	
	Sunfish family	160,178	661	**	
	White sucker	24,733	156	**	
	Yellow perch	0	0	**	
August	Carp and Minnow family	9,142	39	**	
	Sunfish family	9,021	37	**	
	White sucker	0	0	**	
	Yellow perch	0	0	**	
September	Carp and Minnow family	0	0	**	
	Sunfish family	0	0	**	
	White sucker	0	0	**	
	Yellow perch	0	0	**	
Total Entrainment*	Carp and Minnow family	1,005,722	4,335	592,631	2,525
	Sunfish family	388,476	1,604	188,097	777
	White sucker	1,160,036	7,337	1,153,611	9,707
	Yellow perch	49,671	22	443,750	195
	All species combined	2,603,905	13,298	2,378,089	13,204

* Entrainment is estimated on an annual basis for all months combined (Total)
** No samples taken

An adult equivalent loss analysis is one factor to consider in approximating the overall magnitude of the adverse impact of entrainment. It is not, however, the only factor to consider and such analyses have a number of important limitations. First, this type of analysis does not factor in the resource value of eggs and larvae in their individual life stages. As mentioned above, eggs and larvae are a food source for many species and losses within these life stages represent losses to the area's overall energy budget and food web at multiple trophic levels, both now and in the future. These losses may have ripple effects, too, as predators that lose forage due to entrainment may have to shift to other organisms, and compete with other predators, or search elsewhere for prey. Finally, egg and larval losses to CWISs may deplete any compensatory reserve provided by the organisms under natural conditions.

Finally, looking only at adult equivalent numbers provides no understanding of the fractional loss those adults represent to populations in Hooksett Pool. Fish population assessments using trapnet sampling data, which Merrimack Station described in a 1976 report as "the most quantifiable sampling technique employed in the Merrimack River Program," indicate that fish abundance declined by 89.5 percent between the 1970s and 2000s (Normandeau 2007a). A review of recent sampling data provided by PSNH puts the loss of 195 adult-equivalent yellow perch (in 2007) into some context. According to PSNH (Normandeau 2007a), the total of two years (2004, 2005) of electrofish sampling and trapnetting resulted in the capture of only 76 yellow perch, many of which were likely juveniles. PSNH conducted additional sampling in the spring and fall of 2008. Interestingly, this sampling collected a total of 76 yellow perch, as well, but 33 perch (44%) were identified as juveniles, either age-0 or age-1 fish (Normandeau 2009a). In light of the relatively low numbers of adult yellow perch caught over three years of sampling, the loss of 195 adult-equivalents takes on greater significance. *See* Section 5 for a more complete discussion on changes in fish populations in Hooksett Pool.

The entrainment study conducted by Merrimack Station in 2006 and 2007 has limitations, but nevertheless provides useful information for developing an estimate of relatively recent entrainment losses, and identifying the fish species or families most vulnerable to entrainment at this facility. While some eggs were entrained during the study, the entrainment of larvae and post-larval juveniles clearly occur in far greater abundance. The entrainment study did not include sampling from October to April. The decision not to sample during late fall through early spring was likely based on life history information for the species residing in Hooksett Pool indicating that entrainable life stages are not likely to be present during that period. It is certainly possible, however, that some larvae exist in Hooksett Pool during March (most likely late March), given their presence in April, although EPA expects that their numbers would be relatively low. Larva entrainment was at its highest from May to July, tapering off in August. No larvae were collected in September sampling conducted in 2007 (Table 11-4). Additionally, no eggs or larvae of anadromous fish species were collected.

11.2.1b Analysis of Entrainment Impacts

Entrainment estimates presented by PSNH in its entrainment and impingement study report (Normandeau 2007c) are based on actual flow withdrawal data during the sampling period. While this may be a fair representation of entrainment rates for the river flow rates and plant operations during the monitoring period, it does not necessarily reflect the entrainment rates under other flow conditions and plant operation scenarios. In order to better understand entrainment rates that can potentially exist in any year, entrainment is estimated using the plant's design intake flows versus actual intake flows. Entrainment estimates were calculated by PSNH using both approaches, and presented in the PSNH November 2007 CWA § 308 Response (Normandeau 2007d). In this report, PSNH estimates that Merrimack Station entrains approximately 3.5 million eggs and larvae (mostly larvae) in an average year, based on its entrainment sampling conducted in 2006 and 2007, and the design intake flows of both units (Normandeau 2007d).

Certain aspects of PSNH's entrainment estimates based on this sampling effort are questionable. Merrimack Station's sampling program provided two years of data for the months of May and June, and one year of data for the months of April, July, August, and September. PSNH averaged the two years of sampling data for the months of May and June in various ways for use in its analysis. This approach would normally be appropriate in such an analysis, especially when combined with a calculated standard deviation of the mean. In this case, however, sampling at Unit 1 took place on only one date in May 2006 (May 31), while sampling occurred three to five times per month from June to August of the same year. Furthermore, according to PSNH (Normandeau 2007c), this single May sampling effort resulted in zero (0) larvae captured at Unit 1, while sampling approximately 175 feet downstream at Unit 2 on the same date resulted in the estimated entrainment of 742,481 larvae. PSNH then estimated the total abundance of fish larvae entrained for May 2006 from *both units* by taking the sum of 0 and 742,481 (Normandeau 2007c). In a subsequent report (Normandeau 2007d), PSNH averaged the 2006 and 2007 entrainment abundance values for Unit 1 (0 + 556,360/2 = 278,180), and presented the value as representing as an "average" year. EPA does not agree that this number accurately represents an average year. The Unit 1 sampling result of zero larvae seems highly unlikely, and EPA questions its accuracy for representing May 2006 entrainment for Unit 1 given that larval abundance in May is second only to the abundance present in June. For its analysis, EPA rejected the single zero value for the May 2006 sampling for Unit 1. Instead, EPA calculated entrainment in May using the single data point (742,481). Using this value for May and the plant's design intake flows, EPA estimates average annual entrainment rates to be approximately 3.8 million larvae.

The presence of fish eggs and larvae in the Hooksett Pool appears to be largely limited to five months of the year (April – August), according to the entrainment data collected at the plant in 2006 and 2007 (Normandeau 2007c). Entrainment of icthyoplankton from the pool represents an additional stress to a system already degraded by the plant's heated effluent. Furthermore, current entrainment rates may reflect the compromised state of fish populations in Hooksett Pool, with fewer adult fish available to contribute to the icthyoplankton community.

In addition, the Hooksett Pool has a limited capacity to recruit a new "year class" to the larger fish community due to the physical barriers to fish movement from the Garvins Falls and Hooksett dams. While there is likely to be some downstream movement (drift) of larvae into Hooksett Pool – a few notable species are discussed below – the reproductive strategies (*e.g.*, nest builders, negatively-buoyant eggs) of many freshwater species make it less likely for their young to move an appreciable distance from their spawning grounds. Nevertheless, virtually all species (or families) that reside in Hooksett Pool were collected during entrainment sampling during the 2006/2007 study. The plant's study did not differentiate larval sunfish, bass, and minnows to the species level.

White sucker and yellow perch were the numerically-dominant indigenous species in the 2007 entrainment sampling, representing 46 and 18 percent, respectively, of all species sampled. Both species have larval stages that are particularly prone to entrainment. These "cool water" species have also been adversely affected by the Merrimack Station's discharge of heated cooling water so that harm from entrainment puts added stress on these populations already impacted by impaired water quality and habitat. The relative abundance of yellow perch and white sucker in the 1960s was 26 percent and 16 percent, respectively. By the 2000s, those numbers had both dropped to 2 percent. While the recovery of these species will require reduced thermal discharges, EPA expects that continued entrainment at this level would likely interfere with a recovery.

American shad is another species particularly vulnerable to entrainment. While larval shad may not currently be abundant in Hooksett Pool, new state and federal efforts to restore American shad to the Merrimack River should result in greater numbers of their larvae present in Hooksett Pool. The American Shad Restoration Plan for the Merrimack River, which began implementation in 2010, sets a goal of stocking approximately four million American shad fry (larvae) annually in the Merrimack River, upstream of Hooksett Pool. USFWS estimated that one million American shad larvae were stocked in the Merrimack River in 2010. Some of these larvae, which are approximately 5-6 mm long when released in June and July, would be expected to reach Hooksett Pool, according to discussions with USFWS (Personal Com. 5/25/10, 8/9/10).

In addition to the upstream stocking of shad larvae and adults, re-establishing upstream passage for anadromous species to access Hooksett Pool and spawning grounds beyond is an ongoing goal of state and federal anadromous fishery restoration efforts. Were anadromous species, such as American shad and alewife, provided upstream access at Hooksett Dam to reach the Hooksett Pool on their own, the larvae produced from spawning in the pool would also be highly vulnerable to entrainment. While Merrimack Station withdraws on average approximately 19 percent of the available flow in Hooksett Pool during July over the 15-year period from 1993–2007, the plant has withdrawn significantly more during individual years. For example, the plant's mean intake flow in July 1995 represented 42 percent of the available river flow, a period when shad larvae could be present. Looking at specific dates within July 1995 reveals even more extreme flow withdrawal rates. On July 7, 1995, the flow at Garvins Falls Dam was calculated to be 529.9 cfs. Based on this flow rate and the plant's reported average monthly flow of 398.2 cfs for July 1995, EPA calculated that the plant withdrew approximately 75 percent of the available river flow.

Merrimack Station's flow withdrawal rates, as a percentage of available river flow, are even greater in August, a month when eggs and larvae are still present in Hooksett Pool. EPA calculated the mean monthly flow withdrawal rate for August to be 25 percent, based on a 15-year average (1993–2007). In August 2003, the mean flow withdrawal rate reached 64 percent of the available flow, according to EPA's calculations. Merrimack Station's highest daily withdrawal rate (that EPA found) occurred on August 14, 2001, when the percentage of available river flow withdrawn by the plant was calculated to be 83 percent.

In addition to entrainment losses to individual species, the loss of eggs and larvae from all fish species, as well as other zooplankton, represents a significant reduction in available forage for older juvenile fish and other aquatic organisms that typically prey on them. The environmental impact of this loss of forage opportunity cannot be quantified at present, but it clearly creates added stress on the Hooksett Pool ecosystem because, in the absence of the organisms lost, foraging must be directed towards other available sources. Thus, competition increases for what forage is available and the typical predator/prey relationships among resident organisms may be altered. Similarly, although the effect cannot be quantified, entrainment losses may deplete the compensatory reserve that fish species may rely upon to ensure their health and survival under natural conditions.

EPA has concluded that entrainment at Merrimack Station represents a significant adverse environmental impact based on the available entrainment data, the capacity of Merrimack Station to withdraw a significant fraction of the river's flow and planktonic community (and as a result, cause substantial mortality to fish eggs and larvae), the poor status of the Hooksett Pool fish community, and the limited ability for the fish community to recover under current conditions in the pool. Reducing entrainment impacts will not only facilitate the recovery of the resident fish community in Hooksett

Pool, it will also benefit efforts to restore anadromous fish in the Merrimack River watershed.

11.2.2b Impingement at Merrimack Station

When water from Hooksett Pool is drawn into Merrimack Station's two CWISs, organisms too large to pass through the traveling screens, and unable to swim away from the intake current, become impinged against the screens and other parts of the intake structure. Impingement of fishes and other aquatic life on the intake screens can injure or kill those organisms. Data collected at Merrimack Station indicate that impinged organisms are primarily limited to fishes. Therefore, EPA has focused its evaluation of impingement impact on fishes.

Since 1992, impingement monitoring has been routinely conducted at Merrimack Station during warmer weather, under low river flow conditions. The existing NPDES permit, issued in 1992, requires impingement monitoring under the following conditions:

> *PSNH shall conduct impingement monitoring at the Merrimack Station when flows from Garvins Falls Station drop below 900 cfs during any period from July 1st through October 15th. Impingement monitoring shall consist of collecting all fish from both MK-1 and MK-2 traveling screen washes during one continuous 48-hour period per week.*

Prior to this, impingement monitoring for out-migrating Atlantic salmon smolts was required annually from April 15 to June 15, and for clupeids (river herring and American shad) from September 15 to October 31. Following five years of impingement sampling (1976–78, 1985, 1986), PSNH requested that the monitoring requirements be discontinued based on reported low impingement rates. According to a letter from PSNH to EPA, dated April 15, 1987, monitoring results indicated that only 216 alewives and 1 American shad had been impinged during all the monitoring periods (Table 11-5). The same letter did note that between 2,000 – 4,000 juvenile alewives were "entrained" during the period September 20 and October 2, 1984. According to PSNH, juvenile alewives migrating along the river's western bank must have been attracted to the flow entering the plant's intake structures (PSNH 1987). The company noted that there were extremely low flows and water levels during that time period, which likely contributed to the entrainment event. (It is unclear from the correspondence how or why fish that were large enough to be impinged would instead be entrained. Perhaps, the relatively high intake velocities of the plant's two CWISs caused the young herring to be extruded through the screens.) With concurrence from NHFGD, NHDES, and USFWS, EPA later altered the impingement monitoring requirements, as stated in a letter to PSNH dated September 23, 1987. The reduced requirements were retained when the permit was reissued in 1992 and represent the existing impingement monitoring permit conditions.

EPA's current view is that this sampling regime – limited to from July 1 to October 15 at times when flows are below 900 cfs – fails to require monitoring at the times when conditions associated with increased impingement are most likely to exist. Studies conducted for this plant and others indicate that increased impingement rates are often associated with high flows and wet weather events. Also, as previously mentioned, the downstream migration of Atlantic salmon occurs from mid- to late-spring, before impingement monitoring begins. Finally, the downstream migration of young-of-year river herring is often triggered by the high flows associated with wet weather events in late summer and early fall. Yet, under all these circumstances, the current permit does not require monitoring. Results from a two-year study (2005–2007), which are discussed in more detail in Sections 11.2.2b1–3, indicate that impingement is lowest in August and September when river flows are typically at their lowest, and highest in November, December, May and June when flows are comparatively high (Figures 11-2, 11-3). Thus, while the results of impingement monitoring conducted under the existing permit requirement suggest that there is minimal impingement of fish under low flow conditions (i.e., below 900 cfs), greater impingement may well be occurring under higher flow conditions.

Figure 11-2 Monthly mean flow at Garvins Falls Dam, based on USGS flow data from 1993 to 2007.

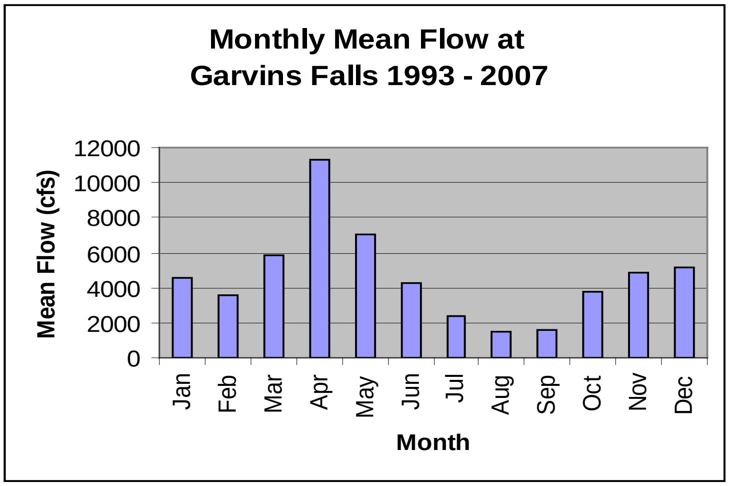
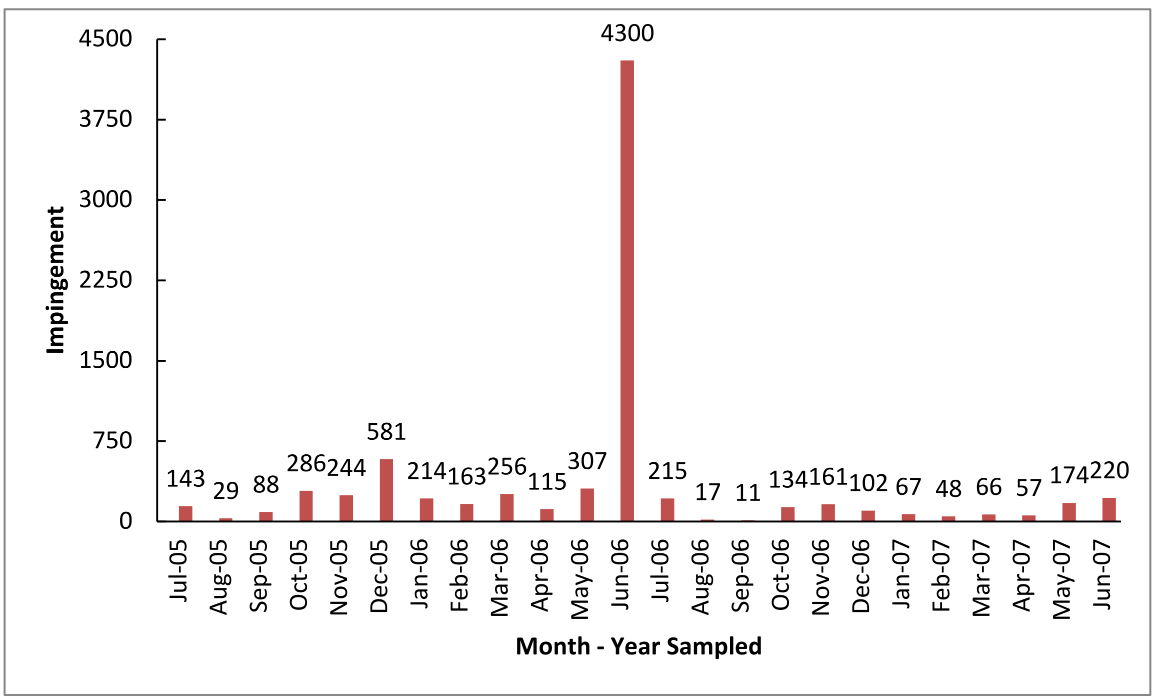


Figure 11-3 Estimated monthly total impingement abundance at Merrimack Station, both units combined adjusted for flow and collection efficiency, data provided in Normandeau (2007c).



The existing discharge permit also requires Merrimack Station to submit to EPA a written report of any extraordinary impingement events ("EIE") at the plant. An EIE is defined as an event in which 50 or more fish at any one time, of any kind or species, are either distressed or killed as a result of impingement. EPA received four EIE reports in 1997 and two in 1998 (Table 11-5).

Table 11-5 River herring impingement and entrainment events at Merrimack Station from 1984 to present, reported by PSNH.

Date of Impingement	Species	Number Impinged	Age Class or Size Range	Unit(s)
September 1984	Alewife	2000–4000	Juvenile	both
September 15–17, 1985	river herring	15	Juvenile (5–7.5 cm)	Unit 2
September 23–25, 1985	river herring	11	Juvenile (7.5–9 cm)	Unit 2
Sept. 30–Oct. 2, 1985	river herring	117	Juvenile (8.5–10 cm)	Unit 1
October 6–8, 1985	river herring	15	Juvenile (9.5–11 cm)	Unit 1
October 14–16, 1985	river herring	54	Juvenile (7.5–12 cm)	Unit 2
October 15–17, 1986	river herring	3	Juvenile (11.5 cm)	Unit 2
October 20–22, 1986	river herring	1	Juvenile (11.5 cm)	Unit 2
September 26, 1997*	river herring	100–150	Juvenile (6.5–9.5 cm)	Unit 2
September 30, 1997*	river herring	103	Juvenile (6.5–9.5 cm)	Unit 2
October 4, 1997*	river herring	63	Juvenile (6.5–9.5 cm)	Unit 2
October 30, 1997*	river herring	147	Juv.-Adult (6.0–25.5 cm)	Unit 2
September 3, 1998*	river herring	274	Juvenile (6.0–9.0 cm)	Unit 2
September 9, 1998*	river herring	72	Juvenile (7.0–10.0 cm)	Unit 2

* Submitted by PSNH to EPA as "extraordinary impingement events"

All of these reports identified the impingement of juvenile river herring, typically ranging in size from 6.5–9.5 cm (2.6–3.7 in). In one case, adult herring up to 25.5 cm (10 in) were impinged. EIE's were reported between September 3 and October 30, with four of the six occurring in September. The number of fish impinged ranged from 63 to 274 herring per event, with a mean of 131 fish. In every report but one (dated September 4, 1998), PSNH stated that the impingement events were due to the increased number of juvenile fish observed in the river that year. While the total number of reported events is low, this may reflect, among other things, the limited spawning activity of herring in Hooksett Pool and waters above the plant. As discussed in Section 11.2.2a of this document, a new multi-state and federal effort to restore American shad to the Merrimack River should result in a significant increase in the number of juvenile shad moving downstream through the Hooksett Pool during their fall outmigration to the sea. All of these fish would have to pass by Merrimack Station's cooling water intake structures. In addition, as upstream fish passage improves and more spawning of herring and shad occur in and above Hooksett Pool, EPA expects that the rate of impingement of these anadromous species will increase, as well. Similarly, impingement rates of resident species would be expected to increase as their populations recover following the restoration of the Hooksett Pool's thermal environment.

11.2.2b1 Impingement Studies

In response to an information request by EPA dated July 3, 2007, PSNH submitted to EPA the document, "Entrainment and Impingement Studies Performed at Merrimack Generating Station from June 2005 Through June 2007," dated October 2007 (Normandeau 2007c). These studies were originally planned and undertaken in response to an information request by EPA to PSNH, dated December 30, 2004. The information requests and other correspondence related to study development are included in the permit record.

The Merrimack Station study conducted between June 2005 and June 2007 was the most comprehensive effort to date for quantifying impingement at the plant, and describing temporal variations in impingement rates. According to the report, "primary sampling units" consisted of weekly or bi-weekly sampling events of approximately 24 hours in duration. Twenty-four-hour impingement samples were collected from approximately 9:30 a.m on Wednesday to 9:30 a.m. Thursday at both Units I and II in each weekly or bi-weekly sampling period (Normandeau 2007c). Weekly sampling occurred from late June through mid-December 2005, from mid-March through November 2006, and from mid-March through the end of June 2007. Biweekly sampling took place during the intervening time periods. Only one 24-hour sample was collected in June 2005, however. Therefore, EPA omitted June 2005 data when calculating the annual impingement for the first sampling year. Sampling was not conducted during extended unit outages for the unit offline, such as during the five-week period during April and May 2006 for Unit 2, and the 4-week period in September 2006 for Unit 1.

11.2.2b2 Impingement Sampling Results

Annual impingement varied considerably between the two 12-month periods sampled with estimated total impingement for both units in Year 1 (July 2005–June 2006) to be 6,054 fish, and Year 2 (July 2006–June 2007) to be 982 fish. When adjusted for collection efficiencies, Merrimack estimates the totals to be 6,736 fish for Year 1 and 1,271 fish for Year 2 (Normandeau 2007c). Twenty-one (21) species were collected during the 24-hour sampling collections, from which six represented 88 percent of the total catch for the two-year period. Bluegill clearly dominated with a relative abundance of 62.6 percent. Spottail shiner (7.4%) was a distant second followed by black crappie (5.3%), largemouth bass (4.6%), yellow perch (4.1%) and pumpkinseed (4.0%). This species composition is similar to results from electrofishing sampling conducted in 2004 and 2005. In that study, spottail shiner and bluegill ranked second and third, respectively, behind largemouth bass, according to the two-year average (Normandeau 2007a).

While impingement at Merrimack Station occurs year-round (*see* Figure 11-3), one month stood out based on the two-year study. According to data provided by the plant (Normandeau 2007c), June had the highest overall impingement rate when both years were averaged, although rates varied significantly from an estimated 4,300 fish impinged in 2006 (both units combined) to 220 fish impinged in 2007 (Figure 11-3). December had the second highest impingement rates, and May was third. Unreported before this impingement study was the relatively high rate of impingement in late spring, fall, and early winter periods, as compared to late summer when Merrimack Station, as required in its existing discharge permit, conducts low-flow impingement monitoring. According to Merrimack Station's 2005–2007 impingement study, August and September ranked lowest (*i.e.*, eleventh and twelfth, respectively) among all months in impingement abundance when averaging the two years of data collected.

According to the Merrimack Station impingement report (Normandeau 2007c), the impingement of an estimated 8,007 fish at various life stages occurred from July 2005 to June 2007, based on actual intake flows during the two-year period. PSNH converted the 8,007 value to a three-year-old adult equivalent value of 1,033 fish. This value, however, only represents impingement rates for the six species that were most abundant during the study, which collectively comprised 90 percent of all species impinged.

As discussed under entrainment impacts (11.2.1b), calculating the estimated adult equivalent loss associated with the mortality of younger life stages is of interest, but is inadequate by itself to assess or characterize the overall impacts of entrainment and impingement. Without an estimate of total fish abundance in Hooksett Pool, EPA cannot determine the percentage of the total local fish population that is lost to impingement. Similarly, because no quantitative assessment was made of the populations of particular fish species in the Hooksett Pool during the impingement studies, there is no way to know the fraction of each species population that is lost to impingement. Nevertheless, studies conducted by the plant in 2004 and 2005 indicate that fish abundance is at a four-decade low in Hooksett Pool. Therefore, while impingement losses result in fewer adult equivalents than losses from entrainment, the numbers are not insignificant based on all available information on the status of the fish community in Hooksett Pool, especially when considered as a cumulative impact on top of other adverse impacts (such as entrainment losses and thermal discharge effects).

11.2.2b3 Analysis of Impingement Impacts

With only two years of impingement data and large variability between those years, the magnitude of impingement-related impacts may still not be fully known. Nevertheless, this data clearly documents that significant impingement events do occur, such as when scheduled sampling in June 2007 resulted in the capture of 4,300 fish. This event could have, and it seems likely would have, gone unnoticed or unreported had sampling not been specially scheduled at that time. Indeed, the existing permit's low-flow impingement monitoring requirement would not have detected this impingement event because it does not require monitoring in June.

This data also demonstrates that fish impingement rates at Merrimack Station are substantially greater than previously indicated from the low-flow impingement monitoring that is conducted from July to October each year. In addition, the data documents that impingement at the facility occurs year-round. Furthermore, impingement survival rates calculated by Merrimack Station are questionable in EPA's view, but even these rates are appreciably lower than rates obtained elsewhere during studies conducted by EPRI (2006). The loss of thousands of juvenile fish per year from an ecosystem already stressed by the plant's thermal effects and entrainment constitutes an adverse environmental impact.

In addition to impingement losses to resident species, the potential to impinge anadromous species such as river herring and American shad during years when juveniles of these species are abundant in Hooksett Pool is an added hazard to these fish as they migrate to sea. As Merrimack Station suggested in "extraordinary impingement event" reports submitted to EPA in 1997 and 1998, such events, which impinged up to 274 herring at one time, likely occurred due to the increased number of juvenile fish in the river. If so, then as herring and shad runs are restored in the Merrimack River, and more juvenile fish are present in Hooksett Pool, the likelihood of extraordinary impingement events occurring would be expected to increase. As discussed above, an increase in juvenile American shad is expected in Hooksett Pool with new long-term shad restoration plans underway. The reported *entrainment* of between 2,000 to 4,000 juvenile herring at Merrimack Station in 1984 illustrates the potential impact that can occur to migrating fish, all of which represent a single year class. By the same token, impingement could contribute to impeding or undermining efforts to restore healthy runs of these fish to the Merrimack River.

