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The Northeast Utilities System

Linda T. Landis
Senior Counsel

July 7, 2010

By Overnight Mail

Mr. John Paul King, Environmental Scientist
U.S. Environmental Protection Agency
5 Post Office Square Suite 100 (OEP06-04)
Boston, Massachusetts 02109-3912

Re: Public Service Company of New Hampshire
Merrimack Station
National Pollutant Discharge Elimination System Permit No. NH0001465
Response to Information Request in Support of NPDES Permit Reissuance

Dear Mr. King:

Public Service Company of New Hampshire ("PSNH") herewith responds to the United States Environmental Protection Agency's ("EPA's") request that PSNH provide additional information and clarification of PSNH's initial §308 Response (dated November 2007) regarding Merrimack Station in Bow, New Hampshire. This information is being provided to assist EPA in the renewal of the Station's existing National Pollutant Discharge Elimination System ("NPDES") permit, including renewal of the Station's existing CWA §316(a) variance pursuant to EPA regulations governing such renewals.

As provided in EPA's letter dated February 18, 2010, PSNH has submitted the information in accordance with a three-tiered schedule. This third response provides the information requested by queries 7-10 and 13-15. The information, as with the prior two submittals, has been integrated into the report *(Response to the Environmental Protection Agency's Information Request for NPDES Permit Re-issuance, PSNH Merrimack Station Units 1 & 2, Bow, New Hampshire)* prepared for PSNH by Enercon Services, Inc.

PSNH respectfully reminds EPA that it has submitted both its initial §308 response and its three-part response to EPA's January 2010 supplemental §308 information request for the purpose of providing technology and fisheries information specifically requested by EPA. In particular, PSNH notes that the thermal and biological monitoring data collected in Hooksett Pool and upper Amoskeag Pool since 1967 provide no historical evidence that Merrimack Station's thermal discharge may reasonably be considered to have caused any prior appreciable harm to the balanced indigenous population or community of shellfish, fish and wildlife that reside within, or are migratory through, the Merrimack River in the sphere of influence of the Station's hydrothermal regime. In fact, the strength of the historical evidence assures the continued protection and propagation of the balanced indigenous population. Similarly, the biological data from the Station's monitoring programs indicate that no adverse environmental impact to the aquatic ecosystems of the Merrimack River in the vicinity of the Station has occurred, as measured by any representative important species or critical aquatic organism population, as a result of the Station's existing cooling water intake operation.

This correspondence respectfully reserves PSNH's rights to challenge any aspect of the Permit that EPA ultimately issues for Merrimack Station. Nothing herein is intended to, or should be in any way construed, as waiving PSNH's rights with respect to any pending considerations.

Please do not hesitate to contact me (603-634-2700) or Allan Palmer (603-634-2439) with any questions or concerns you may have regarding this submittal.

Very truly yours,

Linda T. Landis

Linda T. Landis
Senior Counsel

cc: Allan Palmer, PSNH
William H. Smagula, P.E., PSNH
Elise N. Zoli, Esq., Goodwin Procter

#5

RESPONSE TO ENVIRONMENTAL PROTECTION AGENCY'S INFORMATION REQUEST FOR NPDES PERMIT RE-ISSUANCE

PSNH MERRIMACK STATION
UNITS 1 & 2
BOW, NEW HAMPSHIRE

Prepared for
Public Service Company of New Hampshire

Prepared by:

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July 2010

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EXECUTIVE SUMMARY

Public Service Company of New Hampshire's (PSNH's) Merrimack Station electrical generating facility in Bow, New Hampshire is seeking a renewal of its existing National Pollutant Discharge Elimination System permit. To this end, an engineering and biological assessment was prepared by Enercon Services, Inc. and Normandeau Associates, Inc. and submitted by PSNH to the United States Environmental Protection Agency (EPA) in November 2007 that responded to EPA's request for certain technology and fisheries information to support development of the new permit for Merrimack Station.

After review of PSNH's response, EPA submitted a request in January 2010 for information which in some cases explains items in previous EPA requests, and in other cases requests additional information not previously requested to ensure items are presented clearly. EPA determined that PSNH needed to further respond to the items below:

- An estimate of the most stringent thermal discharge limits that Merrimack Station would be able to comply with utilizing the cooling tower technologies in question.
- An estimate of the most stringent cooling water withdrawal flow and thermal load limits that the facility would be able to comply with utilizing the cooling tower technologies in question.

In addition, EPA also requested information regarding certain assumptions and/or calculations that were used as the basis for the information provided in the 2007 Response.

This report individually reviews each information request, provides clarification of the information provided in the 2007 Response, and, where necessary, conducts new analysis to respond to EPA's information request. Updates to previous analysis result in slight differences in estimated levels of compliance; however, the changes in levels of compliance do not alter the conclusions of the 2007 Response.

The analysis shows that effect of thermal discharge from Merrimack Station on Station S4 river water temperature is driven primarily by Merrimack River flow rate. This effect is demonstrated by the estimated thermal performance of a 10-cell or 14-cell thermal discharge tower, where the effect of river flow rate on thermal performance significantly outweighs the effect of four additional cooling tower cells. The operation of a 10-cell thermal discharge tower would achieve nearly complete attainment of the evaluated 5°F Station N10-Station S4 temperature differential throughout the year under typical daily flow rate conditions; however, attainment may not be achieved during periods of very low flow rates occurring from July through November.

This report has been submitted in three phases:

- Response to information requests #1-5 and #11 was provided on February 24th in Sections 2-6 and 12.
- Response to information requests #6 and #12 was provided on March 31st in Sections 7 and 13.
- Response to information requests #7-10 and #13-15 is provided in this submittal on June 24th in Sections 8-11 and 14-16.

This is the final submittal of responses to EPA's January 2010 information request.

1 Background, Introduction, and Scope

1.1 Background and Introduction

Public Service Company of New Hampshire's (PSNH's) Merrimack Station electrical generating facility in Bow, New Hampshire is seeking a renewal of its existing National Pollutant Discharge Elimination System (NPDES) permit. To this end, an engineering and biological assessment was prepared by Enercon Services, Inc. (ENERCON) and Normandeau Associates, Inc. and submitted by PSNH to the United States Environmental Protection Agency (EPA) in November 2007 that responded to EPA's request for certain technology and fisheries information to support development of the new permit for Merrimack Station.

The November 2007 Response to United States Environmental Protection Agency CWA § 308 Letter (2007 Response) reflects the information requested by EPA and contained the following:

- All fisheries data collected during entrainment and impingement sampling conducted from 2005 to 2007.
- A detailed description of Merrimack Station's cooling system.
- Response regarding projected retirement date for Merrimack Station's existing coal-fired operation.
- A description of the processes employed at Merrimack Station with regard to the operation of the boiler, condenser, cooling water intake structure (CWIS), and effluent treatment.
- A description of the engineering analysis involved with converting the Merrimack Station cooling system from the current once-through cooling to the following cooling scenarios:
    - Mechanical draft cooling towers for use in a recirculating (or "closed-cycle") cooling system for both generating units
    - Mechanical draft cooling towers for use in a recirculating (or "closed-cycle") cooling system for one generating unit
    - Mechanical draft cooling towers for use in a "helper tower" or "chiller" configuration that would be used to reduce thermal discharges by Merrimack Station.
- An analysis of alternate CWIS screening systems, including a discussion of the major components and major modifications that would be required to retrofit Merrimack Station with this technology.
- A discussion of the least expensive, most cost-effective means by which Merrimack Station could meet the evaluated scenario whereby the temperature differential between Stations N10 and S4 in the Hooksett Pool is limited to 5°F.

1.2 Scope

After review of PSNH's response, EPA determined that PSNH needed to further respond to the items below:

- An estimate of the most stringent thermal discharge limits that Merrimack Station would be able to comply with utilizing the cooling tower technologies in question.
- An estimate of the most stringent cooling water withdrawal flow and thermal load limits that the facility would be able to comply with utilizing the cooling tower technologies in question.

As a result, EPA submitted a request for information which in some cases explains items in previous EPA requests, and in other cases requests additional information not previously requested to ensure items are presented clearly. In addition, EPA also requested information regarding certain assumptions and/or calculations that were used as the basis for the information provided in the 2007 Response.

EPA's information request was submitted in January 2010 [Ref. 17.2]. This report individually reviews each information request, provides clarification of the information provided in the 2007 Response, and, where necessary, conducts new analysis to respond to EPA's information request.

2 Information Request #1 – Station Heat Load

2.1 Information Request

The EPA letter requests additional information on the Merrimack Station heat loads and the ability of the defined cooling towers to reject those heat loads [Ref. 17.2]:

> *On pages 34 and 35 of PSNH's November 2007 Response, the Company states that the range and gpm is fixed by the heat load, and that it selected cooling towers with a design approach of 8°F because PSNH determined that a cooling tower designed with an 8°F approach provided the optimum trade-off between total capacity and performance, and size, initial cost, and operation costs.*
>
> *Please confirm that the cooling tower design PSNH put forth is capable of removing a heat load of 9,337,930 British thermal units (Btu) per minute for Unit 1, and 26,356,120 Btu/min from Unit 2; and that the total heat load that the cooling towers must eject, at full station power output, is 35,694,050 Btu/min. If PSNH does not agree that the specified heat loads are correct, please provide the heat load, in Btu/min, that PSNH contends must be removed in order to condense the exhaust steam from both Merrimack Station's generating unit turbines at full power.*

2.2 Information Provided in 2007

As noted in EPA's request, the design range and flow rate are listed in the SPX Cooling Technologies (SPX) specifications on page 35 of the 2007 Response. The listed design range and flow rate can be used to calculate EPA's nominal heat loads of 9,337,930 Btu/min for Unit 1, and 26,356,120 Btu/min from Unit 2, and 35,694,050 Btu/min for Units 1 and 2 combined.

2.3 Engineering Response

The heat load rejected by the cooling towers is dependent on several variables, and is affected both by the heat load discharged from Merrimack Station and the ability of the cooling towers to reject the heat load under ambient environmental conditions. Reviewing the heat balance diagrams, the heat discharged by the Station is based on the input/output parameters of several major components, each with their own operating design range. As a result of this operational flexibility, it would be more accurate to state that the Station operates with a heat load discharge range and not with a fixed heat load discharge design point.

Similar to Station discharge heat load, the cooling tower heat load rejection capacity varies as a function of the ambient environmental conditions (i.e., wet-bulb temperature). A cooling tower transfers heat from the cooling water stream to the surrounding atmosphere, and, as such, the capacity of the cooling tower heat transfer increases when there is a large difference between the water being cooled and the air providing the cooling.

As stated in the 2007 Response, SPX, a leading cooling tower manufacture, was consulted to design the optimum tower design approach and tower sizing. In optimizing the cooling tower design, SPX considered cooling towers of varying size and performance to optimize the cooling towers for the ambient environmental conditions and typical Station performance;

however, due to the Station's design, and the relatively high wet-bulb temperatures present in the summer months, the cooling tower configuration selected by SPX as optimum would still result in reduced plant performance under worst-case ambient conditions (i.e., the cooling towers are not capable of rejecting all of the Station's discharge heat load when the temperature difference between the water being cooled and the air providing the cooling is low). As a result, the cooling tower heat rejection capacity, as calculated from the designed information on page 35 of the 2007 Response, does not reflect the heat load discharged by the Station at full power.

