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NORMANDEAU ASSOCIATES
Environmental Consultants

Normandeau Associates, Inc. Response to EPA's "Statement of Substantial New Questions and Possible New Conditions"

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1.0 Introduction

Normandeau Associates Inc (Normandeau) is submitting these comments as a response to the EPA's "Statement of Substantial New Questions and Possible New Conditions" for both CWA §316(a) with regard to thermal effects on the aquatic communities and §316(b) in regard to the potential installation of wedgewire screens to reduce entrainment at Merrimack Station. For the 316(a) thermal issues, Normandeau is submitting a data report that includes two additional years of fisheries data collected from Garvins, Hooksett and Amoskeag Pools in 2012 and 2013. This report supplements the "*Merrimack Station Fisheries Survey Analysis of 1972-2011 Catch Data*" (Normandeau 2011a), referred to herein as the "1972-2011 Fisheries Report" by updating the observations and results with two additional years (2012 and 2013) of standardized electrofishing data. This 2012-2013 data supplement used the same methodology and analyses as the 1972-2011 Fisheries Report, unless otherwise noted, and is organized into the following three major sections:

1. results and analysis of fish community data collected in Garvins Pool (the thermally uninfluenced impoundment immediately upstream from Hooksett Pool and therefore the appropriate upstream reference), Hooksett Pool and Amoskeag Pool (the impoundment immediately downstream from Hooksett Pool) during 2012 and 2013 (Report Section 2.0),
2. an updated RIS population trends analysis for the 1972-2013 time period that builds on the results first presented in 2007 (Normandeau 2007a), and updated in 2011 (Normandeau 2011a), by adding more recent data collected from Hooksett Pool during the comparable time periods of August and September 2012 and 2013 (Report Section 3.0), and
3. an assessment of biocharacteristics for RIS and other resident fish species during the 2012 and 2013 study periods, that builds on the results first presented in Normandeau 2011a (Report Section 4.0).

In EPA's Substantial New Questions and Possible New Conditions, the agency invited public comment on the question of how shorter-term and longer-term thermal data should be factored into the evaluation under CWA 316(a) and New Hampshire's water quality standards of the effects of Merrimack Station's thermal discharges on the Hooksett Pool and the development of thermal discharge limits for the Merrimack Station permit.

It is Normandeau's position that there needs to be no further analysis of shorter-term or longer-term thermal data because numerous fish and aquatic community analysis conducted over 40 years of Merrimack Station operation have demonstrated there is no appreciable harm to the balanced, indigenous populations of shellfish, fish and wildlife in Hooksett Pool caused by the thermal discharge. An updated summary of these 316(a) studies and results will be presented in Section 2 and the 316(b) comments on the new wedgewire technology will be presented in Section 3.

1.1 Merrimack Station Ecological Studies

PSNH and Normandeau have provided EPA with more than 40 years of comprehensive studies of the Merrimack River ecosystem, including:

- The Effects of Thermal Releases on the Ecology of the Merrimack River (Normandeau 1969);
- The Effects of Thermal Releases on the Ecology of the Merrimack River - Supplemental Report No. 1 (Normandeau 1970);
- Merrimack River Monitoring Program: A Report for the Study Period 1971 (Normandeau 1972);
- Merrimack River Monitoring Program: A Report for the Study Period 1972 (Normandeau 1973a);
- Merrimack River: Temperature and Dissolved Oxygen Studies 1972 (Normandeau 1973b);
- Merrimack River Monitoring Program: A Report for the Study Period 1973 (Normandeau 1974);
- Merrimack River Monitoring Program 1974 (Normandeau 1975a);
- Merrimack River Ecological Studies: Impacts Noted to Date; Current Status and Future Goals of Anadromous Fish Restoration Efforts; and Possible Interactions Between Merrimack Station and Anadromous Fishes (Normandeau 1975b);
- Merrimack River Monitoring Program 1975 (Normandeau 1976a);
- Merrimack River Anadromous Fisheries Investigations: Annual Report for 1975 (Normandeau 1976b);
- Further Assessment of the Effectiveness of an Oil Containment Boom in Confining the Merrimack Generating Station Discharge to the West Bank of the River (Normandeau 1976c);
- Merrimack River Monitoring Program 1976 (Normandeau 1977a);
- Final Report: Merrimack River Anadromous Fisheries Investigations 1975-1976 (Normandeau 1977b);
- Merrimack River Thermal Dilution Study 1978 (Normandeau 1978);
- Merrimack River Monitoring Program 1978 (Normandeau 1979a);
- Merrimack River Monitoring Program: Summary Report (Normandeau 1979b);
- Merrimack River Anadromous Fisheries Investigations: 1978 (Normandeau 1979c);
- Phase I Preliminary Report – Information Available Related to Effects of Thermal Discharge at Merrimack Station on Anadromous and Indigenous Fish of the Merrimack River (Stetson-Harza 1993);
- Merrimack Station: Thermal Discharge Modeling Study (Normandeau 1996);
- Merrimack Station (Bow) Fisheries Study (Normandeau 1997);

- Merrimack Station Thermal Discharge Effects on Downstream Salmon Smolt Migration (Normandeau 2006a);
- An Examination of Fish Catch Between Trap Nets with 0.75-in and 2.00-in Mesh Sizes Deployed in Hooksett Pool of the Merrimack River (Bow, NH) (Normandeau 2006b);
- Merrimack Station Fisheries Survey Analysis of 1967 through 2005 Catch and Habitat Data (Normandeau 2007a);
- Entrainment and Impingement Studies Performed at Merrimack Generating Station from June 2005 through June 2007 (Normandeau 2007b);
- A Probabilistic Thermal Model of the Merrimack River Downstream of Merrimack Station (Normandeau 2007c);
- Biocharacteristics of Yellow Perch and White Sucker Populations in Hooksett Pool of the Merrimack River (Normandeau 2009a);
- Biological Performance of Intake Screen Alternatives to Reduce Annual Impingement Mortality and Entrainment at Merrimack Station (Normandeau 2009b);
- Modeling the Thermal Plume in the Merrimack River from the Merrimack Station Discharge (ASA 2010).

PSNH submitted the following five reports as part of its response to and comments on the Draft NPDES Permit in February 2012:

- Merrimack Station Fisheries Survey Analysis of the 1972-2011 Catch Data (Normandeau 2011a);
- Historic Water Quality and Selected Biological Conditions of the Upper Merrimack River, New Hampshire (Normandeau 2011b);
- Changes in the Composition of the Fish Aggregation in Black Rock Pool in the Vicinity of Cromby Generating Station from 1970 to 2007 (Normandeau 2011c);
- Quantification of the Physical Habitat within Garvins, Hooksett and Amoskeag Pools of the Merrimack River (Normandeau 2011d);
- Comparison of Benthic Macroinvertebrate Data Collected from the Merrimack River near Merrimack Station (Normandeau 2012a).

PSNH has submitted two additional reports as part of its response to the reopening of the comment period. These two reports provide new and substantive supplemental information and analysis regarding the fish community with two more years of fisheries sampling (2012-2013) in all three pools as well as wedgewire screen pilot tests conducted at the Station intakes during 2017.

- 2012-2013 Data Supplement to the Merrimack Station Fisheries Survey Analysis of 1972-2011 Catch Data (Normandeau 2017a).
- Evaluation of the Entrainment Reduction Performance of a 3-mm Wedgewire Screen at Merrimack Station (Normandeau 2017b).

2.0 Recent Fisheries Data Supports the Case for a §316(a) Variance

Merrimack Station is seeking a renewal of its existing thermal discharge variance under CWA §316(a) as part of USEPA's renewal of the Permit. CWA §316(a) provides that a permit applicant may demonstrate that any effluent limitation proposed for the thermal component of a discharge is more stringent than necessary to assure the protection and propagation of the balanced, indigenous population ("BIP") of shellfish, fish and wildlife in and on the body of water into which the discharge is made. Applicants with an existing thermal discharge, such as the Station, may demonstrate that the existing discharge is protective of the BIP by evaluating the BIP over a series of years during which the discharge occurred, and showing an absence of appreciable harm (40 C.F.R. §125.73(c); USEPA 1977). Contrary to USEPA's unfounded assertions, the data and analyses presented in the many reports prepared by Normandeau since 1969 and submitted to USEPA, NHDES and, after 1992, the other members of the Technical Advisory Committee (TAC) demonstrate that Merrimack Station's thermal discharge has not resulted in appreciable harm to the BIP in Hooksett Pool, and that the thermal discharge limits in the existing Permit adequately assure the protection and propagation of that BIP.

One of the most significant flaws in USEPA's §316(a) analysis is the Agency's selection of the 1967-1969 fish community as the Hooksett Pool BIP, and its failure, in making this selection, to account in any way for the severe, non-thermal discharge-related water quality impairments that adversely affected the Merrimack River during the 1960s. In its desire to link *all* of the changes that have occurred in Hooksett Pool since the 1960s to Merrimack Station's thermal discharge after May 1968 (when Unit 2 came on-line), USEPA has overlooked both these severe water quality impairments and how pollution of that magnitude negatively impacts and alters biological communities. Evidence of the Merrimack River's poor water quality during the 1960s is well-documented in the ecological reports produced during the 1960s and 1970s (see Section 1.1 above). Moreover, USEPA, PSNH and Normandeau specifically discussed at a 2006 meeting the potential impacts of the Merrimack River's non-thermal discharge-related water quality impairments during the late 1960s on the biological community in Hooksett Pool. Nonetheless, despite these facts, USEPA does not raise this issue once in the Draft NPDES Permit, the §316(a) Determination Document and again failed to mention this issue in this lastest Substantial New Questions Document. This is puzzling, given that the improvement of Merrimack River water quality is likely the greatest ecological change to have occurred in the river over the past forty years.

The fish community in Hooksett Pool has changed dramatically when compared between 1967-1969 and the present day, with the number of fish species increasing from 16 in the late 1960's to 27 fish species currently inhabiting the pool (Table 2-1). However, by not providing an accurate picture of the current fish community in Hooksett Pool in the Draft NPDES Permit, USEPA obscures the obvious differences, including the nearly doubling of fish species found in the pool and the addition of species that are highly sensitive to pollution. Many of the fish species in the current Hooksett Pool fish community could not have survived the conditions found in the Hooksett Pool of 1967-1969. The high numbers of Yellow Perch, Pumpkinseed, White Sucker, Brown Bullhead and Golden Shiners

Table 2-1. Common name and percent composition for fish captured in Hooksett Pool during 1967-1968 (trapnet and electrofishing), and 2004-2005 (trapnet and electrofishing) / 2010-2013 (electrofishing).