11.2.3 Cumulative Adverse Effects

Losses from fish impingement and entrainment at Merrimack Station must also be considered in the context of other stressors that eggs, larval fish, juvenile fish, and adult fish are routinely subjected to in Hooksett Pool. These cumulative adverse effects have been discussed above. Furthermore, Section 5 of this document details adverse effects related to the plant's discharge of heated cooling water. EPA concludes that the thermal discharge limits proposed in the Draft Permit will help restore aquatic habitat within Hooksett Pool that has been degraded by exposure to thermal effluent for over 40 years. Moreover, these thermal improvements will create conditions that will help to allow the recovery of the aquatic organisms that should reside in, or migrate through, these waters. In addition, EPA concludes that minimizing entrainment and impingement mortality will also contribute to this recovery, whereas failing to reduce entrainment and impingement sufficiently is likely to impede it.

11.3 Options for Ensuring that Merrimack Station=s CWISs Reflect the BTA for Minimizing Adverse Environmental Impacts

As described in Section 10, viewed broadly, and as dictated by CWA ' 316(b), several major aspects of CWISs must be considered in determining the BTA for reducing adverse impacts from CWISs. EPA must consider:

1) Alocation@ options, which for an existing plant would involve *re*-locating the CWIS to a new, less biologically productive or sensitive site or part of the water column in order to reduce entrainment and/or impingement effects;

2) Adesign@ options to lessen entrainment and/or impingement by reducing the velocity of the water drawn into the CWIS, by reducing the mesh size of intake barriers so that additional or all life stages are excluded from entrainment, and by enhancing screening and fish return systems to try to maximize the degree to which impinged organisms can be returned to the source water body unharmed;

3) Acapacity@ (or flow) reduction options, which are considered to reduce the number of organisms entrained and impinged by the CWIS; and

4) "construction" options, which are applicable for any option that requires construction, and which entails considering the adverse environmental impact of constructing the technology along with alternatives for minimizing those impacts. For example, moving a cooling water intake to a new location might offer potential reductions in entrainment and

impingement, but the necessary construction could have adverse environmental effects that would also need to be considered in deciding whether such a re-location should be considered the BTA under CWA ' 316(b).

Within the broad categories described above, there are numerous specific technological options to consider. Some of these technologies have been in use for many years and, as a result, are well-established and understood. Indeed, many of these options are discussed in EPA's 1977 Draft CWA § 316(b) Guidance, the EPA 1976 Development Document, the 1994 EPA Background Paper No. 3, the 1996 EPA Supplement to Background Paper No. 3, and the various past regulatory preambles issued by EPA, including the preambles to the recent proposed and final Phase I CWA § 316(b) regulations (applicable to new facilities).

To determine the BTA for minimizing the adverse environmental impacts of the CWISs at Merrimack Station, EPA examined the plant's existing CWISs as well as a range of technologies and operational measures for reducing their impingement and entrainment. EPA considered the elements for identifying the BTA based on the terms of CWA ' 316(b), *i.e.*, that the location, design, construction, and capacity of the CWIS should reflect the Abest@ technology that is Aavailable@ for Aminimizing@ adverse environmental impacts. EPA first evaluated the performance of the technologies and operational measures in terms of the extent to which they could reduce entrainment and impingement at Merrimack Station. EPA then considered additional relevant factors, such as secondary environmental effects, energy effects, and cost.

11.4 Merrimack Station's Existing Technologies

11.4.1 Existing CWIS Location

The location of CWISs can vary in terms of where they are placed in relation to the shoreline (*i.e.*, at the shoreline or offshore) as well as in terms of where they are located in the water column. Furthermore, the location of CWISs can vary with regard to the type of natural resources present in the water body. For example, a CWIS could be located within an estuary, a lake, a river, or another type of water body, and the water body in question might or might not provide spawning and nursery habitat, migratory corridors, or some other type of significant habitat. EPA's Guidance Document for Best Technology Available for the Location, Design, Construction and Capacity of Cooling Water Intake Structures for Minimizing Adverse Environmental Impact (EPA 1976) recommends selecting CWIS locations to avoid important spawning areas, juvenile rearing areas, fish migration paths, shellfish beds, or areas of particular importance for aquatic life.

Merrimack Station has two CWISs located on the west bank of Hooksett Pool, approximately 2,200 feet upstream from the mouth of the discharge canal (Figure 2-1). The Unit 1 CWIS is approximately 120 feet north of the Unit 2 CWIS. The bulkhead of each CWIS extends about 25 feet from the shoreline and the floor of each CWIS is approximately 12 feet below the river surface.

It is often advisable, when possible, to locate an intake in relatively less sensitive or less biologically productive areas, and/or in areas where low approach velocities can be attained. The natural channel of the river, or thalweg, in the Hooksett Pool runs close to the west bank at Station N-5, which is in fairly close proximity to the plant's CWISs, according to river profiles presented in the plant's 1979 Summary Report (Normandeau 1979). Migrating fish often move along the thalweg, which is a factor when considering the potential of Merrimack Station's CWIS's to impinge migrating fishes, such as river herring, Atlantic salmon, American shad, and American eel, as well as resident species moving within the pool.

The location of a CWIS opening within the water column is another important characteristic that affects the structure's capacity to impinge organisms. Structures that withdraw from mid-water column or surface waters tend to impinge pelagic (*i.e.*, open water) species of fishes, while intakes that withdraw from bottom waters impinge more demersal (*i.e.*, bottom-oriented) species, as well as fish migrating along the river's thalweg. According to information provided in the PSNH Nov. 2007 CWA § 308 Response (Normandeau 2007d), the intake for Unit 1 withdraws water from a horizontal slot five feet wide between elevations 181 feet and 186 feet, or from approximately one-foot above the river bottom to one-foot beneath the surface at low water (*i.e.*, elevation 187 feet). The Unit 2 CWIS, having no upper portion to the concrete barrier, withdraws from nearly the entire water column, from one foot above the bottom up to the surface at the full river elevation of 190 feet (Normandeau 2007d). Based on location of the openings of Merrimack Station's CWISs, which collectively withdraw from the entire water column, the plant's intakes have the capacity to impinge fishes that occupy any portion of the water column, including areas near the bottom.

Despite the potential of Merrimack Station's CWISs to impinge and entrain fish at their current locations, EPA concludes that moving the CWISs to another location in the Hooksett Pool would be unlikely to reduce adverse environmental impacts in a material way, and could cause additional harm to the habitat from in-water construction activities. The Hooksett Pool is a fairly narrow, shallow stretch of the Merrimack River, between Garvins Falls Dam and the Hooksett Dam, averaging approximately 600 feet wide and between 6 and 10 feet deep. Based on the relatively homogeneous nature of the Hooksett Pool, EPA concludes that relocating the CWISs would be unlikely to significantly decrease the facility's impingement or entrainment of aquatic organisms. Therefore, EPA does not consider changing the location of the existing CWISs to be BTA for Merrimack Station.

11.4.2 Existing CWIS Design

Power plant CWISs are designed to provide the raw water necessary for condensing steam in the plant's condensers. At the same time, CWISs can be designed in different ways to reduce harm to aquatic organisms. Although the most effective way to avoid mortality to aquatic organisms from impingement is to avoid the impingement in the first place, some fish species and other aquatic organisms are generally capable of surviving impingement if they are quickly and gently returned to their environment. Several components of a CWIS's design affect whether an impinged organism is likely to be harmed or returned alive and uninjured to the receiving water. These critical components include the intake opening, intake velocity, traveling screens, power spray wash system, and fish return system. These aspects of the existing intake design will be discussed below. Proper maintenance and operation of the existing technologies are also critical to minimizing impingement losses.

11.4.2a Existing Intake Opening Design and Velocities

The quantity of water required for cooling and the dimensions of the intake structure openings dictate the velocity of the water being withdrawn. The speed of the water passing through CWIS screens is commonly referred to as the "through-screen velocity." The speed of water being drawn into the CWIS and toward the screens is often referred to as the "approach velocity." Higher intake velocities tend to represent a greater potential for impingement. When aquatic organisms swim or are pulled into a CWIS, high intake velocities may overwhelm their ability to swim away. Once impinged, the pressure of the fast flowing water can then hold the fish (or other organism) against the screens, increasing the potential for killing or injuring them. In addition, some species, such as Atlantic salmon shad and river herring, cue to water movement in order to migrate downstream and, therefore, may be attracted to intake flows, putting them at greater risk of being impinged.

Merrimack Station operates two intake structures that withdraw water directly from Hooksett Pool. Each intake structure has two openings which provide cooling water to the two circulation pumps. The openings for Unit 1 are approximately 10-feet wide each, and for Unit 2, approximately 11-feet wide, according to engineering plans submitted by Merrimack Station. The openings of both intake structures are protected by vertical bar racks with 3.5-inch spacing on center (Normandeau 2007d). According to the PSNH Nov. 2007 CWA § 308 Response (Normandeau 2007d), the through-screen velocities of the plant's two units are 1.5 feet per second (ft/sec) (Unit 1) and 1.82 ft/sec (Unit 2). These velocities range from three to over three-and-a-half (3.64) times greater than a rate of 0.5 ft/sec, the intake velocity identified by EPA as being effective for minimizing the impingement of a broad range of fish species. EPA identified this target intake velocity in the Phase I CWA § 316(b) Rule, which applies to new facilities with CWISs. *See* 40 C.F.R. § 125.84(b)(2). EPA also later identified the same intake velocity standard in the Phase II Rule for large existing power plants, like Merrimack Station, but the Phase II Rule was later suspended and is not currently in effect. *See* 40 C.F.R. § 125.94(a)(1)(ii) (currently suspended).

Looking at the information underlying this intake velocity standard, EPA found that studies assessing the ability of fish to swim against current velocities found wide variation depending on species, body length, and water temperature. Some resident and anadromous species of interest to this permit were studied, and presented in a report entitled, "Technical Evaluation of the Utility of Intake Approach Velocity as an Indicator of Potential Adverse Environmental Impact under Clean Water Act Section 316(b)" (EPRI 2000). Studies conducted on yellow perch resulted in "critical swimming velocities" that ranged from 0.6 ft/sec to 1.1 ft/sec (Table 11-6). Other species found in Hooksett Pool that were studied include the pumpkinseed sunfish, smallmouth bass, largemouth bass, brown bullhead catfish, and white sucker, as well as anadromous species such as alewife, blueback herring, and Atlantic salmon (Table 11-6). In general, based on the species reviewed, the shorter the length of the fish and/or the lower the temperature, the lower the mean critical velocity observed (EPRI 2000). Prolonged swimming speeds are highly dependent on fish length, with smaller (and younger) fish of a particular species typically being weaker swimmers. EPRI (2000) found that water temperature had a strong effect on the critical swimming speed of nearly all species tested. According to the report, all fish appeared "less motivated" to swim at lower temperatures. As illustrated in Table 11-6, the critical velocities of all the Hooksett Pool species tested were either entirely or partially below the intake velocities of Units I and II at Merrimack Station, which are 1.5 ft/sec and 1.8 ft/sec, respectively. Given the available information, approach velocities of both CWISs at Merrimack Station are sufficiently high to cause or contribute to fish impingement.

Table 11-6 Comparison of mean critical swimming velocities of some resident and anadromous fish species found in Hooksett Pool, based on information provided in EPRI (2000), and intake velocities for Merrimack Station.

Species	Type of Species	Mean Length, or range, in inches (cm)	Experimental Temperature, or range, in ˚F (˚C)	Mean Critical Velocity or Range, in ft/sec (cm/s)	Intake Velocities for Units I and II, in ft/sec
Alewife	Anadromous	3.9–5.4 (9.8–13.7)	68–77 (20–25)	**1.2**–**2.1** (35.7–63.6)	Unit 1 – 1.5 Unit 2 – 1.8
Atlantic salmon	Anadromous	3.8–22.6 (9.6–57.5)	46–64 (8–18)	**1.5**–**7.1** (44.2–216)	
Blueback herring	Anadromous	3.4–3.5 (8.5–8.9)	68–77 (20–25)	**0.7**–**1.1** (22.7–34.7)	
Brown bullhead	Resident	2.0 (5.2)	63 (17)	**1.1** (32.0)	
Largemouth bass	Resident	2.3–5.0 (5.8–12.6)	41–86 (5–30)	**0.7**–**1.6** (20.0–49.7)	
Pumpkinseed	Resident	5.0 (12.7)	68 (20)	**1.2** (37.2)	
Smallmouth bass	Resident	0.8–0.9 (2.0–2.3)	41–95(5–35)	**0.2**–**1.0** (4.8–31.2)	
Yellow perch	Resident	4.1–6.1 (10.5–15.6)	36–68 (2–20)	**0.6**–**1.1** (18.9–34.0)	
White sucker	Resident	6.7–14.6 (17.0–37.0)	54–66 (12–19)	**1.6**–**2.4** (48.0–73.0)	

11.5.2b Existing Traveling Screens

Merrimack Station still utilizes the same traveling screen design and technology that was originally installed with each unit: Unit 1 in 1960 and Unit 2 in 1968. Each unit employs two traveling screens. According to information provided by Merrimack Station (Normandeau 2007d), frames and screens were replaced on Units I and II in 2002 and 1988–1989, respectively. The mesh size of the traveling screens is 3/8-inch square, which is a size commonly used in the industry for CWIS screens. This mesh size should be small enough to prevent the entrainment of adult fish and most juvenile fish through the plant's cooling water system, but not younger and smaller lifestages (*i.e.*, eggs and larvae). In addition, narrow shelves (2–3 inches wide) are attached to the screens which carry debris and fish up as the screen rotates. These shelves are designed primarily for moving debris, not fish. Since there are no buckets or troughs used to carry fish safely to the fish return trough, fish can fall off the screen shelves as the screens emerge from the water. Consequently, fish can suffer injury or exhaustion from being dropped and re-impinged as the screens rotate.

While the mesh size of the screens used by Merrimack Station should be small enough to prevent the entrainment of young fish that have matured beyond the larval stage, entrainment studies by the plant in 2007 indicate that significant numbers of post-larval white suckers were entrained in June 2007. According to Table 5-1 of the plant's entrainment and impingement report (Normandeau 2007c), Merrimack Station estimates that 32,682 young-of-year, or older, white suckers were entrained in June from both units combined. The report further estimated that entrainment of 32,682 juvenile white suckers is equivalent to the loss of 2,618 adult white suckers. No reason is provided in the report for why fish of this size were being entrained. EPA expects that the high intake velocities associated with both intake structures may be part of the reason. Again, high intake velocity can overcome a fish's ability to swim away from an CWIS and can result in fish being pulled through a screen mesh that would be small enough to prevent entrainment if combined with lower intake velocities. The entrainment of larger fish may also reflect deficiencies in the fish removal system, such as if impinged fish are allowed to pass over the traveling screens without being removed.

Merrimack Station's traveling screens are typically rotated twice daily, and more frequently when debris load is high. Fish that are impinged when the screens are stationary suffer the physical trauma of being pinned against the screen, potentially for hours, until the screens are rotated. These fish are much less likely to survive than fish that are promptly removed from the screens and returned to their habitat in a safe manner.

When river temperatures drop below 35˚F (1.7˚C) during the months of December through March, Merrimack Station recirculates hot water back to the intakes of both units in order to prevent ice formation. The hot water is discharged approximately eight feet outboard of the trash racks through six-inch spray nozzles. Both units operate in this mode for approximately 90 days per year. The rate of hot water discharged is 8 MGD (12.4 cfs) for Unit 1 and 13 MGD (20.1 cfs) for Unit 2. The potential effects to impinged fish and other aquatic life have never been assessed. Discharging hot water near the intakes may even attract fish to the CWIS, similar to the way that fish are attracted to heated water in the discharge canal during cooler months. Attracting fish to the intake would make them more vulnerable to impingement. The plant's adjusted impingement estimates, based on averaged annual sampling conducted at both units from June 2005 to June 2007, demonstrated that 20 percent of the estimated total annual impingement abundance occurred during the winter period (December through March). Impingement abundance during December 2005 was calculated to be the second-highest month during the two-year sampling period (Normandeau 2007c).

Fish impinged during this December to March period would have become acclimated over many months to colder water temperatures, but then would be subjected to rapid exposure to much higher water temperatures, in addition to the stress of impingement. Since the plant only operates the traveling screens twice a day during periods of low debris load, these fish may have to endure sudden exposure to high water temperatures for up to 11 hours while the traveling screen is not being rotated. Because the heated water is drawn from the circulation pumps, fish impinged on the screens may also be exposed to biocides such as chlorine, which is injected periodically to remove fouling organisms throughout the cooling system. These exposures, combined with the physical stresses of being impinged, are likely to further reduce the chance of survival.

11.4.2c Spray Wash Systems

As rotating traveling screen panels emerge from the water, laden with fish and debris, a power spray wash system clears the material from the screens. The power spray wash systems employed at Merrimack Station were installed when the units were originally built in 1960 (Unit 1) and 1968 (Unit 2). Each traveling screen has a single-pressure spray header. According to information provided by Merrimack Station, the pressure of the spray wash system in Unit 1 is 85 pounds per square inch (psi), and 80-100 psi in the Unit 2 system (Normandeau 2007d). These are high pressure systems designed primarily for debris removal. More recently, spray wash systems have been developed for use by power plants that use both high and low pressure spray washes for the removal of debris and fish, respectively. With such systems, as the traveling screens rotate, they are first hit by the low pressure spray wash (typically 30 psi or less), which is intended to remove fish from the screens without injuring them. The screen is then hit by a high pressure wash (80 psi or greater) that clears off all remaining debris. The low pressure spray wash used in the EPRI (2006) survival study was 10 psi.

It is evident that the Unit 1 and II spray wash systems are designed to remove debris from the traveling screens, not to safely remove fish and other soft-bodied aquatic organisms. These systems are typical for CWISs built during the 1950s and 1960s. Occasionally, during winter months, one circulation pump and one traveling screen are shut down on Unit 2 due to the formation of frazil ice. By not operating both traveling screens, 100 percent of the screen wash flow is directed at the operating traveling screens. This concentrated flow further increases the spray wash pressure against the impinged fish.

While single-pump operation under these conditions averaged only approximately 8.4 days per year from December 2000 to February 2007, inter-annual variability ranged from 0 to 26 days (Normandeau 2007d).

11.4.2d Fish Return Conduits

Power plants that utilize once-through cooling typically power spray fish and debris off their traveling screens into some form of fish return system which transports the fish (and in some cases debris as well) back to the aquatic habitat from which they were withdrawn. At Merrimack Station, fish and debris washed from the Unit 1 traveling screens drop into a trough where they are carried with wash water into an 18-inch corrugated steel pipe that runs for about 175 feet. The trough servicing the Unit 2 screens carries fish, debris, and wash water from the screens into an 18-inch diameter open-top smooth steel pipe that joins the Unit 1 discharge pipe at a point approximately 25 feet south of the Unit 2 CWIS. The combined fish, debris, and wash water then flow another 75 feet in an 18-inch corrugated steel pipe where they are discharged onto a grate that covers a cement trough.

Even if fish survive the trip through the return system, they are unable to make it back into the river under all but the highest flow conditions. Instead, fish that do survive the trip to the trough are trapped and likely die there. Fish and other living organisms are subjected to significant stress as they travel down the corrugated pipe, according to Merrimack Station's report (Normandeau 2007d). In addition, sharp turns in the pipes associated with the current fish return design further increase the chance of injury or death to fish sent through them. As Merrimack Station notes in its report (Normandeau 2007d), the current fish return system is more of a debris return system.

11.4.3 Existing Cooling Water Flow Requirements

Merrimack Station's once-through cooling system is designed to withdraw up to 286 MGD of water from Hooksett Pool. This design relies on large volumes of water for purposes of condensing steam in the power plant's condensers. In addition, Merrimack Station is considered to be a "base-load" plant meaning that it theoretically will operate more or less continuously, except for scheduled maintenance outages. For Unit 1, maintenance outages occur every two years, and last approximately four weeks. For Unit 2, maintenance outages occur every year, and last approximately four weeks (Normandeau 2007d).

In practice, the generating units at Merrimack Station have not actually run continuously apart from outages. They have, however, run a great deal, and, as discussed in Section 11.2.1, the plant has the capacity to withdraw a sizeable fraction of the river flow, and the fish eggs and larvae drifting within that fraction, during periods when these early lifestages are present.

11.5 EPA's Determination for Merrimack Station's Existing Intake Design and Flow Requirements

EPA concludes that the design of Merrimack Station's existing CWISs does not reflect "best technology available." Specifically, the plant's existing technology does not minimize entrainment mortality because the mesh size of the screens is too large to exclude small life stages, and the plant's intake flow represents a significant proportion of the flow of Hooksett Pool. Furthermore, the existing technology does not minimize impingement mortality because of its high intake velocities, long exposure times before screens are rotated, traveling screens not designed to carry live fish, high pressure spray wash, use of heated water during winter, and a fish return system that does not return fish to the receiving water. Moreover, as discussed below, there are a number of steps that could be taken to upgrade Merrimack Station's cooling system to reduce entrainment and impingement.

EPA assessed a variety of technologies for reducing entrainment and impingement and whether they could be used at Merrimack Station and, if so, how they would perform. This assessment is presented below.

11.6 CWIS Design Options

CWISs can be designed to include various types of "exclusion" technologies that aim to prevent or minimize mortality to aquatic organisms from entrainment and/or impingement by *excluding* them from being drawn into the CWIS and/or through the intake screens. Exclusion technologies typically use some type of screening system to block organisms from being taken from their aquatic habitat and pulled into the CWIS and through the intake screens.[73] There are many different exclusion technologies, but they can generally be grouped into two broad categories: coarse-mesh or fine-mesh screening systems.

It must be understood, however, that to the extent that a screen blocks an organism from being entrained, that organism has necessarily been impinged against that screen.

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[73] EPA does not evaluate "behavioral" systems that have been discussed in the literature and that use lights or sounds to try to prevent impingement (primarily). To EPA's knowledge, the effectiveness of this type of system has not been demonstrated. Moreover, PSNH has not proposed such a system for Merrimack Station. Therefore, EPA focuses its evaluation of exclusion systems on options that seek to prevent or reduce entrainment and/or impingement by reducing intake velocities and/or by blocking organisms with some type of screening system.

Whether this is an environmental benefit depends on whether the newly impinged organisms can be safely removed from the screens and returned to their habitat. This is a particular challenge with regard to tiny, fragile icthyoplankton. Moreover, it is extremely difficult even to try to monitor whether eggs and larvae survive after being impinged, removed from screens and returned to the water. Just the process of collecting and examining these organisms tends to destroy them. Thus, EPA must consider whether an exclusion technology that is capable of preventing entrainment mortality is merely replacing it with impingement mortality.

Fine-mesh screening technologies attempt to reduce both the entrainment of fish eggs and larva and impingement mortality. According to PSNH (Enercon 2009), a mesh size of 0.5 to 1.0 mm is necessary to effectively screen most fish eggs and larvae. The degree of success that mesh of different sizes would have at any particular site will depend, in part, on the size of the mesh in question relative to the size of the eggs and larvae present at the site. It will also depend, in part, on intake velocity, as excessive intake velocity could result in eggs and/or larvae being pulled through the screens. Some exclusion technologies attempt to prevent or reduce any contact of eggs and larvae against the fine-mesh screens by creating very low intake velocities and relying on passing currents within the water body to move the organisms safely away from the CWIS. Other technologies, such as fine-mesh traveling screens, rely on small mesh-size and low intake velocity to try to reduce or prevent entrainment by excluding (or blocking) organisms from being pulled into the plant's CWIS. As explained above, however, once the eggs and larvae have been blocked from being entrained – and are impinged, instead – problems are presented with regard to whether the organisms can survive contact with the screens and whether it is possible to remove any impinged eggs and larvae from the screens and return them to their habitat alive and uninjured.

PSNH reviewed several exclusion technologies. In its initial report, dated November 2007 (Normandeau 2007d), PSNH evaluated narrow-slot wedgewire screens, fine-mesh Ristroph screens, and aquatic microfiltration barriers. In a subsequent report, dated October 2009 (Enercon 2009), PSNH analyzed two other types of fine-mesh traveling screens (dual flow and MultiDisc®), as well as provided additional information on "narrow-slot" wedgewire screens and aquatic microfiltration barriers. Below EPA reviews the exclusion technologies presented by PSNH as potential BTA options.

The following is a discussion of the exclusion technologies evaluated by PSNH, including those proposed by the company as being BTA, as well as EPA's review of these technologies for their "availability" at Merrimack Station.

11.6.1 Wedgewire Screens

A wedgewire screen uses a Av@ or wedge-shaped, cross-section wire welded to a framing system to form a slotted screening element.[74] The slot sizes of wedgewire screens that have been installed or studied have varied from 0.5 mm to 10.0 mm (Normandeau 2007d). In its evaluation of this technology, PSNH differentiated between "wide slot" and "narrow slot" screens. Although neither is specifically defined in the evaluation, PSNH provides data for slot sizes ranging from 0.8 mm – 1.5 mm in its discussion of "narrow slot" wedgewire screens. In the present discussion, the terms "wide slot" and "narrow slot" when used in the context of wedgewire screens are equivalent to the terms "coarse-mesh" and "fine-mesh," respectively, when used in the context of other types of screening systems.

Wedgewire screens can potentially reduce both entrainment and impingement by physically excluding organisms from being drawn into the CWIS. Whether this technology may be effective or not at a particular facility depends on a variety of factors, including the screen slot size, water depths, local hydrodynamics, the relative sizes of the screen mesh and the local organisms, and water withdrawal volumes and velocities. The performance of wedgewire screens depends on, among other things, the presence of sufficient ambient current to sweep eggs and larvae past the intake screens rather than being drawn into or onto them.

The screen=s cylindrical shape and large surface area quickly dissipate through-slot intake velocity. Impingement is prevented or minimized by maintaining a low intake velocity which allows most fish to avoid being trapped against the screens. Entrainment is reduced or prevented by sizing the slot width of the screen small enough to prevent organisms from passing through. Having prevented organisms from being entrained, adequate ambient sweeping velocity is critical to move the organisms away from the CWIS, so that they do not end up being killed as a result of being impinged on the screens. Passing current is also needed to prevent the accumulation of debris on the screen surfaces.[75]

In sum, the design and mesh-size of a narrow slot wedgewire screen is intended to block any organisms that reach the screens from being pulled through, but also to produce low enough through-slot intake velocities to prevent organisms from being pulled through or

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[74] *See* Taft, E.P. 2000. Fish protection technologies: a status report. Environmental Science & Policy Volume 3: S349-S359.

[75] *See* Technical Development Document for Final Section 316(b) Phase II Rule, p. A-13 (Feb. 12, 2004).

against the screens so that ambient currents can move the organisms past and away from the CWIS.

Despite having considerably narrower mesh sizes than many other exclusion technologies, wide-slot wedgewire screens have a mesh size too large to effectively reduce entrainment. They can, however, be effective for reducing impingement. Wedgewire screens have been used or tested at a number of facilities with varying degrees of entrainment and impingement mortality reduction.

Wedgewire Screens – PSNH's Review and Proposal

In its 2007 analysis, PSNH rejected wedgewire screens for two primary reasons. First, PSNH rejected this technology due to the potential for "frazil ice" to form on the screens and disrupt the flow of cooling water into the plant (Normandeau 2007d). Frazil ice forms when turbulent water is cooled below the freezing point of 32°F. As the water temperature passes though the freezing point, tiny ice particles, known as frazil ice, begin to form. Frazil ice is extremely adhesive and could coat the wedgewire screening and clog the mesh. Merrimack Station reports that it already experiences frazil ice formation on its existing, larger mesh traveling screens on about eight days in an average year.