To determine the heat load discharged by the Station at full power, Station data measured during July and August of 2003 through 2006 (i.e., the months typically containing the highest electricity production) was reviewed to determine the increase in cooling water temperature due to Station operation. Using Equation 2-1 below, and an intake flow rate of 59,000 gpm for Unit 1 and 140,000 gpm for Unit 2, the heat load discharged by the Station at full power was estimated to be approximately 16,220,000 Btu/min for Unit 1, approximately 33,820,000 Btu/min for Unit 2, and approximately 50,040,000 Btu/min for Units 1 and 2 combined.

$$\text{Heat Load} = \dot{Q} = \dot{m}c_p\left(T_{in} - T_{out}\right) \qquad (2\text{-}1)$$

where,

m = mass flow rate (lbs/min) = flow (gpm) × density (lbs/gal)

c_p = specific heat of water (Btu / °F × lb)

$T_{in} - T_{out}$ = temperature rise across station (°F)

3 Information Request #2 – Maximum Ambient Conditions

3.1 Information Request

The EPA letter requests clarification of the term "maximum ambient conditions" [Ref. 17.2]:

> *On page 34 of its 2007 Response, PSNH states that "Since the 84°F condenser inlet water would only occur at maximum ambient conditions,..."*
>
> *Confirm that by the phrase "maximum ambient conditions," PSNH is referring to the wet bulb inlet temperature of 76°F and that 84°F would represent the maximum temperature of the discharge (blowdown) from Merrimack Station using the closed-cycle cooling tower design provided on page 35 of the Company's 2007 response. If PSNH cannot confirm this, then please explain the meaning of the term "maximum ambient conditions" as used by the Company in the 2007 response, and provide the maximum temperature that the discharge will reach using the cooling tower design provided on page 35 of the Company's 2007 response.*

3.2 Information Provided in 2007

As noted in response to Information Request #1, Section 2, SPX was consulted for the 2007 Response to design the optimum tower design approach and tower sizing. As an input parameter to this design, ENERCON reviewed climatic design information from the 2001 American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) Fundamentals Handbook [Ref. 17.1], and provided the 74°F 0.4% wet-bulb exceedance temperature listed for the nearest meteorological monitoring station (Concord, NH). SPX designed the optimum tower configuration using an inlet wet-bulb temperature of 76°F (74°F plus a 2°F allowance for recirculation[1]) with an 8°F cooling approach and a resulting cooling water discharge temperature of 84°F.

3.3 Engineering Response

The meteorological conditions SPX used to design the optimum tower design are representative of maximum conditions listed by ASHRAE, and are likely to occur at Merrimack Station only 0.4% of the time. Cooling towers are typically designed to an exceedance value of 0.4% or higher to avoid the considerable overdesign necessary to meet infrequent maximum ambient conditions[2]. However, since 0.4% exceedance translates into approximately 35 hours per year, the SPX design conditions do not represent an absolute maximum design point. Additionally, and as noted in response to Information Request #1, Section 2, since the cooling tower configuration selected by SPX would not be capable of

[1] Recirculation occurs when some portion of the saturated air leaving the tower is drawn back into the cooling tower inlets. The potential for recirculation is primarily related to wind force and direction; however, cooling tower design and orientation assist in both reducing and controlling recirculation [Ref. 17.4].

[2] Cooling towers are typically designed to a 2%, 1%, or 0.4% exceedance value, as listed in the ASHRAE Fundamentals Handbook [Ref. 17.1].

rejecting all of the Station's discharge heat load under worst-case ambient conditions, there are times at which the cooling water discharge temperature would be expected to exceed 84°F. Therefore, 84°F does not reflect the maximum cooling water discharge temperature, but instead a cooling water discharge temperature that is expected to be exceeded infrequently (i.e., 0.4 % of the time). The accurate calculation of an absolute maximum discharge temperature would require a final detailed closed-loop cooling design, and the analysis of long-term local meteorological data.

4 Information Request #3 – Closed-Loop Cooling Flowrate

4.1 Information Request

The EPA letter requests clarification on why the closed-loop cooling flowrates differ from the operating discharge flowrates [Ref. 17.2]:

> *On page 18 of PSNH's November 2007 Response, the Company states that "[t]he Station's normal operating mode is to operate both units at or near full power. When both units are operating, the maximum operating discharge flow rate is as follows: Unit 1: 48,000 gpm; Unit 2: 130,000 gpm ... This value is shown on the Merrimack Station Water Distribution Diagram ... and is also reported on the Discharge Monitoring Reports (DMR) under normal CWIS conditions. It is also the value that will be used to size the thermal discharge canal cooling tower requested to be evaluated by the EPA."*
>
> *On page 35 of PSNH's November 2007 Response, it states that "Based on a load/capacity assessment provided by SPX Cooling Technologies, the following tower configuration and size was evaluated to support a closed cycle cooling configuration for the Merrimack Station site: ... Unit 1 Flow = 59,000 gpm ... Unit 2 Flow = 140,000 gpm ..."*
>
> *Please explain why PSNH chose to evaluate cooling towers designed with the higher flows (59,000 gpm versus 48,000 gpm for Unit 1; 140,000 gpm versus 130,000 gpm for Unit 2).*

4.2 Information Provided in 2007

From Section 3.3.2.1 of the 2007 Response:

"The north (Unit 1) CWIS has two circulating water intake pumps. Each circulating water pump has a design intake capacity of 29,500 gpm (42.5 MGD, 65.7 cfs). The two flows join in a common header resulting in a combined design intake capacity for both pumps at Unit 1 of 59,000 gpm (85.0 MGD, 131.5 cfs). The Unit 1 circulating water pumps supply water to the following:

- 1806 gpm (2.6 MGD, 4.0 cfs) is supplied for the Slag Sluice. This value is an average daily flowrate since this flow is an intermittent demand. Slag sluice is typically run 9 hrs/day from mid-March through mid-December. During the winter, the sluice runs continuously to protect the system from freezing. The slag sluice discharges into the Slag Pond and ultimately into the discharge canal.
- 5556 gpm (8.0 MGD, 12.4 cfs) is supplied for De-Icing Recirculation. This system is only used during periods where the temperature is below freezing. In essence, hot water from either the condenser or equipment cooling water heat exchanger is recirculated back into the intake via 6" spray nozzles at the bar racks. Since 5556 gpm of water is being added to the intake, the demand for water from the River is decreased by the same amount.
- The traveling screen wash system draws suction from the discharge of the circulating water pumps. Each traveling screen has a single-pressure spray header

to wash fish and debris off of the traveling screens and then flush them back to the River. The Unit 1 traveling screen spray wash system draws a total of 560 gpm (0.8 MGD, 1.2 cfs).

- Flow also is supplied to equipment cooling.
- The remainder of the flow supplies the condenser.

The fire pump draws water from the Unit 1 screenwell. It has a design intake capacity of 486 gpm (0.7 MGD, 1.1 cfs) and runs intermittently.

The south (Unit 2) CWIS also has two intake pumps, each with a design intake capacity of 70,000 gpm (100.8 MGD, 156 cfs). The two flows are combined in a common header with a combined design intake capacity for both at Unit 2 circulating water pumps of 140,000 gpm (201.6 MGD, 312 cfs). The Unit 2 circulating water pumps supply water to the following:

- 2780 gpm (4.0 MGD, 6.2 cfs) is supplied for Slag Sluice. This flow is a constant demand, which discharges into the Slag Pond and ultimately into the discharge canal.
- 9028 gpm (13.0 MGD, 20.1 cfs) is supplied for De-Icing Recirculation. This system is only used during periods where the temperature is below freezing. In essence, hot water from the condenser or equipment cooling water heat exchanger is recirculated back into the intake via 6" spray nozzles at the bar racks. Since 9028 gpm of water is being added to the intake, the demand for water from the River is decreased by the same amount.
- The Unit 2 traveling screen spray wash system works the same as the Unit 1 system. However, it draws a total of 588 gpm (0.9 MGD, 1.4 cfs).
- Flow also is supplied to equipment cooling.
- The remainder of the flow supplies the condenser."

4.3 Engineering Response

A closed-loop cooling design utilizing the maximum design intake flow for each unit (59,000 gpm at Unit 1 and 140,000 gpm at Unit 2) was determined to be the most appropriate for the evaluation of closed-loop cooling provided in the 2007 Response based on the flow requirements of the plant.

The 2007 Response notes that, when both units are operating, the maximum operating discharge flowrates are 48,000 gpm at Unit 1 and 130,000 gpm at Unit 2. These values are from the Merrimack Station Water Distribution Diagram (Figure D, Attachment 5, 2007 Response) and are also reported on the Discharge Monitoring Reports (DMR) under normal CWIS conditions. However, these maximum operating discharge flowrates are only for the condensers and do not include the flow required for de-icing recirculation, the traveling screen spray wash systems, and other equipment cooling that discharges to the Slag Pond. As noted in the 2007 Response, the De-Icing Recirculation system is only used during periods where the temperature is below freezing. Since the existing circulating water pumps are single-speed pumps, the flow is utilized as additional flow through the condenser, for additional equipment cooling, or additional flow provided to the slag sluice.

In addition, one or more pumps would be required to provide the necessary make-up flow to the cooling towers even after the conversion to closed-loop cooling. The make-up pump(s) would likely require traveling water screens and spray wash systems in addition to de-icing recirculation. Therefore, it is anticipated that the flow requirements, while possibly reduced, would still be necessary even after conversion to closed-loop cooling.

5 Information Request #4 – Cooling Tower Evaporation

5.1 Information Request

The EPA letter requests explanation of the evaporation coefficient, and, in particular, the term "Evaporation Wet Summer" [Ref. 17.2]:

> *On page 40 of PSNH's November 2007 Response, the Company states that "Evaporation $_{Wet\ Summer}$ can be approximated as Water Flow $_{Total}$ x 0.0167"*
>
> *Please define the term "Evaporation $_{Wet\ Summer}$" as used in PSNH's November 2007 Response. Please also provide the corresponding wet bulb temperature(s) during "Evaporation $_{Wet\ Summer}$"*
>
> *Please explain the basis of the 0.0167 multiplying factor. Please also explain why the factor of 0.0008 was not applied separately for each cooling tower, using the different tower flow rates and different tower range values in order to approximate the evaporation rate.*

5.2 Information Provided in 2007

The term "Evaporation $_{Wet\ Summer}$" from the 2007 Response is used to describe the estimated daily water loss from the Merrimack River due to evaporation by the evaluated cooling tower. The evaporation rate was used as the design point for determining the required make-up flow, and as such it was important to use the maximum evaporation rate (i.e., the evaporation rate from wet mode operation during the warmer summer months). The evaporation rate was approximated as 1.67% of the total water flowrate; this rate was estimated based on information provided by SPX for wet mode operation of a hybrid cooling tower at a wet bulb temperature of 77°F. The approximation was used to produce an evaporation rate of 3323 gpm, as calculated on page 54 of the 2007 Response.

5.3 Engineering Response

From SPX's Cooling Tower Fundamentals [Ref. 17.4], if not accurately known, evaporation can be approximated by multiplying total water flowrate in gpm times the cooling range (°F) times 0.0008. As shown on page 35 of the 2007 Response, a cooling range of 19°F was used for Unit 1 and a cooling range of 22.6°F was used for Unit 2. These cooling ranges can be averaged to obtain a combined range of approximately 20.8°F. This combined range is multiplied by 0.0008 to obtain a factor of 0.0167 and is equal to the approximation described above, thereby resulting in an evaporation rate of approximately 3323 gpm.

A separate way to determine the overall evaporation rate for the cooling tower would be to use the factor of 0.0008 listed in the Cooling Tower Fundamentals [Ref. 17.4] applied separately for each cooling tower at the different cooling tower flowrates and cooling range values. The evaporation rate would, therefore, be calculated as shown in Equation 5-1.

$$Flow_{evap} = (59{,}000\ gpm \times 19°F \times 0.0008) + (140{,}000\ gpm \times 22.6°F \times 0.0008) = 3428\ gpm \qquad (5\text{-}1)$$

This method of approximating the evaporation rate would result in slightly increased blowdown and make-up flowrates. Note that more evaporation would require larger make-up flowrates, resulting in larger make-up pumps and reduced effectiveness of closed-loop cooling. As such, the approximation of the evaporation rate used in the 2007 Response would be conservative.