Hooksett Pool Fish Community 1967-1968		Hooksett Pool Fish Community 2004-2013	
Common Name	**Percent Comp.[1]**	**Common Name**	**Percent Comp.[2]**
Pumpkinseed	31.7%	Spottail Shiner	23.7%
Yellow Perch	22.9%	Largemouth Bass	17.5%
Brown Bullhead	15.4%	Bluegill	12.6%
White Sucker	12.5%	Smallmouth Bass	10.3%
Golden Shiner	7.3%	Fallfish	8.9%
Redbreast Sunfish	4.7%	Redbreast Sunfish	7.7%
Smallmouth Bass	2.1%	White Sucker	3.9%
Yellow Bullhead	1.5%	Yellow Perch	3.6%
Chain Pickerel	1.2%	Pumpkinseed	3.5%
American Eel	0.4%	Alewife	1.4%
White Perch	<0.1%	Common Shiner	1.1%
Walleye	<0.1%	Rock Bass	1.0%
Largemouth Bass	<0.1%	Golden Shiner	0.9%
Fallfish	<0.1%	Chain Pickerel	0.7%
Madtom sp.	<0.1%	American Eel	0.7%
Common Shiner	<0.1%	Black Crappie	0.6%
		Tessellated Darter	0.5%
		American Shad	0.4%
		Sunfish family	0.3%
		Margined Madtom	0.3%
		Eastern Silvery Minnow	0.1%
		Yellow Bullhead	0.1%
		Atlantic Salmon	<0.1%
		Brown Bullhead	<0.1%
		Brown Trout	<0.1%
		Common Carp	<0.1%
		Eastern Blacknose Dace	<0.1%
		White Perch	<0.1%

1 - Based on electrofish and trapnet data from 1967 and 1968

2 – Based on electrofish and trapnet data from 2004-2005 and electrofish data from 2010-2013

captured in 1967-1969 were in abundance because the Hooksett Pool fish community was shaped by the severely impaired water quality that existed in the Merrimack River at the time. Even so, USEPA inappropriately bases the bulk of its §316(a) analysis on that community in an attempt to demonstrate that the drop in abundance for these species was caused solely by the Station's thermal discharge into Hooksett Pool. Omitting any discussion about the dramatic improvements in Merrimack River water quality in the

Draft NPDES Permit or the §316(a) Determination Document allows USEPA to advance the false argument that all of the changes to the Hooksett Pool BIP since the 1960s are solely attributable to Merrimack Station's thermal discharge. Indeed, the changes to the Hooksett Pool fish community that have occurred over the decades as water quality has so significantly improved should not be characterized as a negative outcome. Rather, because of these water quality improvements, the aquatic community that exists in Hooksett Pool today is healthier and far more diverse than the community that existed during the 1960s.

The other most significant flaw in USEPA's §316(a) analysis – which flows directly from the Agency's disregard of the impaired water quality in the Merrimack River during the 1960s and improved river water quality since the 1960s – is the Agency's inaccurate, inadequately supported finding that Merrimack Station's thermal discharge has caused appreciable harm to the BIP in Hooksett Pool. USEPA's finding of appreciable harm is clearly incorrect. Properly interpreted using the recent fisheries data collected from 2008-2013, the data show that over time, there have not been (1) appreciable decreases in *any* coolwater fish species in Hooksett Pool, (2) appreciable increases in warmwater species in Hooksett Pool, (3) appreciable decreases in the diversity of species in Hooksett Pool (as discussed in detail below, the Shannon Diversity Index value shows that the current fish population in Hooksett Pool is more diverse now than it was forty years ago), or (4) appreciable increases in the abundance of generalist feeders or pollution-tolerant species in Hooksett Pool. In fact, when compared to Garvins Pool – the thermally uninfluenced impoundment immediately upstream from Hooksett Pool, and the proper reference to compare to Hooksett Pool – the biocharacteristics of the fish population in Hooksett Pool in general, and of the individual species in Hooksett Pool in particular, indicate no appreciable harm to the BIP.

2.1 Hooksett Pool BIP

As defined in 40 C.F.R. § 125.71(c), the term "balanced, indigenous community" is synonymous with the term "balanced, indigenous population" in the CWA and means a biotic community typically characterized by (1) diversity, (2) the capacity to sustain itself through cyclic seasonal changes, (3) the presence of necessary food chain species and (4) 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, as well as 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 CWA §301(b)(2).

The USEPA's selection of the 1967-1969 Hooksett Pool fish community as the BIP for Hooksett Pool is flawed and does not provide an appropriate basis for USEPA's determinations presented in the §316(a) Determination Document, because the available data show that the aquatic community in the Hooksett Pool during those years was not "balanced," but rather was dominated by fish and macroinvertebrate species able to tolerate the severe pollution present in the Merrimack River prior to the improvements in water quality that followed the 1972 enactment of the CWA. USEPA does not mention, let alone consider in any reasoned, technically sound manner, either the significant systemwide pollution that existed in the Merrimack River during the 1960s or the fact that improvements in water quality can dramatically alter aquatic communities. Instead, the Agency focuses solely on the potential impacts of the thermal releases into Hooksett Pool after Unit 2 came on-line in May 1968. However, unbiased, accurate analysis of the 40 years of ecological monitoring in and on the Merrimack River in the vicinity of Merrimack Station demonstrates that the changes in abundance of the resident biota of Hooksett Pool that occurred from the 1960s to the present were not caused by the Station's thermal discharge, but by the dramatic improvements to Merrimack River water quality that began in earnest in 1972.

The following sections (1) summarize the historic water quality conditions found in the Merrimack River, (2) explain why, based on the fisheries and macroinvertebrate sampling data from 1967-1969, USEPA's selection of the 1967-1969 Hooksett Pool aquatic community as the Hooksett Pool BIP for the purpose of the Draft NPDES Permit is inappropriate, misleading and technically indefensible, and (3) explain why, based on the fisheries and macroinvertebrate sampling data from 1972-2013, that the current Garvins Pool aquatic community, which is not influenced by any thermal discharge, constitutes the proper reference BIP for Hooksett Pool.

2.1.1 Historic Water Quality of the Merrimack River

The Normandeau report *Historic Water Quality and Selected Biological Conditions of the Upper Merrimack River, New Hampshire* (Normandeau 2011b), which PSNH submitted in 2012 as part of its response to and comments on the Draft NPDES Permit, documents the nature and substantial extent of the water pollution that had already impaired the Merrimack River as of May 1968, the month when Merrimack Station's Unit 2 commenced operation, and when, according to USEPA, Merrimack Station's thermal discharge began to cause appreciable harm to the aquatic community in Hooksett Pool (Normandeau 2011b). This historical pollution predating Unit 2's operations significantly altered the river's water quality, especially with respect to nutrients, and had a corresponding impact on resident biota. As noted by Wolf (1965):

> *Historic observations of this contamination give a picture of a river contaminated beyond our current comprehension: sewage so dense that a single drop contains "dangerous" levels of bacteria; coliform bacterial counts exceeding 1 million per 100 ml for several cities; toxic metals and wastes including phenol and cyanide found in the river; suspended solids covering the river bottom and decomposing, causing gas to bubble up "as if the river were cooking"; and a predominant smell of rotten egg from hydrogen sulfide, which can ruin painting on boats and houses (Wolf 1965).*

The sources of contamination were many and included waste from wood and paper processing mills and textile mills (wool and cotton fiber mills) that were situated along the river. However, one of the major sources of significant pollution came from the constant release of untreated sewage wastes into the river (Normandeau 2011b). In 1964, no town in New Hampshire on the mainstem of the Merrimack River treated its wastes (Wolf 1965). As late as the mid-1960s, more than 120 million gallons per day of untreated or minimally treated wastewater were discharged into the Merrimack River (USGS 2003).

The effects of this waste effluent impacted all the aquatic biota in the river, including in Hooksett Pool. The effects of this type of sustained nutrient enrichment, and the resulting enhancement of primary producers, ultimately enhances secondary and tertiary productivity (deBruyn et al. 2003).

The United States Department of the Interior ("USDI") measured nutrient levels (nitrogen and phosphate), total and fecal coliform, dissolved oxygen ("DO") and biological oxygen demand ("BOD") levels in the Merrimack River during 1965 (USDI 1966). Levels of ammonia and nitrate were substantially elevated (approaching and exceeding 1 mg/L) in the Concord to Manchester reach of the river, and total phosphorous levels in excess of 0.1 mg/L to near 1 mg/L were recorded. These values indicate a high level of nutrient loading in the Merrimack River during that time period. In addition to the USDI data collected during 1965, sampling in Hooksett Pool during 1969 also demonstrated elevated nutrient levels, with both total phosphorous and total nitrogen levels significantly greater than what would be expected for uncontaminated waters in northeast rivers (Normandeau 2011b). Figure 3-1 (originally presented in Normandeau 1979b) presents the seasonal mean nitrate and phosphate concentrations recorded in Hooksett Pool for the period 1967-1978, when the river was at its most polluted state. In addition to the elevated nutrient levels, total and fecal coliform levels were also elevated (USDI 1966). High BOD readings, indicative of a high level of organic material in the river, were present when measured during the January-April period, with lower levels measured during the summer months (USDI 1966). Lower summer BOD combined with low DO is indicative of significant organic pollution in the river (Normandeau 2011b).

The reduction in oxygen available to Merrimack River biota that was caused by the nutrient loading to the river was the most important effect on the system as a whole. USDI (1966) notes the sources of pollution to the river were mainly sewage and industrial waste that contained a variety of "obnoxious components", including oxygen "demanding" materials that limited fish and aquatic life by removing DO from the water. Other "greasy substances" in the water formed surface scums, settleable solids and sludge deposits, and other suspended materials made the water turbid, limiting light penetration. Industrial wastes can contain chemical or toxic substances that can kill fish and aquatic organisms or promote slime growth.