Second, PSNH concluded that wedgewire screens were infeasible for implementation at Merrimack Station due to the large impact on the river that would result from the large number of wedgewire screens that would be required (Normandeau 2007d). PSNH calculated that the plant would require a total of 23 screens. Unit 1 would require seven 3-foot diameter T-shaped screens with two 5-foot screen sections, and Unit 2 would require sixteen 3-foot diameter T-shaped screens with two 5-foot screen sections, based on a slot width of 1.75mm and a 0.5 ft/sec through-screen velocity. The overall length of each screen section would be a little over 13-feet, and it was estimated that the entire wedgewire screen array would project from 118 feet to 138 feet out into the river.

In October 2009, PSNH submitted to EPA a supplemental evaluation of alternative technologies that reached different conclusions (Enercon 2009). In it, PSNH proposed that the seasonal use of wedgewire screens would be part of the BTA for Merrimack Station. PSNH did not propose a particular slot size, but evaluated screens with a narrower slot (1.5 mm) and a wider slot (9.0 mm). According to the 2009 proposal, the plant would require anywhere from 44 screens (9.0 mm slot width) to 76 screens (1.5 mm slot width), a substantial increase from the 23 screens the 2007 proposal indicated were required. Despite this increase, PSNH did not explain how its concerns about adverse impacts on the river from installing a large number of wedgewire screens would be alleviated. This concern was a primary reason that the company rejected wedgewire screens in its 2007 proposal.

PSNH proposed that limiting the use of wedgewire screens to what it characterized as the period of highest entrainment and impingement (specifically, April though July) would avoid the potential for frazil ice problems. When wedgewire screens were not in use, PSNH proposed that impingement mortality could be adequately reduced by running the existing traveling screens continuously from August through November and by upgrading the fish return system. PSNH further suggested that the continuous operation of the traveling screens would be unnecessary from January to March because, according to the company, this is a period of minimal impingement. During this period, PSNH proposed operating the traveling screens intermittently and removing the fish return sluice.

According to PSNH, the seasonal use of wedgewire screens with a 1.5 mm slot width and an upgraded fish return system would decrease entrainment by up to 79 percent and impingement by up to 84 percent. PSNH also concluded, however, that using a 9.0 mm slot size would reduce entrainment only slightly less (specifically, by up to 73 percent, with no change in impingement) (Enercon 2009).

<u>Wedgewire Screens – EPA's Review</u>

Having reviewed PSNH's submissions, as well relevant technical and scientific literature, EPA concludes that PNSH's 2009 wedgewire screen proposal would not satisfy the BTA standard of CWA § 316(b) at Merrimack Station. Furthermore, EPA concludes that the rates of entrainment and impingement mortality reduction that the company predicts for its proposal are not supported.

There are specific minimum hydrologic and hydrographic conditions that must exist within the water body used as a cooling water source in order for wedgewire screens to operate effectively. One key condition, given the "passive" nature of wedgewire screen technology, is that sufficient ambient current velocity must exist to sweep eggs, larvae, and fouling debris past the screens. Yet, it is evident that sweeping currents in Hooksett Pool are insufficient at critical times.

PSNH proposes that entrainment is a problem only from April to July, whereas EPA regards entrainment to be a problem from the beginning of April to the end of *August* (and it could also be a problem in March, though no data has been collected for that month). Yet, adequate sweeping currents do not exist throughout this entire time period. PSNH identifies screen fouling to be a significant concern due to "axial" velocities sometimes dropping below 1 ft/sec (Enercon 2009). Indeed, this was the company's primary basis for concluding that wedgewire screens of *any* slot size could not be used from August to November. Current speeds recorded in front of the intake on August 15, 1975, were as low as 0.20 ft/sec (Normandeau 1976). Looking at historic flow data (1969–1976) provided by PSNH (Normandeau 1997), as well as gage data available from the USGS (1993–2007), EPA found that flows drop off appreciably between May and June and that current speeds have also fallen below the 1 ft/sec level on various dates throughout June and July. This indicates that wedgewire screens will not perform effectively because passing currents are unlikely to prevent screen fouling during part of the period when entrainment is a concern. Fouling restricts flow through the screens, which not only can interfere with maintaining adequate water withdrawals for cooling purposes, but it also results in increased intake flow velocity through areas of the screens that are not fouled. This increase in intake flow velocity above design flow can be sufficiently high to cause increased entrainment or impingement of eggs and/or larvae.

EPA recognizes that PSNH's consultant, Normandeau Associates, Inc., recorded current velocities in early May 2009 and found a mean depth-averaged current speed of approximately 1.6 ft/sec along a transect *closest* to the plant's CWIS (Normandeau 2009a), but EPA does not regard this current speed value to be representative of typical conditions in May. The water depth along this transect (running parallel to the shoreline) was reported to be 16 feet (approximately 4 meters), but EPA found that the (limited) historical bathymetry data that exist for this location depict the maximum depth in this area (identified as Station N-5) to be 6–8 ft (Normandeau 1975). Graphic depictions from studies conducted in 1975 indicate that the depths only became shoaler moving east towards the opposite shoreline. EPA reviewed river flow data for early May 2009 to see if they were consistent with high river levels. The specific date in May 2009 when PSNH conducted the flow velocity study was not presented in the report, so EPA averaged the river flows from the first 10 days in May 2009. Based on EPA's calculations, the mean river flow during the first 10 days in May 2009 was 5,435 cfs. This rate was considerably lower than the mean monthly flow rate for the 15-year period from 1993–2007, which was 7,002 cfs. Based on this comparison, it does not appear that river flows were unusually high in early May 2009. Bathymetric studies were conducted by PSNH in 2009, and some data collected during those studies were presented in PSNH's thermal plume model report (ASA 2010). This report depicts water depths near the intakes to be between 11.8 and 13.1 ft (3.6–4.0 m).

If indeed the water depth was 16 feet on the day current velocity sampling occurred, the flows were likely unusually high, and not representative of typical river flows (or current velocities) for most of the period when larvae are present, including the entire months of June and July. Therefore, EPA considers these data to be on the high end of any range of current velocities that might be expected, and not supporting evidence that flow conditions in Hooksett Pool would be conducive to the effective use of wedgewire screens for the entire time period when fish eggs and larvae are present.

In addition to needing adequate sweeping currents, wedgewire screens also must be located in an area with sufficient water depth to enable them to operate effectively.

PSNH specifically states that wedgewire screens must be positioned above the substrate and submerged below the surface, by at least one-half of the diameter of the screen (Enercon 2009). Since PSNH proposes to install two-foot diameter screened cylinders, the cylinders would need to be located in a water depth of at least four feet.

Yet, it is unclear whether adequate water depths exist in Hooksett Pool to accommodate an effective wedgewire screen installation. A detailed study of water depths in this area has not yet been conducted, but graphic depth profiles provided in PSNH's Supplemental Alternative Technology Evaluation (Enercon 2009) suggest that the wedgewire screens located closest to shore would be installed within 25 feet of the shoreline. Under current operations, Merrimack Station is required periodically to dredge sediment that accumulates in front of the intake structures. This indicates that this location – and where the screens would be located – is a depositional environment. Dredging typically occurs in the spring or summer, but sedimentation rates have worsened in recent years, and the plant may need to dredge in the fall, as well (personal comm. A. Palmer, PSNH). Furthermore, the screen structures themselves – of which from 44 (9.0mm slot size) to 76 (1.5 mm slot size), or even more if a smaller slot size is required, could be needed – could accelerate the accretion of sediment by attenuating ambient current velocity in the area. Further, such a field of vertical structures, roughly one-third of an acre in size, would likely trap branches and other debris drifting downstream. Maintaining adequate water depth in this area through dredging, when necessary, could be difficult given the close placement of screen structures to each other and the presence of underground piping to connect them to the plant.

Not only is adequate water depth needed, but the water body itself must be large enough to accommodate the wedgewire screen installation without excessive interference with the water body's beneficial uses. In its 2007 analysis, PSNH concluded that wedgewire screens would be infeasible because, among other reasons, the required array of screens would extend into, and interfere with, the river to an excessive degree. The wedgewire screen array proposed in 2009 by PSNH is even larger than the array evaluated in 2007. As wedgewire screen slot sizes are reduced, and through-screen intake velocities are reduced, both of which are necessary to maximize entrainment and impingement mortality reductions, the size of a wedgewire screen installation must increase in order to ensure that an adequate volume of cooling water is provided to the facility. For this reason, wedgewire screens are most promising – though they may or may not prove to be viable or effective – in cases where the cooling water withdrawal volumes are low relative to the size of the water body in which they are to be located. In such cases, the water body is most likely to be able to accommodate the more limited number of wedgewire screens that would be required to meet cooling water demand. At Merrimack Station, however, the intake flow of 287 MGD is relatively large as compared to the river width and depth, and an adequately sized wedgewire screen installation is likely to interfere excessively with the river.

Another problem with Merrimack Station's wedgewire screen proposal relates to the slot size of the screens. PSNH ruled out slot sizes less than 1.5 mm on the grounds that they would likely result in screen fouling to an extent that would negatively affect Station operations. There is compelling evidence, however, indicating that entrainment will not be adequately reduced at slot sizes of 1.5 mm, or larger. Research indicates that a slot size of 0.5 mm is likely needed to maximize entrainment reductions and that substantially more entrainment will occur as slot sizes increase to 1.0 mm or larger. *See* EPRI 2007; EPA Fact Sheet for NPDES Permit No. MA 0003905, General Electric Aviation, Lynn, Massachusetts, Att. J at 25–29. For example, in one laboratory study of screen retention at different slot sizes (ESEERCO 1981), a 1.0 mm mesh size retained only 1 percent of yellow perch larvae smaller than 6 mm, in comparison to 48 percent retention at a mesh size of 0.5 mm. In the same study, greater than 90 percent of yellow perch larvae longer than 6.0 mm were retained with a 0.5 mm mesh size, but a 1.0 mm mesh size only reliably retained larvae greater than or equal to 9.3 mm in length.

At the same time, however, if the slot size was reduced to 0.5 mm, not only would screen fouling be a problem, but an even larger screen installation would be needed to ensure that adequate water volumes would be provided to the facility while maintaining sufficiently low intake velocity. According to PSNH's proposal (Enercon 2009), 44 to 76 wedgewire screens would need to be installed in Hooksett Pool based on a range of mesh sizes from 9.0 mm to 1.5 mm. An even larger number of screens would interfere with the river to an even larger extent. The number of screens that would be required at Merrimack Station is unprecedented for facilities in the United States, even at the low end of the proposed range (44). The most screens currently in use at any one facility is 24, based on EPA's review. The intake for this facility, Oak Creek Power Plant, in Wisconsin, is approximately 7,900 feet from the shore in Lake Michigan, in approximately 43 feet of water. The wedgewire screens are each 8 feet in diameter and approximately 32 feet long. Due to the significant differences in dimensions and number of screens, as well as differences in the depth, size, and type of water bodies, Oak Creek Power Plant's wedge wire screens in Lake Michigan (over a mile offshore in a large, deep lake) and Merrimack Station's proposal in Hooksett Pool (along the shoreline of a shallow river) are not comparable. The absence of comparable existing wedgewire screen operations raises concerns of the technology's suitability in Hooksett Pool.

Another problem with relying on wedgewire screens at Merrimack Station is the fact that entrainment at Merrimack Station is dominated by the entrainment of larvae. While fish eggs are fragile, fish larvae are considerably more so. For this reason, eggs may be more likely to be able to survive limited contact with wedgewire screens, whereas comparatively fragile larvae may be more likely to be killed or injured upon impact. Regardless of the slot size used, based on the in-river configuration of screens presented in PSNH's supplemental report, larvae and eggs could have to avoid up to six sets of wedgewire screens as they drift downstream past the plant (Enercon 2009). Their ability to survive contact with the screens is questionable, especially with regard to larvae.

Some of PSNH's entrainment reduction estimates are based on the assumption that larvae at given lengths will be able to actively avoid being entrained. Yet, the study PSNH references as support for this concept actually studied striped bass (*Morone saxatilis*) larvae, an anadromous species not found in Hooksett Pool. A study by Heuer and Tomljanovich (1978), which was cited by PSNH (Normandeau 2009a), argues that the design of a fish avoidance screen ". . . is necessarily dictated by the swimming ability and behavior of the species of larval fish that are to be protected as well as the site specific physical characteristics of the intake location." The same study cites earlier work done with larval striped bass that found that 90 percent of the 10–12 mm striped bass tested were able to maintain themselves in a 0.2 ft/sec current. Heuer and Tomljanovich (1978) noted that during their tests, larval striped bass, being an open water species, oriented themselves into the current and swam vigorously towards the flume surface, away from the entraining current.

Other species were also tested, such as channel catfish (*Ictalurus punctatus*), which are demersal, or bottom-oriented, fish. While larval channel catfish are also considered to be strong swimmers, their preference for the bottom may explain why their entrainment rates were relatively high during tests (Heuer and Tomljanovich 1978). Therefore, not only is fish body-type and length important for evaluating the entrainment/impingement potential of larvae, but so is species type and their behavior. The results of entrainment sampling conducted in Hooksett Pool in 2006 and 2007 demonstrated that nearly half of all larvae captured (48%) were those of four demersal species; brown bullhead, white sucker, margined madtom, and tessellated darter (Normandeau 2007c). The selection of appropriate surrogates for vulnerable species when evaluating entrainment and impingement potential is obviously important. Based on the information reviewed, EPA does not consider striped bass larvae to be suitably representative of the species found in Hooksett Pool.

EPA reviewed a study not referenced by the plant that suggests that fish larvae may actually be *attracted* to structures that provide refuges of low water velocities. Niles and Hartman (2009) studied velocity shelters created by dike structures on large rivers and found that larval fish abundance in low velocity areas associated with dike structures was more than twice that found in "high-quality" reference sites and four times higher than found in "low-quality" reference sites. Many of the species collected in the study area are the same as those found in the Hooksett Pool. While wedgewire screens are more hydrodynamic than dikes, placing up to 76 steel structures in an area of approximately one-third of an acre is likely to attenuate water velocity in the river and could, in turn, attract any motile larvae. The number of screens would be even greater if it was determined that the narrowest slot size PSNH evaluated (1.5 mm) was not narrow enough to effectively exclude larvae commonly found in Hooksett Pool.

In sum, under certain environmental conditions, wedgewire screen technology may be capable of substantial reductions in entrainment and impingement mortality at facilities with certain characteristics. EPA concludes, however, that the necessary conditions for an effective wedgewire screen installation are not present at Merrimack Station on a consistent and reliable basis during the period when fish eggs and larvae are present. Indeed, this problem contributed to PSNH's decision only to propose wedgewire screens with a mesh size of 1.5 mm or greater and, at that, only to deploy the screens for four months each year (from April to July). Even during this period, PSNH recognized that low water levels could be problematic and suggested that wedgewire screen operation could be limited to times in which adequate submergence is present (Enercon 2009). As discussed above, EPA has identified a number of problems that are likely to undermine the effectiveness of wedgewire screens at Merrimack Station and, therefore, EPA rejects this technology as an option for the BTA at this facility.

11.6.2 Traveling Screens

Traveling screens at a power plant are self-cleaning screening devices used to remove fish and debris from flowing water prior to its being drawn into the plant's condenser cooling system. Early designs, such as those still in use at Merrimack Station, include a series of screen panels oriented perpendicular to the water flow. When operating, which may be continuously or periodically, these panels rotate vertically on a track, rising upwards on the upstream-side of the screen structure. Fish and debris are collected on shelves or baskets on the upstream-side of the screens structure, raised out of the water, and then washed off by a power spray system into a fish/debris return sluice before the screen descends back down into the water on the downstream side. Fish and debris that are not removed from the screen may drop off on the downstream side of the screen structure. This "carryover" continues into the intake screen well and potentially into the circulating water pump intake (Normandeau 2007d).

In its November 2007 submission (Normandeau 2007d), PSNH identifies the features of a traveling screen that it considers "desirable" for minimizing impingement and entrainment. They are as follows:

- Approach and through-flow intake velocities less than 1 ft/sec;
- Open or short intake channels with "escape routes;"
- Small mesh openings;

- Provisions to gently handle impinged fish;
- Continuous operation, and
- Low-pressure wash system to gently remove impinged fish.

EPA has previously identified additional design features to minimize impingement mortality, including the following:

- Using smooth-woven screen mesh to minimize fish de-scaling;
- Using fish rails to keep fish from escaping the buckets or baskets;
- Performing fish removal prior to high-pressure washing for debris removal, and
- Optimizing the location of spray systems to provide a more gentle fish transfer to the return sluice.

See EPA Technical Development Document for the CWA § 316(b) Final Phase II Rule, Chapter 4. In addition, in the Phase I CWA § 316(b) Rule, EPA designated a maximum through-screen intake velocity rate of 0.5 ft./sec. as a component of the BTA for minimizing impingement mortality at new facilities.

PSNH evaluated several types of traveling screen technologies; namely Ristroph, Multi-Disc, Dual Flow, and Beaudrey W Intake Protection screens. Some of these technologies use coarse-mesh screening designed to prevent the entrainment of juvenile and adult fish, but not the smaller egg and larval stages. Other technologies employ (or are capable of employing) fine-mesh screens designed to prevent the entrainment of all life stages of fish. These technologies, and evaluations of their suitability for Merrimack Station by EPA and PSNH, are discussed below.

11.6.2.1 Ristroph Screens

11.6.2.1a Coarse-Mesh Ristroph Screens

Conventional traveling screens can be replaced with coarse-mesh Ristroph screen panels fitted with fish buckets. PSNH (Normandeau 2007d) identifies the following features of the Ristroph screen that are designed to significantly reduce impingement mortality:

- The mesh size minimizes harm to fish;
- The basket maximizes the screening area available;
- The fish bucket opening is designed to encourage fish to enter the bucket;
- The bucket is large enough to safely retain fish in the bucket;
- The bucket provides a hydraulically stable “stalled” fluid zone that attracts fish, prevents injury to the fish while in the bucket, and prevents fish from escaping the bucket;
- The bucket is shaped to allow gentle and complete removal of impinged fish, and
- The bucket maintains a minimum water depth while transporting fish.

The buckets on Ristroph screens are designed to collect fish and hold them in water as the screen rotates up, lifting the fish to a point where they can be gently sluiced away with a low-pressure spray prior to debris removal. Converting to this type of system would not change the through-screen velocity.

Coarse-Mesh Ristroph Screens – PSNH's Review

PSNH estimates that Ristroph screens, when combined with an upgraded fish return sluice, would reduce impingement mortality by 50.3% for Unit 1 and 53.1 percent for Unit 2 (Normandeau 2007d). Oddly, the report seems to suggest that coarse-mesh Ristroph screens would actually somewhat *reduce* impingement survival at Unit 2 since it estimates that a new fish return sluice *alone* would reduce impingement mortality by 54.2% at Unit 2, as well as by 45.9% at Unit 1. The construction cost for this option is estimated at $1.36 million, and PSNH does not expect appreciably higher maintenance of Ristroph screens compared to the existing screens.

Coarse-Mesh Ristroph Screens – EPA's Review

EPA finds that Ristroph screens could potentially be part of the BTA for reducing impingement mortality, and that this technology warrants further review for this purpose. *See* Section 12. This technology does not, however, reduce entrainment.

EPA also notes that PSNH likely underestimates the impingement mortality reductions that could be provided by modifying Merrimack Station's existing screens to use Ristroph-type technology. (EPA also cannot see any reason that using Ristroph screens would reduce survival rates for impinged fish at Unit 2, as compared to the existing screens.) The Electric Power Research Institute (EPRI) conducted impingement survival studies using Ristroph screens and included several species resident to Hooksett Pool. According to the EPRI (2006) study, 48-hour survival rates exceeded 95 percent for bluegill, golden shiner, largemouth bass, white sucker, and yellow perch at an intake velocity of 2 ft/sec.

Yet, PSNH's analysis finds little difference between impingement survival rates for coarse mesh Ristroph screens and for Merrimack Station's existing coarse mesh traveling screens, which are not equipped with the fish protection features of the Ristroph screens. EPA finds a number of issues with PSNH's analysis and conclusions in this regard.

PSNH's estimates for impingement survival using coarse-mesh Ristroph screens are based on studies conducted from April 15 to December 7, 1985, at a plant (Indian Point, Unit 2) in New York on the Hudson River. PSNH then compares these results with results from its own impingement survival studies at Merrimack Station using "non-Ristroph" screens. There are, however, a number of problems with this comparison. To begin with, the Indian Point information is not adequately explained to demonstrate whether data from that facility can be considered representative of the specific conditions and species found in Hooksett Pool, or if the components of Indian Point's CWIS are similar to those of Merrimack Station. Furthermore, while impingement survival studies conducted at Indian Point measured mortality after 96 hours (four days), Merrimack Station measured mortality 24 hours after impingement. Given that stress, injuries, and infections related to impingement can lead to fish mortality days after impingement occurred, this difference in the time period used for measuring "latent" mortality could skew the comparison between the two facilities. In addition, while Merrimack Station assumes that the results of its survival studies, combined with the survival estimates from an effective fish return trough, would result in an accurate estimate of survival that is achievable at the plant using the existing traveling screens, EPA has identified a number of aspects of PSNH's survival studies that raise questions about the accuracy of study's survival estimates as they apply to fish residing in Hooksett Pool. As a result, in EPA's view, PSNH's impingement survival estimates have limited value for purposes of comparing the effectiveness of various technologies at Merrimack Station.

11.6.2.1b Fine-Mesh Ristroph Screens

Unlike coarse-mesh screens, fine-mesh Ristroph screens have mesh small enough to reduce entrainment by excluding fish eggs and larvae from being drawn into the condenser cooling system. The efficacy of the screens for preventing entrainment at a specific site will depend primarily on the size of the mesh relative to the sizes of the aquatic organisms of concern. In essence, entrainment is reduced or prevented by impinging eggs and larvae on the fine-mesh screens. The extent to which any of these tiny, fragile organisms may survive being impinged on the screens will depend on how hardy the organisms are, the nature of the contact they have with the screens, and whether a system can be designed to safely remove them from the screens and return them to the aquatic environment. In addition to fine mesh screens, the other modifications identified for coarse-mesh Ristroph screens would also need to be provided.

The existing 3/8-inch (9.5 mm) screens at Merrimack Station are ineffective for excluding fish eggs and larvae from being entrained through the facility. In fact, *entrainment* studies conducted at Merrimack Station in 2007 captured white suckers as large as large as 24.4 mm (0.9 inches) (Normandeau 2007c). Although more than twice as long as the width of the screen mesh, these fish are not as wide as they are long, and they may have been extruded through the screens due to the CWISs' relatively high through-screen intake velocities. Alternatively, they may have been carried over the traveling screens and into the circulating water pump intake.

Fine-Mesh Ristroph Screens – PSNH's Review

PSNH rejected fine-mesh Ristroph screens because the present CWIS structures at Merrimack Station could not be readily modified to accept this technology. Installation of fine-mesh Ristroph screens in the present CWIS configuration would cause a head loss across the screens potentially sufficient to "starve" the cooling water pumps for water and reduce pumping efficiency. Yet, in order to maintain the existing head loss experienced across the fine-mesh screens, a larger, or additional, mesh screen would have to be installed to match the course-mesh screen's total open area. PSNH does not consider retrofitting its CWISs with fine-mesh Ristroph screens to be a viable option since the head loss across the traveling screens would be so great that the CWIS intakes would have to be greatly expanded to provide the facility with sufficient water for cooling (Normandeau 2007d).

Fine-Mesh Ristroph Screens – EPA's Review

EPA evaluated the availability of fine-mesh traveling screens at Merrimack Station based on BTA factors. At Merrimack Station, a 0.5-1.0 mm mesh size would be needed to effectively prevent the entrainment eggs and larvae. As PSNH has pointed out, the surface area of the screens would need to be substantially larger than the current configuration in order to provide enough water for cooling and still maintain a low through-screen velocity of approximately 0.5 ft/sec. As a result, the existing CWISs would need to be totally replaced and expanded, and new fine-mesh traveling screens, with their associated machinery, would need to be added.

As explained above, preventing entrainment by using fine-mesh screens to block eggs and larvae from being drawn into the facility's condenser cooling system necessarily results in the impingement of these organisms. Thus, the survival of eggs and larvae following impingement on fine-mesh screens is integral to the overall performance of the technology. The probability of such survival is species- and life stage-specific, and is influenced by a number of factors, including the hardiness of the organisms, the through-screen intake velocity, the duration of impingement, and the methods of removing organisms from the screens and returning them to the receiving waters. Even if the fish initially survive the trip back to the receiving waters, studies of fish survival (juveniles and adults) on fine-mesh traveling screens conducted at Somerset Station, in New York, demonstrated that survival rates 96 hours later can be considerably lower (McLaren and Tuttle 2000), with rates varying considerably based on species and season. Some species, such as alewife and American shad, have poor survival rates once impinged, regardless of the technology used (Taft 2000). The only data available for pre-juvenile fish (*i.e.*, eggs and larvae) at Somerset Station was for post-yolk-sac rainbow smelt. The 96-hour survival rate was estimated to be only 26.9 percent (McLaren and Tuttle 2000).

Like PSNH, EPA does not consider fine-mesh Ristroph screening technologies to be the BTA for Merrimack Station. It appears likely that to the extent that this technology can reduce entrainment of fish eggs and larvae, it will simply replace it with impingement mortality for those organisms. Without site-specific survival studies to demonstrate the efficacy of this system in keeping impinged organisms alive and uninjured, EPA must assume that impinging these tiny, delicate organisms will lead to their mortality. In addition, converting to fine-mesh Ristroph screens would require a major expansion of the CWISs which PSNH does not consider viable. Finally, while fine-mesh screens would be unlikely to introduce major secondary environmental effects and would not necessitate changes to the existing processes employed at the plant, but they would require additional maintenance (e.g., cleaning the screens to address any biofouling and/or to remove any aquatic debris caught on the screens).

11.6.2.2 Multi-Disc Screens

Geiger MultiDisc7 screens are oriented the same way as traditional through flow screens, but they have very different designs, according to information presented in the PSNH November 2007 CWA § 308 Response (Normandeau 2007d). Geiger Multi-Disc screens are comprised of circulating sickle-shaped mesh panels that are connected to a frame via a revolving chain. PSNH evaluated coarse-mesh and fine-mesh versions of this technology, a summary of which is presented below.

11.6.2.2a Multi-Disc Screens – Coarse Mesh

Multi-disc screen systems include special components that should be more protective of impinged fish and other aquatic organisms. Fish buckets attached to the screen panels retain some of the water during their upward travel, thereby allowing any captured fish to remain within water once the buckets rise above water level. A low pressure spray header recovers organisms that are transported upwards on the screen surface to the bucket. Fish buckets are gently discharged into the fish return sluice.

<u>Multi-Disc Screens – Coarse Mesh – PSNH's Review</u>

Based on survival studies conducted at another power plant, PSNH estimates that impingement mortality would be reduced by 69% in Unit 1 and 80% in Unit 2. Due to the manner in which Geiger MultiDisc7 screens would be installed across the intake chamber, they can be can retrofitted into the space of the existing traveling screens, minimizing structural modifications. The construction cost, including the installation of an upgraded fish return sluice, is estimated by PSNH to be $2.27 million. Maintenance requirements for multi-disc screens are predicted to be lower than those of the existing traveling screens.

Multi-Disc Screens – Coarse Mesh – EPA's Review

As with coarse-mesh Ristroph screens, EPA believes Geiger MultiDisc7 coarse-mesh screens warrant further consideration as a potential BTA for reducing impingement mortality, but this technology does not address entrainment. *See* Section 12.