6 Information Request #5 – Closed-Loop Cooling Makeup

6.1 Information Request

The EPA letter requests clarification of the closed-loop cooling makeup flowrates, and in particular the term "wet mode tower operation" [Ref. 17.2]:

> *On page 41 of PSNH's November 2007 Response, the Company states that the "Plant makeup from the River, wet mode tower operation would hence equal Unit 1 M_{wet} = 1232 gpm, and Unit 2 $_{Wet}$ = 2923 gpm.*
>
> *Please explain and/or define the term "wet mode tower operation" as used in PSNH's November 2007 Response. Also, please confirm whether the total value of 4155 gpm represents the maximum value of make-up water necessary.*

6.2 Information Provided in 2007

The term "wet mode tower operation" refers to operation of a hybrid (i.e., plume abated) cooling tower in non-plume abated mode. This operational mode would typically result in higher evaporation rates, which would in-turn result in higher make-up flowrates. It is important to design equipment based on the maximum make-up flowrates required to ensure that the cooling towers would be able to operate under all design conditions.

6.3 Engineering Response

Make-up water requirements are the sum of evaporation, drift, and blowdown from each Unit's closed-loop cooling system. As stated in the response to Information Request #4 (Section 5.3), the evaporation rates presented in the 2007 Response were estimated based on information provided by SPX for wet mode operation of a hybrid cooling tower. Likewise, the drift rate was estimated using information provided for the same hybrid cooling tower; however, since drift rate are based by on the physical geometry of the drift eliminators, one constant drift rate was provided for both hybrid and wet mode operation. The blowdown requirements are a function of evaporation, drift, and the cycles of concentration; whereby, the 2007 Response calculated blowdown at 5 cycles of concentration to account for worst case intake water quality. Using each of these inputs, the expected maximum make-up flowrates were calculated in the 2007 Response, and are provided in Equations 6-1 and 6-2.

$$\text{Make - Up} = \text{Evaporation} + \text{Drift} + \text{Blowdown} \quad (6\text{-}1)$$

$$\text{Blowdown} = \frac{\text{Evaporation - }[(\text{Cycles of Concentraion - 1}) \times \text{Drift}]}{\text{Drift}} \quad (6\text{-}2)$$

Unit 1 Water Flow = 59,000 gpm

Evaporation_{wet} = 0.0167 x 59,000 gpm = 985.3 gpm

Drift = Water Flow x 0.00001 gpm = 0.6 gpm

Blowdown_{wet} = 245.7 gpm

Make-Up_{wet} = 1231.6 gpm

Unit 2 Water Flow = 140,000 gpm

$Evaporation_{wet}$ = 0.0167 x 140,000 gpm = 2338.0 gpm

Drift = Water Flow x 0.00001 gpm = 1.4 gpm

$Blowdown_{wet}$ = 583.1 gpm

$Make\text{-}Up_{wet}$ = 2922.5 gpm

Summing the expected maximum make-up requirements, Merrimack Station would require a make-up flowrate of approximately 4155 gpm. It should be noted that a higher rate of evaporation, drift, or blowdown is possible dependent on the final design of the cooling towers and further investigation in river water quality and absolute maximum ambient wet-bulb temperature; however, any increase to the make-up water flowrates would result in larger make-up pumps and reduced effectiveness of closed-loop cooling. As such, the approximation of make-up flowrates used in the 2007 Response would be conservative.

7 Information Request #6 – Cooling Tower Blowdown (both Units)

7.1 Information Request

The EPA letter requests additional analysis to calculate the monthly thermal discharge from the cooling tower blowdown of both units [Ref. 17.2]:

> *On page 100 of PSNH's November 2007 Response, the Company states that "Complete closed loop conversion, as described in Section 6, would effectively eliminate all thermal discharges to the Merrimack River and is therefore assumed to represent a complete thermal reduction (i.e., river water temperature unaltered by the Station operation)."*
>
> *Please explain how it would be possible to "effectively eliminate all thermal discharges to the Merrimack River" or to achieve "a complete thermal reduction" using wet cooling towers, given that using that technology, the Station will still have a thermal discharge from the towers in the form of cooling tower "blowdown", based on 5 cycles of concentration.*
>
> *Please explain what assumptions or analyses went into the above-referenced statement that a complete thermal reduction could be achieved by converting to closed-loop cooling using wet cooling towers.*
>
> *Please confirm whether it is PSNH's position that a NPDES thermal limit derived from closed cycle cooling for Merrimack Bow would properly be zero (0.0) Btus. Given that any thermal limit would be monitored by determining the temperature difference between the intake water and the temperature of the blowdown (delta T), multiplied by the mass of blowdown, using the standard value heat capacity of water of 1.0 Btu/°F· lb, please explain whether, and how, PSNH concludes that Merrimack Station would be able to comply such an NPDES thermal permit limit.*
>
> *If PSNH determines that the thermal discharge would not actually be completely eliminated through the use of wet cooling towers, then please provide an accurate, estimated monthly thermal discharge (in Btu/month) that would be discharged from Merrimack Station as a result of conversion to closed-loop cooling using wet cooling towers as discussed and evaluated in PSNH's November 2007 Response (sum of daily: blowdown flow rate x 8.33 x (intake temperature - discharge temperature). Please also provide a separate estimated Btu discharge for each month of the year.*

7.2 Information Provided in 2007

The 2007 Response assumed that a determination of the thermal discharge to the Merrimack River from cooling tower blowdown was unnecessary. This assumption was based on the following:

1) The blowdown flow rate from any cooling tower(s) would be extremely limited as compared to the current, once-through operation (i.e., the amount of flow discharged as cooling tower blowdown would make up less than 1% of the current maximum combined discharge flow rate).

2) The blowdown from any cooling tower(s) would be cooled by the cooling tower(s) prior to discharge.

3) The current discharge canal would remove additional residual heat from the cooling tower blowdown.

While no specific determination was made, the overall effect of each of these factors on discharge temperature to the Merrimack River was estimated while preparing the 2007 Response. This initial estimation was based on five years (2002-2006) of meteorological data and river water temperatures used in conjunction with the cooling tower performance (defined by SPX Cooling Technologies) and the current Discharge Canal performance [Ref. 17.3, Section 3.4.3]. The estimate focused on the aggregate discharge temperature from a complete closed-loop conversion, making the assumption that the volume of the discharge canal was adequate to support thermal mixing of warmer blowdown during daylight hours with cooler blowdown during nighttime hours. This, coupled with the assumption that the Discharge Canal would provide the necessary additional cooling, lead to a non-conservative determination that, on average, no thermal discharge would be associated with a complete closed-loop conversion.

7.3 Updated Analysis

In updating the 2007 estimate, the thermal discharge from a complete closed-loop conversion was calculated making the following conservative assumptions,

1) The maximum combined cooling tower blowdown of approximately 830 gpm is assumed constant throughout the year (see Section 6),

2) Thermal discharge is measured directly as the difference between the temperature of make-up water drawn from the Merrimack River at N0 and the temperature discharged from the cooling tower blowdown, and does not account for any potential cooling in the discharge canal or in the river between S0 and S4.

Since cooling tower blowdown is drawn from the cooling tower basin, the temperature of the blowdown is identical to that cooled by the tower for recirculation back to the condenser. Thus, the blowdown thermal analysis uses a cooling tower performance calculation similar to that of the closed-loop cooling performance analysis [Ref. 17.3, Section 6.2.2]. Five years (2002-2006) of meteorological data and river water temperatures were coupled with the cooling tower performance calculation to determine the average and maximum monthly blowdown temperatures, as shown in Table 7-1.

Table 7-1 Cooling Tower Blowdown Temperature Differential

Month	**Closed-Loop Cooling Temperature Differential***	
	Hourly Average (°F)	*Hourly Maximum (°F)*
January	11.6**	22.2**
February	12.1**	20.1**
March	13.7**	24.1**
April	12.1**	24.1**
May	9.8	20.0
June	6.8	13.6
July	3.3	10.6
August	2.9	11.0
September	5.4	14.7
October	8.9	19.3
November	12.7**	26.1**
December	12.7**	22.4**
Annual	9.3**	26.1**

*Calculated using five years (2002-2006) of meteorological data and river water temperatures

**Calculated using a monthly data set where 32°F was used when river water temperatures were not measured

Using Equation 7-1 (as listed in EPA's Information Request) and the monthly average and maximum blowdown temperatures calculated above, the monthly thermal discharges resulting from the blowdown of a complete closed-loop conversion are calculated in Table 7-2.

$$\text{Thermal Discharge} = 828.8 \text{ gpm}\left(T_{\text{make-up}} - T_{blowdown}\right)\left(8.33\frac{\text{lb}}{\text{gpm}}\right)\left(1\frac{\text{Btu}}{^{\circ}\text{F}\times\text{lb}}\right) \quad (7\text{-}1)$$

Table 7-2 Complete Closed-Loop Cooling Thermal Discharge

Month	Closed-Loop Cooling Thermal Discharge*	
	Average (MBtu/Month)	*Maximum (MBtu/Month)*
January	3,584**	6,846**
February	3,367**	5,605**
March	4,238**	7,417**
April	3,604**	7,200**
May	3,024	6,156
June	2,038	4,058
July	1,021	3,260
August	897	3,388
September	1,606	4,389
October	2,745	5,941
November	3,795**	7,784**
December	3,899**	6,910**
Annual	33,811**	94,703**

*Calculated using five years (2002-2006) of meteorological data and river water temperatures
**Calculated using a monthly data set where 32°F was used when river water temperatures were not measured

7.4 Engineering Response

The 2007 Response used non-conservative assumptions to conclude that a determination of the thermal discharge to the Merrimack River from cooling tower blowdown was unnecessary. Using a methodology identical to the closed-loop cooling performance analysis, Table 7-2 was created to list the monthly thermal discharge of a complete closed-loop system at Merrimack Station assuming both an average temperature difference and a maximum temperature difference condition. In summary, an annual average and maximum thermal discharge of approximately 33,860 MBtus and 94,840 MBtus, respectively, would occur under a complete closed-loop conversion. As shown in Table 7-2, on average March is the most impactive month with a total monthly thermal discharge of approximately 4,244 MBtus, while November has the highest maximum with a thermal discharge of 7,795 MBtus.

For comparison, the annual maximum thermal discharge of approximately 94,840 MBtus is less than 0.4% of the combined heat load discharged by the Station at full power[3]. Conservatively assuming that no cooling is provided by the discharge canal or from the river surface between S0 and S4, the annual maximum thermal discharge would increase the river

[3] The combined heat load discharged by the Station at full power is calculated in Section 2 as approximately 50,040,000 Btu/min, or 26,301,024 MBtu/year.

water temperature by approximately 0.01°F at average river flow rate conditions (approximately 4,500 cfs[4]).

[4] Average river flow rate of approximately 4,500 cfs based on 21 years (1984-2004) of Merrimack River flow measurements.

8 Information Request #7 – Historical River Temperature Differential

8.1 Information Request

The EPA letter requests explanation of the methodology used to determine the historical measured attainment of 5°F Station N10 - Station S4 temperature differential [Ref. 17.2]:

> *On page 20 of PSNH's November 2007 Response, the Company states that "Five years (2002-2006) of Merrimack River water temperatures in discrete 15 minute intervals were provided by PSNH ... and the remaining values averaged into 1 hour intervals to be consistent with National Weather Service (NWS) data used in further analysis. The resulting hourly average river water temperatures were then reviewed ... The table below displays the number of hours per month, and the percentage of measured hours per month that the Station achieved the evaluated 5°F Station N10 - Station S4 temperature differential during 2002 - 2006."*
>
> *Please provide:*
>
> > *(a) the equation(s) that were used to develop the table on page 21;*
> >
> > *(b) the inputs for the calculations, including the heat load in Btu/hr, the discharge temperature, the ambient river temperature, the discharge volume, the wet bulb temperature, and any other relevant parameters that were used to determine the Station N10 - Station S4 temperature differential; and*
> >
> > *(c) the actual Station N10 – Station S4 temperature differential that was used to determine the percentages provided in the table.*

8.2 Information Provided in 2007

The table on page 21 of the 2007 Response provides the number of hours per month, and the percentage of measured hours per month that Merrimack Station achieved the evaluated 5°F Station N10 – Station S4 temperature differential during 2002 – 2006. The only inputs for the calculations used to create the table were the recorded river water temperature at Station N10 and Station S4.