USEPA and most states consider DO levels below 5 mg/L as detrimental to most temperate freshwater ecosystems (Normandeau 2011b). The DO levels measured during 1965 in the upper Merrimack River were often below 5.0 mg/L during the June through September period throughout the river reach between East Concord and Manchester, NH (USDI 1966). Minimum DO values of 2.8 mg/ L were measured during September at Garvins Falls Dam, just upstream from Hooksett Pool. Low levels of DO were also recorded during studies conducted in Hooksett Pool during the late 1960s, and it was reported in 1969 that rhythmic, daily oxygen pulses, resulting from photosynthetic and respiratory activity of aquatic organisms, ranged up to 80% during days with low flows (Normandeau 1970). Concentrations of DO during the daytime were usually well above 5 mg/L and at times as high as 10 mg/L or higher, but during the evening would fall to as low as <1 mg/L, depending on conditions (Normandeau 1969). Large diurnal changes in DO levels are indicative of a eutrophic condition, caused by high levels of nutrients such as nitrates and phosphorous being discharged into a waterbody (Normandeau 2011b). High nutrient levels result in enhanced primary productivity, which causes large phytoplankton blooms. These phytoplankton blooms were primarily responsible for the large diurnal changes in DO levels recorded in Hooksett Pool during the 1960s, which ranged from supersaturated conditions recorded during the day (due to photosynthesis) to values approaching zero during pre-dawn hours. Eutrophication can decrease biodiversity and change species composition and dominance for all aquatic biota. It can increase growth of gelatinous zooplankton, decrease epiphytic algae and change macrophyte biomass and composition (Smith et al. 1999). It is evident from these data that the pollution levels present in the Merrimack River, and in particular in Hooksett Pool, during the late 1960s were harmful to the resident aquatic biota. Indeed, trout, salmon and other fish species sensitive to low DO levels could not survive in the Merrimack River during the 1960's. Tests conducted by the New Hampshire Water Supply and Pollution Control Commission in 1968 demonstrated that Brook Trout placed in live boxes and lowered to the bottom in Hooksett Pool at Station N-10, 0 and S-17 resulted in mortalities to *all fish* at every station (Normandeau 1969).

In the 1960s, New Hampshire Water Use Classification and Quality Standards included Classes A through D for rivers, based primarily on dissolved oxygen, coliform bacteria and pH, among other parameters. When the USDI issued its report in 1966, New Hampshire had not yet classified the Merrimack River, but it was expected to do so by June 1967 according to the Federal Water Pollution Control Act (USDI 1966). Had the river been classified as of June 1967, the USDI data would have supported a Class D rating – a level of water pollution unheard of today.

An annual monitoring program conducted in Hooksett Pool between 1971 and 1978 observed that DO levels were higher than those measured during 1965, 1967 and 1968. During the mid-1960s, DO levels had averaged in the mid-3 mg/L range during low flow conditions at the Garvins Falls Dam. By 1972, DO values remained above 6.4 mg/L at Hooksett Pool Monitoring Station N-10. Hooksett Pool water quality was beginning to improve during the 1970s, with the reduction in nutrient loading (Figure 2-1) acting as a major driving force behind those improvements (Normandeau 2011b).

As stated in Normandeau (1979b), "[n]itrite, nitrate, orthophosphate and total phosphate concentrations decreased by an order of magnitude from 1971 to 1972. Municipal and industrial pollution abatement activity in the upper Merrimack River basin prior to 1971 was most likely responsible for this decrease in Hooksett Pond nutrient concentration."

2.1.2 1960s Aquatic Community in Hooksett Pool

Despite the foregoing, USEPA determined that the fish community observed in Hooksett Pool during 1967-1969 should serve as the BIP to which the current Hooksett Pool fish community should be compared to assess the potential impacts of Merrimack Station's thermal discharge. In so doing, USEPA either ignored or overlooked the fact that the abundance of pollution-tolerant fish species in Hooksett Pool was higher in 1967-1969

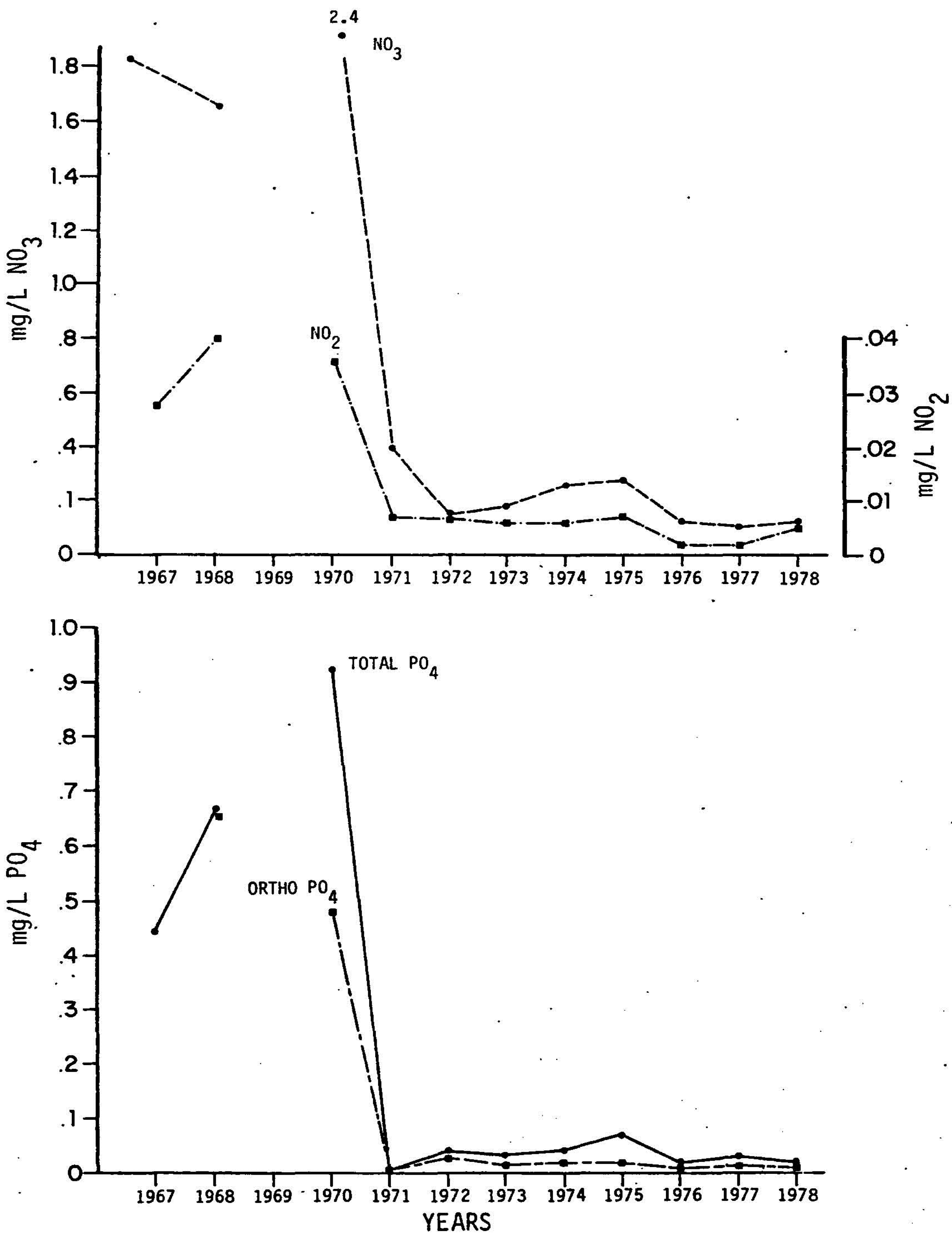

Figure 2-1. Seasonal Mean Concentrations of PO4, NO3 and NO2 (mg/L) in Hooksett Pool 1967-1978 (Merrimack Summary Report, Normandeau 1979).

Table 2-2. Percent composition, USEPA trophic guild and tolerance classifications for fish captured in Hooksett Pool during 1967-1968 (trapnet and electrofishing).

Hooksett Pool Fish Community 1967-1968			
Common Name	**Percent Comp.[1]**	**Trophic Guild[2]**	**Tolerance[2]**
Pumpkinseed	31.70%	Generalist	Intermediate
Yellow Perch	22.90%	Piscivore	Intermediate
Brown Bullhead	15.40%	Generalist	Tolerant
White Sucker	12.50%	Generalist	Tolerant
Golden Shiner	7.30%	Generalist	Tolerant
Redbreast Sunfish	4.70%	Generalist	Intermediate
Smallmouth Bass	2.10%	Generalist	Intermediate
Yellow Bullhead	1.50%	Generalist	Tolerant
Chain Pickerel	1.20%	Piscivore	Intermediate
American Eel	0.40%	Piscivore	Tolerant
White Perch	<0.1%	Piscivore	Intermediate
Walleye	<0.1%	Piscivore	Intermediate
Largemouth Bass	<0.1%	Piscivore	Intermediate
Fallfish	<0.1%	Generalist	Intermediate
Madtom sp.	<0.1%	Insectivore	Intermediate
Common Shiner	<0.1%	Generalist	Intermediate
Total	**16 Species**	**3 Guilds**	**2 Tolerance Levels**

1 - Based on electrofish and trapnet data from 1967 and 1968
2 - Barbour et al. 1999
3 - Based on electrofish and trapnet data from 2004-2005 and electrofish data from 2010-2013.

than under current conditions because of the ability of those species to survive in an aquatic habitat impaired by conventional and toxic pollutants.

The Hooksett Pool fish community and relative abundance as sampled by boat electrofishing and trap nets during 1967-1968 and described by Wightman (1971) is presented in Table 2-2. For reference, Table 2-3 presents the Hooksett Pool fish community and relative abundance as sampled by boat electrofishing and trap nets during the 2000s and described by Normandeau (2007a, 2011a, 2017a).

A review of species-specific tolerance to environmental perturbations (Barbour et al. 1999) for the fish species observed in Hooksett Pool during 1967-1968 reveals that the Hooksett Pool fish community during those years consisted only of fish species listed as tolerant or intermediate in tolerance to pollution (Table 2-2). USEPA's own definition of "balanced, indigenous community" (i.e., BIP) provides that a BIP does not include species whose presence or abundance is attributable to the introduction of pollutants that will be

Table 2-3. Percent composition, USEPA trophic guild and tolerance classifications for fish captured in Hooksett Pool during 2004-2005 (trapnet and electrofishing) / 2010-2013 (electrofishing).