11.6.2.2b Multi-Disc Screens – Fine Mesh

The MultiDisc® system uses circulating sickle-shaped mesh panels that are orientated perpendicular to the water flow. The joined panels appear as a race track, with one side ascending and the other descending. Intake water flows directly through the mesh panels. Debris retained on the ascending panels is transported to the floor level where it is removed by a water spray. Fish buckets, attached to the screen panels, transport fish in water to the floor level. At that point any impinged organisms, such as eggs and larvae, are recovered by a low-pressure spray wash (5–15 psi) which washes the impinged organisms into the buckets. As each panel turns down, any fish, other organisms and retained water are gently discharged from the buckets to a sluice way for return to the river.

Multi-Disc Screens – Fine Mesh – PSNH's Review

PSNH states, AMortality of fish that would have been impinged on standard, *i.e.*, coarse, mesh (3/8-inch square openings) could be assumed to be reduced by 80–95% because of the low through-screen velocity.@ (Enercon 2009). PSNH estimated that the Geiger MultiDisc7 Screen would reduce the number of fish killed by impingement by 69% for Unit 1 and 80% for Unit 2 based on the assumption that swimming capabilities of juvenile and adult fish would enable them to avoid being impinged if the intake current is less than 0.5 ft/sec (Normandeau 2007d). This assumption cannot be generally applied to eggs and larvae, however, because they are drifting organisms or have only limited swimming capability. Since the ability of fine mesh screens to reduce impingement mortality at Merrimack Station is unknown, PSNH argues that a site-specific biological study at the Merrimack Station site would be needed before it could select this technology (Enercon 2009).

PSNH=s original estimate of the cost to construct the Geiger MultiDisc7 Screen option was $2.27 million. PSNH=s updated cost estimated is $59.92M to install the Geiger MultiDisc7 Screen, with a related lost generation cost during the installation of $11.47M. The nearly $60M installation cost includes the total replacement of Merrimack Station's existing CWISs since these structures cannot be retrofitted for a fine-mesh traveling screen technology. The annual operation and maintenance cost is estimated at $0.60M per year. PSNH estimates the cost of operating the ten Geiger MultiDisc7 Screens would be up to 10 times what is required to operate and maintain the existing CWIS.

In addition, PSNH expresses concern that the build-up of frazil ice during winter months would result in damage to, and clogging of, the screens. Frazil ice can be controlled by using a de-icing recirculating system which injects heated cooling water from the condensers into the fore bays of the CWISs. Screen clogging could also result in separation of the fine mesh panels from the screen housing. The fine mesh panels would also be susceptible to fouling from biological material and other suspended solids. According to PSNH, a three-year study would be warranted to determine if a sodium hypochlorite system is required to limit biological growth and fouling.

<u>Multi-Disc Screens – Fine Mesh – EPA's Review</u>

As with fine-mesh Ristroph screens, the ability of fine-mesh MultiDisc7 screening technology to reduce the mortality rates of fish eggs and larvae is questionable. Even if blocked from entrainment, the organisms are likely to die as a result of impingement. EPA finds that this uncertainty, combined with the appreciable cost and complexity of retrofitting Merrimack Station's CWISs for this technology, renders it unsuitable to be the BTA at Merrimack Station.

11.6.2.3 Dual-Flow Traveling Screens

Dual-flow traveling screens are essentially a through-flow system turned 90 degrees, placing the screens' surfaces parallel to the flow (Enercon 2009). This re-orientation allows more of the screen surface to be utilized at one time, which results in a decrease in the current velocity through the screens. Additionally, since all the flow is going through the screens, the potential for carryover of fish and debris into the condenser cooling system is eliminated (Normandeau 2007d). A dual flow system typically uses a low-pressure wash to transfer organisms to a sluice and return them to the river, followed by a high-pressure wash to remove debris.

<u>Dual-Flow Traveling Screens – Coarse Mesh – PSNH's Review</u>

PSNH originally considered the dual-flow option too costly to install at Merrimack Station based on the work necessary to expand the CWIS to accommodate the larger screen size (Normandeau 2007d). However, in its October 2009 supplemental report (Enercon 2009), PSNH further investigated this technology using fine-mesh screens. According to PSNH, a total of three dual-flow traveling screens, would be required at Merrimack Station.

PSNH=s reevaluation of the dual-flow system estimates an installation cost for the dual-flow system with an upgraded fish return system at $42.92M, with a related lost generation cost during the installation of $11.47M. The nearly $55M installation cost includes the total replacement of Merrimack Station's existing cooling water intake water structures since these structures cannot be retrofitted for a fine mesh traveling screen technology. The annual operation and maintenance cost is estimated at $0.29M per year.

Dual-Flow Traveling Screens – Fine Mesh – EPA's Review

As with the fine-mesh Ristroph and MultiDisc7 screening technologies, the effectiveness of fine-mesh dual flow screening technology in reducing the mortality rates of fish eggs and larvae is questionable. While fine-mesh screens might reduce entrainment, eggs and larvae are still likely to be killed as result of being impinged on the screens. Therefore, EPA finds that this uncertainty, combined with the appreciable costs and complexity of retrofitting Merrimack Station's CWISs for this technology, render it unsuitable to be the BTA at Merrimack Station.

11.6.2.4 Beaudrey W Intake Protection Screen

A Beaudrey W Intake Protection Screen (WIP) system places a rotating screening disk with a mesh panel in the intake to arrest debris and fish. A recuperation channel or scoop is situated adjacent to the mesh panel, with the concave side of the scoop facing the filter element. The rotating screening disk guides fish to this scoop where suction is applied by a Afish safe pump@ to cause an opposite circulation of water through the mesh panel in the area of the scoop. The scoop acts as a safeguard for the fish and the opposite circulation of water at the scoop detaches fish from the filter element in the area of the scoop and carries them to a fish return pipe. The WIP system utilizes coarse-mesh screens and, therefore, is not designed to reduce the entrainment of eggs and larvae.

WIP System – PSNH's Review

PSNH estimates that the WIP system would reduce the number of fish killed by impingement by 66% at Unit 1 and 74% at Unit 2. The WIP system is designed to fit into the existing traveling screen guides, therefore no modifications to the intake would be required (Normandeau 2007d). Since the WIP system can be raised out of the water, PSNH expects that it would be easier to maintain than its existing traveling screens. The construction cost for this option is estimated at $2.07 million (Normandeau 2007d).

WIP System – EPA's Review

Like coarse-mesh Ristroph screens and Multi-Disc screens, EPA considers the WIP System to be worthy of further consideration as the potential BTA for minimizing impingement mortality, but the technology does not reduce entrainment. *See* Section 12.

11.6.2.5 Traveling Screens – PSNH's Proposal

PSNH proposes to withdraw cooling water through wedgewire screens from April through July, and to use the existing coarse-mesh traveling screens from August through

March, but with a new low-pressure spray wash system (Enercon 2009). PSNH further proposed to rotate the traveling screens continuously from August through November, but only intermittently from December through March.

11.6.2.6 Traveling Screens – EPA's Review

EPA has determined that three coarse-mesh traveling screen technologies are "available" and warrant further review as potential BTA selections for minimizing impingement mortality at Merrimack Station. These coarse-mesh technologies are Ristroph screens, Multi-Disc screens, and the WIP system, and they only address impingement. EPA has also determined that PSNH's proposal to use its existing traveling screens without additional screening technology from August through March, even with the addition of a low-pressure spray wash system, does not satisfy the BTA standard of CWA § 316(b). The existing technology, developed in the 1950s and 1960s, does not include provisions to gently handle impinged fish and, like the existing fish return sluices, the existing traveling screens are designed more for handling debris than live fish. Moreover, there are available technologies that have been developed since the existing traveling screens were installed that would reduce current levels of impingement mortality at Merrimack Station.

In order to satisfy the BTA standard, EPA considers it a fundamental requirement for any traveling screen technology to have an effective fish return system in place. This means that the CWIS's screening system should be operational at all times when the plant is withdrawing water and impingement may be occurring, and that the system should be capable of safely catching fish on the screens, removing them from the screens, and returning them to the water body. PSNH has proposed to run its current traveling screens continuously from April through December, but only intermittently from January through March. Under this approach, fish impinged on the screens during the latter period could remain impinged for hours, greatly increasing the risk of impingement mortality. Furthermore, the accumulation of fish and debris on the screens reduces the amount of screen area through which water can pass. This can cause an increase in through-screen velocity which, in turn, can increase the impingement of fish unable to escape the higher intake velocities.

PSNH states that continuous operation of the screens from January to March is not necessary because this is a period of minimal impingement. This statement is not, however, supported by the plant's own sampling data. The month of March ranked third in impingement rates during sampling conducted in 2006, and ranked fifth highest of the 24 consecutive months sampled between July 2005 and June 2007. The months of January and February ranked fifth and sixth, respectively in 2006. While impingement numbers were lower in 2007, the 2006 data provide clear evidence that impingement from January through March is not so low that it can be ignored when evaluating technologies for minimizing impingement mortality.

PSNH states that the traveling screens will be operated on only an intermittent basis from December to March because of "personal safety issues associated with maintaining the fish return systems when ice is present" (Enercon 2009). PSNH does not provide further explanation or supporting information to document or explain the "safety issues" it raises. It is EPA's understanding that other power plants in northern climes are able to operate fish return systems during all months of the year. Continuous operation of the traveling screens and an effective fish return sluice can reduce mortality to impinged organisms at relatively little cost. Therefore, EPA considers these features to be necessary components of the BTA at Merrimack Station unless PSNH provides more compelling reasons why they are not available from December through March.

11.6.3 Fish Return Sluice

After having been drawn into a plant's cooling system through the CWIS, impinged against a traveling screen, raised out of the water, and dislodged from the screen with a pressurized spray wash, an impinged organism then begins the trip back to its aquatic habitat. The fish return system is a critical component of any CWIS designed to return fish safely to the waters from which they were taken. All of the screening technologies discussed above would require the construction of a new fish return sluice or trough.

<u>Fish Return Sluice – PSNH's Proposal</u>

In its November 2007 CWA § 308 Response (Normandeau 2007d), PSNH describes what it considers to be a "quality" fish return trough, or sluice, that would adequately return fish to the Merrimack River with a minimum of stress. Such a trough would be designed so that:

- Maximum water velocities within the trough are 3–5 ft/sec;
- A minimum water depth of 4–6 inches is maintained;
- There would be no sharp-radius turns;
- It would discharge slightly below the low water level;
- It would be covered with a removable cover to prevent access by birds, etc;
- The removable cover should have escape openings along the portion of the trough that could potentially be submerged, and
- It would use the optimal slope for maximum survival, which is a 1/16 foot drop per linear foot.

In order to maintain a 1/16 slope and discharge the fish downstream from the plant's cooling water intakes – which is needed to avoid re-impingement problems – a new fish return sluice at Merrimack Station would have to be 225 ft long. However, at this length, the sluice would only reach the top of the river bank. PSNH proposes a ¼ slope for the "slide" section of the return that runs from the top of the river bank to approximately six inches below the river surface. The length of the slide is estimated to be 25 ft.

PSNH estimates that impingement mortality will be reduced by 45.9% for Unit 1 and 54.2% for Unit 2 with the installation of upgraded fish return sluices (Normandeau 2007d). These estimates are based on the assumption that the upgraded fish return sluices will only be operable from April through December (Normandeau 2007d). The total estimated capital cost to upgrade the fish return sluices is $315,100 (Normandeau 2007d).

Fish Return Sluice – EPA's Review

Merrimack Station's present fish returns are unacceptable. The returns from both units empty into a concrete pit on the riverbank above normal water elevation. Therefore, fish survival for impinged fish over the past 50 years of plant operation has been virtually zero. This does not satisfy the BTA standard.

Because survival studies using the existing fish return trough are fairly predictable, and do not reflect the more effective trough that Merrimack Station intends to construct, PSNH estimated reductions in impingement mortality from an improved fish return sluice using survival study results conducted for another plant, Indian Point, located on the Hudson River, in New York. PSNH provides only limited information about the Indian Point study, however. It did note that white perch (*Morone Americana*), a species not found in Hooksett Pool, was used as proxy for most species impinged at Merrimack Station (Normandeau 2007d). According to a report on alternate intake technologies developed for Indian Point (Enercon 2010), the fish return pipe for Unit 2 extends 185 ft. into the Hudson River and discharges 34 ft below mean sea level. This fish return neither appears to be the one used for the impingement survival study, given how difficult it would be to collect meaningful survival data from the discharge point of this return, nor is representative of PSNH's proposed fish return sluice. Absent more information on the specifics of Indian Point's survival study, EPA cannot assess its applicability to Merrimack Station, or verify PSNH's predicted survival rates.

At the same time, EPA generally agrees with PSNH's description of the features of a "quality" fish return that would be part of the BTA for minimizing impingement mortality, but has two primary concerns. First, PSNH does not explain why the optimal slope of the sluice cannot be maintained all the way to the water. According to the company, due to practical considerations, a drop of ¼ foot per linear foot would need to be used for the slide, which is the last 25 feet of the trough from the top of the bank to the water (Normandeau 2007d). Second, in its November 2007 CWA § 308 Response

(Normandeau 2007d), PSNH indicates that it assumes that the upgraded return sluice will only be operable in the ice-free months of April – December. Therefore, regardless of the effectiveness of the upgraded fish return, survival during three months of the year will likely be zero since the fish will not be discharged directly back into the river, much like current conditions. As discussed in Section 11.6.2.5 of this document, impingement occurs in every month of the year at Merrimack Station and, therefore, must be addressed on a year-round basis. EPA is not convinced that winter conditions are so severe at Merrimack Station that no available technology exists to safely return impinged fish to the river. Unless PSNH provides compelling information to the contrary, EPA has determined that the BTA for Merrimack Station will need to include an effective fish return sluice that is in place and operational year-round.

11.6.4 Aquatic Microfiltration Barriers

PSNH and EPA also investigated aquatic microfiltration barriers, another type of exclusion system. This technology is composed of a custom-designed and sized filtration fabric installed in a boom-like configuration in front of a facility's CWISs to reduce or eliminate entrainment and impingement of fish eggs, larvae, and larger organisms. The filtration fabric has a very small pore size which enables it not only to block juvenile and adult fish from being drawn into the CWIS, but also, at least theoretically, to block most eggs and larvae. This technology can also be used to reduce intake volumes to 0.5 ft/sec or less, which can prevent impingement mortality by enabling most fish species to swim away from the CWIS. Having excluded icthyoplankton from being entrained, the question, once again, arises as to whether the organisms can be safely removed from the barriers and returned to their aquatic habitat.

One type of aquatic microfiltration barrier, a Gunderboom Marine Life Exclusion System (MLES™), has been used at a power plant on the Hudson River, in New York (Lovett Station). Although there have been problems anchoring the device, the system has been reported to significantly reduce entrainment at that plant, though concerns about biofouling undermining performance have also been raised.[76]

Aquatic Microfiltration Barriers – PSNH's Review
In its November 2007 CWA § 308 Response (Normandeau 2007d), PSNH rejected the seasonal deployment of the MLES™ as infeasible because the length of the curtain would impair Aother uses@ of the Merrimack River. The depth of the Merrimack River is 6–10 feet in the location where the MLES™ would need to be deployed. At those

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[76] *See* Taft, E.P., AFish Protection Technologies: A Status Report,@ Environmental Science and Policy (2000); *but see also* P.A. Henderson, R. M. Seaby, C. Cailes and J.R. Somes (Pisces Conservation Ltd.), "Gunderboom Fouling Studies in Bowline Pond" (July 2001).

depths, PSNH estimated that a 3,000-foot curtain would be required in order to allow the needed cooling water flow while maintaining an intake velocity of 0.5 ft/sec (to minimize impingement). PSNH based its analysis on commercially-available technical information without directly contacting Gunderboom, the manufacturer of the MLES.
In its October 2009 report, PSNH again analyzed seasonal deployment of the Gunderboom MLES™ to reduce entrainment and impingement at Merrimack Station (Enercon 2009). This time, PSNH obtained information from Gunderboom directly. This information responded to site-specific considerations such as river depth, a required cooling water flow of 100,000 and 200,000 gallons per minute per CWIS, and a through-microfilter velocity of 0.5 ft/sec or less. Based on these factors, it was estimated that Merrimack Station would require a MLES™ curtain of approximately 3,500 feet. While not specifically rejecting this technology as infeasible, as it had in its 2007 report, PSNH reiterated its opinion that the deployment of the MLES™ would potentially restrict river use for recreational purposes by approximately 50 percent of the river width along the curtain=s deployed length. Regulatory agencies, such as the U.S. Army Corps of Engineers and the NHDES would have to review and approve the placement of such a barrier structure in the Merrimack River.

Since the MLES™ fabric is susceptible to ice formation, PSNH indicated that the curtain could only be deployed from April to November. An automatic air burst system would need to be used to periodically remove impinged organisms, biofouling and debris from the fabric. The degree to which eggs and larvae or other tiny organisms would survive being caught on the barriers and then removed with an air burst system is unclear. PSNH would cease operation of the MLES™ in August. PSNH considers the risk of problematic fouling of the curtain to significantly increase after the month of July. Additionally, PSNH=s biological consultant, Normandeau Associates, stated that the highest observed period of entrainment of eggs and larvae present in the river is May through June. Based on these two considerations, PSNH proposes that it would remove the Gunderboom MLES™ after July and then depend on an upgraded fish return system to return any impinged organisms to the Merrimack River.

PSNH estimate a cost of $9.96M to acquire and install the Gunderboom MLES™ and an upgraded fish return system. It also estimates annual operation and maintenance costs of $0.46M per year.

PSNH also reviewed data from a study of a Gunderboom MLES™ conducted at Lovett Generating Station on the Hudson River from 2004 through 2007. Based on this study, the Gunderboom MLES™ exhibited an average exclusion effectiveness of 79 percent for all species and life stages of ichthyoplankton combined, with inter-annual variations ranging from 40% in 2004 to a high of 95% in 2007. The degree to which the organisms that are excluded will survive being caught on, and removed from, the barriers remains unclear. Normandeau Associates predicted that the following impingement and entrainment reductions could be achieved at Merrimack Station with deployment of the Gunderboom MLES™:

Table 11-7. Predicted entrainment and impingement reductions, and related reductions in adult equivalent losses associated with the deployment of Gunderboom MLES™ , from Enercon (2009).

Scenario	Impingement Mortality Reduction	Entrainment Reduction	Adult Equivalent Loss Reduction
Current Operations	18%	17%	17%
MLES™ Apr – Jul w/ Fish Return System Aug-Nov	78%	82%	80%
MLES™ Apr – Nov	82%	83%	81%

Since there are operational issues concerning the fouling of the MLES™, PSNH argues that the operation of the MLES™ needs to be limited to April through July each year. This is also the period that PSNH considers to be the peak entrainment season.

Aquatic Microfiltration Barriers – EPA's Review

As previously explained, in 2007, PSNH rejected the use of a Gunderboom microfiltration barrier based on its estimate that a 3,000-foot long barrier would be required, which it concluded would excessively interfere with public use of the river. A barrier of this length (over a half-mile long) was needed in order for the plant to obtain the required flow at the plant's intakes given the shallow depths of the Hooksett Pool in front of the plant. In 2009, PSNH estimated that a 3,500-foot long barrier would be needed.

EPA is concerned that maintenance of such a lengthy microfiltration barrier would be difficult, particularly during spring high flow events when turbidity is high. High turbidity could clog the fine-mesh fabric causing a reduction in its effectiveness in excluding eggs and larvae. In addition, enclosing a substantial portion the riverine habitat – Hooksett Pool is approximately five-miles long – would prevent movement of fish and other aquatic organisms into and out of this area for up to five months. This could have unintended adverse effects on fish spawning success, migration, and/or foraging opportunities. EPA also shares PSNH's concern about such a large barrier interfering with public uses of a large proportion of the river. Finally, the ultimate survival of eggs and larvae that may be caught on the filtration fabric is uncertain and, as a result, while entrainment reductions may be estimated, reductions in icthyoplankton mortality remain uncertain.

In light of all these issues, EPA does not consider the use of a microfiltration barrier, such as the Gunderboom MLES, to represent the BTA for Merrimack Station.

11.6.5 Intake Barrier Net

PSNH=s November 2007 submission briefly evaluated the possibility of installing a wide-mesh barrier net in front of the intake structures at Merrimack Station. PSNH calculated the net size needed to provide a through-velocity of 0.5 ft/sec, but then concluded that Hooksett Pool is too shallow to deploy a net that would encompass the 250-foot total length of the cooling water intake structures. A wide-mesh barrier net would provide no protection against entrainment as small aquatic organisms (*e.g.*, eggs and larvae) would go through the net openings. The technology is, accordingly, intended only to reduce the impingement of fish against a facility's existing intake screens. Yet, even as an impingement reduction technology, there would be a number of problems with using this technology at Merrimack Station. For example, this type of barrier net would likely only be able to be deployed in ice-free months and would likely be subject to significant fouling from debris during autumn and other periods with high debris loadings. Given these concerns, EPA, like PSNH, does not consider this technology a component of the BTA for Merrimack Station.

11.6.6 Other Technologies

EPA tasked PSNH to consider alternative technologies such as Aair bubble curtains,@ light and acoustic barriers, and louvers, none of which effectively reduce entrainment,[77] but which might conceivably play a role in impingement reduction as a component of an overall BTA. PSNH's review of these technologies, however, identifies problems with their effectiveness in reducing impingement mortality and/or applying them to Merrimack Station. Most studies of Abehavioral barriers,@ such as bubble curtains or acoustic barriers, have been inconclusive or have shown no significant reduction in

[77] *See* Technical Development Document for the Final Section 316(b) Phase II Rule, Feb. 12, 2004, at 4-16 & 4-19.

impingement.[78] Louvers, which rely solely on changing the direction of flow to minimize impingement, are ineffective because the Hooksett Pool lacks a constant water depth which is required to maintain an effective flow velocity. Porous dikes and artificial filter beds provide a porous barrier that prevents fish from entering the CWIS. As with microfiltration barrier technology, the breakwater housing a porous dike or artificial filter bed would have to be lengthy and would protrude well into the Merrimack River. For these reasons, EPA has eliminated these alternative technologies as BTA at Merrimack Station.

11.7 Capacity Options

Under CWA § 316(b), a CWIS's "capacity," as well as its location, construction, and design, must reflect the BTA for minimizing adverse environmental impacts (such as entrainment and impingement mortality). Capacity in this sense refers to the volume of water being withdrawn by a CWIS. Reduced CWIS capacity is considered to reduce entrainment by the same proportion that the flow is reduced. Indeed, intake capacity reductions have often been referred to as the most effective means of reducing entrainment. Similarly, impingement can be reduced through flow reductions, as well as by a reduction in the approach velocity in front of the intake structures. There are a number of different technological and operational measures that could reduce a facility's intake capacity (or flow volume). Methods of capacity reduction evaluated here include: (1) operational (maintenance) outages; (2) operating a reduced number of circulation pumps; (3) reducing flow by installing and operating variable frequency drives; and (4) reducing flow by installing and operating mechanical draft cooling towers.

11.7.1 Maintenance Outage Scheduling – PSNH's Proposal

The permittee considered a scheduled operational shutdown or outage option as a means of reducing the plant's intake flow and associated impingent and entrainment. Presently, Merrimack Station has maintenance outages for Unit 1 every two years and for Unit 2 every year. The outages for both units last approximately four weeks. "Relocating unit maintenance outages to the seasonal periods of highest impingement and entrainment. . . would yield the greatest increase in estimated annual impingement and entrainment reduction. . . ."[79]

According to PSNH, the periods of highest impingement and entrainment occur in early May-early June for Unit 1, and late May-late June for Unit 2. PSNH proposes, therefore,

[78] *See id.*, at 4-19.

[79] *See* PSNH November 2007 CWA § 308 Letter at 91.

that the optimal maintenance outage scenario would be to shut down Unit 1 in May and Unit 2 in June, which would reduce impingement mortality by 10% and entrainment by 43%, according to the company. PSNH concludes, however, that this scenario is infeasible because operational constraints and power pool demands preclude scheduled outages extending beyond mid-June. In addition, since Unit 1 has scheduled maintenance every two years versus every year for Unit 2, Unit 1 would be operating during the peak entrainment and impingement period on alternate years when scheduled maintenance is not required.

Alternatively, by scheduling just Unit 2 for maintenance outage from mid-May until mid-June, PSNH states there is the potential to reduce annual impingement by 41% and entrainment by 40% (Normandeau 2007d). According to PSNH scheduling Unit 2's outage during this period would cost $127,000. Further, PSNH states that installation of an upgraded fish return system, in combination with outage rescheduling, could potentially reduce impingement mortality by 51.1 percent and entrainment by 27.3 percent. The report does not explain why the predicted reduction in entrainment rates would decrease from 40% to 27.3% when factoring in the use of an upgraded fish handling system.

Since PSNH does not schedule maintenance outages later than mid-June and considers back-to-back outages impractical, the company indicates that Unit 1's bi-annual outages would be scheduled in the fall. Scheduling Unit 1's outage in October, according to PSNH, would contribute to a five percent reduction in impingement. There would no reduction in entrainment because, according to PSNH, entrainment is negligible during the fall.

Maintenance Outage Scheduling – EPA's Review

EPA concurs, at least conceptually, that reducing flow by suspending operations during periods when early life stages of fish are present can be an effective strategy for reducing both entrainment and impingement during the outage period. However, this approach, as proposed by PSNH, does not cover the entire period when fish eggs and larvae are present, nor does it reduce entrainment losses related to the operation of Unit 1. Furthermore, it does not address impingement mortality outside the scheduled outage periods. PSNH has demonstrated through its impingement sampling (2005–2007) that impingement occurs year-round. Therefore, EPA does not consider the scheduled outages proposed by PSNH to be BTA for Merrimack Station.

That said, scheduling the annual Unit 2 maintenance outage for mid-May to mid-June could be a *component* of the BTA under CWA § 316(b). To the extent that maintenance outages for Unit 2 need to happen each year and can involve suspending cooling water withdrawals, it makes sense from the perspective of reducing adverse environmental impacts to schedule the outages during the high entrainment season.

11.7.2 One-Pump Circulating Water Operation (Unit 2 Only) – PSNH's Proposal

Merrimack Station operates only one of Unit 2's two circulating water pumps during winter months. This is done to concentrate all the screen wash on one traveling screen, which prevents frazil ice and chunks of small ice from building up on the traveling screen. This type of icing problem occurs approximately eight days each winter, on average.

According to PSNH, Merrimack Station could potentially reduce estimated total annual impingement by 53 percent by shifting Unit 2 to a single circulating pump mode from December 15 through March 15 (Normandeau 2007d). PSNH estimates this option would cost about $75,000. This cost is incurred because the lower condenser tube velocities lead to increased tube fouling. Additionally, an upgrade in the fish handling system to return live fish to the river would be required to achieve any potential decrease in impingement mortality. There would be no decrease in entrainment.