8.3 Updated Analysis

In reviewing the 2007 estimate, it was noted that the hours for February 29, 2004 (i.e., leap day) were omitted from the original calculation. Since no measured data was available in February this omission does not impact the measured attainment; however, the annual attainment will be marginally effected by the addition of 24 hours of additional attainment (annual attainment is calculated assuming all non-measured values are within attainment). Table 8-1 provides the updated table incorporating the additional annual attainment hours.

Table 8-1 Updated Historical Measured Attainment of 5°F Station N10 – Station S4 Temperature Differential Scenario

Historical Measured Attainment of 5°F Station N10 - Station S4 Temperature Differential Scenario										
	2002		2003		2004		2005		2006	
Month	*Hrs.*	*Perc.*	*Hrs.*	*Perc.*	*Hrs.*	*Perc.*	*Hrs.*	*Perc.*	*Hrs.*	*Perc.*
January	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]
February	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]
March	24	29.3%	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]	33	97.1%
April	386	53.6%	152	47.1%	251	100.0%	350	57.3%	531	78.8%
May	492	100.0%	439	99.8%	744	100.0%	739	99.3%	740	100.0%
June	397	62.2%	483	67.1%	339	47.1%	664	97.9%	719	100.0%
July	179	24.1%	241	32.5%	148	20.1%	406	55.8%	691	93.1%
August	127	17.1%	321	45.7%	110	14.8%	87	11.7%	312	42.0%
September	233	32.6%	179	24.9%	279	38.8%	85	11.8%	163	22.7%
October	497	67.3%	380	54.3%	154	20.7%	491	70.4%	505	67.9%
November	84	64.1%	279	67.6%	196	52.8%	267	67.4%	593	82.4%
December	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]	N/A[1]	110	31.3%
Measured Attainment[2]	2419	48.3%	2474	52.0%	2221	44.2%	3089	58.1%	4397	71.1%
Annual Attainment[3]	5830	69.3%	6053	72.6%	5655	66.8%	6426	74.3%	6916	79.5%

[1]*N/A values indicates times when Merrimack River data was not recorded due to freezing conditions*
[2]*Measured attainment calculated by dividing the average hours within compliance by the number of hours with recorded data*
[3]*Annual attainment calculated assuming all N/A values are within 5°F temperature differential scenario*

8.4 Engineering Response

In order to develop the table presented on page 21 of the 2007 Response, a Microsoft Excel spreadsheet was used to combine five years (2002 – 2006) of temperature data from Station N10 and Station S4. As discussed in the 2007 Response, the original Merrimack River water temperature data that was provided in discrete 15 minute intervals was reviewed and erroneous temperature data was removed from the raw data set; the remaining values were averaged into 1 hour intervals to be consistent with National Weather Service (NWS) data. The hourly temperature data set is provided in Attachment 2.

A function was written in the Microsoft Excel worksheet to determine if the temperature differential between Stations N10 and S4 was less than 5°F for a given hour. If a temperature value did not exist for both Stations (e.g., a temperature was not recorded or an erroneous value was removed), the hour was not counted. Equation 8-1 shows the Microsoft Excel formula used to determine if the Station achieved the 5°F Station N10 - Station S4 temperature differential:

```
=IF(N10="","",IF(S4="","",IF(S4-N10<5,1,"")))
```
(8-1)

where

N10 = the river temperature at Station N10 in °F

S4 = the river temperature at Station S4 in °F

A pivot table was then used in Microsoft Excel to count the number of hours that achieved the 5°F temperature differential in each month of each year (Hrs.). The resultant values were then inserted into the 'Hrs.' columns of the table on page 20 of the 2007 Response.

The percentage of measured hours per month that the Station achieved the evaluated 5°F Station N10 - Station S4 temperature differential was calculated by dividing the number of hours that achieved the 5°F temperature differential by the number of hours with temperature data collected at each Station.

The measured attainment was calculated by dividing the average hours within attainment by the number of hours with recorded data. As noted in the 2007 Response, river water temperatures are not monitored once the river water temperature approaches freezing and result in N/A temperature values. Therefore, it is not possible to determine hours outside the evaluated temperature differential. In order to provide a bounding annual analysis, the annual attainment was calculated by assuming all N/A values are within 5°F temperature differential scenario.

9 Information Request #8 – Cooling Tower Blowdown (Unit 1)

9.1 Information Request

The EPA letter requests additional analysis to calculate the thermal discharge from the cooling tower blowdown of Unit 1 only [Ref. 17.2]:

> *On page 100 of PSNH's November 2007 Response, the Company states that "... Unit 1's 48,000 gpm of discharge heated by operation of 120 MWe would be recirculated and thus not discharged to the Merrimack River." On page 40 of PSNH's November 2007 Response, the Company calculates that the blowdown for Unit 1 equals 245.7 gpm (using the 59,000 gpm value for Unit 1 flow).*
>
> *Please explain whether and, if so, why PSNH believes that the residual heat contained in the blowdown stream for Unit 1 can be ignored in this evaluation. Also, please confirm whether it is PSNH's position that a NPDES permit limit of zero (Btu's) would be appropriate for a closed-cycle system for Unit 1.*

9.2 Information Provided in 2007

The 2007 Response assumed that a determination of the thermal discharge to the Merrimack River from cooling tower blowdown was unnecessary. As discussed in Section 7, this assumption was based on the substantially decreased flow rate and cooler temperature of cooling tower blowdown in comparison to once-through cooling flow, in conjunction with the non-conservative assumption that the current discharge canal would provide the additional cooling required to remove residual heat from the cooling tower blowdown. Based on this assumption, the thermal discharge associated with conversion of only Unit 1 to closed-loop cooling was calculated by considering only thermal discharge from Unit 2 in once-through operation.

9.3 Updated Analysis

In updating the 2007 estimate, the thermal discharge from Merrimack Station after a conversion of Unit 1 to closed-loop cooling was calculated making the following conservative assumptions:

1) The maximum Unit 1 cooling tower blowdown of approximately 246 gpm is assumed constant throughout the year (see Section 6),

2) The thermal discharge from Unit 1 operating in a closed-loop configuration is measured directly as the difference between the temperature of make-up water drawn from the Merrimack River at N0 and the temperature discharged from the Unit 1 cooling tower blowdown, and does not account for any potential cooling in the discharge canal or in the river between S0 and S4.

Since cooling tower blowdown is drawn from the cooling tower basin, the temperature of the blowdown is identical to that cooled by the tower for recirculation back to the condenser. Thus, the blowdown thermal analysis uses a cooling tower performance calculation similar to that of the closed-loop cooling performance analysis [Ref. 17.3, Section 6.2.2]. Five years (2002-2006) of meteorological data and river water temperatures were coupled with the cooling tower performance calculation to determine the average and maximum monthly Station N10 - Station S4 temperature differential, as shown in Table 7-1. Using Equation 7-1 and the monthly average and maximum temperature differential (Table 7-1), the monthly thermal discharges resulting from the blowdown of a Unit 1 closed-loop conversion are calculated in Table 9-1.

Table 9-1 Unit 1 Closed-Loop Cooling Thermal Discharge

Month	**Unit 1 Closed-Loop Cooling Thermal Discharge***	
	Average (MBtu/Month)	*Maximum (MBtu/Month)*
January	1,063**	2,029**
February	998**	1,661**
March	1,256**	2,199**
April	1,069**	2,134**
May	896	1,825
June	604	1,203
July	303	966
August	266	1,004
September	476	1,301
October	814	1,761
November	1,125**	2,308**
December	1,156**	2,048**
Annual	10,023**	28,075**

*Calculated using five years (2002-2006) of meteorological data and river water temperatures

**Calculated using a monthly data set where 32°F was used when river water temperatures were not measured

It should be noted that the level of conservatism in the thermal discharge calculation increases as the length of time considered is extended, i.e., the highest daily maximum temperature differential is applied to a monthly flowrate, and the highest monthly differential is applied to a yearly flowrate. Lower thermal load discharge would have been calculated if each corresponding hourly maximum differential and hourly flow rate were used and then summed over monthly and yearly periods. However, the more conservative method was used to ensure that reported thermal load discharge could be met.

9.4 Engineering Response

As discussed in Section 7, the 2007 Response used non-conservative assumptions to conclude that a determination of the thermal discharge to the Merrimack River from cooling tower blowdown was unnecessary. Using a methodology identical to the closed-loop cooling performance analysis, Table 9-1 was created to list the monthly thermal discharge of Unit 1 after a conversion to a closed-loop system assuming both an average temperature difference and a maximum temperature difference condition. In summary, an annual average and maximum thermal discharge of approximately 10,036 MBtus and 28,109 MBtus, respectively, would occur after a Unit 1 conversion to closed-loop cooling. As shown in Table 9-1, on average March is the most impactive month with a total monthly thermal discharge of approximately 1,258 MBtus, while November has the highest maximum with a thermal discharge of 2,310 MBtus.

10 Information Request #9 – River Water Temperature Differential (Unit 1)

10.1 Information Request

The EPA letter requests explanation of the methodology used to estimate the percentage of time in attainment of the 5°F Station N10 - Station S4 temperature differential if closed-loop cooling where implemented on Unit 1 only [Ref. 17.2]:

> *On page 100 of PSNH's November 2007 Response, the Company states that "Under this scenario, the ambient river water temperature at Station S0 would be calculated as a function of the electrical output of Unit 2, Station N10 river water temperature, and dry bulb temperature."*
>
> *Please explain how dry bulb temperature was considered in the evaluation presented in the table on page 101.*
>
> *Please also provide:*
>
> *a) the equation(s) that were used to develop the table on page 101;*
>
> *b) the inputs for the calculations, including the heat load, in Btu/hr, the electrical output of Unit 2, the discharge temperature, the discharge volume, the dry bulb temperature, and any other relevant parameters that were used to determine the Station N10 - Station S4 temperature differential; and*
>
> *c) the actual Station N10 - Station S4 temperature differential that was used to determine the percentages provided in the table.*

10.2 Information Provided in 2007

Several sets of data were combined to estimate the thermal discharge from Merrimack Station after a conversion of Unit 1 to closed-loop cooling:

1. Five years (2002-2006) of Merrimack River water temperatures in discrete 15 minutes intervals were provided by PSNH. Temperature sensors are removed from the Merrimack River at near freezing conditions; therefore, the data set does not include temperatures during the winter months of each year. All freezing temperature values in the data set were considered erroneous and removed. A data availability analysis was conducted and is included in Attachment 3, Section 1, of the 2007 Response.
2. Five years (2002-2006) of Concord Municipal Airport (WBAN: 14745) meteorological data in hourly intervals were obtained from the National Climatic Data Center. The Concord Municipal Airport meteorological data recovery rate was calculated and is included in Attachment 3, Section 1, of the 2007 Response.
3. Twenty-one years (1984-2004) of measured daily average Merrimack River flow rates were provided by PSNH.

4. Five years of measured data from thirty-one Station operating parameters (analysis limited to bounding PSNH data provided for July and August 2002-2006) was provided by PNSH.