Hooksett Pool Fish Community 2004-2013			
Common Name	**Percent Comp.[3]**	**Trophic Guild[2]**	**Tolerance[2]**
Spottail Shiner	23.7%	Insectivore	Intermediate
Largemouth Bass	17.5%	Piscivore	Intermediate
Bluegill	12.6%	Generalist	Tolerant
Smallmouth Bass	10.3%	Piscivore	Intermediate
Fallfish	8.9%	Generalist	Intermediate
Redbreast Sunfish	7.7%	Generalist	Intermediate
White Sucker	3.9%	Generalist	Tolerant
Yellow Perch	3.6%	Piscivore	Intermediate
Pumpkinseed	3.5%	Generalist	Intermediate
Alewife	1.4%	Filter feeder	Intermediate
Common Shiner	1.1%	Generalist	Intermediate
Rock Bass	1.0%	Piscivore	Intermediate
Golden Shiner	0.9%	Generalist	Tolerant
Chain Pickerel	0.7%	Piscivore	Intermediate
American Eel	0.7%	Piscivore	Tolerant
Black Crappie	0.6%	Piscivore	Intermediate
Tessellated Darter	0.5%	Insectivore	Intermediate
American Shad	0.4%	Filter feeder	Intermediate
Sunfish family	0.3%	Generalist	Intermediate
Margined Madtom	0.3%	Insectivore	Intermediate
Eastern Silvery Minnow	0.1%	Herbivore	Intolerant
Yellow Bullhead	0.1%	Generalist	Tolerant
Atlantic Salmon	<0.1%	Piscivore	Intolerant
Brown Bullhead	<0.1%	Generalist	Tolerant
Brown Trout	<0.1%	Piscivore	Intolerant
Common Carp	<0.1%	Generalist	Tolerant
Eastern Blacknose Dace	<0.1%	Generalist	Tolerant
White Perch	<0.1%	Piscivores	Intermediate
Total	**27 Species**	**5 Guilds**	**3 Tolerance Levels**

1 - Based on electrofish and trapnet data from 1967 and 1968

2 - Barbour et al. 1999

3 - Based on electrofish and trapnet data from 2004-2005 and electrofish data from 2010-2013.

eliminated by compliance by all sources with CWA §301(b)(2) (40 C.F.R. §125.71(c)). Of the sixteen fish species collected during 1967-1968, five are considered tolerant to pollution, including Brown Bullhead, White Sucker, Golden Shiner, Yellow Bullhead and American Eel (Table 2-2; Barbour et al. 1999). Those five tolerant species accounted for 37% of the total fish catch from Hooksett Pool collected during 1967-1968. In addition, the 1967-1969 Hooksett Pool fish community was composed solely of species considered to be members of the generalist, insectivore and piscivore trophic guilds. The lack of any fish species considered to be intolerant to pollution, and the lack of any fish species representing the filter feeder or herbivore trophic guilds in the 1967-1969 Hooksett Pool fish community reflects the high degree to which Hooksett Pool water quality was impaired by pollutants other than heat in the late 1960s.

The five most abundant fish species collected in Hooksett Pool during the 1967-1968 fish sampling – Pumpkinseed, Yellow Perch, Brown Bullhead, White Sucker and Golden Shiner – represented 89.8% of the total catch. All of these fish are known for their capability to withstand low DO conditions (Holtan 1990, Fox 1994, Trial et al. 1983, Scarola 1987, Twomey et al. 1984, Becker 1983). Three of those species – White Sucker, Brown Bullhead and Golden Shiner – are also classified as tolerant to pollution (Barbour et al. 1999). It stands to reason that the increased abundance of these five fish species in Hooksett Pool during the 1960s is attributable to their ability to withstand pollutants that were greatly reduced following the 1972 enactment and subsequent enforcement of the CWA and parallel state clean water regulations.

Further evidence of the polluted nature of Hooksett Pool during the 1960s is evidenced by macroinvertebrate sampling conducted during that time period. Macroinvertebrate communities are useful indicators of anthropomorphic perturbation due to their limited mobility. They are unable to avoid adverse environmental conditions and are often eliminated from areas where stresses exceed tolerance levels. In response to stressed conditions, the macroinvertebrate community often shifts towards high numbers of a few tolerant taxa. Data from USDI (1966) clearly indicates that pollution in the Merrimack River was adversely affecting the river's macroinvertebrate community. Less than 15 miles of the Merrimack River, from a total of 115 miles studied, contained benthic organisms.

A review of shoreline kick net samples collected at Hooksett Pool Monitoring Stations N-10, S-0, S-4 and S-16 during 1972 revealed low values for Ephemeroptera/Plecoptera/Trichoptera (EPT) richness, taxa richness and EPT/Chironomid ratio, all of which can be attributed to the low water quality conditions in Hooksett Pool prior to the Clean Water Act (Normandeau 1973a). Kick net data collected in October 2011 at these same monitoring stations (N-10, S-0, S-4 and S-16) showed that EPT richness had increased by 150-300% from 1972, and taxa richness had increased from 7-10 species in 1972 to 21-23 species in 2011 (Normandeau 2012a). The 2011 EPT/chironomid ratios were also higher than their 1970s counterparts, as would be expected from samples collected in a river with improved water quality and habitat tolerated by more pollution-sensitive species (Normandeau 2012a). Benthic samples collected by ponar during 1972, 1973 and 2011 at Monitoring Stations N-10, S-0, S-4 and S-16 also show indications of improved riverine conditions over time, although these are not as dramatic as the shoreline samples, likely due to the sand substrate typically inhabited by tolerant organisms even in pristine conditions (Normandeau 2012a).

In short, the substantial improvements in water quality in the Merrimack River since the enactment of the CWA in 1972 (Normandeau 2011b) have appreciably influenced the fish community in the river, including in Hooksett, Garvins Pools and Amoskeag pools during the operation of Merrimack Station. When the "natural variability inherent in aquatic communities" (USEPA 1990) is considered along with such significant changes in water quality, it is clear that there was not an unaffected, unchanging fish community in Hooksett Pool during the 1960s and 1970s that can now be used as a baseline for comparison to the pool's current fish community. As a result, USEPA's use of the Hooksett Pool resident biotic community as sampled during 1967-1969 as the BIP by which the current species assemblage in Hooksett Pool is to be compared when assessing potential impacts related to Merrimack Station's thermal discharge is misguided, inappropriate and unsupportable using the available sampling data.

2.1.3 Current Aquatic Communities in Hooksett Pool and Garvins Pool

Rather than designate the compromised fish community that survived in the conventional and toxic pollutant-impaired Hooksett Pool of the 1960s as the Hooksett Pool BIP, USEPA should find that the current fish community in Garvins Pool provides an appropriate point of comparison that may allow the identification of trends in Hooksett Pool that are potentially due to Merrimack Station's thermal discharge. The current fish community in Garvins Pool meets USEPA's definition of "balanced indigenous population," because it is a community characterized by (1) diversity at all trophic levels, (2) the capacity to sustain itself through cyclic seasonal changes, (3) the presence of necessary food chain species, and (4) non-domination by pollution-tolerant species (40 C.F.R. §125.71(c)).

A spatial comparison among the fish communities sampled in Garvins, Hooksett and Amoskeag Pools during the years of 2010, 2011, 2012, and 2013 was performed using the Bray-Curtis percent similarity index (Normandeau 2011a; Normandeau 2017a). This analysis showed that differences existed among the fish communities of each of the three pools, and that there was a trend of decreasing similarity among pools moving downriver from Garvins Pool to Hooksett Pool to Amoskeag Pool. Comparing the 2010 fish communities, the Bray-Curtis similarity was greater between Garvins and Hooksett Pools (64.4%) than it was between Garvins and Amoskeag Pools (23.4%). Results for subsequent sampling years produced a comparable trend; Garvins and Hooksett Pool values of 43.2%, 61.5% and 72.8% and Garvins and Amoskeag Pool values of 23.4%, 41.0%, and 65.8% for the years 2011, 2012, and 2013, respectively. Differences in community similarity of fish residing in a regulated river have been observed elsewhere for spatially separated segments (Pegg and McClelland 2004; Pegg and Taylor 2007). These results indicate that the fish community in Garvins Pool, which is not subject to Merrimack Station's thermal discharge, is not wholly distinct from the fish community in Hooksett Pool.

Garvins Pool, located immediately upstream of Hooksett Pool (the two pools are separated by Garvins Falls Dam), is uninfluenced by the Station's thermal discharge but has similarly benefited from the significant water quality improvements that have occurred in the Merrimack River since 1972. The pool is contained within the natural banks of the Merrimack River and extends approximately eight miles upstream of the Garvins Falls Dam to near Sewalls Falls (PSNH 2003). There are discrete differences between Garvins and Hooksett Pools in habitat and physical area. The Garvins Pool impoundment has a surface area of approximately 640 acres at full pond versus 350 acres at full pond for Hooksett Pool (PSNH 2003). Additionally, abundance of submerged aquatic macrophytes is greater in Garvins Pool than in Hooksett Pool, and fish in Garvins Pool have access to productive oxbow and backwater habitats that are not available in Hooksett Pool. Backwater habitat in riverine systems serve as important nursery and spawning areas for resident fish species. Nonetheless, sand/silt/clay is the dominant substrate type within both pools, followed by boulder and woody debris (Normandeau 2011d), and both pools have undergone similar environmental changes over the last four decades due to improved water quality and the introduction of non-native species. Merrimack River fisheries sampling was undertaken during 2008 and 2009 to examine and compare biological characteristics of two fish species, Yellow Perch and White Sucker, among Garvins, Hooksett and Amoskeag Pools (Normandeau 2009a). Additional sampling was undertaken from 2010 through 2013 to provide a current assessment of the whole fish community in Garvins, Hooksett and Amoskeag Pools (Normandeau 2011a; 2017a). As discussed in detail below, the biocharacteristics data collected during this 2008-2013 sampling confirms that when compared to the fish community in Garvins Pool, the fish community in Hooksett Pool in general is diverse, healthy and productive, as are individual species in Hooksett Pool.

2.2 No appreciable harm to the Hooksett Pool BIP

2.2.1 No Appreciable Harm to the Hooksett Pool Fish Community

CWA §316(a) provides that a permit applicant may demonstrate that any effluent limitation proposed for the thermal component of any discharge is more stringent than necessary to assure the protection and propagation of the BIP in and on the body of water into which the discharge is made. Applicants with an existing thermal discharge may demonstrate that the existing discharge is protective of the BIP by evaluating the BIP over a series of years during which the discharge occurred, and showing an absence of appreciable harm (40 C.F.R. §125.73(c); USEPA 1977). Here, support for a finding of "no appreciable harm" to the fish community in Hooksett Pool from Merrimack Station's thermal discharge is provided through assessment of trends in abundance and an examination of the health and condition of fish species within the waterbody segment, as well as by comparison of these metrics from an appropriate reference BIP, the current fish community in Garvins Pool.

USEPA's finding of appreciable harm is clearly incorrect because properly interpreted, the data show that over time, there have not been (1) appreciable decreases in *any* coolwater fish species in Hooksett Pool, (2) appreciable increases in warmwater species in Hooksett Pool, (3) appreciable decreases in the diversity of species in Hooksett Pool (as discussed in detail below, the Shannon Diversity Index value shows that the current fish population in Hooksett Pool is more diverse now than it was forty years ago), or (4) appreciable increases in the abundance of generalist feeders or pollution-tolerant species in Hooksett Pool (Normandeau 2011a; Normandeau 2017a). In fact, when compared to Garvins Pool –

the thermally uninfluenced impoundment immediately upstream from Hooksett Pool, and the proper reference to compare to Hooksett Pool – the biocharacteristics of the fish population in Hooksett Pool in general, and of the individual species in Hooksett Pool in particular, indicate no appreciable harm to the BIP (Normandeau 2011a; Normandeau 2017).