One-Pump Circulating Water Operation (Unit 2 Only) – EPA's Review

PSNH's prediction that "total annual impingement at Merrimack Station" could be reduced by 53 percent simply by operating Unit 2 with one circulating pump for three months is not supported by the company's data and, conceptually, does not make sense. According to PSNH's two-year impingement study (July 2005–June 2007), the number of fish impinged from December through March represented only 19 percent of all fish impinged from both units (Normandeau 2007c). Of that, Unit 2's operation accounted for only 8.5 percent of the total impingement during the two-year study period. Therefore, PSNH is not basing its estimate on its own most recent impingement data. Furthermore, PSNH claims that impingement mortality for Unit 2 can be reduced by 54 percent simply by upgrading the fish return sluice (Normandeau 2007d). The company's analysis does not make a clear distinction if impingement reduction and impingement *mortality* reduction are considered to be one-in-the-same in this case. If it is, then there is no perceived benefit by operating Unit 2 with only one circulating pump from December 15 to March 15. In addition, EPA is concerned that concentrating all the spray wash onto one traveling screen increases the pressure of the spray, thereby increasing the potential to injure fish that are impinged on the screens. EPA finds that little benefit would accrue from operating only one circulating pump on Unit 2 from December 15 to March 15 and, therefore, does not consider this operational modification to represent BTA for Merrimack Station.

11.7.3 Variable Speed Pumps

Each CWIS at Merrimack Station has two single-speed, circulating pumps. Unit 1 has a combined design pumping capacity of about 85 MGD, and Unit 2 has a combined designed pumping capacity of 201 MGD. Single speed pumps essentially always withdraw water at their design capacity. As an alternative to single-speed pumps, variable speed pumps enable a facility to adjust the volume of water it withdraws from the source water body for cooling to better match its actual cooling needs.

Since Merrimack Station is a base-load electrical generating facility, all four pumps are normally operated.[80] PSNH indicated that if four new circulating water pumps with variable speed drives were installed at Merrimack Station, reductions in intake volumes (and corresponding reductions in impingement and entrainment) could nevertheless occur only during periods when the Merrimack River provides a favorable thermal heat sink. Those favorable river temperature conditions tend to occur from late fall to early spring. In colder months, less cooling water is required to remove heat in order to maintain the required vacuum in Merrimack Station's condensers. Therefore, during such conditions, variable speed pumps could be used to reduce withdrawals. In such cases, there would be some decrease in impingement because of reduced flows. There would, however, be little reduction in entrainment because little entrainment is expected during those cold weather months. The abundance of entrained larvae at Merrimack Station varied seasonally with a primary peak in May through June.[81] During the months of May and June some marginal reduction in circulating water flow could potentially be achieved through the use of variable speed drive pumps, but the direct result of reduced flows during these months would be a significant increase in the discharge temperature of Merrimack Station's effluent. Less circulating water flow (*i.e.*, less volume of water through the condenser) directly results in hotter circulating water discharged from the condensers.

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[80] An exception is that during periods in the winter when frazil ice begins to build up on the CWIS trash racks, one of the Unit 2 circulating pumps is secured and only one traveling water screen is used. Having 100% of the screen wash flow on a single traveling water screen helps prevent ice build-up. According to PSNH, the need to secure one of Unit 2's circulating pumps occurs, on average, eight days per year (Normandeau 2007d).

[81] See Normandeau Associates, Response and Impingement Studies Performed at Merrimack Station Generating Station from June 2005 Through June 2007 (Oct. 2007), Table 5-6 at 123.

Further reducing circulating water flow velocity through the condensers will result in increased fouling of the condensers' tubes. In order to counter this fouling, a new condenser cleaning system would need to be installed or increase use of bio-fouling chemicals would be required.

Variable Speed Pumps – EPA's Review

Variable speed pumps are generally a less-promising option for base-load power plants because they are generally running at a high capacity level and provide less opportunity for reducing cooling water withdrawals. For Merrimack Station, EPA concludes based on current flow levels and the technological requirements of existing equipment, that installation of circulating water pumps with variable speed drives would be unlikely to substantially reduce impingement and entrainment, at least without impairing Merrimack Station's ability to effectively generate electricity. Given the availability of alternative technologies capable of minimizing entrainment and impingement without disrupting power generation, EPA does not consider circulating water pumps with variable speed drives to represent BTA at this time.

11.7.4 Closed-Cycle Cooling

Steam electric power plants can generate electricity while using substantially less water than is required for a once-through cooling system by using a "closed-cycle" cooling system. Generally, steam electric power plants employ one of four basic types of circulating water systems to reject waste heat. These systems are: (1) once-through cooling, (2) once-through cooling with supplemental cooling of the heated discharge, (3) entirely closed-cycle or recirculating cooling, and (4) combinations of these three systems. In a once-through (or non-recirculating) system, the entire amount of waste heat is discharged to the receiving water body.

A once-through system with supplemental cooling (*e.g.*, from "helper" cooling towers or in the case of Merrimack Station power spray modules ("PSMs") removes a portion of the plant=s waste heat from the effluent and transfers this energy to the atmosphere before discharging the effluent to the receiving water. At Merrimack Station, a once-through system is used in conjunction with a cooling water discharge canal and PSMs. In 1971, the cooling canal was reconfigured and enlarged for the installation of 56 PSMs each containing four spray nozzles. PSNH explains that the PSMs cool thermal effluent "in a manner similar to evaporative cooling towers …"[82] by spraying a portion of the heated water in the cooling canal into the air to promote heat dissipation before the water

[82] *See* PSNH November 2007 CWA § 308 Response at 20.

falls back into the canal and is then discharged to the Merrimack River. This type of system does not, however, offer a reduction in the volume of water used and, as a result, does not reduce entrainment or impingement and would not satisfy the BTA standard of CWA § 316(b).

Closed-cycle or recirculating cooling water systems employ a cooling device that withdraws the plant=s waste energy from the cooling water and releases it directly to the atmosphere. The facility is then able to recirculate and reuse the previously heated water for additional cooling. This enables the facility not only to reduce discharges of heat, but also to reduce withdrawals of water for cooling. As a result, entrainment and impingement mortality are substantially reduced. Specifically, water withdrawals can be reduced by up to 95% or more, depending on certain site-specific factors. There are two basic methods of heat rejection for closed-cycle recirculating cooling water systems. The first is to use wet (or evaporative) cooling towers.[83] The second uses cooling ponds or lakes. These two methods dramatically reduce cooling water use, though they do require a small amount of "makeup" water. The makeup water is required to replace cooling water lost to evaporation and leaks. Again, water withdrawals, and entrainment and impingement, can be reduced by up to 95% or more.

A third type of closed-cycle cooling system does not use cooling water at all and, instead, employs "dry cooling towers" ("or air-cooled condensers"). This method eliminates the use of cooling water and rejects heat directly to the atmosphere from the surface of the condenser. No evaporation of water is involved. Dry cooling systems are generally regarded to be more expensive and to require more space to install than wet cooling tower systems.[84]

Another type of closed system worthy of note is the "hybrid" (or "wet/dry") system which combines elements of both wet and dry tower operations. The advantage of this type of cooling system is that it can be used to reduce and/or eliminate any problematic water vapor plumes from mechanical draft cooling towers.[85] This technology would be less expensive than dry cooling but more expensive than a wet cooling tower system.[86]

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83 *See, e.g.*, 66 Fed. Reg. at 65,282; EPA Economic and Engineering Analysis, App. A at 14.

84 *See, e.g.*, 66 Fed. Reg. at 65,282–83.

85 *See* 65 Fed. Reg. at 49,081 (discussion of wet/dry tower); 39 Fed. Reg. at 36,192; EPA Economic and Engineering Analysis, App. A at 14.

86 *See* 65 Fed. Reg. at 49,081 (discussion of wet/dry tower); Science Applications International Corporation (SAIC) Report (Mar. 15, 2002), Table 5.

As a general matter wet, dry, and wet/dry cooling towers are all practicable, available technologies for power plants. Wet cooling towers have been widely used at power plants for many years.[87] Dry cooling is also clearly a viable technology as dry cooling systems have been installed or proposed for installation at a number of facilities in the United States, including new units at the Mystic Station and the Fore River Station in Massachusetts.[88] In addition, wet/dry cooling towers are also a practicable technology used at a number of plants.[89]

Finally, a single power plant could use both open-cycle and closed-cycle cooling technologies. For example, different types of cooling systems could be provided for different generating units. Alternatively, closed-cycle cooling equipment could be installed for an entire facility but only used during certain parts of the year, while open-cycle cooling would be used at other times. This approach has been taken at various power plants, such as the Vermont Yankee nuclear facility. Such "combination options" or "partially closed-cycle cooling options" could be selected for a variety of reasons, such as to address seasonally-focused environmental issues, to reduce overall plant flows and/or thermal discharges to some predetermined level, to deal with a facility's space constraints, or to stay below some specified cost threshold.[90]

In the context of permitting for an existing facility, such as Merrimack Station, EPA must assess whether one or more of the above cooling technologies can be retrofitted to the facility. EPA research has identified a number of existing power plants with open-cycle cooling systems that have converted to closed-cycle cooling by retrofitting wet cooling towers at the facilities. *See, e.g.*, *Draft Permit Determinations Document for Brayton Point Station NPDES Permit*, at 7-37 to 7-38; *Responses to Comments for Brayton Point*

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[87] *See, e.g.*, *id.*; 65 Fed. Reg. at 49,080-81; 1996 EPA Suppl. to Background Paper No. 3, at A-3; 41 Fed. Reg. at 17,388; 1976 Draft EPA CWA §316(b) Guidance at 13; EPA 1976 Development Document at 149–57, 191; 39 Fed. Reg. at 36,192.

[88] *See also* 65 Fed. Reg. at 49,080–81; Letter from Vernon Lang, USFWS to EPA Proposed Rule Comment Clerk at 3 (Nov. 6, 2000) (comments on EPA's proposed regulations under CWA § 316(b) for new power plants listing a number of facilities currently operating, under construction, or recently approved for dry cooling); EPA Economic and Engineering Analysis, App. A at 14.

[89] *See, e.g.*, 65 Fed. Reg. at 49,080–81; EPA Economic and Engineering Analysis, App. A at 14–15; 39 Fed. Reg. at 36,192; Literature from Marley Cooling Tower Company; Pub. Serv. Comm'n of Wis./Wisc. Dep't of Natural Res., Final Environmental Impact Statement, Badger Generating Company, LLC, Electric Generation and Transmission Facilities (Jun. 2000, 9340-CE-100), Exec. Sum.

[90] *See* 1994 EPA Background Paper No. 3, at 2–3.

Station NPDES Permit, at IV-115.[91] Retrofits have typically involved wet mechanical draft cooling towers, but the Brayton Point Station facility in Somerset, Massachusetts, is retrofitting natural draft towers to its formerly open-cycle facility. This establishes that converting an existing open-cycle facility to a closed-cycle operation using wet cooling towers is practicable as a general matter.

EPA has not, however, found a single example of an existing power plant converting from open-cycle cooling to closed-cycle cooling by retrofitting a dry cooling system at the facility. Dry cooling is generally considered to be more expensive, and to require more space for installation, than wet cooling. Therefore, converting to dry cooling would tend to pose greater difficulty than a conversion to wet cooling. Of course, none of this establishes that such a retrofit would be impracticable in all cases and it seems, theoretically, that a retrofit of dry cooling should be possible. Nevertheless, in the absence of a single example of such a conversion ever having taken place, EPA is reticent to draw a firm conclusion at this time about the practicability of such a conversion in the future.

Beyond the issue of a technology's practicability (or "availability"), EPA also considers other issues pertaining to the effects of using a particular technology that may be pertinent in determining whether the capacity reductions from a particular closed-cycle cooling technology should be determined to reflect the BTA at a specific plant. Such considerations may include the secondary environmental effects, direct and indirect, of using cooling towers (*e.g.*, sound emissions, air emissions of water vapor, mist, or other substances, visual or "aesthetic" effects). Moreover, if such effects require mitigation measures, additional project costs may need to be considered. Finally, use of any closed-cycle cooling technology will also likely result in a marginal loss of electrical output to the power grid by the power plant due to marginally reduced electric generation efficiency ("efficiency penalty") and the need to use some of the plant's output to power cooling tower fans and pumps. This reduced output has an associated economic cost to the power plant and in an extreme set of circumstances could conceivably affect the adequacy of local energy supplies. Moreover, it could result in the facility, or another facility, burning additional fossil fuel and emitting more air pollution to provide

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[91] In the Phase I CWA ' 316(b) Rule, EPA determined that entrainment and impingement mortality reductions commensurate with the use of closed-cycle cooling reflect the BTA for *new* facilities with CWISs. *See* 40 C.F.R. Part 125, Subpart I (Phase I CWA ' 316(b) Rule).

"replacement power" to offset the lost output to the grid. These kinds of issues are discussed further below.

Moving beyond this general discussion, it is necessary to determine whether the above closed-cycle cooling technologies are available specifically for retrofitting at Merrimack Station.

11.7.4.1 "Air" or "Dry" Cooling Towers at Merrimack Station

As discussed above, using air (or dry) cooling towers would yield the maximum reduction in flow of any cooling technology by essentially eliminating the use of water for cooling. Thus, this option would essentially eliminate both the heat load to the Merrimack River and the losses to aquatic life resulting from impingement and entrainment associated with cooling water withdrawals.

<u>"Air" or "Dry" Cooling Towers at Merrimack Station – PSNH's Review</u>

PSNH's analysis concluded that retrofitting air cooling at Merrimack Station would be impracticable. Specifically, the permittee concluded that dry cooling towers would require far greater surface area for construction than is available at Merrimack Station. Dry cooling towers are less efficient than wet or hybrid cooling towers using evaporative cooling and this contributes to their greater space requirements. The permittee also stated that lower efficiency of dry cooling towers is such that they ". . . are not capable of supporting condenser temperatures and associated backpressures necessary to be compatible with either of the [*electrical generating*] Unit's turbine design. . . ."[92] Furthermore, PSNH stated that a dry cooling system would be substantially more expensive than using wet cooling towers.[93] Various estimates put the cost of dry cooling at 1.75 to 3 times more than the cost of wet cooling.

<u>"Air" or "Dry" Cooling Towers at Merrimack Station – EPA's Review</u>

EPA has decided based on current information to eliminate dry cooling towers from further consideration for retrofitting at Merrimack Station. In PSNH's view, dry cooling would be impracticable because of space constraints. While EPA has not independently verified this conclusion, we have previously noted that dry cooling requires more space, and is likely to have greater feasibility problems as a result, than wet cooling towers. Furthermore, as stated above, EPA has not identified a single case of a facility retrofitting

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92 *See* PSNH November 2007 CWA § 308 at 32–33.

93 *See* 66 Fed. Reg. at 65,282–84, 65,304–06.

from open-cycle cooling to dry cooling. Dry cooling would also be more expensive and create larger marginal energy penalties, while likely achieving only a small marginal additional reduction over the high end of the reduction range for wet cooling towers. In light of the above considerations, including the absence of a single example of an open-cycle plant converting to dry cooling, EPA has determined based on current information that converting to dry cooling is not the BTA for Merrimack Station. *See also Riverkeeper I*, 358 F.3d at 194–96 (upholding EPA's rejection of dry cooling as the BTA for the Phase I § 316(b) Rule addressing new facilities).

11.7.4.2 Wet Cooling Towers at Merrimack Station

There are two principal types of wet cooling towers that are used in closed cycle systems: natural draft and mechanical draft towers. Natural draft towers have no mechanical device to create air flow through the tower and are usually applied in either very small or very large applications.[94] Mechanical draft towers use fans in the cooling process.[95] A third type of cooling tower combines elements of both wet and dry cooling and is referred to, alternatively, either as "wet/dry" cooling towers, "hybrid" cooling towers or "plume abated" cooling towers.

11.7.4.2.1 Mechanical Draft Wet Cooling Towers – PSNH's Review

According to PSNH, it would be feasible to convert Merrimack Station from open-cycle to closed-cycle cooling by retrofitting mechanical draft cooling towers at the facility. The company estimates that this approach would reduce intake flow, and associated entrainment and impingement, by about 97%. PSNH also indicates that mechanical draft towers at Merrimack Station would require about 1.77 MGD of make-up water for Unit 1 and 4.20 MGD make-up water for Unit 2. This make-up water would be needed to replace: (1) blow-down; (2) evaporation losses; and (3) drift (water particles carried out by the tower plume). The company also estimates that about 0.3 MGD of blow-down would have to be discharged to the Merrimack River. The company notes that the evaporative losses of about 1.4 MGD would result in marginally lower river flows and that mechanical draft cooling towers would present possible adverse noise and visual impacts. In addition, PSNH notes concern about the possibility of water vapor plumes causing fogging and/or icing problems in cold weather. As a result, PSNH focused its evaluation on hybrid (or wet/dry) mechanical draft cooling towers. The permittee has

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[94] *See* 1994 EPA Background Paper No. 3, at 2-4.

[95] *See id.*; EPA Economic and Engineering Analysis, at 11-2 to 11-3; App. A, at 14.

estimated that the total present worth cost of this option to be nearly $68 million, with an annual operating cost estimated at slightly over $6.5 million.

Mechanical Draft Wet Cooling Towers – EPA's Review

EPA agrees with PSNH that converting Merrimack Station from open-cycle to closed-cycle cooling by retrofitting mechanical draft wet cooling towers at the facility is a feasible option that should be further considered as the potential BTA under CWA § 316(b). Under § 316(b), use of this technology should be considered on both a year-round and on a seasonal basis, if appropriate due to seasonal variation in entrainment and impingement concerns. In addition, EPA has determined that mechanical draft cooling towers should be evaluated in both a wet and a wet/dry configuration.

EPA evaluated mechanical draft wet and wet/dry cooling towers on a year-round basis in Section 7 of this document as part of the determination of the Best Available Technology economically achievable (BAT) for controlling Merrimack Station's thermal discharges. This evaluation looked at cost as well as direct and indirect secondary environmental and energy effects and found nothing to require mechanical draft cooling towers to be ruled out. Rather than repeat that analysis here, EPA refers the reader to Section 7.4.3.1 of this document and incorporates that analysis here by reference. It should also be noted that if closed-cycle cooling is only required on a seasonal basis, then costs and any secondary effects attributable to the BTA would be correspondingly less than if closed-cycle cooling was required year-round.

Finally, to determine the BTA for Merrimack Station under CWA § 316(b), EPA will also consider a comparison of the costs and benefits of the various options remaining for consideration. This additional analysis is presented in Section 12 below.

11.7.4.2.2 Natural Draft Wet Cooling Towers – PSNH's Review

PSNH evaluated natural draft cooling towers and concluded that this technology should be eliminated as the potential BTA. Natural draft cooling towers function because a "chimney effect" within the tower produces an air flow which provides the cooling medium to cool the heated non-contact cooling water discharged by the condenser. The permittee concluded that the cooling water (*i.e.*, circulation flow) at Merrimack Station would not provide an ". . . adequate heat load . . . to fuel the thermal differential required to create and sustain the "chimney effect."[96]

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[96] *See* PSNH November 2007 CWA §308 Response at 33.

Natural Draft Wet Cooling Towers – EPA's Review

Again, in Section 7 of this document, EPA evaluated natural draft towers in the context of its determination of the BAT for controlling thermal discharges from Merrimack Station. Rather than repeat that analysis here, EPA refers the reader to Section 7.4.2.2.2 of this document and incorporates that analysis here be reference. In this analysis, EPA explained that PSNH had concluded that natural draft cooling towers were infeasible at Merrimack Station for certain reasons, but EPA further explained that it had not independently verified PSNH's conclusions in this regard and that EPA was not prepared, without further justification, to agree that it would be infeasible to use natural draft towers in a closed-cycle configuration at Merrimack Station given the widespread use of this technology.

At the same time, given PSNH's expressed position and given the undisputed availability of other cooling tower technologies equally effective at reducing thermal discharges, EPA considers it unnecessary to further investigate natural draft wet cooling tower technology as the potential BTA for Merrimack Station. At the same time, PSNH may use any lawful technology, including natural draft cooling towers, to meet the permit limits ultimately included in the final permit.

11.8 EPA's Conclusions on Alternative Technologies

EPA rejected wedgewire screens, aquatic microfiltration barriers, fine-mesh traveling screens, and flow restrictions associated with scheduled unit outages or variable-speed pumps for the reasons discussed earlier in this section. This left closed-cycle cooling as the only technology available with the capability to appreciably reduce the mortality to aquatic organisms associated with entrainment. Impingement mortality could potentially be reduced by closed-cycle cooling or a number of other technologies. EPA evaluated a range of options, some of which included closed-cycle cooling for one or both generating units at Merrimack Station, and on a year-round or seasonal basis. A detailed discussion of EPA's BTA determination and decision process follows in Section 12.

12.0 EPA=S BEST PROFESSIONAL JUDGMENT DETERMINATION OF BEST TECHNOLOGY AVAILABLE FOR MINIMIZING ADVERSE ENVIRONMENTAL IMPACT FOR THE MERRIMACK STATIONS DRAFT NPDES PERMIT

12.1 Introduction

CWA § 316(b)'s legal requirements are discussed in Section 10 of this document. As explained more fully therein, absent controlling national categorical technology standards, EPA applies CWA ' 316(b)'s requirements for CWISs on a site-specific, BPJ basis.[97] Neither the CWA nor EPA regulations dictate a specific methodology for developing permit limits based on a BPJ determination of the BTA under ' 316(b).

The statute does, however, demand that "the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact." 33 U.S.C. § 1326(b). While none of the operative terms of § 316(b) are defined in the statute, these terms have been interpreted by EPA over years of practice and, in some cases, by federal court decisions. EPA has also looked for additional guidance in developing BTA requirements on a BPJ basis to the Agency's practice in the BPJ development of effluent limits.[98]

As is also discussed in Section 10 of this document, in addition to satisfying technology-based requirements under CWA § 316(b), permit requirements governing CWISs must

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[97] Thus, a BPJ analysis results in a valid, facility-specific BTA determination. In Nat'l Res. Def. Council, 859 F.2d at 199, the court explained:

> *[i]n what EPA characterizes as a >mini-guideline= process, the permit writer, after full consideration of the factors set forth in section 304(b), 33 U.S.C. ' 1314(b) (which are the same factors used in establishing effluent guidelines), establishes the permit conditions >necessary to carry out the provisions of [the CWA].= ' 1342(a)(1). These conditions include the appropriate . . . BAT effluent limitations for the particular point source. . . . [T]he resultant BPJ limitations are as correct and as statutorily supported as permit limits based upon an effluent limitations guideline.*

Id. See also Texas Oil, 161 F.3d at 929 ("Individual judgments thus take the place of uniform national guidelines, but the technology-based standard remains the same.").

[98] Although the CWA's technology-based effluent discharge standards are not identical to the BTA technology standard for CWISs, Congress used some of the same words for both, albeit combined in different ways and these standards are all designed for setting technology-based requirements. Therefore, it is reasonable and appropriate to analogize to setting effluent limits in seeking guidance for how to develop intake requirements. Furthermore, § 316(b) indicates that CWIS requirements are to be included in standards developed under CWA §§ 301 and 306, which suggests that it is reasonable to look to effluent limitation standards for guidance concerning factors to consider in setting a BTA-based limit for CWISs under § 316(b). *See Riverkeeper II*, 475 F.3d at 97–98; *Riverkeeper* I, 358 F.3d at 186, 195. Looking to the effluent standards development process for *guidance* does not, however, mean that the requirements for determining effluent standards are legally applicable to the development of BTA requirements under CWA § 316(b); they are not.

also satisfy any applicable state water quality standards. In this case, New Hampshire has water quality standards applicable to the effects of CWIS operations. *See* Section 10.2.3.b.

12.2 In General, the Best Performing Technology for Reducing the Adverse Environmental Effects of Cooling Water Intake Structures at Existing, Open-Cycle Cooling Power Plants Is to Convert the Facility to Closed-Cycle Cooling

As explained above in Section 10, in developing effluent limits based on the BAT standard, the CWA calls for EPA to look to the single Abest@ performing plant in the industry – in terms of effluent reduction – as the starting point for determining the Abest available technology" for that industry.[99] In identifying the best performing technology (or technologies), EPA has also determined that it may look to viable Atransfer technologies@ – that is, a technology from another industry that can be Atransferred@ to the industry in question – and to technologies shown to be viable in research though not yet implemented at a full-scale facility.[100]

The above practices for developing BAT effluent limitations are also appropriate to apply to the BPJ development of BTA requirements under ' 316(b). Therefore, EPA has identified the best-performing CWISs in the same industrial category as Merrimack Station. Given that Merrimack Station is a large, existing power plant, EPA identified the technologies used by large, existing power plants that have achieved the greatest reductions in adverse environmental impacts from their CWISs. In addition, EPA considered technologies that might potentially be feasible for use at Merrimack Station even if not previously used to retrofit an existing facility.[101]

Identifying the best performing technology for the industrial category provides a *starting point* for determining the BTA, but it is not determinative by itself. The BPJ application

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[99] *E.g.*, *Texas Oil*, 161 F.3d at 928; *Pac. Fisheries*, 615 F.2d at 816–17; *Am. Meat*, 526 F.2d at 462–63.

[100] These approaches to determining BAT are supported by the CWA=s legislative history and have been upheld by the courts. *E.g., Am. Petroleum*, 858 F.2d at 264–65; *Pac. Fisheries*, 615 F.2d at 816–17; *BASF Wyandotte*, 614 F.2d at 22; *Am. Iron*, 526 F.2d at 1061; *Am. Meat*, 526 F.2d at 462–63.

[101] In this regard, EPA could consider, for example, whether a technology used at a new power plant could constitute a viable Atransfer technology@ for use at an *existing* plant.

of the BTA standard to a particular facility is conducted on a case-by-case, site-specific basis, and a technology that works at one power plant might not actually be feasible at another plant due to site-specific issues (*e.g.,* space limitations). Accordingly, a technology that would be infeasible at Merrimack Station would not be the BTA for this permit, even if that technology worked at a different facility. In addition, various other pertinent factors beyond the degree of adverse impact reduction and technical feasibility may also be considered. Such factors may include considerations such as economic feasibility, secondary environmental effects, and others, and they would be evaluated specifically with regard to Merrimack Station.

For this permit development process, EPA has determined that the best performing technology for reducing the adverse environmental impacts of CWISs at existing open-cycle power plants is to convert the facility to closed-cycle cooling using some type of "wet" cooling tower(s).[102] EPA=s research has identified a number of facilities that have made this type of technological improvement. *See Draft Permit Determinations Document for Brayton Point Station NPDES Permit*, at 7-37 to 7-38; *Responses to Comments for Brayton Point Station NPDES Permit*, at IV-115. *See also California's Coastal Power Plants: Alternative Cooling System Analysis*, *Tetra Tech* (Feb. 2008). Converting to closed-cycle cooling using wet cooling towers can reduce intake flow – and attendant entrainment and impingement – by 70 to 98%, depending on factors such as any restrictions on cooling tower cycles of concentration due to limits on chloride discharges.[103] No other technology is broadly capable of reducing the mortality of eggs

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[102] Similarly, for the now-suspended Phase II Rule, EPA found that converting to closed-cycle cooling was the best performing technology for reducing the adverse environmental effects of CWISs at large, existing power plants and promulgated a regulation providing that any facility with closed-cycle cooling would be regarded to be in compliance with § 316(b)'s BTA requirements. *See* 40 C.F.R. § 125.94(a) (currently suspended). In addition, EPA also determined for the Phase I CWA ' 316(b) Rule, that entrainment and impingement mortality reductions commensurate with the use of closed-cycle cooling reflect the BTA for *new* facilities with CWISs. *See* 40 C.F.R. Part 125, Subpart I.