To calculate the thermal discharge, the river water and meteorological data sets are combined into one common hourly data set. First, since the 5-year river water temperature data was measured in 15-minute intervals, hourly data was created by averaging all non-erroneous data over each hour. The hourly meteorological data was then matched with the coincident hourly water temperature data. Since the 21-year daily river flow rate data is not coincident with the meteorological and river water temperatures, it could not be directly matched to create a common hourly data set; however, in an effort to provide a bounding analysis, the minimum river flow rate for each calendar day was determined and matched with the meteorological and river water temperature for that given day (see Attachment 4 for example). The combined hourly meteorological and river water temperature and flow rate data set is provided in Attachment 2.

Operational data corresponding to Station performance set points is used to determine empirical correlations with Station discharge temperature (e.g., the correlation between power output and discharge temperature). To determine whether or not a particular operational parameter affected Station discharge temperature, each was plotted against coincident S0 temperatures and reviewed to determine if a relationship existed. Due to the recovery percentage variability between each operational parameter this process was not done by calculating an ANOVA / regression table using a statistical software package, but by individually reviewing each operational parameter against its resultant S0 temperature. An example of an operational parameter with a relationship and one without a relationship is provided in Attachment 3.

Through this analysis it was determined that Station discharge temperature (S0 temperature) is strongly correlated with the net power produced by the Station, the river water temperature at N10, and the dry-bulb temperature. Each of these parameters and how they affect Station discharge temperature is described below:

Station Net Power: The net power produced by the Station is associated with both the discharge flow rate and the amount of heat rejected, by the Station to the discharge canal. For example, if Unit 1 is offline but Unit 2 is online the amount of flow and heat added to the discharge canal would be reduced in proportion to the drop in Station net power.

N10 River Water Temperature: The river water temperature at N10 is just upstream of Merrimack Station and is representative of the water temperatures draw in by the Station.

Dry-Bulb Temperature: Several atmospheric factors (e.g., dry-bulb temperature, wet-bulb temperature, relative humidity, solar radiation, etc.) affect the PSM / discharge canal cooling performance. After review of the empirical data, dry-bulb temperature had the strongest relationship with changes in S0 temperature.

To determine the coincident effect each of these parameters had on the discharge temperature, a least squares regression analysis was conducted. The resultant equation (Equation 10-1) is provided below, where temperature is input as °F and power is input as MWe. It should be noted that Equation 10-1 is based on empirical data, and represents a "best fit" estimation of S0 temperature. As with any empirically determined correlation Equation 10-1 is most accurate over the range of frequently occurring conditions, and analysis utilizing outlier conditions will result in decreased accuracy.

$$T_{S0} = 0.125P_{Net} + 0.754T_{N10} + 0.024T_{Dry.Bulb} + 18.953 \quad (10\text{-}1)$$

In a manner similar to that conducted for the evaluation of S0 temperature, ambient environmental parameters were used to determine empirical correlations with river water temperature at S4 (e.g., the correlation between river flow rate and S4 river water temperature). To determine whether or not a particular environmental parameter affected S4 river water temperature, each was plotted against coincident S4 temperatures and reviewed to determine if a relationship existed. Again, due to the recovery percentage variability between each environmental parameter, this process was not done by calculating an ANOVA / regression table using a statistical software package, but by individually reviewing each environmental parameter against its resultant S4 temperature.

Through this analysis, it was determined that S4 river water temperature is both strongly correlated with the ratio between the flow rate drawn in by the Station and the total river flow rate ($F_{Station}/F_{River}$) and well-correlated with the Station discharge temperature, N10 river water temperature, and dry-bulb temperature. Each of these parameters, and how each affect Station discharge temperature, is described below:

$F_{Station}/F_{River}$: The ratio between the intake flow rate drawn into the Station and the river water flow rate is the dominant factor in determining the affect Station discharge temperature has on S4 river water temperature (a lower $F_{Station}/F_{River}$ ratio results in less Station impact on S4 river water temperature).

Station Discharge Temperature: The Station discharge temperature (S0 temperature) is representative of the water heated by the Station that mixes with the overall river water flow rate.

N10 River Water Temperature: The river water temperature at N10 is just upstream of Merrimack Station and is representative of the river water temperature that mixes with Station discharge temperature.

Dry-Bulb Temperature: Several atmospheric factors (e.g., dry-bulb temperature, wet-bulb temperature, relative humidity, solar radiation, etc.) affect in-river cooling/heating. After review of the empirical data, dry-bulb temperature had the strongest relationship with changes in S4 temperature.

Unlike the S0 temperature estimate, where each parameter had a large degree of independence, the S4 estimate incorporates $F_{Station}/F_{River}$ ratio which impacts the degree to which each of the three remaining parameters affects S4 river water temperature. If a least squares regression analysis was conducted on all four parameters, the resulting equation would be dominated by the $F_{Station}/F_{River}$ ratio and only produce accurate results over a narrow band of frequently occurring river flow rates. As a result, the $F_{Station}/F_{River}$ ratio was instead correlated with each of the remaining parameters to determine individual $F_{Station}/F_{River}$ coefficients. Once each $F_{Station}/F_{River}$ coefficient was determined, a least squares regression analysis was conducted on the three modified parameters and the $F_{Station}/F_{River}$ coefficient. The resultant equation (Equation 10-2) is provided below, where temperature is input as °F.

$$T_{S4} = AT_{S0} + BT_{N10} + CT_{Dry.Bulb} + D \tag{10-2}$$

where

$$A = -42.18\left(\frac{F_{Station}}{F_{River}}\right)^3 + 25.10\left(\frac{F_{Station}}{F_{River}}\right)^2 - 2.15\left(\frac{F_{Station}}{F_{River}}\right) + 0.22 \tag{10-3}$$

$$B = 33.85\left(\frac{F_{Station}}{F_{River}}\right)^3 - 22.29\left(\frac{F_{Station}}{F_{River}}\right)^2 - 3.07\left(\frac{F_{Station}}{F_{River}}\right) + 0.67 \tag{10-4}$$

$$C = 2.30\left(\frac{F_{Station}}{F_{River}}\right)^3 + 0.67\left(\frac{F_{Station}}{F_{River}}\right)^2 - 0.70\left(\frac{F_{Station}}{F_{River}}\right) + 0.03 \tag{10-5}$$

$$D = 1225.82\left(\frac{F_{Station}}{F_{River}}\right)^3 - 758.28\left(\frac{F_{Station}}{F_{River}}\right)^2 - 59.40\left(\frac{F_{Station}}{F_{River}}\right) + 2.21 \tag{10-6}$$

It should be noted that Equation 10-2 is based on empirical data, and represents a "best fit" estimation of S4 river water temperature. As with any empirically determined correlation, particularly one reliant on higher order polynomial equations, Equation 10-2 is most accurate over the range of frequently occurring conditions, and analysis utilizing outlier conditions will result in decreased accuracy.

The table provided on page 101, "Merrimack Station Current PSM and Discharge Canal Performance (Unit 1 Closed-Loop - Unit 2 Full Power)", was calculated by inputting the 5-year data set discussed into the S0 and S4 temperature estimates above; however, since the lowest recorded river water flow rate for each day was selected out of the 21-year data set, additional analysis was necessary to ensure accurate results were calculated at high outlier $F_{Station}/F_{River}$ ratios. High outlier $F_{Station}/F_{River}$ ratios were reviewed, and it was identified that the $F_{Station}/F_{River}$ ratio was correlated with N10 river water temperature (e.g., lower $F_{Station}/F_{River}$ ratios occurred when river flow rate was relatively high and N10 temperature was relatively low during the spring runoff). Accounting for this relationship, Equation 10-7 was created by performing a least squares regression analysis on the threshold $F_{Station}/F_{River}$ ratios that constituted high outliers.

$$\left(\frac{F_{Station}}{F_{River}}\right)_{Outlier} = (-2.50\text{E-}6)\left(\frac{F_{Station}}{F_{River}}\right)^3 + (4.84\text{E-}4)\left(\frac{F_{Station}}{F_{River}}\right)^2 - (2.62\text{E-}2)\left(\frac{F_{Station}}{F_{River}}\right) + 0.67 \tag{10-7}$$

To correct for potential inaccuracies encountered from using high outlier $F_{Station}/F_{River}$ ratios, Equation 10-8 was used to calculate the S4 temperature assuming perfect mixing and no in-river cooling/heating were to occur. While it is difficult to estimate S4 temperature from the nominal amount of outlier empirical data measured, Equation 10-8 does reflect the increased N10 and S0 river water temperature mixture expected when the river flow rate is abnormally low.

$$T_{S4} = \frac{F_{Station}}{F_{River}}(T_{N10} + T_{S0}) \tag{10-8}$$

Using the combined hourly 5-year meteorological and river water data set, and the estimations for S0 and S4 described above, the S4 river water temperature after conversion of Unit 1 to closed-loop cooling was calculated and summarized in the table provided on page 101 of the 2007 Response.

10.3 Updated Analysis

The 2007 Response assumed that determination of the thermal discharge to the Merrimack River from cooling tower blowdown was unnecessary, as discussed in Section 9. The percentage of hours in which the 5°F Station N10-Station S4 temperature differential could be attained, as shown in the table on page 101 of the 2007 Response, was calculated under this assumption. Additional thermal discharge from cooling tower blowdown would reduce these attainment percentages. Using empirical data it is difficult to ascertain the effect of cooling tower blowdown, as there is no measured data on which to base the analysis; however, significant measured data does exist over the current range of operating conditions, including those at higher and lower power levels. By comparing the cooling tower blowdown flow rate with the design flow rate of Unit 1, a scaling factor was computed and used to determine a surrogate power factor representative of thermal discharge from the cooling tower blowdown. The updated attainment percentages were then calculated using the estimation process detailed in Section 10.2, but at a marginally higher power factor and flow rate to account for thermal discharge from cooling tower blowdown. The complete set of hourly input data (including the electrical output of Unit 2, the discharge temperature, the discharge volume, and the dry bulb temperature) and calculated values is provided in Attachment 2, and summarized in Table 10-1. It should be noted that the analysis for the 2007 Response utilized an iterative solving process with a moderately coarse level of resolution. To improve accuracy, the process was updated to directly calculate S0 and S4 temperatures.

The updated analysis differs from the 2007 analysis by an average of 32.2 hours per year, resulting in a total change of 0.6% in measured attainment percentage. As such, the change in attainment percentage does not alter the conclusions of the 2007 Response.

Table 10-1 Thermal Discharge Performance: Unit 1 Closed-Loop – Unit 2 Full Power

Month	Percentage of Hours in Compliance with 5°F Temp. Differential Scenario[1]					
	2002	*2003*	*2004*	*2005*	*2006*	*Average*
January	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]
February	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]
March	8.4%	N/A[2]	N/A[2]	N/A[2]	100.0%	35.0%
April	46.2%	14.7%	56.9%	62.8%	80.3%	56.5%
May	16.1%	17.7%	39.7%	19.2%	31.3%	24.7%
June	2.7%	0.0%	0.0%	2.4%	3.3%	1.7%
July	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
August	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
September	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
October	3.9%	1.9%	0.4%	0.1%	1.5%	1.6%
November	6.9%	0.5%	6.2%	3.5%	7.4%	4.7%
December	N/A[2]	N/A[2]	N/A[2]	0.0%	0.0%	0.0%
Measured Compliance[3]	9.7%	3.6%	11.3%	10.0%	14.9%	10.1%
Annual Compliance[4]	45.0%	43.2%	46.3%	41.1%	39.4%	43.0%

[1]*Compliance is calculated under daily minimum measured river flow rate conditions, based on 21 years of recorded daily averages (1984-2004)*

[2]*N/A values indicates times when Merrimack River data was not recorded due to freezing conditions*

[3]*Measured compliance calculated by dividing the average hours within compliance by the number of hours with recorded data*

[4]*Annual compliance calculated assuming all N/A values are within 5°F temperature differential scenario*

10.4 Engineering Response

As discussed in Section 9, the 2007 Response used non-conservative assumptions to conclude that a determination of the thermal discharge to the Merrimack River from cooling tower blowdown was unnecessary. The updated estimate of thermal discharge includes cooling tower blowdown, resulting in slightly decreased percentage of hours in which the 5°F Station N10-Station S4 temperature differential could be attained. As shown in Table 10-1, the greatest percentage of hours in which the 5°F Station N10-Station S4 temperature differential could be attained under this scenario occurs from March through May; however, even in these months there is significant percentage of historical occurrences beyond the evaluated temperature differential. Overall, conversion of Unit 1 to closed-loop operation would not greatly impact the Station's current thermal discharge performance, as concluded in the 2007 Response.