- There has been no appreciable harm to the BIP in Hooksett Pool based on decreases in *any* coolwater species. Aquatic habitat that has been adversely impacted by a thermal discharge characteristically contains a higher abundance of fish species that are tolerant of warmer water, and a lower abundance of fish species that prefer cooler water. Merrimack Station's thermal discharge has not adversely impacted the abundance and distribution of fish in Hooksett Pool (the area of the Merrimack River from which Merrimack Station withdraws cooling water and into which it discharges heated effluent). If the Station's thermal discharge adversely impacted the abundance and distribution of fish in Hooksett Pool during 1972-2013, it would be expected that the abundance of resident coolwater species in the pool (as estimated by standardized electrofish sampling efforts conducted between 1972 and 2013), should have significantly decreased over time. However, no such significant decrease in abundance was observed for *any* of the five coolwater fish species resident in Hooksett Pool. The abundance of one coolwater fish, Black Crappie, has increased significantly in Hooksett Pool since its introduction and first detection during 2004. The lack of significantly decreasing trends for the other native and resident coolwater fish species (Chain Pickerel, Fallfish, White Sucker and Yellow Perch) are not consistent with the hypothesis that Merrimack Station's thermal discharge has caused appreciable harm to the BIP in Hooksett Pool (Normandeau 2017a).
- There has been no appreciable harm to the BIP in Hooksett Pool based on increases in warmwater species. As estimated by the same standardized electrofish sampling efforts, there have not been significant increases in abundance for nine of the ten warmwater fish species resident in Hooksett Pool during the 1972-2013 time period. Abundance of the native Pumpkinseed has significantly decreased and abundance of Rock Bass has significantly increased since its introduction and first detection during 1995 sampling. There were no significant differences in the abundance of Rock Bass within Garvins and Hooksett Pools during the period of comparable sampling in those locations (2010-2013) indicating Rock Bass in Hooksett Pool have not increased at a rate greater than that in the thermally uninfluenced Garvins Pool. The lack of a significant increase in the abundance of any warmwater fish species other than Rock Bass during the period of comparable sampling is not consistent with the hypothesis that Merrimack Station's thermal discharge has caused appreciable harm to the BIP in Hooksett Pool (Normandeau 2017a).
- There has been no appreciable harm to the BIP in Hooksett Pool based on a decrease in diversity of the fish community. Based on the 1972-2013 electrofish sampling efforts, the highest Shannon diversity index values for the Hooksett Pool fish community observed were in 2011 and 2013.

Moreover, all of the per year diversity index values from the sampling years in the 2000s were higher than the values from the sampling years in the 1970s, indicating that the diversity of the fish community in Hooksett Pool – and therefore the biological health of that community – has generally increased, not decreased, over the past forty years. Community evenness values for each year of comparable sampling between 1972 and 2013 indicate the current Hooksett Pool fish community is distributed more equitably among species than the community during the 1970's which was dominated by a limited number of fish species. Examination of richness, diversity and evenness values for each year of comparable sampling supports a finding that Merrimack Station's thermal discharge has not reduced the diversity of the fish community in Hooksett Pool. These findings support the hypothesis that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in the Hooksett Pool (Normandeau 2017a).

- There has been no appreciable harm to the BIP in Hooksett Pool based on an increase in generalist feeders. The percentage of generalist feeders in a fish community increases as the physical and chemical habitat deteriorates (Barbour et al. 1999). The percentage of generalist feeders was highest in Hooksett Pool in 1976 and lowest in 2010 across the 1972-2013 data set. The decrease in percent generalist feeders from the 1970's to present can be attributed to the decrease in abundance of Pumpkinseed, a generalist feeder that represented more than 50% of the Hooksett Pool fish community in the early 1970's. Decreases in Pumpkinseed are linked to improved water quality leading to decreases in submerged aquatic habitat and subsequently an increase in competition with Bluegill, a species that could not survive the low DO levels that existed in the pool in the early 1970's. The reduced percentage of generalist feeders in Hooksett Pool from 1972 to 2013 supports a finding that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in Hooksett Pool.
- Aquatic habitat that has been adversely impacted by a thermal discharge characteristically contains a higher percentage of pollution-tolerant individuals. Following a peak in the percentage of pollution-tolerant fish (primarily Bluegill) during the 1995 sample year, the percentage of pollution-tolerant fish observed during 2010 through 2013 are similar to the range of percentages observed during the 1970's. It should be noted that although the Bluegill is considered "Tolerant" to pollution, it could *not survive* in Hooksett Pool in the 1960's because it could not tolerate the low dissolved oxygen (DO) levels that existed at the time. Indeed, fish such as Pumpkinseed and Yellow Perch are actually considered "Intermediate" in pollution tolerance, but these fish were able to survive and reproduce in the severe pollution that existed at the time because they could withstand the low DO levels. The uniform dominance of Bluegill within both Hooksett and the thermally uninfluenced Garvins Pool based on the electrofishing sampling conducted from 2010-2013 demonstrate that the Bluegill didn't become abundant in Hooksett Pool due to thermal input as EPA speculated because this fish is just as abundant in

Garvins Pool. In 2013, Bluegill was the dominant fish captured in both Garvins Pool (32% of catch) and Hooksett Pool (24% of catch). These findings support the hypothesis that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in the Hooksett Pool (Normandeau 2011a; 2017a).

- A review of warmwater and coolwater species compared between Hooksett Pool and Garvins Pool indicates that there has been no appreciable harm to the BIP in the Hooksett Pool. As noted above, aquatic habitat that has been adversely impacted by a thermal discharge characteristically contains a higher abundance of fish species that are tolerant of warmer water, and a lower abundance of fish species that prefer cooler water. However, a comparison of the 2010 through 2013 fish communities in Hooksett Pool and Garvins Pool (the thermally uninfluenced impoundment immediately upstream from Hooksett Pool) shows no clear pattern consistent with the hypothesis that Merrimack Station's thermal discharge has caused an increase in the abundance of warmwater species or a decrease in the abundance of coolwater species in the pool. The EPA stated numerous times in the draft permit that the rise of Bluegill and Spottail Shiner abundance in Hooksett Pool was due to the thermal input from the Station because these fish can tolerate warm water and even suggested that these two fish species should not be included in certain analyses of fish abundance because they were not part of the 1960's fish community. However this hypothesis was rejected after four years of fisheries sampling in Garvins Pool, the thermally uninfluenced impoundment immediately upstream from Hooksett Pool. Spottail Shiner was the dominant fish species in Garvins Pool in electrofish samples in 2010 (51% of catch), 2011(45%) and 2012 (46%), and in 2013 Bluegill was the dominant fish collected, representing 32% of total catch in Garvins Pool (Normandeau 2011a; Normandeau 2017a). Fallfish, a coolwater fish, was the dominant fish species collected in Hooksett Pool in 2011 electrofish sampling and represented 20% of the total catch that year. Fallfish had significantly higher CPUE in Hooksett Pool electrofish sampling compared to Garvins Pool in 2011, 2012 and 2013. Additionally, White sucker, a coolwater fish, had significantly higher CPUE in Hooksett Pool electrofish sampling compared to Garvins Pool in 2010, 2011 and 2013. These comparisons, therefore, support the hypothesis that Merrimack Station's thermal discharge has not caused appreciable harm to the BIP in the Hooksett Pool (Normandeau 2011a; Normandeau 2017a).
- A review of generalist feeders and pollution tolerant species compared between Hooksett Pool and Garvins Pool indicates that there has been no appreciable harm to the BIP in the Hooksett Pool. As noted above, aquatic habitat that has been adversely impacted by a thermal discharge characteristically contains a higher percentage of both generalist feeders and pollution-tolerant individuals. Although the percentage of generalist and tolerant species were higher in Hooksett Pool than Garvins Pool during 2010 through 2013, (except for 2013 when pollution tolerant fish were higher in Garvins Pool), these differences were the result of increased relative abundance of both coolwater and warmwater species in Hooksett Pool. In 2011, 2012 and

2013, the coolwater Fallfish and coolwater White Sucker along with the warmwater Bluegill contributed to the higher percentage of generalist feeders in Hooksett Pool. The percentage of generalist feeders in all three pools in most years is dominated by warmwater fish and in 2013 Bluegill, Pumpkinseed and Redbreast Sunfish accounted for 96.9% of the generalist feeders in Garvins Pool, 92.7% in Amoskeag Pool and in Hooksett Pool the three sunfish species plus Fallfish and White Sucker (coolwater fish) accounted for more than 92% of the generalist feeders captured. The data demonstrates that the dominant generalist species in Hooksett Pool were similar to those present in Garvins Pool during each sampling year. The percentage of pollution tolerant fish species in most years is dominated by Bluegill in all three pools. The uniform dominance of Bluegill as a tolerant fish species within both Hooksett and the thermally uninfluenced Garvins Pool suggests factors other than thermal regime (e.g., habitat diversity, food resources) are likely contributing to the observed differences. If Merrimack Station's thermal discharge has adversely impacted the BIP in Hooksett Pool by increasing the percentage of generalist feeders or pollution-tolerant individuals, it would not be expected that coolwater species would have significantly contributed to these increases, as documented (Normandeau 2011a; 2017a).

- A review of length-weight-curve sampling data of fish compared between Hooksett Pool and Garvins Pool indicates that there has been no appreciable harm to the BIP in Hooksett Pool. Where aquatic habitat has been adversely impacted by a thermal discharge, sampling data tend to show a decreasing slope to the length-weight curve, signifying progressively lower weight for a given length for a resident fish species over time or in comparison to the same species residing in a thermally uninfluenced habitat. Such a decreasing slope indicates a reduction in quality of body condition due to the thermal impact. Adequate length-weight data was available to compare within-year condition for four coolwater species in Garvins and Hooksett Pools for the time period 2008-2011 (Normandeau 2011a) and for three coolwater species between Garvins and Hooksett Pools for the time period 2012-2013 (Normandeau 2017a). Of the seven possible comparisons for the 2008-2011 time period, there were no significant differences observed in weight growth relative to a constant increase in length in three cases (2011 chain pickerel, 2009 white sucker, 2009 yellow perch). In three instances (2011 fallfish, 2011 white sucker, 2008 yellow perch), the length-weight curves showed coolwater species in Hooksett Pool grew significantly more rotund (or "fatter") with increasing length than in Garvins Pool. Only yellow perch during 2011 grew significantly more rotund with increasing length in Garvins Pool than was observed in Hooksett Pool. For the 2012-2013 time period, slope differences in the length-weight relations indicated that coolwater Fallfish and Yellow Perch grew significantly less rotund (or "fatter") with increasing length in Hooksett Pool than in Garvins Pool. Conversely, White Sucker grew significantly more rotund in Hooksett Pool than in Garvins Pool. Here, the observations of similar or increased growth among some coolwater species and age groups residing in Hooksett Pool compared to the same species residing in thermally uninfluenced Garvins Pool during years of comparable sampling (2008-2011 and 2012-2013) indicate that there has been no appreciable harm to the BIP in Hooksett Pool (Normandeau 2011a; Normandeau 2017a).