[103] While the use of "dry" cooling might achieve an even greater marginal reduction in entrainment and impingement, EPA has not identified a single case of a facility retrofitting from open-cycle cooling to dry cooling. Although EPA is unaware of any technical reason that such a conversion would necessarily be impracticable at all facilities, it is likely to be infeasible at a larger proportion of existing facilities than would a conversion to wet cooling because of factors such as the greater space needed for dry cooling, and it would likely achieve only a small additional marginal reduction over the high end of the reduction range for wet cooling towers and would be significantly more expensive. In light of these considerations, and in the absence of a single example of such a conversion, EPA is unable to conclude that a conversion to dry cooling

and larvae *entrained* by open-cycle cooling systems to a similar level.[104] Closed-cycle cooling is also the best performing technology for reducing harm to aquatic organisms by *impingement*, though there are also other technologies that may perform well in particular cases.

Thus, EPA's analysis leads to the conclusion that converting an existing, open-cycle cooling system to a closed-cycle cooling system with wet cooling towers would be the best performing technology for reducing the adverse environmental effects of CWISs in this industrial category.[105],[106] Again, as explained above, finding the technology to be

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at an existing open-cycle facility is the best performing technology for this industrial category. *See also Riverkeeper I*, 358 F.3d at 194–96 (upholding EPA's rejection of dry cooling as the BTA for the Phase I § 316(b) Rule addressing new facilities).

[104] There might, however, be individual facilities, or a relatively narrow subset of facilities, at which prevailing conditions could enable an alternative technology (*e.g.*, fine-mesh wedgewire screens) to achieve comparable levels of adverse impact reduction

[105] As discussed above, flow reduction improvements could also be made without changing to closed-cycle cooling by simply reducing the amount of cooling water used by the power plant. This approach, however, would likely require either substantial generating unit outages or increased thermal discharge, which could indirectly require curtailed generation if permitted thermal discharge limits would be exceeded. (Indeed, as discussed above, it is expected that this would be a problem at Merrimack Station.) Requiring such cutbacks in generation, sometimes on a seasonal basis, has been required in some permits. *See, e.g.*, Bulletin, Marine Resources Advisory Council, Vol. IX, No. 4, "Effects of Power Plants on Hudson River Fish," (requirements for plant included scheduled plant outages); *In Re Florida Power Corp., Crystal River Power Plant, Units 1, 2 and 3, Citrus County, Florida* (Findings and Determinations Pursuant to 33 U.S.C. ' 1326; NPDES Permit No. FL 0000159) at 8. Achieving flow reductions with closed-cycle cooling, however, allows a facility to reduce entrainment and impingement while also reducing its thermal discharges and continuing to generate and sell nearly the same amount of electricity. In this case, the permittee and EPA have evaluated intake flow reductions without utilizing closed-cycle cooling, but have determined that this approach does not represent the BTA at Merrimack Station due to its expense and other considerations. This site-specific evaluation is discussed both above and farther below. Of course, Merrimack Station always has the option of meeting permit limits by curtailing operations.

[106] In the Phase I CWA ' 316(b) Rule, EPA also determined that entrainment and impingement mortality reductions commensurate with closed-cycle cooling with wet cooling towers reflect the BTA for new facilities with CWISs. *See* 40 C.F.R. Part 125, Subpart I (Phase I CWA ' 316(b) Rule). This is secondarily supportive of the identification of closed-cycle cooling with wet cooling towers as the best performing technology for Merrimack Station because closed-cycle cooling at new facilities can be viewed as a potential "transfer technology" for existing facilities at which a retrofit would be feasible. Of course, retrofitting a technology to an existing plant is

the *best performing* for reducing adverse environmental effects within an industrial category is not the same thing as finding it to be the *best technology available* for that category under CWA § 316(b). This is because additional considerations may factor into the determination of the BTA. Furthermore, finding a technology to be the best performing for an industrial category does not mean that the technology will necessarily will be feasible at every individual facility within the category. Site-specific analysis is needed for a BPJ determination of the BTA.

12.3 Converting To Closed-Cycle Cooling Using Wet Cooling Towers Is the Best Performing, Available Technology for Reducing the Adverse Environmental Impacts of CWIS Operation at Merrimack Station

Having determined that converting to closed-cycle cooling using wet cooling towers would *generally* be the best performing available technology for reducing the adverse environmental effects of CWISs at large, existing open-cycle power plants, EPA then evaluated what would be the best performing available technology for Merrimack Station in particular. The record for this permit development establishes that converting to closed-cycle cooling using wet cooling towers would also be the best performing available technology for minimizing adverse environmental impacts from CWISs at Merrimack Station. PSNH/Enercon and EPA both concluded that closed-cycle cooling with wet cooling towers was a practicable (or Aavailable@) technology for Merrimack Station and would reduce adverse environmental impacts from CWISs to the greatest degree from among the alternatives assessed.[107] The bases for this conclusion are discussed in detail below.

Various types of screening systems were evaluated and either were infeasible (*i.e.*, were "unavailable" or "impracticable") (*e.g.*, wedgewire screens, aquatic mircrofiltration barriers) and/or provided uncertain and/or inferior performance (*e.g.*, fine-mesh traveling

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different than installing that technology at a new plant; for example, the costs, engineering considerations, and other considerations may differ substantially.

[107] EPA uses the term Apracticable@ here essentially as a synonym for Afeasible,@ consistent with its dictionary definition. *The American Heritage Dictionary* (2nd Ed.) (1982), defines Apracticable@ as, Acapable of being effected, done or executed; feasible.@ A technology that is impracticable or infeasible, on either technical or economic grounds, cannot reasonably be regarded to be "available," as required by CWA § 316(b). *See also Riverkeeper II*, 475 F.3d at 98–100; *Riverkeeper I*, 358 F.3d at 195.

screens). PSNH/Enercon (and EPA) also evaluated the alternative of retaining open-cycle cooling but reducing entrainment and impingement mortality by simply restricting the volume of cooling water withdrawals. While this could be achieved by shutting down or throttling pumps, using variable speed pumps, or periodically curtailing generating unit (and cooling water withdrawal) operations, PSNH and EPA both rejected these options. PSNH and EPA both rejected the installation of variable speed cooling water pumps as impractical. The cooling water flow required to remove Merrimack Station=s normal heat load can be met at lower pumping rates for only a few months per year. Those months are in the winter, when the population of eggs and larvae are at their lowest. Thus, this will not achieve appreciable reductions in entrainment. Nevertheless, PSNH has proposed securing one of Unit 2's cooling water pumps from December 15 through March 15 each year. This would be a positive step as it would help to reduce impingement – as well as the facility's energy costs – but it would not reduce entrainment.

In sum, converting to closed-cycle cooling with wet cooling towers would be the most assured means of achieving large-scale reductions in entrainment and impingement mortality – as a result of the large-scale reduction in water withdrawal volumes that are associated with closed-cycle cooling –while allowing Merrimack Station to continue to generate and sell electricity at essentially current levels.

12.4 Determination of the BTA under CWA § 316(b) for Merrimack Station's CWISs

Having determined that converting to closed-cycle cooling would be the best performing available technology for reducing the adverse environmental impacts of Merrimack Station's CWISs, EPA then turned to considering the full range of relevant factors to support a determination of the BTA for the Station's CWISs. This evaluation and determination are presented below.

12.4.1 Adverse Environmental Impact from Merrimack Station's CWISs

Merrimack Station is a steam-electric power plant that primarily burns coal and operates as a "base-load" facility with an electrical output of 478 MW. The plant has two primary power generating units: Unit 1 began operation in 1960 and has a nameplate rating of 120 MW, while Unit 2 began operation in 1968 and has a nameplate rating of 350 MW. The facility currently utilizes a once-through (or open-cycle) cooling system designed to withdraw up to 287 MGD of water from the Hooksett Pool portion of the Merrimack River (85 MGD for Unit 1 and 202 MGD for Unit 2) for once-through condenser cooling, and then to discharge the heated water back to the river. Merrimack Station currently operates traveling screens that are primarily designed to remove debris from the CWIS.

In addition to heating the river as a result of its thermal discharges, Merrimack Station's water withdrawals result in the mortality of approximately 3.8 million eggs and larvae per year from entrainment and approximately 4,903 fish per year from impingement (*see* Sections 11.2.1 and 11.2.2). It should also be noted that were it not for the depleted state of fish populations in the Hooksett Pool, these numbers would likely be even higher. Stated differently, if efforts to restore and support fish populations in the river are successful – including current efforts to restore the river's runs of American shad and Atlantic salmon – then these numbers would be expected to be higher without any changes to Merrimack Station's cooling system and operational profile.

12.4.1a Entrainment

EPA regards the number of eggs and larvae entrained at Merrimack Station to represent a significant degree of adverse environmental impact. In this analysis, EPA assumed 100-percent mortality for all eggs and larvae entrained. This is a reasonable approach commonly used by EPA and others in the absence of a site-specific survival study demonstrating some lesser percentage of mortality. Based on this assumption, a reduction in entrainment is equivalent to a reduction in entrainment mortality. The existing traveling screens at Merrimack Station are too coarse (9.5 mm) to exclude eggs and larvae from being entrained. The estimated total number of eggs and larvae currently entrained each year at Merrimack Station (3.8 million) is based on the plant's design intake flow and sampling conducted at the plant's intakes in 2006 and 2007.

As discussed in Section 11, the fraction of the river that runs through the plant, and the corresponding plankton community that is entrained with it, varies with the river flow. Under minimum flow conditions, based on mean flow rates calculated for Garvins Falls Dam over the 15-year period (1993–2007), the fraction of the river flow withdrawn by Merrimack Station ranges from approximately nine percent in April to as high as 64 percent in August (Figure 11-1). In June, the month when larvae are most abundant in Hooksett Pool, the fraction of the flow withdrawn for cooling has reached 24 percent of the available river flow under low flow conditions. Daily flow rates can range even higher. For example, EPA calculated that on July 7, 1995, Merrimack Station had withdrawn approximately 75 percent of the river flow. This represents a sizable fraction of the river flow and, by extension, a sizable fraction of the larva community during peak larval abundance.

White sucker and yellow perch were the numerically dominant indigenous species in the 2007 entrainment sampling, representing 46 and 18 percent, respectively, of all species sampled. Both species have larval stages that are particularly prone to entrainment. The abundance of these two species has declined over the years as water quality and habitat in the river have degraded. In the 1960s, the relative abundance of yellow perch and white sucker was 26 percent and 16 percent, respectively. By the 2000s, those numbers had both dropped to 2 percent. These "cool water" species have been adversely affected by the Merrimack Station's discharge of heated cooling water. The cumulative impact from entrainment puts added stress on populations already impacted by impaired water quality and habitat. While the recovery of these species will require reduced thermal discharges, EPA expects that continued entrainment at current levels would likely interfere with a recovery.

Another species particularly vulnerable to entrainment is American shad. Restoring American shad populations to the Merrimack River has long been a goal of both USFWS and NHFGD. A new long-term effort to stock both adult and larval shad in the upper Merrimack River began in 2010. The American shad restoration plan sets a goal of stocking approximately four million shad fry (larvae) annually to augment natural spawning of stocked adult fish. The larvae are approximately 5-6 mm in length when released at locations upstream from the Hooksett Pool in June and July. The USFWS expects some of these larvae will drift downstream into Hooksett Pool, which could expose them to entrainment at Merrimack Station, as well as the potentially lethal temperature conditions within the plant's discharge plume.

In addition to entrainment losses to individual species, the loss of eggs and larvae from all fish species, as well as other zooplankton, represents a significant reduction in available forage for older juvenile fish and other aquatic organisms that typically prey on them. The environmental impact of this loss of forage opportunity cannot be quantified at present, but it clearly creates added stress on the Hooksett Pool ecosystem because, in the absence of the organisms lost, foraging must be directed towards other available sources. Thus, competition increases for what forage is available and the typical predator/prey relationships among resident organisms may be altered.

Although we cannot be certain what portion of the larger ichthyoplankton community in the pool is represented by this "baseline" entrainment figure because PSNH did not conduct in-river ichthyoplankton sampling, the portion of the ichthyoplankton community could be large given the large proportion of available river flow that Merrimack Station withdraws during some periods. In addition, entrainment rates may also reflect the compromised state of fish populations in Hooksett Pool, with fewer adult fish available to contribute to the ichthyoplankton community. In light of the above factors, EPA deems entrainment at Merrimack Station to represent a significant adverse impact to the Hooksett Pool.

12.4.1b Impingement

Studies conducted at Merrimack Station from July 2005 to June 2007 demonstrated that impingement occurs year-round at the facility. Assuming that this relatively limited data set (the only data available) is representative, it indicates that, contrary to the earlier assumption of EPA and other reviewing agencies that impingement was likely to be most frequent during the summer period of low river flow, impingement is actually more common during periods of higher flow. The data suggest that monthly impingement rates typically range from 11 to 581 fish, but that higher peak levels are possible, as 4,300 fish were estimated to have been impinged in June 2006 alone. The species composition of the fish impinged is comparable to the sampling results of in-river studies conducted in 2004–2005.

Merrimack Station's CWISs have several features that are likely to cause impingement mortality. First, the approach velocities of the CWISs for Units I and II are 1.5 ft/sec and 1.8 ft/sec, respectively. These rates are three to over three and a half (3.64) times greater than the 0.5 ft/sec intake velocity that EPA has identified to be low enough to allow many fish species to swim away from an intake velocity and avoid becoming impinged. Higher intake velocities are likely to increase the risk of impingement. Second, the existing traveling screens are built with narrow ledges, which are designed to carry debris, not live fish. Fish drop off the ledges into the water and can be repeatedly re-impinged. In addition, the existing power spray wash system is powerful enough to de-scale or otherwise injure impinged fish. Both repeated impingement and powerful spray wash subject organisms to additional physical stress that can contribute to impingement mortality. Finally, the fish return system at Merrimack Station discharges fish and debris through a metal grate into a cement pit that is located above the normal water elevation, so most fish never reach the river. For these reasons, EPA determined that the existing traveling screens are not the BTA for impingement. Under current conditions at Merrimack Station, EPA assumes that the rate of impingement mortality is the same as the rate of impingement.

The impingement levels at Merrimack Station appear to be comparable to those of Vermont Yankee Nuclear Power Station ("VYNPS"), which withdraws cooling water from the Vernon Pool, an impounded section of the Connecticut River. According to impingement data provided in the Nuclear Regulatory Commission's ("NRC") Draft Generic Environmental Impact Statement ("DGEIS"), VYNPS impinged fish at an average rate of 26 fish per day between 1981 and 1989, or approximately 9,490 fish per year (NRC 2006). Merrimack Station, which has a design intake capacity that is roughly half (55 percent) that of VYNPS (when operating in open-cycle mode), impinged an average of 13 fish per day from July 2005 through June 2007, or approximately 4,903 fish per year (Normandeau 2007d). More recent impingement data for VYNPS were provided in the DGEIS, as well. Impingement sampling conducted in 2001, 2003, and 2004 during the months of April–June and August–October resulted in the estimated impingement of 700, 1,142, and 237 fish for those months in those years, respectively (NRC 2006). Based on those values, 693 fish were impinged annually during those months over this non-consecutive, three-year period. Impingement sampling at Merrimack Station from July 2005 through June 2007, for the same months sampled at VYNPS (April–June, August–October) resulted in the estimated impingement of 2,361 fish per year for those months (Normandeau 2007c). There was insufficient information provided in the DGEIS to know if the sampling techniques conducted at the two plants were directly comparable, although the same consulting firm was involved.

Comprehensive year-round impingement sampling appears to have been conducted only once before at Merrimack Station, based on EPA's review of the plant's permit file. According to PSNH's Merrimack River Monitoring Program 1978 Report (Normandeau 1979a), annual "entrapment" (now commonly referred to as "impingement") was estimated to be 2,504 fish during 1976 and 1977. PSNH's estimated annual impingement rate (4,903 fish) for the 2005–2007 study period is nearly twice the reported impingement rate for 1976–1977. Increased impingement rates combined with evidence of declining populations suggests that the facility's level of impingement may represent significant harm as a cumulative stress to fish populations already struggling to maintain themselves.

Members of the herring family (clupeids), which may at times be present in Hooksett Pool, are structurally fragile and demonstrate low survival rates under most study conditions. These species (*i.e.*, alewife, blueback herring, American shad) tend to move in dense schools during their fall migration downstream to the sea, which for Merrimack River populations means, in most cases, migrating through the Hooksett Pool. In addition, the stocking of American shad fry (larvae) upstream of Hooksett Pool could provide the opportunity for juvenile shad to spend their first months of life inhabiting Hooksett Pool. Studies conducted by EPRI (2000) found that the "mean critical velocity" – the ability of a fish to swim against specific current velocities – for juvenile herring ranged from 1.1 ft/sec to 1.3 ft/sec for herring 8.9 cm–9.8 cm long. These critical swimming rates are lower than the intake approach velocities for either unit (1.5 ft/sec, 1.8 ft/sec) at Merrimack Station.

While the impingement of clupeids has not been reported by Merrimack Station in recent years, there is a documented history of 14 "extraordinary impingement events" that occurred primarily in the mid-1980s and late 1990s. These reported events typically covered several days in September or October with the estimated number of herring impinged ranging from 1 to 274 fish, but in one case the plant estimated the number to be 2,000 to 4,000 fish. Of those measured, the lengths of most fish impinged fell within the range of 6.5 cm – 9.5 cm. These lengths are comparable to those evaluated in the critical swimming velocity studies referenced above (8.9 cm–9.8 cm), which may explain why fish in this size range were impinged at the high CWIS velocities. According to PSNH, juvenile alewives migrating along the river's western bank may have been attracted to the flow from the plant's intake structures during a period of particularly low river flow.

This is certainly conceivable since the herring key in on flow direction in order to find their way downstream to the sea. In other correspondence, the plant suggests that extraordinary impingement events are a result of the increased number of juvenile fish (*i.e.*, herring) observed in the river that year. This is also plausible, and warrants special consideration in light of new and ongoing state and federal efforts to rebuild American Shad and river herring stocks, and the fact that the Hooksett Pool is the only conduit between upstream spawning and juvenile rearing habitat and the sea. In light of the above factors, EPA deems impingement at Merrimack Station also to represent a significant adverse impact to the Hooksett Pool.

12.5 Summary of Candidate Technologies for the BTA at Merrimack Station

EPA evaluated the potential availability of a variety of technologies for minimizing the adverse environmental effects of impingement and entrainment by Merrimack Station's two CWISs. EPA also considered a variety of issues that would be associated with the application of these technologies at Merrimack Station. With regard to reducing entrainment, EPA considered a number of technologies designed to physically exclude eggs and larvae from being entrained (*e.g.*, narrow slot wedgewire screens, aquatic microfiltration barriers), but determined that these technologies were unavailable or ineffective at this site. At Merrimack Station, the only effective available technology to reduce entrainment mortality is to convert the facility to closed-cycle cooling ("CCC"). While Merrimack Station could achieve similar levels of reduction simply by reducing cooling water withdrawals, this option was rejected because it would entail dramatic reductions in generation, while CCC would not.

EPA also considered technologies designed to reduce impingement mortality, either by preventing impingement in the first place by decreasing intake volume and intake velocity to a protective level that allows most fish to swim away (*e.g.*, CCC), or by reducing mortality to fish that are impinged. At Merrimack Station, several types of upgraded traveling screens (*e.g.*, Ristroph, Multi-disc, and WIP) were identified as available to increase survival of impinged fish, when combined with an updated fish return system that returns fish to the river at all flows and all times of year.

EPA selected several options representing different combinations of CCC for one or both generating units on a year-round or seasonal basis, coupled with a combination of improvements to the existing traveling screen systems.

Thus, EPA indentified the following five options as BTA candidates at Merrimack Station:

1. Operate Unit 1 using CCC year-round, operate Unit 2 using once-through cooling ("OTC") year-round, install and operate upgraded traveling screens at Unit 2;
2. Operate Unit 1 using OTC year-round, operate Unit 2 using CCC year-round, install and operate upgraded traveling screens at Unit 1;
3. Operate both units using CCC year-round;
4. Operate both units using CCC seasonally from April 1 to August 31 and using OTC for the remainder of the year, and
5. Operate both units using CCC seasonally from April 1 to August 31 and using OTC for the rest of the year, install and operate upgraded traveling screens at both units.

Again, all options include the installation and year-round use of a redesigned fish return system. The costs and entrainment and impingement reductions associated with each option were compared among the options and to a baseline representing existing conditions (*i.e.*, no changes to the facility). In addition, the secondary environmental effects of the options were considered (*e.g.*, effects on air pollution), energy effects and requirements, and ratepayer effects of all of the options were considered. Finally, EPA also compared the costs and benefits of the options and considered the cost-effectiveness of various options. All of these factors were considered as part of determining which technological option(s) satisfies the technology standard of CWA § 316(b), which requires that design, location, construction and capacity of CWISs reflect the "best technology available for minimizing adverse environmental impacts."

12.5.1 Evaluation of Biological Effectiveness

The five candidate BTA options were evaluated in terms of their ability to reduce the mortality of aquatic organisms from entrainment and impingement by Merrimack Station's CWISs.

With regard to reducing entrainment, all of the options under detailed evaluation rely on flow reduction through conversion to CCC. Other technologies, such as the wedgewire screen system proposed by PSNH, were also considered, but determined to be unavailable and/or ineffective. Using CCC would greatly reduce entrainment mortality while still allowing the plant to operate at full capacity. The differences among the five options turn on whether one or both generating units are converted to CCC, and on whether CCC is required year-round or on a seasonal basis.

With regard to reducing impingement mortality, all the options include upgrades to Merrimack Station's current, ineffective fish return system. This does not reduce impingement, but it should improve survival rates for organisms that are impinged. Options 1, 2, and 5 also feature upgrading the traveling screens at one or both units to further enhance the survival of impinged organisms. Furthermore, all of the options will reduce impingement to the extent that they require closed-cycle cooling. Closed-cycle cooling reduces impingement by decreasing both the volume of water withdrawn and the intake velocity. Specifically, CCC results in a reduction in intake velocity from 1.5 ft/sec (or more) to a level consistent with EPA's recommended maximum intake velocity of 0.5 ft/sec. Indeed, by decreasing water withdrawal volumes and the intake velocity, CCC is the most effective method of reducing mortality from impingement because it *prevents* impingement rather than relying on steps that try to enhance the survival of fish that are impinged. The various options differ in the extent to which they utilize CCC and require improvements to the CWIS screening systems and, thus, can be differentiated from each other for the purpose of impingement mortality reduction.

EPA assumed that reductions in entrainment were commensurate with reductions in intake flow through the use of CCC. This is a reasonable approach commonly used by EPA and others to estimate entrainment reductions.

EPA considered several configurations of CCC, including converting a single unit or both units, and requiring CCC to be operated for only a portion of the year. Given that entrainment reductions are directly proportional to intake flow reductions, using CCC for *both* of Merrimack Station's generating units during the period when eggs and larvae are expected achieves substantially greater entrainment reductions than using CCC at only one unit while permitting the other to remain in OTC mode during that period (Table 12-1). Converting only Unit 1 or 2 to CCC provides incremental reductions in entrainment of 28 percent and 67 percent, respectively, while a reduction of 95 percent is realized when both units are converted to CCC (Table 12-1).

The presence of fish eggs and larvae in the Hooksett Pool – an impounded freshwater section of the Merrimack River – is largely limited to five months of the year (April – August). Therefore, EPA considered options requiring only the seasonal use of technology that protects early life stages of fish. Such options would require CCC during the time when these life stages are expected to be present, while open-cycle operations would be permitted during the months when entrainable organisms are not expected to be in the river. Operating CCC at both units on a seasonal basis reduces entrainment by 95 percent when cooling towers are operational and 0 percent when they are not (Table 12-1). Still, because few eggs and larvae are present when cooling towers would be shut down, seasonal use of CCC would be as effective as year-round CCC for reducing entrainment. EPA also notes that this type of seasonal operation of CCC is a feasible technological option which is in use at other facilities.

EPA also evaluated the merits of the available technology options for reducing the mortality of fish as a result of impingement. EPA recognizes that, as discussed above, using CCC reduces impingement (and, thus, impingement mortality) by reducing intake flow volume and velocities. As indicated in Table 12-1, PSNH estimated that year-round use of CCC (Option 3) would reduce impingement by 95 percent. It also provides the most certain method of reducing impingement mortality by preventing impingement in the first place, rather than by relying solely on efforts to safely return impinged organisms to the river.

Still, fish may be impinged year-round, even if CCC is operational due to "make-up water" withdrawals. Although the numbers of fish impinged under Option 3 would be lower than the alternative options, some fish would still be at risk for impingement, particularly under the unusual impingement events that characterize impingement of herring species (discussed in Section 12.4.2 above). Thus, EPA determined that under all potential BTA options, Merrimack Station's fish return system should be modified to reduce fish mortality resulting from the harmful features of the existing fish return system (*e.g.*, fish are not returned to the river except under highest flow regimes).

Specifically, EPA concluded that the facility could, at relatively low expense, install and operate year-round a new (or modified) fish return sluice that safely returns fish to the river at a location where they are unlikely to be re-impinged. PSNH estimates that replacing the existing fish return system with a new system designed to return fish safely to the receiving water would increase survival of impinged fish by 47 percent (Table 12-1).

Table 12-1 Comparison of the estimated reduction in flow, entrainment, and impingement associated with available technology options.

Available Technologies	Combined Flow[1] (gpm)	Percent Reduction in Flow and Entrainment	Estimated Annual # Eggs & Larvae Saved Over Entrainment Baseline (3,806,764)[1]	Estimated Annual Impingement[1]	Total # of Fish Saved Over Impingement Baseline (4,903)[2]	Estimated Percent Reduction[3]	
						Impinge-ment	Impingement Mortality
Existing (OTC) Both Units - existing fish return	200,150	0	0	4,903 (baseline)	0	0	0
1. Unit 1(CCC)[4] Type 1[5] Unit 2 (OTC) Type 2[6]	144, 190	28	1,065,894	3,640	2,974	26%	47%
2. Unit 1 (OTC) Type 2 Unit 2 (CCC) Type 1	65, 850	67	2,550,532	1,508	4,104	69%	47%
3. Unit 1 (CCC) Type 1 Unit 2 (CCC) Type 1	9,890	95	3,616,426	245	4,773	95%	47%
4. Units I, II (CCC) Seasonal[7] Type 1	9,890	95(5 months)	3,616,426	1,728	3,987	65%	47%
	200,150	0 (7 months)					
5. Units I, II (CCC) Seasonal[7] Type 2	9,890	95 (5 months)	3,616,426	1,728	4,125-4,315	65%	55%-66%[8]
	200,150	0 (7 months)					

Footnotes for Table 12-1:

[1] Based on design flows.

[2] Total number of fish saved is the sum of number of fish that avoid impingement and the number of those that survive impingement.

[3] First column represents estimated percent reduction in impingement based on reduction in intake volume and velocity with CCC. Second column represents increase in survival of impinged fish based on Type 1 or Type 2 Fish Return System.

[4] Once-Through Cooling (OTC) and Closed-Cycle Cooling (CCC).

[5] Type-1 Fish Return: includes year-round (12 months) continuous operation of existing traveling screens and new fish return system.

[6] Type-2 Fish Return: includes Ristroph thru-flow traveling screens (or equivalent), low and high pressure wash, continuous screen operation, new fish return system. Operation is year-round (12 months).

[7] Seasonal: CCC (both units) from April 1 – August 31; OTC from September 1 – March 31.

[8] Survival rates vary from 55% (Ristroph screens) to 64 % (MultiDisk screens) to 66% ("WIP" screens).

EPA also considered options for reducing impingement mortality during the months when the entrainment of fish eggs and larvae is not a concern (*i.e.*, September – March) and CCC would not be required under Options 4 and 5. EPA compared impingement rates for the time periods under Options 1 through 3, when CCC would be utilized for one or both units year-round, with the rates for Options 4 and 5, which would require seasonal use of CCC. Under all scenarios, CCC would be in operation (for one or both units) from April 1 to August 31. OTC would potentially be used at both units from September 1 to March 31 in Options 4 and 5.