11 Information Request #10 - Cooling Tower Blowdown / River Water Temperature Differential (Unit 2)

11.1 Information Request

The EPA letter both requests additional analysis to calculate the thermal discharge from the cooling tower blowdown on Unit 2 only and requests an explanation of the methodology used to estimate the percentage of time in attainment of the 5°F Station N10 - Station S4 temperature differential if closed-loop cooling were implemented on Unit 2 only [Ref. 17.2]:

> *On page 101 of PSNH's November 2007 Response, the Company states that "... conversion of Unit 2 would remove 130,000 gpm of discharge heated by operation at 350 MWe from the Merrimack River. Likewise, under this scenario, the Station S4 river water temperature would be calculated as a function of the electrical output of Unit 1, Station N10 river water temperature, dry bulb temperature, and river water flow rate." On page 40, PSNH calculates that the Blowdown for Unit 2 equals 583.1 gpm (using the 140,000 gpm value for Unit 2 flow).*
>
> *Please explain whether and, if so, why PSNH believes the residual heat contained in the Unit 2 blowdown stream can be ignored in this evaluation. Also, please confirm whether it is PSNH's position that a NPDES permit limit of zero (Btu's) would be appropriate for Unit 2 with a closed-cycle system utilizing wet cooling towers.*
>
> *Please also explain how dry bulb temperature was considered in the evaluation presented in the table on page 102.*
>
> *In addition, please provide:*
>
> *a) the equation(s) that were used to develop the table on page 102;*
>
> *b) the inputs for the calculations, including the heat load, the electrical output of Unit 1, in Btu/hr, the discharge temperature, the discharge volume, the dry bulb temperature, and any other relevant parameters that were used to determining the Station N10 - Station S4 temperature differential; and*
>
> *c) the actual Station N10 - Station S4 temperature differential that was used to determine the percentages provided in the table.*

11.2 Information Provided in 2007

The 2007 Response provided an estimate of the thermal discharge performance of the Station after conversion of Unit 2 only to closed-loop cooling. The thermal discharge estimate was calculated with the same data and methodology used to estimate thermal discharge after conversion of Unit 1 only to closed-loop cooling. Using a combined hourly 5-year meteorological and river water data set and correlations for S0 and S4, as described in response to Information Request #9, Section 10, the S4 river water temperature after conversion of Unit 2 to closed-loop cooling was calculated and summarized in the table provided on page 102, "Merrimack Station Current PSM and Discharge Canal Performance (Unit 1 Full Power - Unit 2 Closed-Loop)", of the 2007 Response.

The 2007 Response assumed that a determination of the thermal discharge to the Merrimack River from cooling tower blowdown was unnecessary. As discussed in Section 7, this assumption was based on the substantially decreased flow rate and cooler temperature of cooling tower blowdown in comparison to once-through cooling flow, in conjunction with the non-conservative assumption that the current discharge canal would provide the additional cooling required to remove residual heat from the cooling tower blowdown. Based on this assumption, the thermal discharge associated with conversion of only Unit 2 to closed-loop cooling was calculated by considering only thermal discharge from Unit 1 in once-through operation. The Station net power and the flow rate were modified to represent the Unit 2 conversion conditions, while all other parameters in the calculation are identical to the corresponding calculation for the Unit 1 conversion.

11.3 Updated Analysis

In updating the 2007 estimate, the thermal discharge from a closed-loop conversion of Unit 2 was calculated making the following conservative assumptions,

1) The maximum Unit 2 cooling tower blowdown of approximately 583 gpm is assumed constant throughout the year (see Section 6),

2) The thermal discharge from Unit 2 operating in a closed-loop configuration is measured directly as the difference between the temperature of make-up water drawn from the Merrimack River and the temperature discharged from the Unit 2 cooling tower blowdown, and does not account for any potential cooling in the discharge canal or in the river between S0 and S4.

Since cooling tower blowdown is drawn from the cooling tower basin, the temperature of the blowdown is identical to that cooled by the tower for recirculation back to the condenser. Thus, the blowdown thermal analysis uses a cooling tower performance calculation similar to that of the closed-loop cooling performance analysis [Ref. 17.3, Section 6.2.2]. Five years (2002-2006) of meteorological data and river water temperatures were coupled with the cooling tower performance calculation to determine the average and maximum monthly blowdown temperatures, as shown in Table 7-1. Using Equation 7-1 and the monthly average and maximum blowdown temperatures (Table 7-1), the monthly thermal discharges resulting from the blowdown of a Unit 2 closed-loop conversion are calculated in Table 11-1.

Table 11-1 Unit 2 Closed-Loop Cooling Thermal Discharge

Month	Unit 2 Closed-Loop Cooling Thermal Discharge*	
	Average (MBtu/Month)	*Maximum (MBtu/Month)*
January	2,522**	4,816**
February	2,369**	3,943**
March	2,981**	5,218**
April	2,536**	5,065**
May	2,127	4,331
June	1,434	2,855
July	718	2,293
August	631	2,383
September	1,130	3,088
October	1,931	4,180
November	2,670**	5,476**
December	2,743**	4,861**
Annual	23,788**	66,628**

*Calculated using five years (2002-2006) of meteorological data and river water temperatures

**Calculated using a monthly data set where 32°F was used when river water temperatures were not measured

Additional thermal discharge from cooling tower blowdown would reduce the percentage of hours in which the 5°F Station N10-Station S4 temperature differential could be attained under this scenario, as calculated and shown in the table on page 102 of the 2007 Response. As discussed in Section 10.3, a scaling factor was computed and used to determine a surrogate power factor representative of thermal discharge from the Unit 2 cooling tower blowdown. The updated attainment percentages were than calculated using the estimation process detailed in Section 10.2, but at a marginally higher power factor and flow rate to account for thermal discharge from cooling tower blowdown. It should be noted that the analysis for the 2007 Response utilized an iterative solving process with a moderately coarse level of resolution. To improve accuracy, the process was updated to directly calculate S0 and S4 temperatures. The complete set of hourly input data (including the electrical output of Unit 1, the discharge temperature, the discharge volume, and the dry bulb temperature) and calculated values is provided in Attachment 2, and summarized in Table 11-2.

Table 11-2 Thermal Discharge Performance: Unit 1 Full Power – Unit 2 Closed-Loop

Month	Percentage of Hours in Compliance with 5°F Temp. Differential Scenario[1]					
	2002	*2003*	*2004*	*2005*	*2006*	*Average*
January	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]
February	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]
March	100.0%	N/A[2]	N/A[2]	N/A[2]	100.0%	100.0%
April	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
May	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
June	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
July	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
August	95.3%	96.6%	96.5%	95.4%	94.1%	95.6%
September	96.6%	96.7%	96.7%	96.7%	96.7%	96.7%
October	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
November	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
December	N/A[2]	N/A[2]	N/A[2]	100.0%	100.0%	100.0%
Measured Compliance[3]	98.9%	99.0%	99.0%	99.0%	98.9%	99.0%
Annual Compliance[4]	99.3%	99.4%	99.4%	99.3%	99.2%	99.3%

[1]Compliance is calculated under daily minimum measured river flow rate conditions, based on 21 years of recorded daily averages (1984-2004)

[2]N/A values indicates times when Merrimack River data was not recorded due to freezing conditions

[3]Measured compliance calculated by dividing the average hours within compliance by the number of hours with recorded data

[4]Annual compliance calculated assuming all N/A values are within 5°F temperature differential scenario

The updated analysis differs from the 2007 analysis by an average of less than one hour per year, resulting in a negligible total change in measured annual attainment percentage. As such, the change in attainment percentage does not alter the conclusions of the 2007 Response.

It should be noted that the level of conservatism in the thermal discharge calculation increases as the length of time considered is extended, i.e., the highest daily maximum temperature differential is applied to a monthly flowrate, and the highest monthly differential is applied to a yearly flowrate. Lower thermal load discharge would have been calculated if each corresponding hourly maximum differential and hourly flow rate were used and then summed over monthly and yearly periods. However, the more conservative method was used to ensure that reported thermal load discharge could be met.

11.4 Engineering Response

As discussed in Section 7, the 2007 Response used non-conservative assumptions to conclude that a determination of the thermal discharge to the Merrimack River from cooling tower blowdown was unnecessary. Using a methodology identical to the closed-loop cooling performance analysis, Table 11-1 was created to list the monthly thermal discharge of Unit 2 after a conversion to a closed-loop system assuming both an average temperature difference and a maximum temperature difference condition. In summary, an annual average and maximum thermal discharge of approximately 23,784 MBtus and 66,617 MBtus, respectively, would occur after a Unit 2 conversion to closed-loop cooling. As shown in Table 11-1, on average March is the most impactive month with a total monthly thermal discharge of approximately 2,981 MBtus, while November has the highest maximum with a thermal discharge of 5,475 MBtus.

Unlike the thermal performance attributable to Unit 1 closed-loop conversion, conversion of Unit 2 to closed-loop cooling would result in nearly complete attainment of the 5°F Station N10-Station S4 temperature differential. Abnormally high $F_{station}/F_{river}$ ratios occurring in August and September would result in minor occurrences outside this temperature differential; however, these conditions would be unlikely to occur with any frequency. With respect to attaining the 5°F Station N10-Station S4 temperature differential, conversion of Unit 2 to closed-loop operation represents an alternative that would attain similar results as the conversion of both units, as concluded in the 2007 Response.

12 Information Request #11 – Power Spray Module Performance

12.1 Information Request

The EPA letter requests confirmation that PSM performance was included in the results of the Unit 1 only and Unit 2 only analyses [Ref. 17.2]:

> *The heading to the tables on pages 101 and 102 of PSNH's November 2007 Response contain the phrase "Merrimack Station Current PSM and Discharge Canal Performance"*
>
> *Please explain why the tables are labeled this way and confirm whether or not the performance of the Power Spray Module (PSM) is reflected in the results presented in the tables.*

12.2 Engineering Response

The tables on pages 101 and 102 of the 2007 Responses are labeled as "Merrimack Station Current PSM and Discharge Canal Performance" because the tables present a comparative evaluation which includes PSM operation under the current operational scheme. An empirical analysis of the discharge canal temperature data provided by Merrimack Station, which included PSM operation, was conducted and input over five years of meteorological data and river water temperatures. As described in the 2007 Response, this data was compared against 21 years of daily average measured river flowrate values (1984 - 2004).