- Where aquatic habitat has been adversely impacted by a thermal discharge, sampling data tend to show lower mean length at age for resident fish species compared to the same species in a thermally uninfluenced area, due to a reduction in growth rates associated with thermal stress. Adequate age data for comparison of mean length at age for individual cohorts between Garvins and Hooksett Pools were collected for three coolwater species (White Sucker, Yellow Perch and Fallfish) and four warmwater species (Bluegill, Pumpkinseed, Largemouth Bass, and Smallmouth Bass) during 2008-2013 (Normandeau 2011a; Normandeau 2017a). Of the 15 available comparisons from the 2008-2013 time period for warmwater species, eleven showed no significant difference for mean length at age for individuals residing in Hooksett and Garvins Pools. Mean length at age was significantly greater in Hooksett Pool than in Garvins Pool for the remaining four comparisons. Of the 18 available comparisons from the 2008-2013 time period for coolwater species, ten showed no significant difference for mean length at age for individuals residing in Hooksett and Garvins Pools, six demonstrated greater mean length at age for individuals in Garvins Pool versus Hooksett Pool and two demonstrated greater mean length at age for individuals in Hooksett Pool versus Garvins Pool. Based on the assumption that warmer water conditions will enhance the growth of warmwater fish and inhibit growth of coolwater fish, these observations are not consistent with the hypothesis that the operation of Merrimack Station has caused appreciable harm to the balanced, indigenous fish population in the Merrimack River.
- Where aquatic habitat has been adversely impacted by a thermal discharge, sampling data typically show a greater total mortality (Z) for a resident fish species compared to the same species in a thermally uninfluenced area, due to increased stress associated with thermal impacts. Here, the mortality levels observed in Hooksett Pool are lower than or equal to those observed in Garvins Pool for five of the seven species examined (Normandeau 2017a). Mortality of the coolwater Fallfish and Yellow Perch was significantly higher in Hooksett Pool than in Garvins Pool, but mortality of the coolwater White Sucker was significantly lower in Hooksett Pool than in Garvins Pool. The increased mortality of Yellow Perch in Hooksett Pool compared to Garvins Pool is directly linked to the mortality of 777 Yellow Perch individuals that were harvested for the biocharacteristics study between 2008-2012 and cannot be conclusively attributed to thermal stress. When this analysis was conducted in 2011 (prior to the 2012 fish collections), the mortality of Yellow Perch was not significantly higher in Hooksett Pool compared to Garvins Pool (Normandeau 2012). No significant differences in mortality of warmwater species (Bluegill, Largemouth Bass, Pumpkinseed, and Smallmouth Bass) were detected between the pools. These observations are not consistent with the hypothesis that the

operation of Merrimack Station has caused appreaciable harm to the balanced, indigenous fish population in the Merrimack River.

- Where aquatic habitat has been adversely impacted by a thermal discharge, sampling data tend to show lower fecundity for resident coolwater fish species compared to the same species in a thermally uninfluenced area, due to thermal stress. Fecundity of Yellow Perch and White Sucker was significantly higher in Hooksett Pool compared to Garvins Pool in 2012 (Normandeau 2017a). The observation of greater fecundity of two sensitive coolwater species in Hooksett Pool is not consistent with the hypothesis that the operation of Merrimack Station has caused appreciable harm to the balanced, indigenous fish population in Hooksett Pool.
- A comparison of external and internal parasites on the same resident species in both Hooksett Pool and Garvins Pool indicates that there has been no appreciable harm to the BIP in Hooksett Pool. Resident fish species in aquatic habitat that has been adversely impacted by a thermal discharge characteristically manifest more frequent infestation of internal and external parasites compared to the same species resident in a thermally uninfluenced area, indicating a reduction in the overall health and conditions of the fish due to thermal impacts. Internal parasites were assessed for two coolwater fish, White Sucker and Yellow Perch and they were equal or in greater abundance in Garvins Pool for both species (Normandeau 2017a). Of the six warmwater species examined, the prevalence of external parasites was greater in Hooksett Pool compared to Garvins Pool for two species, Smallmouth Bass (2012, 2013) and Spottail Shiner (2012). External parasites were equal or in greater abundance in Garvins Pool for Bluegill (2012, 2013), Largemouth Bass (2012, 2013), Pumpkinseed (2012-2013) and Redbreast Sunfish (2013). Of the five coolwater fish species, the prevalence of external parasites was greater in Hooksett Pool for Black Crappie (2012), Fallfish (2012), White Sucker (Spring 2012, 2013) and Yellow Perch (2012). External parasites were equal or greater in Garvins Pool for Fallfish (2013), White Sucker (Fall 2012), and Yellow Perch (2013). Based on the assumption that warmer water conditions will enhance the frequency of parasitic infection of both warmwater and coolwater fish species, the inconsistent results do not provide support for the hypothesis that the operation of Merrimack Station has caused appreciable harm to the balanced, indigenous population in the Merrimack River.

In sum, observations on the 1972-2013 time series of abundance data for both coolwater and warmwater fish in Hooksett Pool demonstrated that there was no significant decrease in abundance observed for *any* of the five coolwater fish species resident in Hooksett Pool (Normandeau 2017). The abundance of one coolwater fish, Black Crappie, has increased significantly in Hooksett Pool since its introduction and first detection during 2004. The lack of significantly decreasing trends for the other native and resident coolwater fish species (Chain Pickerel, Fallfish, White Sucker and Yellow Perch) is not consistent with the hypothesis that Merrimack Station has caused appreciable harm to the balanced, indigenous population. There has been no appreciable harm to the BIP in Hooksett Pool based on increases in warmwater species. As estimated by the same standardized electrofish sampling efforts, there have not been significant increases in abundance for nine of the ten warmwater fish species resident in Hooksett Pool during the 1972-2013 time period. Abundance of the native Pumpkinseed has significantly decreased and abundance of Rock Bass has increased since its introduction and first detection during 1995 sampling. There were no significant differences in the abundance of Rock Bass within Garvins and Hooksett Pools during the period of comparable sampling in those locations (2010-2013) indicating Rock Bass in Hooksett Pool have not increased at a rate greater than that in the thermally uninfluenced Garvins Pool. The lack of a significant increase in the abundance of any warmwater fish species other than Rock Bass during the period of comparable sampling is not consistent with the hypothesis that Merrimack Station's thermal discharge has caused appreciable harm to the BIP in Hooksett Pool (Normandeau 2017a).

Finally, where aquatic habitat has been adversely impacted by a thermal discharge, fish sampling data typically show a reduction in quality of body condition, lower mean length at age, higher total instantaneous mortality rate, decreased reproductive potential and more frequent infestation of parasites when compared to an appropriate BIP. Here a review of biocharacteristics for thirteen fish species resident in both Hooksett Pool and Garvins Pool did not indicate a consistent pattern of impaired health and condition for either warmwater or coolwater individuals residing in Hooksett Pool (Normandeau 2011a; Normandeau 2017a) which is supportive of a finding of "no prior appreciable harm" due to Merrimack Station operations.

2.2.1.2 Adequate Fish Passage as Evidence of No Appreciable Harm

Hooksett Pool is used by both resident and anadromous fish species. For the purposes of assessing the potential impact of Merrimack Station's thermal discharge on the BIP in Hooksett Pool, the entire length of Hooksett Pool should be considered a single water body, because fish residing in the pool are not limited in their ability to move about. The absence of any fish passage structure at Hooksett Dam prevents adult anadromous species from accessing Hooksett Pool unless directly stocked in or above Hooksett Pool. While several species of anadromous fish are occasionally present in Hooksett Pool due to stocking, the pool is not used as spawning or juvenile rearing habitat. With regards to anadromous species, the major role of Hooksett Pool is to serve as a downstream passage route and, once fish passage is installed, an upstream passage route. Concerns related to the interaction of migrating anadromous fish species and Merrimack Station's thermal discharge have been examined. Telemetry studies using Atlantic Salmon smolts (Normandeau 2006) and adult American Shad (Normandeau 1979c) indicated that the thermal plume did not act as a barrier to upstream or downstream migration.

2.2.2 No Appreciable Harm to the Hooksett Pool Phytoplankton, Zooplankton and Meroplankton Communities

Lower Hooksett Pool is a segment of the Merrimack River that is considered a low potential impact area for phytoplankton, (USEPA 1977), because it is in a portion of the Merrimack River continuum where the annual carbon cycle is typically dominated by heterotrophic activities in a detrital food chain (Hynes 1970). Annual studies of the community composition and standing crop of phytoplankton and periphyton overa four-year study period (1975-1978), demonstrated that

- no endangered or threatened species were found,
- no shift towards nuisance species was observed in either the upstream or downstream portions of Hooksett Pool, and
- there were no long-term reductions or increases in autotrophic production of the periphyton or phytoplankton components of the algal community that could be attributed to Merrimack Station's thermal discharge (Normandeau 1979a).
- the same study looked at zooplankton and meroplankton communities and found there was no appreciable harm to these communities because no endangered or threatened species were found and no reduction or adverse change was observed in exhaustive studies performed upstream and downstream of Merrimack Station
- there was minimal entrainment mortality of net zooplankton and meroplankton due to passage through the condenser cooling system and cooling canal of Merrimack Station (Normandeau 1979a), indicating that the heated discharge did not alter the standing crop, relative abundance, natural population fluctuations or free drift of these components of the BIP.

2.2.3 No Appreciable Harm to Hooksett Pool Aquatic Vegetation

Aquatic vascular plants (i.e., "macrophytes") are the primary habitat formers in the impounded freshwater riverine ecosystem found in lower Hooksett Pool. This segment of the Merrimack River is considered a low potential impact area (USEPA 1977) for aquatic macrophytes, because no endangered or threatened species were found, and because within-year comparison of similar habitats upstream and downstream from the cooling canal discharge revealed that Merrimack Station's thermal discharge has generally had no adverse effect on the distribution and abundance of aquatic macrophytes in Hooksett Pool (Normandeau 1979a). Within-year variability among stations sampled from 1970 through 1974 in both the upstream ambient and thermally influenced portions of the study area was lower in magnitude than inter-annual variation at each station, supporting classifying the study area as one of low potential impact for habitat formers.