Based on the 2005–2007 studies, the mean impingement rate for the April–August period was 2,789 fish. However, it should be noted that this value includes a single monthly impingement rate of 4,300 fish (June 2006). If that value is omitted and only the June 2007 sampling value is used (220), then the mean for that period drops to 749 fish. The mean impingement rate for the September–March period is 1,213 fish. This comparison demonstrates that impingement continues to be substantial during the seven-month period when OTC would be used in Options 4 and 5, and highlights the need for a secondary technology to improve survival of impinged fish (*e.g.*, a traveling screen and/or updated fish return system). Further, this rate does not reflect the potential for the impingement of herring and American shad during their fall migrations since none were collected during the 2006–2007 study period. The restoration of self-sustaining populations of American shad and river herring to the Merrimack River is identified in the NHFGD, Inland Fisheries Division, 2010 Master Operational Plan (NHFGD 2010). Given the new federal and state plans to increase stocking efforts for these depressed fisheries within the Merrimack River watershed, the potential for impingement events to occur for these species is likely to increase in the future.

EPA evaluated improvements, in addition to upgrading the fish return system, which could be made to the CWIS's traveling screens that would tend to minimize injuries inflicted on impinged fish. Section 11.6.2 identified several types of traveling screens, including "Ristroph" screens, MultiDisc screens, and WIP screens, which feature technological improvements that tend to increase survival of impinged fish. PSNH estimates that replacing the existing traveling screens with a newer model specifically designed for safe fish removal would increase survival of impinged fish by 55 to 66 percent (Table 12-1).

Finally, in its 308 Response, PSNH alleged that due to winter safety considerations the fish return sluice could not be deployed, and the traveling screens could be operated only intermittently, from January to March. EPA has not, however, been provided with any information to support this claim. Based on this record, EPA determines that since impingement has been documented in all months, including January – March, an operational and effective fish return system is required year-round to reflect the best technology available for minimizing the adverse environmental effects of impingement. If safety or technical considerations preclude the operation of a functional fish return system during these months, then alternative measures that will prevent impingement in the first place may be necessary at those times (*e.g.*, reduced flow and intake velocity).

12.5.2 Assessment of Costs and Benefits

The five candidate BTA options (and the option of making no changes) were evaluated in terms of their estimated cost and the qualitative and quantitative benefits that each would achieve from reducing entrainment and impingement mortality at Merrimack Station. Neither the statute nor the regulations dictate how EPA should assess the costs and benefits of BTA options under CWA § 316(b). However, consistent with Agency policy and principles of natural resource economics, EPA has tried to consider both costs and benefits in a manner that would allow a reasonably complete comparison of the two.

EPA's effort to consider and compare costs and benefits has entailed considering both quantitative and qualitative assessments. As is typically the case in evaluations under § 316(b), EPA was able to develop reasonable estimates of the monetary cost of the BTA options. EPA did this using information submitted by PSNH as well as information gathered or developed by the Agency. One-time and recurring costs were considered and the results are presented on both a total net present value cost basis and an annualized cost basis. EPA considered the costs *to PSNH* in a variety of ways when determining whether the costs were affordable to the company. EPA also converted the costs to "social costs" (*i.e.*, the costs to society) for the purpose of comparing costs and benefits. Converting to social costs tends to result in higher values because, among other things, tax breaks realized by the company in association with expenditures on pollution control equipment are removed.

As is also typically the case, assessing the benefits of CWIS improvements presents a number of issues, options, and challenges. On one hand, each BTA option can be assessed and compared purely in terms of the number of organisms it saves. EPA has generated and considered such quantitative measures.

On the other hand, translating the fish eggs, fish larvae, juvenile fish, and adult fish saved by each BTA option, along with the ecological improvements that may accompany these savings, into a dollar value that fully represents the benefit of each BTA option – *i.e.*, developing a monetized benefits estimate – presents a nearly insurmountable task. This is especially so for regulatory agencies making site-specific BTA determinations on a BPJ basis for individual NPDES permits.

The benefits of saving fish (in all their life stages) can be classified in terms of "use values" (either commercial or recreational) and "non-use values" (including items such as "existence value" and "bequest value"). Estimating the monetary value of all these benefits, however, requires specialized data and expertise and is difficult, time-consuming, controversial and expensive. This is especially so with regard to estimating recreational use values and, even more so, for estimating non-use values arising from ecological improvements. All the benefits or values of ecological improvements, such as protecting fish, cannot necessarily be reduced to a money value, or at least reduced to a money value that can be generated with a reasonable effort and that will be generally accepted.

Thus, EPA and state permitting authorities have rarely even attempted to develop estimates of the full monetized benefit of saving aquatic organisms by using the BTA under § 316(b). Benefits have, instead, been assessed qualitatively, which is a reasonable, legally acceptable approach. Indeed, the only case that we are aware of in which a permitting agency attempted to generate a complete monetary benefits estimate (addressing both use and non-use values) for a BPJ determination of the BTA under § 316(b) for an individual permit was for a permit issued by this office (*i.e.*, EPA Region 1) for the Brayton Point Station power plant in Massachusetts. EPA hired expert contractors to assist in the work and the effort was extremely difficult, time-consuming, and expensive. Moreover, despite the Agency's major effort in this regard, the estimates that were produced were controversial. While undertaking the analysis, EPA also clearly stated its view that it was not legally required to generate such monetized estimates and that it would not necessarily do so for other permits, though it thought that it was reasonable to try the approach for the Brayton Point Station permit. EPA *also* relied on qualitative assessments for the Brayton Point Station permit, however, and clearly indicated that such reliance was appropriate. *See, e.g.*, EPA Responses to Comments for Brayton Point Station NPDES Permit No. MA0003654 (Oct. 3, 2003) at IV-18 to IV-21.

For the Merrimack Station permit, EPA has decided to assess the benefit of BTA options through quantitative non-monetary measures and qualitative evaluations. EPA will not attempt to generate a complete monetized estimate of benefits. EPA concludes that this is reasonable and appropriate in this case for a number of reasons.

First, efforts to develop a monetized commercial use benefits estimate are not warranted in this case. Significant commercial use values are unlikely to be associated with fish lost to the Merrimack Station CWISs because the Merrimack River is not a commercial fishing resource.[108] Moreover, while developing a monetized estimate of the direct

[108] While Merrimack Station's CWISs could have an indirect effect on commercial fishing by killing anadromous fish, such as river herring, that may be subject to commercial fishing at sea, any such effects are likely to lead to small values.

commercial use value of fish is relatively straightforward for qualified experts, EPA Region 1 does not have this type of expert on staff and, therefore, would likely need to expend funds to hire expert consulting services to develop such an estimate. Such an expenditure would not be justified here given that the result would be unlikely to have a material effect on the ultimate decision.

Second, efforts to develop a monetized estimate of the recreational use benefits (direct and indirect) that would be derived from the aquatic organisms that would be saved by the various BTA options are also not warranted. Given the use of the Merrimack River for recreational fishing, and the effect of entrainment and impingement on species that are fished for recreation, it is possible that recreational use benefits of some significance could exist. For instance, according to the NHFGD, Inland Fisheries Division, 2010 Master Operational Plan, yellow perch rank among the top 10 species fished for by recreational anglers (NHFGD 2010). As the report points out, warmwater fisheries are sustained through natural reproduction, and are popular with the state's anglers. Nevertheless, developing a complete monetized recreational use benefits estimate, taking into account both direct and indirect benefits, is a complex, time-consuming exercise which is subject to uncertainty and controversy. Again, specialized expertise and data collection would be needed to undertake such an analysis and EPA would need to expend considerable funds to retain outside expert contractor assistance. EPA does not think that this type of expenditure of time and money is warranted in this case given that recreational benefits can be assessed qualitatively, and because the most important quotient of the benefits in this case is likely to be from the overall ecological improvements that the various BTA options will provide which can be suitably evaluated from a qualitative perspective.

Third, efforts to develop a monetized estimate of the non-use benefits (direct and indirect) to be derived from the aquatic organisms saved by each BTA option, and from the various ecological improvements (*e.g.*, healthier community of aquatic organisms, improved habitat value) that would accompany saving those organisms, are not warranted. As with recreational values, EPA can suitably evaluate these matters qualitatively without undertaking great expense to hire outside contracting assistance. Moreover, attempting to develop an estimate of the non-use values of protecting these natural resources would be an exceedingly difficult, time-consuming and expensive task. Once again, specialized expertise and data collection would be needed to undertake such an analysis. EPA would need to expend considerable funds to retain outside expert contractor assistance and any results would nevertheless undoubtedly be highly controversial. Undertaking that sort of effort for the BPJ determination of the BTA under CWA §316(b) for this permit is not reasonable and, indeed, will rarely be sustainable for individual permits given current economic analysis tools.

EPA's discussion below looks first at options for reducing entrainment and then at options for reducing impingement mortality. In addition, the options for reducing entrainment and impingement mortality are also considered together. The reason for evaluating these options separately and together is that there are options for reducing impingement mortality that bear consideration but have no effect on entrainment and can be combined with whatever entrainment reduction option is selected, while ultimately the approaches taken to address these two problems must work together.

12.5.2a Entrainment

For Merrimack Station, converting to closed-cycle cooling is by far the most effective technology for reducing entrainment. Indeed, it is the only available technology that will result in any significant improvement. No other technology available would perform remotely as well at Merrimack Station.

Accordingly, having screened out other options (*see* Section 11 of this document), EPA evaluated in closer detail a range of options providing for closed-cycle cooling for either Unit 1, Unit 2 or both units, and either on a year-round or seasonal basis. These options generate different benefits and have different costs. EPA compared the options with each other and also considered them as compared to current conditions (*i.e.*, assuming no changes to the facility). The cost of each option—and its performance in terms of reducing intake flow, entrainment and impingement mortality – are presented in Table 12-1, above, and in Tables 12-2, 12-3 and 12-4, below, and in Figures 12-2 and 12-3, below.

EPA estimates that Merrimack Station currently kills more than 3.8 million eggs and larvae annually as a result of entrainment under open-cycle operations (*see* Table 12-1 above). As detailed in Figure 12-1, under low flow conditions, the fraction of the river flow withdrawn by the plant ranges from a monthly average of nine percent in April to as high as 64 percent in August. In June, the month when larvae are most abundant in Hooksett Pool, the average monthly flow withdrawn for cooling can reach 24 percent of the available river flow under minimum flow conditions, and nine percent under mean flow conditions, based on the plant's reported monthly data from 1993 to 2007. Historical daily river flow rates further illustrate how much of the available river flow can be withdrawn by the plant. For example, EPA calculated that Merrimack Station withdrew approximately 64 percent of the available river flow on June 29, 1995; 75 percent on July 7, 1995; and 83 percent on August 14, 2001. These represent sizable fractions of the river flow and, by extension, a sizable fraction of the ichthyoplankton community when fish larvae are known to be present in Hooksett Pool.

As explained previously, the facility currently lacks any technology for reducing entrainment. Therefore, any eggs and larvae in the water withdrawn through the CWIS will be entrained and killed. EPA believes that these losses undermine the value of the affected habitat and will interfere with the recovery of the Hooksett Pool's fish community, a community which has been seriously degraded by a number of factors, including but not limited to Merrimack Station's thermal discharges, impingement and entrainment.

Focusing on each option's performance in terms of reducing entrainment, it is evident that taking no action will result in no improvement, while the options under evaluation will produce varying levels of improvement. *See* Tables 12-1, 12-3 and 12-4, and Figure 12-2. The greatest benefits in terms of saving aquatic organisms from entrainment are provided by Options 3, 4 and 5, while lesser benefits are provided by Options 1 and 2, and no benefits accrue from taking no action. Providing closed-cycle cooling year-round solely at Unit 1 reduces water withdrawals and entrainment by 28 percent, saving 1.065 million eggs and larvae per year (out of the 3.8 million that are currently entrained each year). Providing closed-cycle cooling year-round solely at Unit 2 reduces water withdrawals and entrainment by 67 percent, saving 2.55 million eggs and larvae per year (out of 3.8 million). Providing closed-cycle cooling at both Units I and II reduces water withdrawals and entrainment by 95 percent, saving 3.616 million eggs and larvae (out of 3.8 million).[109]

Significantly, the options calling for closed-cycle cooling at both units reduce entrainment by the same amount whether closed-cycle cooling is required year-round or seasonally. This is so because eggs and larvae are expected to be present in the Hooksett Pool in appreciable numbers for only a part of the year. Therefore, using closed-cycle cooling for just that part of the year would reduce entrainment by essentially as much as would using it all year.

The capital and O&M costs to retrofit Merrimack Station with closed-cycle cooling are substantial. EPA evaluated the cost of the five options on a private (or company) cost basis as well as on a social cost basis. These costs are presented in Table 12-2, below.

[109] To the extent that fish abundance recovers in the future, larger numbers of eggs and larvae would be expected in the river. This would also mean that each technology improvement would end up saving larger numbers of organisms each year.

Table 12-2 Comparison of the predicted private and social costs of available technology options. (Values in Table are drawn from Memorandum by Abt Associates, Inc., "Cost and Affordability Analysis of Cooling Water System Technology Options at Merrimack Station, Bow, NH" (September 14, 2011) (*see* Tables 1-3, 2-1)). (All present values are as of 2010, which was estimated to be the project construction year for the assessment.)

Available Technologies	Private Cost		Social Cost	
	Total After-Tax Cash Flow Cost, Present Value at 5.3% (using nominal (i.e., not inflation adjusted) dollars, millions)	Annual Equivalent Cost at 5. 3% over 21 Years (using nominal (i.e., not inflation adjusted) dollars, millions)	Total Cost, Net Present Value at 7.0% of Capital & O&M Cost (millions) (using inflation adjusted 2010 dollars, millions)	Annual Equivalent Cost at 7.0% Over 21 Years (millions) (using inflation adjusted 2010 dollars, millions)
Existing (OTC)[1] Both Units - existing fish return	-	-	-	-
1. Unit 1(CCC)[1]Type 1[2] Unit 2 (OTC) Type 2[3]	$32.3	$2.6	$44.7	$4.1
2. Unit 1 (OTC) Type 2 Unit 2 (CCC) Type 1	$88.2	$7.1	$123.8	$11.4
3. Unit 1 (CCC) Type 1 Unit 2 (CCC) Type 1	$112.7	$9.1	$158.54.7	$14.3
4. Units 1,2 (CCC) Seasonal[4] Type 1	$77.1	$6.2	$10.1	$10.2
5. Units 1,2 (CCC) Seasonal[4] Type 2	$79.2	$6.4	$111.3	$10.3

Footnotes:
[1] Once-Through Cooling (OTC); Closed-Cycle Cooling (CCC)
[2] Type-1 Fish Return: includes year-round (12 months) continuous operation of existing traveling screens and new fish return system.
[3] Type-2 Fish Return: includes Ristroph thru-flow traveling screens (or equivalent), low and high pressure wash, continuous screen operation, new fish return system. Operation is year-round (12 months)
[4] Seasonal: CCC (both units) from April 1 – August 31; OTC from September 1 – March 31

EPA previously determined in Section 7 – in the context of determining the BAT for controlling Merrimack Station's discharges of thermal effluent – that PSNH could afford to retrofit both Units 1 and 2 with closed-cycle cooling and operate in a closed-cycle cooling mode year-round. Therefore, all of the five options being considered here under CWA § 316(b) would be affordable to the company.

In the context of determining the BTA under § 316(b), EPA considered a comparison of the costs and benefits of the options. For this comparison, EPA used the options' social costs, which are presented in Table 12-2 above. In addition, Table 3 below combines the environmental performance measures of Table 12-1 above (*i.e.*, the number of organisms saved from entrainment and impingement mortality by the different options) with the social cost figures from Table 12-2 above.

The social costs ranged from \$44.7 to \$158.5 million on a present value, total cost basis, depending on the number of units for which closed-cycle cooling is installed and the number of months of closed-cycle cooling system operation. *See* Tables 12-2, 12-3, and 12-4.[110] Corresponding annualized social costs range from \$4.1 million to \$14.6million per year (over 21 years). No cost increase is associated with taking no action. The lowest social costs (and least environmental improvement) are associated with Option 1, while the highest social costs (and greatest environmental improvements) are associated with Option 3 (CCC year-round for both units). Options 4 and 5 (CCC seasonally (for 5 months) for both units) achieve equivalent entrainment reductions to Option 3, but at

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[110] EPA notes that to the extent these cost estimates are based on the use of hybrid wet/dry cooling towers to address any concern about fogging/icing during cold weather, then costs for a seasonal BTA option that only required cooling tower use during warm weather would render hybrid towers unnecessary and make the option less costly. *See* n. 34, *supra* ("if wet cooling towers were substituted for hybrid cooling towers in the cost estimate that PSNH provided for applying hybrid towers in a closed-cycle configuration for both units, the total capital budget for the project would decline by \$9.7 million").

significantly lower social cost (with total costs ranging from approximately $1107.5 to $111.3 million and annualized social costs of approximately $10.2 – $10.3 million per year). Indeed, Options 4 and 5 also have lower social costs than Option 2 while achieving greater environmental benefit. (It should be noted that for purposes of entrainment reduction, Options 4 and 5 are largely the same; they vary only with regard to screening system improvements related to reducing impingement mortality. Impingement mortality reduction is discussed below.)

From the perspective of entrainment reductions alone, Options 2 and 3 do not make sense because they have higher social costs than Options 4 and 5 but achieve less or equivalent environmental performance, respectively. This leaves a comparison between (1) Options 4 or 5, (2) Option 1, and (3) the "no action" (or "as is") option. "No action" involves no additional cost but achieves no environmental benefit from reducing entrainment. Option 1 (CCC for Unit 1 only) reduces entrainment by an estimated 28 percent at an estimated total present value social cost of $44.7 million (or an annualized cost of $4.1 million). Options 4 and 5 reduce entrainment by an estimated 95 percent at a total present value social cost of approximately $110.1 – $111.3 million (and an annualized cost of $10.2 – $10.3 million).

Table 12-3 Comparison of predicted flow, entrainment, and impingement reductions, and their related costs, associated with available technology options. (Social Cost Values in Table are drawn from Memorandum by Abt Associates, Inc., "Cost and Affordability Analysis of Cooling Water System Technology Options at Merrimack Station, Bow, NH" (September 14, 2011), *see* Table 2-1.) (All present values are as of 2010, the project construction year assumed for the analysis.)

Available Technologies	Combined Flow (gpm)	Percent Reduction in Flow and Entrainment	Estimated Annual # Eggs & Larvae Saved Over Entrainment Baseline (3,806,764)[1]	Estimated Annual Impingement[1]	Total # of Fish Saved Over Impingement Baseline (4,903)[2]	Estimated Percent Reduction[3]		Social Cost (millions)	
						Impingement	Impingement Mortality	Total Cost, Net Present Value at 7.0% of Capital & O&M Cost	Annual Equivalent Cost at 7.0% Over 21 Years
Existing (OTC)[4] Both Units - existing fish return	200,150	0	0	4,903 (baseline)	0	0	0	-	-
1. Unit 1(CCC)[4] Type 1[5] Unit 2 (OTC) Type 2[6]	144,190	28	1,065,894	3,640	2,974	26%	47%	$44.7	$4.1
2. Unit 1 (OTC) Type 2 Unit 2 (CCC) Type 1	65,850	67	2,550,532	1,508	4,104	69%	47%	$123.8	$11.4
3. Unit 1 (CCC) Type 1 Unit 2 (CCC) Type 1	9,890	95	3,616,426	245	4,773	95%	47%	$158.5	$14.6
4. Units I, II (CCC) Seasonal[7] Type 1	9,890	95 (5 months)	3,616,426	1,728	3,987	65%	47%	$110.1	$10.2
	200,150	0 (7 months)							
5. Units I, II (CCC) Seasonal[7] Type 2	9,890	95 (5 months)	3,616,426	1,728	4,125-4,315	65%	55%-66%[8]	$111.3	$10.3
	200,150	0 (7 months)							

Footnotes:

[1] Based on design flows.

[2] Total number of fish saved is the sum of number of fish that avoid impingement and the number of those that survive impingement.

[3] First column represents estimated percent reduction in impingement based on reduction in intake volume and velocity with CCC. Second column represents increase in survival of impinged fish based on Type 1 or Type 2 Fish Return System.

[4] Once-Through Cooling (OTC) and Closed-Cycle Cooling (CCC).

[5] Type-1 Fish Return: includes year-round (12 months) continuous operation of existing traveling screens and new fish return system. [6] Type-2 Fish Return: includes Ristroph thru-flow traveling screens (or equivalent), low and high pressure wash, continuous screen operation, new fish return system. Operation is year-round (12 months) .

[7] Seasonal: CCC (both units) from April 1 – August 31; OTC from September 1 – March 31.

[8] Survival rates vary from 55% (Ristroph screens) to 64% (MultiDisk screens) to 66% ("WIP" screens).

As discussed above, in EPA's estimation, the fish community of the Hooksett Pool has declined at least in part due to the operation of Merrimack Station's open-cycle cooling system. EPA suspects that the facility's thermal discharges play a greater role due to their ability to alter a significant portion of the aquatic habitat within Hooksett Pool, but it is not possible, at least based on reasonably available information, to define the relative contribution of the various stressors affecting aquatic life in the pool. In any event, as explained above, EPA concludes that entrainment not only kills individual organisms but has contributed to the decline of fish populations in the Hooksett Pool and undermines the value of the affected habitat. Moreover, entrainment continuing at current levels is likely to impede or interfere with the recovery of the Hooksett Pool's fish community.

Cooling water withdrawal impacts in Hooksett Pool must be considered within the context of the conditions that currently exist in the pool. These conditions reflect the effects of 43 years of thermal impairment, combined with the continual losses of fish and forage from entrainment and impingement. In rejecting the plant's request for a thermal variance, EPA has recognized the degraded state of the existing habitat in Hooksett Pool, and the resulting loss of its biological integrity. Closed-cycle cooling would provide an opportunity to restore the biological integrity of the Hooksett Pool by reducing both thermal discharges and the loss of fish and forage to entrainment and impingement. Conversely, failing to require such reductions would likely prevent or interfere with a recovery.

Furthermore, EPA takes note of the fact that species harmed (and potentially harmed) by entrainment and impingement at Merrimack Station include fish that are popular for recreational fishing (including yellow perch and potentially American shad). Thus, entrainment and impingement losses at Merrimack Station not only undermine the biological integrity of the Merrimack River, but they undermine the value of the water body as a resource for recreational fishing. State and federal resource agencies have for years been trying to restore anadromous fish runs, such as those of the American shad, in the Merrimack River. Indeed, a new American shad stocking program is currently underway, at public expense. Entrainment and impingement at Merrimack Station could interfere with the success of this program.

The Merrimack River and the aquatic organisms that use it for habitat are natural resources belonging to the public. Protecting and preserving these resources is an important public good and would provide important public benefits. This is evident in a number of ways. To begin with, one of the Clean Water Act's primary stated goals is to restore the biological integrity of the Nation's waters. Another of its primary stated goals is, in essence, to render the Nation's waters "fishable and swimmable."

In addition, New Hampshire's water quality standards essentially adopt these goals of the federal Clean Water Act as goals of the state. Furthermore, the state's standards also prescribe the following water quality criterion for "biological and aquatic community integrity":

> (a) The surface waters shall support and maintain a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of similar natural habitats of a region.
> (b) Differences from naturally occurring conditions shall be limited to non-detrimental differences in community structure and function.

N.H. Code R. Env-Wq 1703.19. Thus, the state, too, has a strong public interest in protecting fish in the Merrimack River, especially to the extent that it is necessary to preserve the biological integrity of the waterway.

EPA concludes that allowing Merrimack Station to continue, unchecked, to entrain and kill an appreciable number of fish larvae, including those of species exhibiting population declines in the pool, would be inconsistent with the objectives of the Clean Water Act and New Hampshire water quality standards and, as such, would be contrary to the public interest.

This conclusion is reinforced by the results of the following survey: "1997 Assessment of Outdoor Recreation in New Hampshire: A Summary Report," Robertson, R.A. (App. A in New Hampshire's 2008 Statewide Comprehensive Outdoor Recreation Plan). Respondents in this survey were asked to rank 22 different programs or projects as high, moderate, or low priority with regard to future state expenditures and 58.6% of respondents ranked preservation/restoration of native wildlife as a high priority while 36.3% ranked enforcement of environmental laws as a high priority. Respondents were also asked to rank the top three priorities for New Hampshire state government from the list of 22 programs/projects and they indicated that the top three priorities were protection/improvement of water quality in rivers, streams, lakes, and ponds (69.9%), preservation/restoration of native wildlife (31.9%), and enforcement of environmental laws (23.7%). *See* http://www.nh.gov/oep/programs/recreation/SCORP_2008-2013/documents/AppendixAAdobe.pdf.

It should also be noted that segments of the Merrimack River both upstream and downstream of the Hooksett Pool have been designated for special protection under New Hampshire's Rivers Management & Protection Act, N.H. Rev. Stat. Ann. § 483. The Rivers Management & Protection Act program is intended to manage and protect particular rivers or segments of rivers with outstanding natural and cultural resources. While the Hooksett Pool, itself, was not so designated, preserving aquatic life and habitat in the Pool will contribute to achieving the state's special goals for the upstream and downstream segments of the river.

The state designated the "Upper Merrimack River," a segment of the river extending northward from the Garvins Falls Dam, which marks the northern boundary of the Hooksett Pool. Among the reasons provided by the state for the designation are that the Upper Merrimack River provides nesting sites for bank swallow and kingfisher, bald eagle wintering habitat, habitat for osprey, anadromous fish habitat, and is a designated cold water fishery with 19 resident species (8 of which are of sport or recreational importance). The state further notes that as a major north-south river in New England, the Merrimack provides a migratory route for waterfowl and songbirds, and that the river is included in the Anadromous Salmon Restoration Program – a cooperative effort between state and federal agencies to recreate and maintain upstream access for anadromous fish. Finally, the state notes that the New England River Protection and Energy Development Project ranked the Upper Merrimack River "of highest significance" as an anadromous fishery and "highly significant" as an inland fishery.

The Upper Merrimack River could be adversely affected by environmental degradation in the immediately adjacent Hooksett Pool. Conditions in the Hooksett Pool that cause mortality to all life stages of fish could affect organisms that utilize the Upper Merrimack River, such as anadromous fish, sport or recreational fish, and birds and other organisms that prey on fish.

The state also designated the "Lower Merrimack River," a segment of the river extending from the Merrimack/Bedford town line to the New Hampshire/Massachusetts border. Again, the state noted that this segment provided important habitat for various types of organisms, including wintering habitat for bald eagle. The state further pointed out that the river provided an important migratory pathway for waterfowl and songbirds, and noted continuing efforts to restore Atlantic salmon and American shad runs to the river. Again, the state did not designate the Hooksett Pool segment of the river, but adverse conditions for fish in the Hooksett Pool could also adversely affect conditions downstream.

In the 1979 Summary Report (Normandeau 1979b), PSNH suggests that any adverse effects of Unit 2 entrainment upon the indigenous fish community probably would have occurred within the first few years of operation. At this time, the report explains, the station may have induced additional mortality upon the parent stock populations, and therefore reduced reproductive potential and subsequent standing crops. Whether or not entrainment by Merrimack Station's CWISs initially caused the decline in the balanced, indigenous community of fish that should inhabit the Hooksett Pool, or in the overall abundance of fish that should be present in the pool, EPA concludes that allowing the facility to continue entraining a high proportion of the eggs and larvae that are in the water will prevent or impede a recovery of these populations, and the balanced community that once existed. In addition, EPA is concerned that harm to aquatic life and habitat in Hooksett Pool will adversely affect the environment of the Merrimack River upstream and downstream. In EPA's qualitative judgment, achieving substantial reductions in entrainment in Hooksett Pool will have significant public benefits.