13 Information Request #12 – Equipment Cooling

13.1 Information Request

The EPA letter requests additional analysis to determine the heat load added by the Station's equipment cooling system, including a listing of equipment and each component's cooling flowrate, cooling flow temperature rise, and the incremental heat load added to the equipment cooling system [Ref. 17.2]:

> *Figure D in Attachment 5 of PSNH's November 2007 Response shows that some Unit 1 and Unit 2 intake water is for equipment cooling, and that that water is ultimately discharged to the cooling canal and out outfall 003 to the River.*
>
> *Please provide the amount of heat, in Btu/hr, that must be transferred to the cooling water from such equipment. Please also list the equipment, the flow rate used to provide cooling for each piece of equipment, and the resulting increase in temperature of the cooling water after it has cooled the equipment.*
>
> *Please also clarify if the heat load from this equipment was considered when PSNH evaluated closed-cycle cooling for entire plant, closed-cycle cooling for Unit 1, closed-cycle cooling for Unit 2, the 10-cell helper tower, and/or the 14-cell helper tower.*

13.2 Updated Analysis

As shown in Drawings MK1-M-186 / -187 / -191 and MK2-M-215 / -216 in Attachment 1, components that are cooled by the equipment cooling flow at each Unit include the following:

<u>Unit 1 Equipment Cooling</u>

- Cyclone Vertex Cooling Jackets
- Air Conditioning and Admin Bldg
- Seal Oil Cooler
- High Pressure Drip Pump
- Hydrogen Coolers
- Turbine Lube Oil Coolers
- Boiler Feed Pumps
- Control Air Compressor
- Forced Draft Fan Bearings
- Gas Recirculation Fan
- Sampling Coils

<u>Unit 2 Equipment Cooling</u>

- Exciter Air Coolers
- H2 Seal Oil Coolers
- Generator Hydrogen Coolers
- Deaerator Pumps
- Start Up B.F. Pump Oil Cooler
- Sample Cooling Coils
- Turbine Lube Oil Coolers
- Coupling Oil Coolers
- Air Compressor
- F.D. Fans
- Gas Recirculation Fans
- Cyclone Door Cooling Jackets

Each piece of equipment rejects heat to a secondary cooling water loop, which in turn rejects heat through the Cooling Water Heat Exchangers to the equipment cooling flow drawn from the River. Cooling flow rates and temperature increases have not historically been recorded at each piece of equipment. Temperature and pressure measurements were recorded at the Cooling Water Heat Exchangers, on the secondary cooling water loop side, at full load conditions on March 26th, 2010. These measurements were used in conjunction with the rated cooling water pump capacity to calculate the heat load rejected by the Cooling Water Heat Exchangers. This calculation provides a complete evaluation of the total equipment cooling heat load because the total heat load is transferred through the Cooling Water Heat Exchangers to the equipment cooling flow drawn from the River. As shown in Attachment 1, the calculated equipment cooling heat loads at Units 1 and 2 are 11,702,854 BTU/hr and 58,629,610 gpm, respectively. These heat loads are equal to less than 3% of the condenser heat loads at each Unit, discussed in response to Information Request #1, Section 2.

The outlet temperature of the equipment cooling flow supplied to the Cooling Water Heat Exchanger is bounded by the hot inlet temperature of the secondary loop cooling water (i.e., the river water side of the Cooling Water Heat Exchanger cannot heat to a temperature above the hot inlet temperature of the secondary loop). The average temperature difference between the hot inlet temperatures of the secondary loop cooling water and the cold inlet temperatures of the equipment cooling flow is 17.9°F at Unit 1 and 22.4°F at Unit 2[5]. Using the calculated Cooling Water Heat Exchangers heat loads and the bounding average ranges, the equipment cooling flow rate can be estimated to be 1310 gpm at Unit 1 and 5235 gpm at Unit 2. These estimated flow rates result in flow velocities typical of heat exchanger supply piping (Unit 1: 3.7 ft/sec; Unit 2: 5.3 ft/sec).

13.3 Engineering Response

As discussed in Sections 6.1 of the 2007 Response, the closed-loop cooling tower configurations were sized to accommodate the maximum design intake flow rate and condenser cooling range of Units 1 and 2, individually and combined. The maximum design intake flow rate includes the equipment cooling flow rate.

As discussed in Sections 10.2 of the 2007 Response, the thermal discharge cooling tower configurations were sized to accommodate the maximum discharge flow rate and condenser outlet temperature of Units 1 and 2, combined. The maximum discharge flow rate includes the equipment cooling flow rate.

A comparison of the flow rates and cooling ranges of the condensers and Cooling Water Heat Exchangers is provided in Table 13-1.

[5] Cooling Water Heat Exchanger average ranges are based on historical operational data taken during July and August of 2003-2006.

Table 13-1 Comparison of Equipment Cooling and Condenser Cooling

Unit	Parameter	Condenser	Cooling Water Heat Exchanger	Comparison
1	Range [°F]	19	17.9	Equipment cooling range is slightly smaller than condenser cooling range
	Discharge Flow Rate [gpm]	48,000	1309	Equipment cooling flow is equal to approximately 2.7% of condenser flow
2	Range [°F]	22.6	22.4	Equipment cooling range is approximately equal to condenser cooling range
	Discharge Flow Rate [gpm]	130,000	5235	Equipment cooling flow is equal to approximately 4.0% of condenser flow

The temperature increases in the equipment cooling flow are less than the temperature increases in the condenser cooling flow; further, due to the relatively low flow rates of the equipment cooling flow compared to the condenser cooling flow, any abnormal differences in temperature increase would not have a significant impact on the cooling tower performance. In summary, the closed-loop and thermal discharge cooling towers were adequately sized to accommodate equipment cooling heat load at the Stations, both individually and combined.

14 Information Request #13 - River Water Temperature Differential (10-cell Cooling Tower)

14.1 Information Request

The EPA letter requests explanation of the methodology used to estimate the percentage of time in attainment of the 5°F Station N10 - Station S4 temperature differential if a 10-cell thermal discharge cooling tower were utilized [Ref. 17.2]:

> *On page 106 of PSNH's November 2007 Response, the Company states that "... analysis of the 10-cell thermal discharge cooling tower utilized Station N10 river water temperature, Station electrical output, and SPX provided cooling tower performance to calculate the Station S0 river water temperature. In turn, the Station S4 river water temperature was calculated as a function of Station S0 river water temperature, Station N10 river water temperature, dry bulb temperature, and river water flow rate."*
>
> *Please provide the equation(s) that were used to develop the table on page 107 of PSNH's November 2007 Response. Please also provide the inputs for the calculations, including the heat load, in Btu/hr, Station electrical output, the discharge temperature (S0), the discharge volume, the dry bulb temperature, the river water flow rate, and any other relevant parameters that were used to determine the Station N10 - Station S4 temperature differential. In addition, please provide the actual Station N10 - Station S4 temperature differential that was used to determine the percentages provided in the table.*

14.2 Information Provided in 2007

Unlike the closed-loop cooling scenarios described in Sections 10 and 11, thermal discharge cooling towers utilize a new active cooling component in series between the condenser discharge and the Station discharge to the river at S0. To account for this new component, for which no empirical data has been measured at the Station, it was necessary to first calculate the condenser discharge temperature, and in turn enter this information into the performance curves provided by SPX Cooling Technologies.

In a manner similar to that conducted for the S0 estimation, condenser discharge temperature was determined by individually reviewing each operational parameter against its resultant condenser discharge temperature. Through this analysis it was determined that condenser discharge temperature is strongly correlated with the net power produced by the Station and river water temperature at N10. Each of these parameters, and how they affect condenser discharge temperature, is described below:

> Station Net Power: The net power produced by the Station is associated with both the discharge flow rate and the amount of heat rejected by the condenser discharge.
>
> N10 River Water Temperature: The river water temperature at N10 is just upstream of Merrimack Station and is representative of the water temperatures drawn in by the Station.

While Station net power is strongly correlated with condenser discharge temperature, it is assumed to be held constant at design conditions throughout this scenario. As a result, it was more effective to restrict the analysis between N10 river water temperature and condenser discharge temperature to design conditions rather than account for the relationship with Station net power.

To determine the coincident effect N10 river water temperature had on condenser discharge temperature, a least squares regression analysis was conducted. The resultant equation (Equation 14-1) is provided below, where temperature is input as °F. It should be noted that Equation 14-1 is based on empirical data, and represents a "best fit" estimation of condenser discharge that is most accurate over the range of frequently occurring conditions.

$$T_{Condsener.Out} = 1.06T_{N10} + 19.68 \quad (14\text{-}1)$$

Calculated condenser output temperature was then matched to coincident wet-bulb temperatures, and the cooled discharge temperature of the cooling tower calculated using the performance curves provided by SPX Cooling Technologies provided in Attachment 1, Section 1 (b) of the 2007 Response. Since the PSMs were not considered to remain in service post installation of a thermal discharge cooling tower, S0 temperature is assumed to be equal to that of the cooling tower discharge.

As noted in the 2007 Response, the thermal discharge analysis is based on the bounding historical daily flow rate measured over the 21-year data set, i.e., each day of the month is considered to be at the lowest historical river flow rate. As a result, the estimated percentage of time in attainment of the 5°F Station N10-Station S4 temperature differential if a 10-cell thermal discharge cooling tower were utilized is conservative, and at typical historical daily flow rates the percentage attainment is expected to be higher.

14.3 Updated Analysis

The analysis for the 2007 Response utilized an iterative solving process with a moderately coarse level of resolution. To improve accuracy, the process was updated to directly calculate S0 and S4 temperatures. The complete set of hourly input data (Station electrical output, the discharge temperature, the discharge volume, the dry bulb temperature, the river water flow rate) and calculated values is provided in Attachment 2. The updated attainment percentages are shown in Table 14-1.

Table 14-1 10-Cell Thermal Discharge Cooling Tower Performance: Unit 1 & 2 Full Power
Daily Minimum Measured River Flow Rate Condition

Month	Percentage of Hours in Compliance with 5°F Temp. Differential Scenario[1]					
	2002	*2003*	*2004*	*2005*	*2006*	*Average*
January	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]
February	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]
March	100.0%	N/A[2]	N/A[2]	N/A[2]	100.0%	100.0%
April	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
May	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
June	80.9%	91.5%	95.8%	79.5%	76.0%	84.8%
July	58.0%	87.5%	61.7%	70.7%	46.2%	64.8%
August	66.9%	35.3%	46.6%	62.9%	54.5%	53.3%
September	22.7%	20.3%	23.4%	27.2%	27.1%	24.1%
October	34.5%	23.9%	31.7%	35.7%	32.5%	31.6%
November	55.7%	62.2%	77.1%	60.7%	61.3%	63.4%
December	N/A[2]	N/A[2]	N/A[2]	100.0%	93.1%	93.4%
Measured Compliance[3]	66.4%	62.0%	64.6%	66.7%	64.1%	64.8%
Annual Compliance[4]	79.6%	77.6%	78.6%	78.2%	74.4%	77.7%

[1]*Compliance is calculated under daily minimum measured river flow rate conditions, based on 21 years of recorded daily averages (1984-2004)*

[2]*N/A values indicates times when Merrimack River data was not recorded due to freezing conditions*

[3]*Measured compliance calculated by dividing the average hours within compliance by the number of hours with recorded data*

[4]*Annual compliance calculated assuming all N/A values are within 5°F temperature differential scenario*

As noted, the analysis for the 2007 Response utilized the bounding historical daily river flow rate to estimate the limiting thermal discharge performance of a 10-cell thermal discharge tower installed at Merrimack Station. The effect any level of thermal discharge has on downstream temperatures is driven primarily by the Merrimack River flow rate, as highlighted by the discussion on S4 river water temperature in Section 10.2. Therefore, the estimated percentage attainment based on minimum flow conditions is conservative and provides an appropriate basis for a thermal discharge permit that does not include provisions for periods of low river flow rate. However, at typical daily flow rates, the percentage attainment would be expected to be higher. The estimated percentage attainment was recalculated using five recent years of coincident meteorological and Merrimack River water conditions (2005-2009), following the processes outlined in Sections 10.2 and 14.2. The resulting estimated percentage attainment at typical historical daily flow rates is shown in Table 14-2. Although the higher percentage attainment could not be guaranteed in periods of low river flow, a NPDES permit that included a provision for low river flow could base typical operating permit conditions on the higher percentage attainment.

The minimum flow rate measured during the five year coincident meteorological and river data set was 761.8 cfs, which was measured on September 8, 2007. Over the larger twenty-six year river data set[6], the measured flow rate is at or below 761.8 cfs only 2.1% of the recorded days.