Trends in the abundance of submerged aquatic vegetation can be linked to changes in nutrient loading associated with impaired water quality in the system prior to the 1972 enactment of the CWA (Normandeau 2011b). Increases in system production due to algal growth have been linked to the addition of sewage to a receiving water (Mackenthun 1965). Semi-quantitative submerged aquatic vegetation data were collected in Hooksett Pool by Normandeau in 2002 and 2010. Looking at presence-absence only, a decline in overall extent of submerged aquatic vegetation in Hooksett Pool is implied between the 1970s data and the 2002 and 2010 data. This apparent decrease in submerged aquatic vegetation is likely attributable to the reduction in nutrients in the Merrimack River. Such improvement has likely resulted in corresponding changes to the river's indigenous aquatic populations.

2.2.4 No Appreciable Harm to Hooksett Pool Shellfish and Macroinvertebrate Communities

Kick net macroinvertebrate sampling was conducted within Garvins Pool and at Monitoring Station N-10 in Hooksett Pool during late 2011 to validate the use of N-10 as a control site for the assessment of potential impacts to the macroinvertebrate community due to Merrimack Station's thermal discharge. Due to the limited mobility of benthic organisms in Hooksett Pool and the presence of ambient water temperatures at Station N-10, its use as such a control site is appropriate. Among the metrics examined for kick net data, no consistent pattern was detected to suggest that a significant difference in the macroinvertebrate communities within Garvins Pool and Hooksett Pool at Station N-10 exists. Kick net sampling provides the best representation of macroinvertebrate species available as a food source to fish residing within shallow water littoral habitats (Flotemersch et al. 2006). Even though the wadeable shore zone only accounts for a small proportion of the entire river channel, it may be the most productive and diverse zone for benthic macroinvertebrates (Wetzel 2001).

Macroinvertebrate sampling was conducted during October 2011 using the same sampling techniques and sampling locations as was performed during 1972. When compared to samples collected during 1972, kick net data collected in 2011 at Monitoring Stations N-10, S-0, S-4 and S-17 showed an increase in EPT richness of 150-300%. Taxa richness increased from 7-10 in 1972 to 21-23 in 2011. The 2011 EPT/chironomid abundance ratio was higher than that recorded during the 1970s, as would be expected from samples collected in a river with improved water quality and habitat tolerable for more pollution sensitive species (Normandeau 2012a). Degraded habitat conditions that might be caused by continued exposure to Merrimack Station's thermal discharge should result in a consistent pattern of reduced diversity and increased abundance of pollution-tolerant species for the Hooksett Pool macroinvertebrate population located downstream of Merrimack Station over time (1970s to present). That hypothesis is not supported by the data collected during 2011.

2.3 §316(A) Summary

USEPA has erroneously rejected PSNH's request for renewal of Merrimack Station's §316(a) variance because it has selected the compromised fish community that survived in the conventional and toxic pollutant-impaired Hooksett Pool of the 1960s as the Hooksett Pool BIP. The current fish community in Hooksett Pool (and Garvins Pool) meets USEPA's definition of "balanced indigenous population," because it is a community characterized by (1) diversity at all trophic levels, (2) the capacity to sustain itself through cyclic seasonal changes, (3) the presence of necessary food chain species, and (4) non-domination by pollution-tolerant species (40 C.F.R. §125.71(c)).

2.3.1 Diversity

Support for diversity at all trophic levels is provided in the numerous reports detailing the ecology of Hooksett Pool over the last four decades. Detailed studies of phytoplankton, zooplankton and meroplankton were last conducted during the late 1970s and no reduction or adverse changes were detected that could be attributed to Merrimack Station's thermal discharge (Normandeau 1979b). Submerged aquatic vegetation species that dominated during the 1970s were still the dominant species during a 2003 survey (Normandeau 2011b). Diversity in the number of macroinvertebrate species as sampled by kick net has increased in Hooksett Pool, and additional metrics indicate that the observed increase is due to an increase in pollution-sensitive species, which require improved water quality to survive (Normandeau 2012a).

Similarly, diversity in the fish community has also been observed in Hooksett Pool. During the 1972-2013 time period, species diversity has increased as indicated by taxa richness and Shannon Diversity Index values (Normandeau 2011a, 2017a). Moreover, when Hooksett Pool fisheries sampling during comparable periods between 2010 and 2013 is compared to sampling in the thermally uninfluenced but otherwise comparable Garvins Pool, taxa richness is similar (22 and 19 fish species, respectively) (Normandeau 2011a; 2017a).

2.3.2 Sustainability Through Cyclic Seasonal Changes

Support for the ability of the Hooksett Pool BIP to sustain itself through cyclic seasonal changes is provided by the intensive age and growth analyses conducted for multiple species of fish in Hooksett and Garvins Pools during 2008-2013. A similar range of ages for each of the Merrimack Station RIS was detected within Hooksett Pool when compared to fish resident to Garvins Pool (Normandeau 2011a, 2017a). Pumpkinseed have decreased in abundance since initial electrofish sampling in 1972, but are still represented by a range of age classes within Hooksett Pool. In the most recent sampling year (2013), Pumpkinseed comprised 13% of all fish collected via electrofishing and was fourth in total catch that year (Normandeau 2017a). In addition, the age data-dependent catch curve analysis conducted for Pumpkinseed showed no significant difference in the total instantaneous mortality rates when compared to an appropriate reference BIP (i.e., in Garvins Pool). A higher mortality for Yellow Perch in Hooksett Pool compared to Garvin's Pool occurred after the 2012/2013 data were included in the long-term trends analysis (Normandeau 2017a). It is important to mention that this dip was observed following the direct mortality of 777 Yellow Perch individuals harvested for the biocharacteristics fisheries studies, of which nearly half were adults. Additionally, fecundity of Yellow Perch and White Sucker, both sensitive coolwater fish species, was *significantly higher* in Hooksett Pool than Garvins Pool in 2012. The observation of greater fecundity of two sensitive, coolwater species in Hooksett Pool is not consistent with the hypothesis that the operation of Merrimack Station has caused appreciable harm to the balanced indigenous population (Normandeau 2017a). In addition, evidence of successful spawning for other resident fish was supported through the entrainment of eggs and larvae during entrainment studies at the Station (Normandeau 2007b).

2.3.3 Presence of Necessary Food Chain Species

Support for the continued presence of necessary food chain species is provided through an examination of recent macroinvertebrate and fisheries data within Hooksett Pool. Benthic macroinvertebrate data collected from littoral areas of Hooksett Pool, where numerous young of year and juvenile fish reside and forage, showed that total abundance, taxonomic richness, EPT richness, and the abundance of EPT taxa to chironomid taxa were all much higher in 2011 compared to 1972. A review of recent fisheries sampling indicates that forage species such as Spottail Shiner, Fallfish, Common Shiner and Golden Shiner are important components of the Hooksett Pool fish community as they were during the 1970s (Normandeau 2011a; 2017a). Abundance of these forage species are comparable to levels observed during sampling conducted during the same years in Garvins Pool.

2.3.4 Non-Domination by Pollution-Tolerant Fish Species

Support for non-domination by pollution-tolerant fish species is provided by a review of historic and recent fisheries sampling. During recent fisheries sampling (2010-2013) a comparable number of pollution tolerant species were detected in Hooksett Pool (ranged from 4 to 6 fish species per year) and Garvins Pool (ranged from 3 to 6 fish species per year). The percent contribution of tolerant fish species was slightly greater to the overall fish community in Hooksett Pool than in Garvins Pool (except in 2013, when it was higher in Garvins Pool). However, that increased contribution can be attributed to the greater relative abundance of Bluegill (a warmwater fish species) and White Sucker (a thermally sensitive coolwater species) in Hooksett Pool. Although Bluegill are considered tolerant to pollution, it should be noted that this species *could not survive* in Hooksett Pool during the 1960's because of the low DO levels present and that two other fish species that were able to survive that severe pollution, Yellow Perch and Pumpkinseed are actually considered intermediate in tolerance to pollution. Any fish species surviving and reproducing in the river during the 1960's should be considered tolerant to pollution, given that the river was in its most polluted state during that time frame. Trends in the overall contribution of tolerant fish species to the Hooksett Pool fish community over the 1972-2013 time period reveal an inconsistent pattern. The percentage of pollution-tolerant species in Hooksett Pool was highest during 1995 and lowest during 1973. It was lowest during 1973 because Pumpkinseed and Yellow Perch are considered intermediate in tolerance to pollution and those two fish species *comprised 71% of all the fish* captured that year. The increased abundance of Bluegill in Hooksett Pool during 1995 and the reduction in Pumpkinseed and Yellow Perch are the principal factors in the elevated percentage of pollution tolerant species in Hooksett Pool observed during that year and subsequent years.

3.0 316(b) Comments

The EPA's "Statement of Substantial New Questions and Possible New Conditions" posed a number of questions about the potential use of wedgewire screens at Merrimack Station, including questions about mortality to aquatic life with the use of this new technology. The following section addresses those questions from the EPA, which are shown in italics below.

- *the extent to which wedgewire screens with different screen slot sizes can prevent mortality to aquatic life from entrainment and/or impingement and satisfy the BTA requirements of CWA § 316(b);*

The entrainment reduction performance of the 3-mm narrow slot wedgewire screens designed by ENERCON for full scale installation at Merrimack Station Units 1 and 2 and tested by Normandeau for 17 consecutive weeks during the predominant entrainment season from 22 May through 3 September 2017 provided an overall entrainment reduction compared to the paired Unit 1 cooling water intake structure control of 89% for all ichthyoplankton taxa and life stages combined (Normandeau 2017b). The entrainment reduction for fish larvae only (i.e., eggs excluded) was 90% (Normandeau 2017b). With regard to impingement mortality reduction benefits of the 3-mm narrow slot wedgewire screens proposed for installation and operation at Merrimack Station Units 1 and 2, the screens are designed with a through screen velocity of 0.4 feet per second or less (ENERCON 2017) and therefore are compliant with the §125.94(c)(2) criterion as the best technology available (BTA) standards for impingement mortality specified by CWA §316(b) when in use.