In section 12.5.1, EPA determined that retrofitting both units with closed-cycle cooling is much more effective than only requiring conversion of a single unit. As discussed above, EPA has already rejected Option 2, which involves converting only Unit 2 to closed-cycle cooling. Option 1, which involves converting only Unit 1, would likely save only 28 percent of the currently entrained eggs and larvae, albeit at a lower social cost of $4.1 million annually. Converting both units under Options 4 and 5, however, is expected to save 95 percent of eggs and larvae at an annual social cost of $110.1 – 111.3 million (*see* Table 12-3 above, and Table 12-4 and Figure 12-1 below). EPA regards the entrainment reduction of Options 4 and 5 to provide substantially greater environmental benefit than Option 1, and regards these benefits to warrant the additional cost. More particularly, the costs of Options 4 and 5 are neither wholly disproportionate to, nor significantly greater than, the benefits they would produce. At the same time, EPA is concerned that reducing entrainment by only 28 percent (using Option 1) will not provide an adequate chance for fish in the Hooksett Pool to recover.[111]

[111] EPA also considered the question of the options' relative cost-effectiveness but decided that cost-effectiveness would not be a useful criterion for choosing between the options in this case. While EPA is concerned with reducing adverse cooling water intake structure effects sufficiently to allow for the restoration of habitat quality and fish populations in the Hooksett Pool, the Agency could not identify a cost-effectiveness metric pertinent to these concerns.

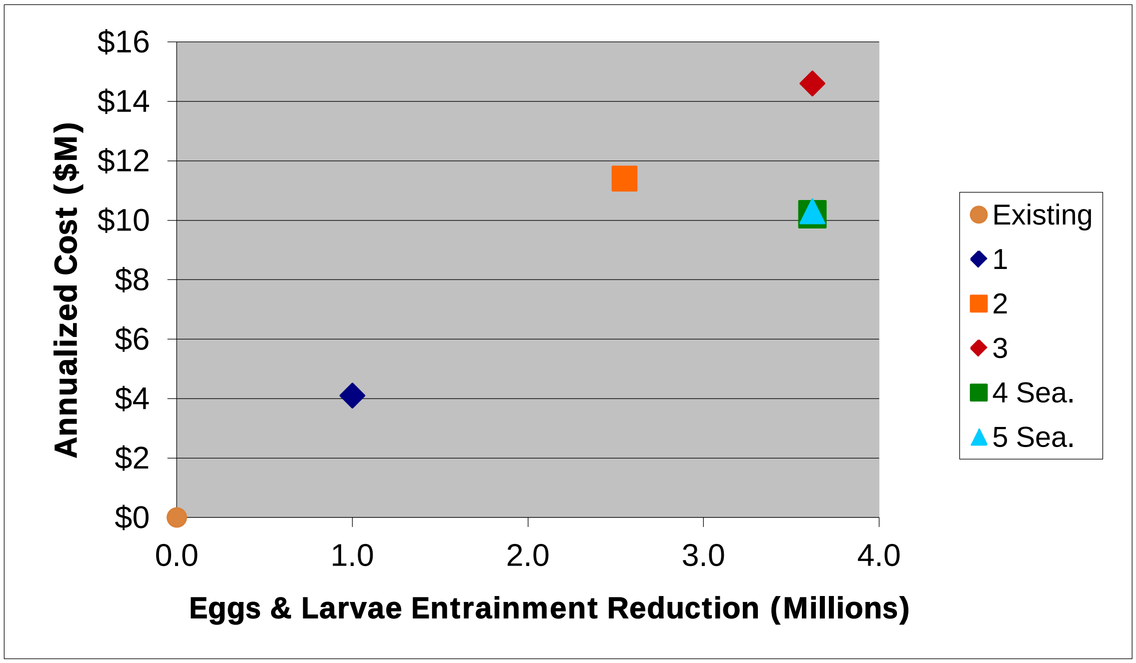
Table 12-4 Comparison of predicted annual environmental benefits and costs associated with available technology options. (Social Cost Values in Table are drawn from Memorandum by Abt Associates, Inc., "Cost and Affordability Analysis of Cooling Water System Technology Options at Merrimack Station, Bow, NH" (September 14, 2011) (*see* Table 2-1)).

Option	Eggs & Larvae Saved Over Entrainment Baseline (Millions)	Fish Saved Over Impingement Baseline (Thousands)	Annualized Social Cost ($M)	Option Description
Existing	0.00	0.00	$0.6	Unit 1 (OTC) Unit 2 (OTC)
1	1.07	2.97	$4.1	Unit 1 (CCC)/ TYPE 1 Unit 2 (OTC)/ TYPE 2
2	2.55	4.10	$11.4	Unit 2 (CCC)/ TYPE 2 Unit 1 (OTC)/ TYPE 1
3	3.62	4.77	$14.6	Unit 1 (CCC)/ TYPE 1 Unit 2 (CCC)/ TYPE 1
4	3.62	3.99	$10.2	Unit 1 (CCC)/ TYPE 1 Unit 2 (CCC)/ TYPE 1
5	3.62	4.22	$10.3	Unit 1 (CCC)/ TYPE 2 Unit 2 (CCC)/ TYPE 2

For this analysis under CWA § 316(b), it is also important to remember that Merrimack Station can generate nearly the same amount of electricity for sale with (seasonal) closed-cycle cooling as with open-cycle cooling. In other words, Merrimack Station can continue its current business operation without taking the same severe toll on the Merrimack River and its aquatic life, which are, after all, public natural resources. EPA recognizes that converting to closed-cycle cooling will present significant cost, but EPA also recognizes that Congress clearly infused the Clean Water Act with a technology-forcing mandate intended to take advantage of the best technology available to reduce adverse environmental effects, and converting to closed-cycle cooling is an available technological improvement for the facility. Having been allowed to run in an open-cycle mode for decades, upgrading the facility now seems appropriate in light of the environmental issues discussed above and the Clean Water Act's technology-forcing scheme.

In addition, as discussed in Section 7, EPA estimates that retrofitting Merrimack Station with wet mechanical draft cooling towers and operating in a closed-cycle mode on a year-round basis could lead to an average increase in electric rates for residential consumers ranging from approximately $1.15 to $1.35 per month per household over an assumed 20-year operating period for the installed closed-cycle cooling system equipment. *See* Memorandum by Abt Associates, Inc., "Cost and Affordability Analysis of Cooling Water System Technology Options at Merrimack Station, Bow, NH" (September 14, 2011), Section 3.2. This assumes that PSNH is able to recover all of its costs from its customers. The rate effect attributable to requirements under CWA § 316(b) would be even less if one of the options requiring only seasonal or partial closed-cycle cooling is determined to be the BTA. In EPA's judgment, this rate effect is not unreasonable in light of the environmental improvements that would result.

Figure 12-1 Estimated number of fish eggs and larvae saved annually from entrainment mortality, and the predicted cost, associated with available technology options.

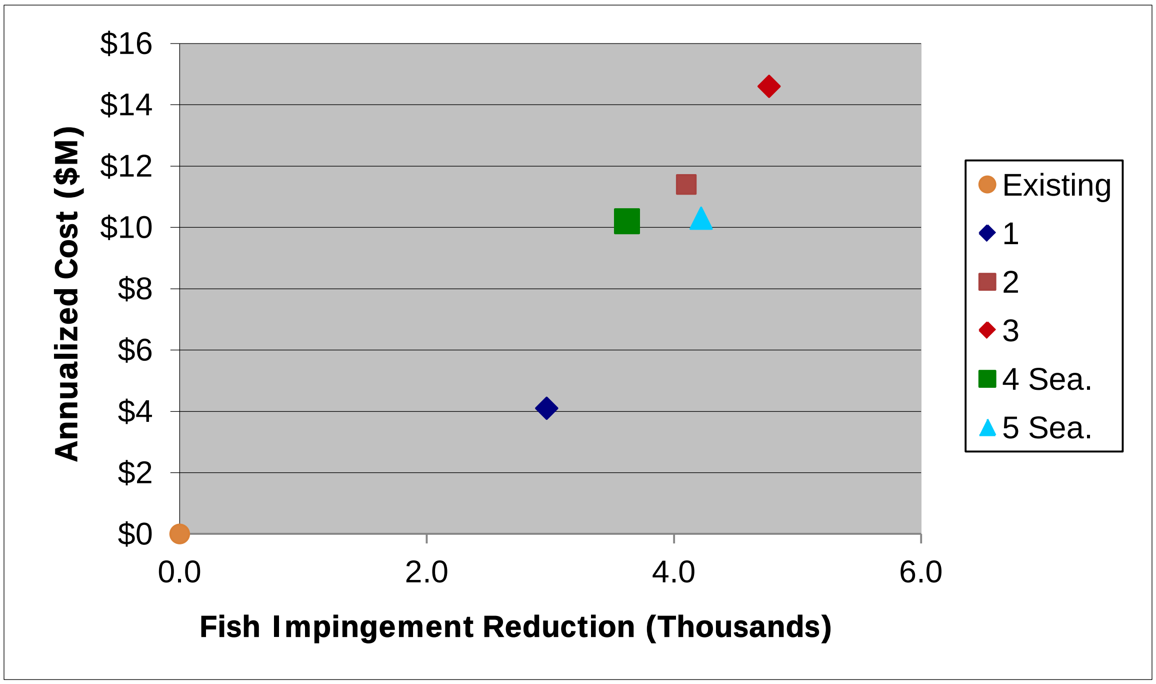


Finally, there are no adverse secondary environmental effects associated with converting to closed-cycle cooling that are significant enough in this case to undermine EPA's conclusion that the benefits of Options 4 and 5 are warranted by their costs. In Section 7, in the context of determining the BAT for controlling Merrimack Station's thermal discharges, EPA evaluated the secondary environmental and energy effects of converting to closed-cycle cooling by retrofitting wet mechanical draft cooling towers at Merrimack Station and then using them on a year-round basis. EPA incorporated this evaluation into Section 11 of this document for purposes of determining the BTA under CWA § 316(b). To the extent that the BTA only involves seasonal closed-cycle cooling, then the secondary environmental effects attributable to the BTA would be even less in many respects. For example, if the BTA does not require closed-cycle cooling in the winter months, then the BTA poses no concern about cooling towers causing fogging or icing in cold weather, and sound emissions from cooling towers would be even less.

12.5.2b Impingement Mortality

Closed-cycle cooling is the most effective method of reducing impingement mortality because it *prevents* impingement in the first place, rather than focusing on trying to safely transport already impinged organisms back to the river. Closed-cycle cooling prevents impingement by reducing the volume of water withdrawn from the river, and by reducing intake velocity to relatively safe levels for most species. Preventing impingement in the first place is important because there is always some uncertainty about how organisms will fare after having been impinged and sent back to a water body through a fish return system. This is a particular concern when especially fragile fish species, such as herring, are impinged. Such species are more likely to die as a result of impingement and transport despite possible improvements to the screening and fish return systems. In addition, closed-cycle cooling is also a benefit in that it can be used during winter months when PSNH argues that river icing may interfere with improved screening and fish return systems. PSNH estimates that year-round closed-cycle cooling at both units (Option 3) would reduce impingement mortality by approximately 95 percent (Table 12-1, Figure 12-2). EPA agrees that this is a reasonable estimate.

Figure 12-2 Estimated number fish saved annually from impingement mortality, and the predicted cost, associated with available technology options.



As discussed above, Merrimack Station's current fish return system is inadequate, as it fails to return fish to the river on a reliable basis. Upgrading the fish return system so that it safely returns fish to the river is expected to increase survival of impinged fish by 47 percent at a relatively minimal cost ($335,000), as estimated by PSNH at 2007, or $370,000, as estimated by EPA for 2010. Such upgrades are not likely to have any significant adverse environmental or energy effects and will not have a material effect on consumer electric rates. EPA concludes that an effective fish return system is a necessary, minimum part of any BTA requirements to be designed under CWA § 316(b). Put differently, a fish return system that fails even to return fish to the river on a reliable basis cannot reflect the BTA, when these shortcomings can be remedied at modest expense. In Table 12-1, fish return system improvements (without also making screening system improvements) are referred to as “Type 1” modifications.

Impingement may continue to occur with any of the options under consideration, including Option 3 (year-round closed-cycle cooling for Units I and II). Impingement can occur even with closed-cycle cooling in operation because facilities still withdraw make-up cooling water (albeit at about 5 percent of the volume of water withdrawals for an open-cycle system). For example, operating in closed-cycle mode, Merrimack Station would be expected to withdraw approximately 14 million gallons of water per day from the Merrimack River for make-up water (287 MGD x 0.05 = 14.35 MGD). For options that do not call for closed-cycle cooling year-round (or at all), or do so for only one unit, water withdrawals would obviously be greater. For these options, impingement would be expected to be greater as well, which makes the fish return system even more important. Again, given the relatively low cost of a new fish return system and the large improvement in survival it would generate, EPA determines that an improved fish return system is a component of the BTA for all options considered.

As discussed above, EPA also evaluated several options for improving Merrimack Station’s CWIS screening systems to reduce impingement mortality. These options involve upgrading the screening system to make the process of an organism being impinged, removed from the screens, and transported back to the river less damaging to the organism. EPA evaluated the costs and benefits of replacing the existing traveling screens with new screens designed specifically to reduce injury and improve fish survival. The package of modifications including both screening system improvements and return system improvements is referred to in Table 12-1 as a “Type 2” modification.

Compared to closed-cycle cooling, installing new screens is inexpensive and does not substantially change the annualized cost of the options already reflecting closed-cycle cooling costs. *See* Tables 12-2, 12-3, and 12-4 (cost differences between Options 4 and 5). EPA evaluated the use of the Type 2 screens/fish return in Options 4 and 5 for both units, then applied this evaluation to Options 1 and 2 for the unit not converted to closed-cycle cooling. Despite the small cost, the type 2 screen/fish return system is estimated to improve survival of impinged fish by approximately 55–66 percent when operational as compared to a 47 percent improvement in survival with the Type 1 system (*see* Tables 12-1, 12-3, and 12-4). Options 2, 4, and 5 are estimated to save relatively similar numbers of fish and to have similar annualized costs, but Option 5 projects as the most effective of the three (*see* Tables 12-2, 12-3, and 12-4 and Figure 12-2). Option 1 saves only about 70 percent of what Option 5 would save at approximately 40 percent of the cost, while Option 3 would save additional fish but at significant additional cost (*see* Tables 12-2, 12-3, and 12-4 and Figure 12-2).

EPA determined above that Options 4 and 5, which both entail providing seasonal closed-cycle cooling for both of Merrimack Station's generating units, would satisfy the BTA standard for reducing entrainment mortality and that Options 1, 2 and 3 should be rejected. EPA's assessment of impingement mortality does not alter EPA's conclusion with regard to Options 1, 2 and 3, but does provide a basis for choosing between Options 4 and 5. Thus, EPA rejects Options 1 and 2 which involve closed-cycle cooling at only one unit. Turning to options 3, 4 and 5, one can see that based on existing data, year-round closed-cycle cooling for both units (Option 3) is estimated to save 786 more fish annually than Option 4, and from 458 to 648 more fish each year than Option 5 (depending on the type of improvements to the traveling screen technology that are implemented). Option 3 also involves, however, annualized social costs that are approximately $4 million more than those for Options 4 and 5. The differences in the number of fish saved between these options reflect the fact that impingement, unlike entrainment, is a year-round problem, and the fact that the different technologies reduce impingement mortality at different rates. Although EPA has some concern that impingement mortality could adversely affect efforts to restore anadromous fish runs, the Agency finds that Options 4 and 5 achieve substantial improvements at far less social cost. Indeed, the anadromous fish restoration program should benefit from these improvements, even if Option 3 might conceivably help even more.

Ultimately, EPA concludes on a cost/benefit basis that Option 3 is not warranted for the additional impingement mortality reduction it could achieve as a result of using closed-cycle cooling for seven additional months each year.[112] In addition, EPA concludes that as between Options 4 and 5, the small marginal additional cost of the latter option is warranted by its additional reduction in impingement mortality. More specifically, EPA concludes that the social cost of installing the Type 2 screening and fish return system (with Option 5), so that impingement and mortality from impingement are further reduced, is warranted and is neither wholly disproportionate to, nor significantly greater

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[112] EPA also considered the question of the options' cost-effectiveness, but concluded that cost-effectiveness would not be a useful criterion for choosing between the options given the disparities in number of fish saved from impingement mortality by Options 3, 4 and 5 as compared to Option 1. *See* Table 12-3, *supra*. Furthermore, while EPA is concerned with reducing adverse cooling water intake structure effects sufficiently to allow for the restoration of habitat quality and fish populations in the Hooksett Pool, the Agency could not identify a cost-effectiveness metric pertinent to these concerns.

than, its benefits. Furthermore, EPA finds that there are no secondary environmental (or energy) effects or other considerations that negate this conclusion.

12.6 Water Quality Standards

CWA § 316(b) requires CWISs to satisfy the BTA standard. This federal technology standard establishes the minimum requirements that all CWISs must meet. As detailed above, EPA has determined that permit requirements based on Option 5 are necessary to satisfy the minimum federal technology-based standard under § 316(b).

CWISs must also satisfy any more stringent state law requirements that may apply, including any applicable requirements of state water quality standards. *See* CWA §§ 301(b)(1)(C), 401(a)(1) & (d), & 510; 40 C.F.R. §§ 122.4(d), 122.44(d), & 125.84(e). *See also Dominion,* 12 E.A.D. at 626. The application of state water quality standards to CWIS requirements, in general, is discussed above in Section 10.2.3.a, whereas the application of New Hampshire's water quality standards to CWISs is discussed in Sections 10.2.3.b. and 12.5.2, above.

New Hampshire's standards state as follows:

> *[t]hese rules shall apply to any person who causes point or nonpoint source discharge(s) of pollutants to surface waters, or who undertakes hydrologic modifications, such as dam construction or water withdrawals, or who undertakes any other activity that affects the beneficial uses or the level of water quality of surface waters.*

N.H. Code R. Env-Wq 1701.02(b) (Applicability). *See also id.* 1708.03 (Submittal of Data). This language clearly indicates the applicability of the standards to cooling water withdrawals from the state's waters. Furthermore, the state's standards also prescribe the following water quality criterion for "biological and aquatic community integrity":

> *(a) The surface waters shall support and maintain a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of similar natural habitats of a region.*
> *(b) Differences from naturally occurring conditions shall be limited to non-detrimental differences in community structure and function.*

N.H. Code R. Env-Wq 1703.19. This criterion applies to the Hooksett Pool portion of the Merrimack River.

As stated above, EPA concludes that allowing Merrimack Station to continue, unchecked, to kill and injure by entrainment and impingement an appreciable number and percentage of the fish larvae, fish eggs, and juvenile and adult fish in the Hooksett Pool, including the larvae of species exhibiting population declines in the pool, would be inconsistent with New Hampshire water quality standards. More specifically, EPA concludes that continued year-round open-cycle operations would not satisfy the water quality criterion for biological and aquatic community integrity quoted above. This is especially so when one considers Merrimack Station's entrainment and impingement as cumulative adverse effects on the Hooksett Pool ecosystem in addition to Merrimack Station's thermal (and other) discharges.

At the same time, EPA also concludes that permit requirements consistent with Option 5 will not only satisfy the CWA § 316(b)'s BTA standard, but will also satisfy New Hampshire's water quality standards. As a result, no additional, more stringent CWIS-related permit requirements are needed to satisfy state water quality standards. In addition, however, EPA also concludes that if the permit's CWIS-related requirements were made significantly less stringent they would be inconsistent with the state's water quality standards as they would likely interfere with attaining the state's water quality criterion for protecting biological and aquatic community integrity.

12.7 Conclusion

EPA concludes that Option 5 is the BTA for Merrimack Station under CWA § 316(b) and the draft NPDES permit include limits and conditions corresponding to Option 5, with the exception that the permit does not contain conditions requiring the installation of new travelling screens because EPA recognizes that the permit's thermal discharge conditions are based on using closed-cycle cooling on a year-round basis. As a result, closed-cycle cooling would be in place, and providing even greater reductions in impingement mortality that would be realized with the screening system improvements included in Option 5. Specifically, these permit limits and conditions require the following:

- that Units I and II limit intake flow volume to a level consistent with operating in CCC mode from, at a minimum, April 1 through August 31;
- that a low-pressure (≤30 psi) spray wash system be used for each traveling screen to remove fish prior to high-pressure washing for debris removal;
- that the location of the low-pressure spray systems shall be optimized to transfer fish gently to the return sluice;
- that a new fish return sluice with the following features be installed for each CWIS:
    - Maximum water velocities of 3–5 ft/sec within the sluice;
    - A minimum water depth of 4–6 inches at all times;
    - No sharp-radius turns (*i.e.*, no turns greater than 45 degrees);
    - A point of discharge to the river that is slightly below the low water level at all times;
    - A removable cover to prevent access by birds, etc;
    - Escape openings in the removable cover along the portion of the sluice that could potentially be submerged; and

    - A slope not to exceed 1/16 foot drop per linear foot, unless the plant can demonstrate this is not feasible.
- that the fish return sluice will be in place and operational at all times.

13.0 Interplay of Thermal Discharge and Cooling Water Withdrawal Permit Limits

The draft permit's limits create performance standards for reducing thermal discharges and withdrawals of river water for cooling. Reduced water withdrawals, in turn, result in reduced entrainment and impingement mortality. These performance standards are based on the performance of closed-cycle cooling using either wet or hybrid wet-dry mechanical draft cooling towers. (Additional impingement mortality reduction requirements are specified in the permit in the form of CWIS design standards.)

Although the performance standards are based on wet or hybrid wet-dry mechanical draft cooling towers, the permit does not preclude the facility from using other lawful, feasible methods of meeting the limits. For example, the permit would not preclude Merrimack Station from using dry cooling instead of wet cooling. As another example, if the facility was able to meet the permit's water withdrawal limits by purchasing municipal water (or treated municipal wastewater) for its cooling processes, the permit would not prevent that approach.

The draft permit's thermal discharge and cooling water withdrawal limits have separate, independent foundations, and both types of limits must be complied with. In a sense, the thermal discharge and water withdrawal limits partially overlap because the same technology can be used to comply with both. Because of this partial overlap, it is important to understand the interplay between the limits.

EPA determined that wet or hybrid wet-dry mechanical draft cooling towers are the BAT *year-round* for controlling thermal discharges at Merrimack Station. Therefore, EPA set thermal discharge limits for the permit at levels consistent with what would be discharged using that technology for all 12 months of the year. These technology-based limits are included in the permit because EPA determined that they are more stringent than the applicable water quality-based limits and because EPA rejected PSNH's application for a variance under CWA § 316(a). In addition, EPA determined that *for minimizing entrainment*, using wet or hybrid wet-dry mechanical draft cooling towers *from April 1 through August 31* is the BTA. From the entrainment perspective, open-cycle cooling is acceptable from September 1 through March 31 because entrainment is not a problem at Merrimack Station during that period. With regard to reducing impingement mortality, which is a year-round problem, EPA determined that the BTA involves implementing certain improvements to the fish return system and the intake screens, but that the screening system improvements were not needed during closed-cycle cooling operations because closed-cycle cooling was even more effective for reducing impingement mortality.

The manner in which these permit limits interact is discussed below. If the permittee decides to meet the permit's thermal discharge limits by using closed-cycle cooling on a year-round basis, then it would more than satisfy the permit's entrainment and impingement mortality reduction requirements with the exception that it would still need to upgrade the fish return system. If, hypothetically, the thermal discharge limits were relaxed and only necessitated closed-cycle cooling on a seasonal basis, then closed-cycle cooling would only be needed during the months specified for entrainment reduction and thermal discharge reduction. In that case, open-cycle cooling could be permitted at times, but the intake screen improvements that are part of the BTA (i.e., Option 5) would be required for to minimize impingement mortality during the period that closed-cycle cooling was not in use. (The fish return system improvements would be needed year-round in any case.)

If closed-cycle cooling was not required during the colder months, then the increased thermal discharges during that period could raise some additional issues that would need to be addressed and could trigger additional requirements during that period. In evaluating whether the operation of Merrimack Station in open-cycle mode during periods of colder ambient temperatures would be adequately protective of the balanced, indigenous fish community, EPA would need to consider the implications of large volumes of heated effluent potentially attracting certain species to the plant's discharge canal.

As discussed in Sections 5.6.3.3f and 8.3.1.1a, yellow perch require prolonged exposure to low temperatures to ensure proper gonadal development. This period extends for up to six months, from early November into April. Sampling data collected in December and March by PSNH demonstrated that yellow perch are attracted to Merrimack Station's discharge canal during this period. Other species that require a "winter phase" in their life cycle may also be attracted to the elevated temperatures within the canal. Gonadal development for those species (e.g., white sucker, brown bullhead catfish) may also be compromised due to prolonged exposure to elevated temperatures. Furthermore, the metabolism of fish in the elevated temperatures of the discharge canal would likely be increased over levels they would maintain in the colder ambient temperatures of the river (Coutant 1970). Increased metabolism can increase the need for food consumption at a time when forage is typically not as readily available, and competition for forage in concentrated aggregations within the discharge canal would increase. Studies by Marcy (1976) at a power plant on the Connecticut River identified significantly lower weights and significantly poorer condition of brown bullhead and white catfish (*Ictalurus catus*) in the discharge canal during winter months than fish of similar lengths collected in cooler water outside the canal. Yellow perch were among the species that made up the vast majority of species that were attracted to, and then resided in, the discharge canal (Marcy 1976).

Another concern raised by thermal discharges during the colder seasons is the risk of "cold shock." If an abrupt shutdown of power generating units occurs during winter months, such as due to some type of forced outage, a rapid decline in discharge water temperature can result. Studies referenced by Coutant (1970) show that acclimation to cooler temperatures, at least for fish, is considerably slower (e.g., days versus hours) than acclimation to warmer temperatures. The relatively rapid reduction in discharge temperature associated with winter shutdowns can lead to the physiological impairment of fish, and even to death. While Merrimack Station has never reported a fish kill associated with unplanned winter shutdowns, winter fish kills have been documented at a number of power plants (Coutant 1970).

The State of New Hampshire does not consider Merrimack Station's discharge canal to be "waters" of the State. Therefore, permit limits designed to be protective of aquatic life are generally not applied within the discharge canal. Nevertheless, the wildlife resources of the State (e.g., fish) should not be exposed to discharge temperatures that are lethal or will impair their ability to reproduce successfully. In particular, chronic exposure to heat during yellow perch's critical winter phase represents yet another stressor to the population; a species that has been adversely affected by both the plant's discharge of heat and the entrainment of its larvae through the cooling water intake structures.

One way that it might be possible to address the concern about fish entering the warm water of the discharge canal during the winter would be to identify and install a technology for preventing fish from entering the discharge canal during the colder months when conditions may result in lethality or impaired spawning success. So-called "barrier nets" have been used at other facilities.

EPA notes that it does not expect the above-discussed problem discharge conditions to occur if Merrimack Station is operating with closed-cycle cooling in the winter months. Although there will still be a thermal discharge resulting from cooling tower blowdown, the amount of heat discharged will be so much less that it does not raise the same concerns.

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