- *which months (e.g., April 1 through August 31, April 1 through July 31), if any, should wedgewire screens be implemented as the BTA for controlling entrainment; and*

The table below shows percentage and cumulative percentage of total annual entrainment density observed by week and month based on the weekly entrainment densities observed in the sampling study performed at Merrimack Station Unit 1 and Unit 2 from May 2006 through June 2007 (Normandeau 2007):

These data reveal that 96.3% of the annual total entrainment density observed at Merrimack Station Units 1 and 2 combined from studies performed weekly during 2006 and 2007 occurred from 2 April through 29 July, and 100% of the entrainment was observed during the period 1 April through 31 August. This seasonal pattern of weekly entrainment densities was confirmed during the May to September 2017 3-mm wedgewire screen evaluation study at Merrimack Station Unit 1 (Normandeau 2017).

- *And for impingement…*
    - *whether Merrimack Station's impingement mortality should be considered to be de minimis all year, during certain months, or not at all?*

Normandeau performed an analysis of the Merrimack Station Unit 1 and Unit 2 weekly impingement rates from the 2005 through 2007 impingement abundance study (Normandeau 2007), scaled these weekly rates up to the 2011 through 2013 weekly actual intake flows (AIF), and then summed the weekly rates over 52 consecutive weeks to represent the annual impingement rates for 2011 through 2013. These 2011 through 2013 annual impingement rates for Merrimack Station were then compared to annual impingement rates obtained from a data base supplied by EPRI (2011) consisting of results supplied in response to a detailed questionnaire from 166 power generating facilities from throughout the United States with similar once-through cooling systems (Normandeau Attachment 1 to ENERCON October 2014). Based on this comparison of annual impingement rates, Normandeau concluded that annual impingement rate at Merrimack Station (Units 1 and 2 combined) of 0.27% of the national average is *de minimis*.

Week of Year		Month	Percent Of 2006-2007 Annual Entrainment Density Units 1 And 2 Combined	
#	begin		Weekly %	Cumulative %
14	2Apr	Apr	0.4%	0.4%
15	9Apr		0.4%	0.8%
16	16Apr		0.4%	1.2%
17	23Apr		0.4%	1.6%
18	30Apr	May	0.4%	2.0%
19	7May		5.3%	7.3%
20	14May		10.1%	17.4%
21	21May		4.1%	21.5%
22	28May		8.1%	29.6%
23	4Jun	Jun	26.0%	55.6%
24	11Jun		6.1%	61.7%
25	18Jun		6.3%	68.1%
26	25Jun		13.4%	81.5%
27	2Jul	Jul	4.5%	86.0%
28	9Jul		3.5%	89.4%
29	16Jul		2.4%	91.9%
30	23Jul		4.5%	96.3%
31	30Jul	Aug	2.0%	98.4%
32	6Aug		0.8%	99.2%
33	13Aug		0.4%	99.6%
34	20Aug		0.0%	99.6%
35	27Aug		0.4%	100.0%
36	3Sep	Sep	0.0%	100.0%
37	10Sep		0.0%	100.0%

- *if wedgewire screens are used, should PSNH be authorized to "bypass" the screens under certain conditions and, if so, should additional protective measures for impingement be required during those periods?*

The response to this question depends on what time of the year bypass would occur, the duration of the bypass flows, and is largely based on engineering and plant operation considerations identifying the need for bypassing the full scale wedgewire screen arrays. Therefore, ENERCON and Merrimack Station should address this question. However, because the annual impingement rate at Merrimack Station (Units 1 and 2 combined) of 0.27% of the national average is considered *de minimis*, additional seasonal or monthly constraints on CWIS flows that bypass the installed and operated full-scale wedgewire screen array at Merrimack Station Units 1 and 2 are unnecessary.

4.0 References

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish. 2nd edition. EPA 841-B-99-002. US Environmental Protection Agency, Office of Water, Washington, DC.

Becker, G.C. 1983. Fishes of Wisconsin. The University of Wisconsin Press. Madison, Wisconsin.

deBruyn, A. M. H., D. J. Marcogliese, and J. B. Rasmussen. 2003. The Role of Sewage in a Large River Food Web. Canadian Journal of Fisheries and Aquatic Sciences 60: 1332-1344.

Flotemersch, J.E., J.B. Stribling, and M.J. Paul. 2006. Concepts and Approaches for the Bioassessment of Non-wadeable Streams and Rivers. 2nd edition. EPA 600-R-06-127. U.S. Environmental Protection Agency, Cincinnati, Ohio.

Fox, M.G. 1994. Growth, Density, and Interspecific Influences on Pumpkinseed Sunfish Life Histories. Ecology. 75(4), pp. 1157-1171.

Holtan, P. 1990. Yellow Perch (*Perca flavescens*). Wisconsin Department of Natural Resources Bureau of Fisheries Management. PUBL-FM-710 90. February 1990.

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

Mackenthum, K.M. 1965. Nitrogen and phosphorus in water: an annotated selected bibliography of their biological effects. U.S. Department of Health, Education and Welfare.

Normandeau (Normandeau Associates, Inc.) 1969. The Effects of Thermal Releases on the Ecology of the Merrimack River. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 1970. The Effects of Thermal Releases on the Ecology of the Merrimack River - Supplemental Report No. 1. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 1972. Merrimack River Monitoring Program: A Report for the Study Period 1971. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 1973a. Merrimack River Monitoring Program: A Report for the Study Period 1972. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 1973b. Merrimack River: Temperature and Dissolved Oxygen Studies 1972. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 1974. Merrimack River Monitoring Program: A Report for the Study Period 1973. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 1975a. Merrimack River Monitoring Program 1974. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 1975b. Merrimack River Ecological Studies: Impacts Noted to Date; Current Status and Future Goals of Anadromous Fish Restoration Efforts; and Possible Interactions Between Merrimack Station and Anadromous Fishes. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 1976a. Merrimack River Monitoring Program 1975. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 1976b. Merrimack River Anadromous Fisheries Investigations: Annual Report for 1975. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 1976c. Further Assessment of the Effectiveness of an Oil Containment Boom in Confining the Merrimack Generating Station Discharge to the West Bank of the River. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 1977a. Merrimack River Monitoring Program 1976. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 1977b. Final Report: Merrimack River Anadromous Fisheries Investigations 1975-1976. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 1978. Merrimack River Thermal Dilution Study 1978. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 1979a. Merrimack River Monitoring Program 1978. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 1979b. Merrimack River Monitoring Program: Summary Report. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 1979c. Merrimack River Anadromous Fisheries Investigations: 1978. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 1996. Merrimack Station: Thermal Discharge Modeling Study. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 1997. Merrimack Station (Bow) Fisheries Study. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 2006a. Merrimack Station Thermal Discharge Effects on Downstream Salmon Smolt Migration. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 2006b. An Examination of Fish Catch Between Trap Nets with 0.75-in and 2.00-in Mesh Sizes Deployed in Hooksett Pool of the Merrimack River (Bow, NH). Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 2007a. Merrimack Station Fisheries Survey Analysis of 1967 through 2005 Catch and Habitat Data. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 2007b. Entrainment and Impingement Studies Performed at Merrimack Generating Station from June 2005 through June 2007. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 2007c. A Probabilistic Thermal Model of the Merrimack River Downstream of Merrimack Station. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 2009a. Biocharacteristics of Yellow Perch and White Sucker Populations in Hooksett Pool of the Merrimack River. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 2009b. Biological Performance of Intake Screen Alternatives to Reduce Annual Impingement Mortality and Entrainment at Merrimack Station. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 2011a. Merrimack Station Fisheries Survey Analysis of the 1972-2011 Catch Data. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 2011b. Historic Water Quality and Selected Biological Conditions of the Upper Merrimack River, New Hampshire. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 2011c. Changes in the Composition of the Fish Aggregation in Black Rock Pool in the Vicinity of Cromby Generating Station from 1970 to 2007. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 2011d. Quantification of the Physical Habitat within Garvins, Hooksett and Amoskeag Pools of the Merrimack River. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 2012a. Comparison of Benthic Macroinvertebrate Data Collected from the Merrimack River near Merrimack Station. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 2017a. 2012-2013 Data Supplement to the Merrimack Station Fisheries Survey Analysis of the 1972-2011 Catch Data. Prepared for Public Service Company of New Hampshire.

Normandeau (Normandeau Associates, Inc.) 2017b. Evaluation of the Entrainment Reduction Performance of a 3-mm Wedgewire Screen at Merrimack Station. Prepared for Public Service Company of New Hampshire.

Pegg, M.A. and M.A. McClelland. 2004. Spatial and temporal patterns in fish communities along the Illinois River. Ecology of Freshwater Fish. 13: 125-135.

Pegg, M.A., and R. M. Taylor. 2007. Fish species diversity among spatial scales on altered temperate rivers. Journal of Biogeography. 34: 549-558.

PSNH (Public Service of New Hampshire). 2003. Merrimack River Project (Amoskeag, Hooksett and Garvins Falls) FERC No 1893-NH. Application for new license for major project existing dams. Volume 1.

Scarola, J. F. 1987. Freshwater Fishes of New Hampshire. New Hampshire Fish and Game Department.

Smith, V.H., G.D. Tilman, and J.C. Nekola. 1999. Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems. Environmental Pollution 100: 179–196.

Trial, J.G., C.S. Wade, J.G. Stanley, and P.C. Nelson. 1983. Habitat suitability information: fallfish. U.S. Dept. Int., Fish Wildl. Serv. FWS/OBS-82/10.48. 15 pp.

Twomey, K.A., K.L. Williamson, and P.C. Nelson. 1984. Habitat suitability index models and instream flow suitability curves: White sucker. U.S. Fish Wildl. Serv. FWS/OBS-82/10.64 56 p.

USDI (United States Department of the Interior). 1966. Report on Pollution of the Merrimack River and Certain Tributaries, Part II- Stream Studies- Physical, Chemical and Bacteriological. US Department of the Interior, Federal Water Pollution Control Administration. Northeast Region- Merrrimack River Project. Lawrence, Massachusetts.

USEPA (United States Environmental Protection Agency). 1977. Draft interagency 316(a) technical guidance manual for thermal effects sections of nuclear facilities environmental impact statement.

USGS (United States Geological Survey). 2003. Water quality trends in New England rivers during the 20th century. Water Resources Investigations Report 03-4012. National Water Quality Assessment Program. Pembroke, New Hampshire.

Wetzel, R.L. 2001. Limnology: lake and river ecosystems 3rd edition. Academic Press, New York.

Wightman, P.H. 1971. Merrimack River thermal study. New Hampshire Fish and Game Department, Division of Inland and Marine Fisheries. 111pp.

Wolf, Leonard. 1965. Cleaning up the Merrimack. Bulletin of the Atomic Scientist 21:16-22.