Table 14-2 10-Cell Thermal Discharge Cooling Tower Performance: Unit 1 & 2 Full Power *Daily Coincident Measured River Flow Rate Condition*

Month	Percentage of Hours in Compliance with 5°F Temp. Differential Scenario					
	2005	*2006*	*2007*	*2008*	*2009*	*Average*
January	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]
February	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]
March	N/A[2]	100.0%	N/A[2]	N/A[2]	N/A[2]	100.0%
April	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
May	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
June	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
July	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
August	100.0%	100.0%	99.3%	100.0%	99.8%	99.8%
September	98.7%	100.0%	97.7%	100.0%	100.0%	99.3%
October	100.0%	100.0%	99.7%	100.0%	100.0%	99.9%
November	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
December	100.0%	100.0%	N/A	N/A	100.0%	100.0%
Measured Compliance[3]	99.8%	100.0%	99.6%	100.0%	100.0%	99.9%
Annual Compliance[4]	99.9%	100.0%	99.7%	100.0%	100.0%	99.9%

[1]*River flow rate conditions based on coincident daily measurements*

[2]*N/A values indicates times when Merrimack River data was not recorded due to freezing conditions*

[3]*Measured compliance calculated by dividing the average hours within compliance by the number of hours with recorded data*

[4]*Annual compliance calculated assuming all N/A values are within 5°F temperature differential scenario*

As shown in Table 14-2, the installation of a 10-cell thermal discharge tower would allow the Station to achieve nearly complete attainment of the evaluated 5°F Station N10-Station S4 temperature differential under typical historical daily flow rate conditions. However, as previously noted, the typical attainment percentages are based on coincident meteorological and Merrimack River conditions and are less conservative than the attainment analysis done utilizing the minimum daily river water flow rates from the 21-year data set (1984-2004). In this manner, the typical attainment percentages represent conditions which may occur in an average year and do not represent limiting condition scenarios (i.e., attainment may not be achieved during periods of low flow rates occurring from July through November, as shown in Table 14-1).

[6] The twenty-one year data set (1984-2004) of measured daily average Merrimack River flow rates was combined with the updated five-year data set (2005-2009) provided by PSNH, for a total of twenty-six years of measured daily Merrimack River flow rates.

14.4 Engineering Response

The implementation of a 10-cell thermal discharge cooling tower would improve thermal discharge performance over the current Station performance utilizing PSMs; however, even with a 10-cell thermal discharge cooling tower in operation, there is a risk of exceeding the evaluated 5°F Station N10-Station S4 temperature differential from July through November during periods of very low flow rates. As noted, the effect any level of thermal discharge has on downstream temperatures is driven primarily by the Merrimack River flow rate; operation of a 10-cell thermal discharge tower would achieve nearly complete attainment of the evaluated 5°F Station N10-Station S4 temperature differential throughout the year under typical daily flow rate conditions.

15 Information Request #14 - River Water Temperature Differential (14-cell Cooling Tower)

15.1 Information Request

The EPA letter requests explanation of the methodology used to estimate the percentage of time in attainment of the 5°F Station N10 - Station S4 temperature differential if a 14-cell thermal discharge cooling tower were utilized [Ref. 17.2]:

> *On page 108 of PSNH's November 2007 Response, the Company presents an assessment of a 14-cell cooling tower and states that the assessment uses a neatly "identical" analysis to that used to calculate the 10-cell cooling tower performance.*
>
> *Please provide the equation(s) that PSNH used to develop the table on page 108. Please also provide the inputs for the calculations, including the heat load, in Btu/hr, the Station electrical output, the discharge temperature (S0), the discharge volume, the dry bulb temperature, the river water flow rate, and any other relevant parameters that were used to determine the Station N10 - Station S4 temperature differential. In addition, please also provide the actual Station N10 - Station S4 temperature differential used to determine the percentages provided in the table.*

15.2 Information Provided in 2007

The thermal discharge estimate for a 14-cell thermal discharge tower is calculated with the same data and methodology utilized in evaluating the 10-cell thermal discharge tower, as described in response to Information Request #13, Section 14. The addition of four cells to the thermal discharge tower decreases the flow rate through each cell, while all other parameters in the calculation are identical to the corresponding calculation for the 10-cell tower. The decreased flow rate through each cell improves the cooling performance of the tower and increases the number of hours in which the 5°F Station N10-Station S4 temperature differential could be attained (as shown in the table on page 108 of the 2007 Response).

15.3 Updated Analysis

The analysis for the 2007 Response utilized an iterative solving process with a moderately coarse level of resolution. To improve accuracy, the process was updated to directly calculate S0 and S4 temperatures. The complete set of hourly input data (Station electrical output, the discharge temperature, the discharge volume, the dry bulb temperature, the river water flow rate) and calculated values is provided in Attachment 2. The updated attainment percentages are shown in Table 15-1.

Table 15-1 14-Cell Thermal Discharge Cooling Tower Performance: Unit 1 & 2 Full Power
Daily Minimum Measured River Flow Rate Condition

Month	Percentage of Hours in Compliance with 5°F Temp. Differential Scenario[1]					
	2002	*2003*	*2004*	*2005*	*2006*	*Average*
January	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]
February	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]
March	100.0%	N/A[2]	N/A[2]	N/A[2]	100.0%	100.0%
April	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
May	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
June	95.2%	98.7%	100.0%	95.7%	94.9%	96.9%
July	91.7%	100.0%	97.4%	98.7%	96.5%	96.9%
August	97.6%	79.7%	93.3%	97.3%	95.8%	92.7%
September	71.7%	65.8%	74.4%	79.8%	74.3%	73.2%
October	68.1%	60.5%	77.0%	67.9%	74.2%	69.6%
November	100.0%	88.8%	98.4%	86.9%	88.1%	90.1%
December	N/A[2]	N/A[2]	N/A[2]	100.0%	97.7%	97.8%
Measured Compliance[3]	89.6%	85.4%	91.8%	90.8%	90.9%	89.8%
Annual Compliance[4]	93.7%	91.4%	95.0%	94.0%	93.5%	93.5%

[1] *Compliance is calculated under daily minimum measured river flow rate conditions, based on 21 years of recorded daily averages (1984-2004)*

[2] *N/A values indicates times when Merrimack River data was not recorded due to freezing conditions*

[3] *Measured compliance calculated by dividing the average hours within compliance by the number of hours with recorded data*

[4] *Annual compliance calculated assuming all N/A values are within 5°F temperature differential scenario*

The analysis for the 2007 Response utilized the bounding historical daily river flow rate to estimate the limiting thermal discharge performance of a 14-cell thermal discharge tower installed at Merrimack Station. The effect any level of thermal discharge has on downstream temperatures is driven primarily by the Merrimack River flow rate, as highlighted by the discussion on S4 river water temperature in Section 10.2. Therefore, the estimated percentage attainment based on minimum flow conditions is conservative and provides an appropriate basis for a thermal discharge permit that does not include provisions for periods of low river flow rate. However, at typical daily flow rates, the percentage attainment would be expected to be higher. The estimated percentage attainment was recalculated using five recent years of coincident environmental and Merrimack River water conditions (2005-2009), following the processes outlined in Sections 10.2 and 14.2,. The resulting estimated typical percentage attainment of a 14-cell thermal discharge tower operating at typical historical daily flow rates is shown in Table 15-2. Although the higher percentage attainment could not be guaranteed in periods of low river flow, a NPDES permit that included a provision for low river flow could base typical operating permit conditions on the higher percentage attainment.

The minimum flow rate measured during the five year coincident meteorological and river data set was 761.8 cfs, which was measured on September 8, 2007. Over the larger twenty-six year river data set, the measured flow rate is at or below 761.8 cfs only 2.1% of the recorded hours.

Table 15-2 14-Cell Thermal Discharge Cooling Tower Performance: Unit 1 & 2 Full Power *Daily Coincident Measured River Flow Rate Condition*

Month	Percentage of Hours in Compliance with 5°F Temp. Differential Scenario					
	2005	*2006*	*2007*	*2008*	*2009*	*Average*
January	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]
February	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]
March	N/A[2]	100.0%	N/A[2]	N/A[2]	N/A[2]	100.0%
April	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
May	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
June	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
July	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
August	100.0%	100.0%	100.0%	100.0%	99.8%	100.0%
September	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%
October	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
November	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
December	100.0%	100.0%	N/A[2]	N/A[2]	100.0%	100.0%
Measured Compliance[3]	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Annual Compliance[4]	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

[1]*River flow rate conditions based on coincident daily measurements*

[2]*N/A values indicates times when Merrimack River data was not recorded due to freezing conditions*

[3]*Measured compliance calculated by dividing the average hours within compliance by the number of hours with recorded data*

[4]*Annual compliance calculated assuming all N/A values are within 5°F temperature differential scenario*

As shown in Table 15-2, the installation of a 14-cell thermal discharge tower would allow the Station to achieve nearly complete attainment of the evaluated 5°F Station N10-Station S4 temperature differential under typical historical daily flow rate conditions. However, as previously noted, the typical attainment percentages are based on coincident meteorological and Merrimack River conditions and are less conservative than the attainment analysis done utilizing the minimum daily river water flow rates from the 21-year data set (1984-2004). In this manner, the typical attainment percentages represent conditions which may occur in an average year and do not represent limiting condition scenarios (i.e., attainment may not be achieved during periods of low flow rates occurring in September and October, as shown in Table 15-1).

15.4 Engineering Response

Minimal improvements in thermal performance would result from adding four additional tower cells to the 10-cell thermal discharge tower; however, some occurrences beyond the evaluated temperature differential in September and October remain during periods of very low flow rates. As noted, the effect any level of thermal discharge has on downstream temperatures is driven primarily by the Merrimack River flow rate. The comparison of typical percentage attainment (provided in Table 14-2 and Table 15-2) to the limiting percentage attainment (provided in Table 14-1 and Table 15-1) shows that the effect of Merrimack River flow rate on S4 temperature significantly outweighs the effect of an additional four cells between the 14-cell and 10-cell thermal discharge tower. Additional tower cells provide diminishing returns, as demonstrated by the minimally improved thermal performance shown in Table 15-2.

16 Information Request #15 – Thermal Discharge Limit / Summary

16.1 Information Request

The EPA letter requests a monthly summary of the heat load discharged by Merrimack Station under each cooling tower configuration, including volume and temperature of the intake flow, volume and temperature of the effluent discharge, and an estimate of the lowest thermal discharge limit attainable by each cooling tower option [Ref. 17.2]:

> *EPA's July 3, 2007, letter to PSNH requesting information pursuant to CWA § 308 directed PSNH to analyze the following cooling tower scenarios: (1) mechanical draft wet cooling towers for use in a recirculating (or "closed-cycle") cooling system for both generating units at Merrimack Station, (2) mechanical draft wet cooling towers for use in a recirculating (or "closed-cycle") cooling system for only one of the Station's generating units (with Units 1 and 2 both separately analyzed), or mechanical draft wet cooling towers for use in a "helper tower" configuration that would not result in a recirculating (or "closed-cycle") cooling system but would reduce thermal discharges. With regard to each of these technological options or scenarios, please provide the following information:*
>
> *a. An estimate of the lowest thermal load discharge attainable by Merrimack Station utilizing the technology in question. Stated differently, please identify the most stringent thermal discharge limits that could be met using each technological option. The thermal load limits should be expressed in terms of Btu/day, Btu/month, and Btu/year.*
>
> *b. An estimate of the volume of water (in gallons per day) that would need to be withdrawn from the Merrimack River for cooling when utilizing each of the technological options.*
>
> *c. An estimate of the volume of effluent discharge flow (in gallons per day) when utilizing each of the technological options.*
>
> *d. An estimate of the cooling water flow, cooling tower water inlet temperatures and cooling tower water outlet temperatures associated with each technological option.*
>
> *e. The information requested in (a) through (d) above shall be calculated for each calendar month, and all ambient environmental conditions assumed for these calculations shall be clearly stated and explained.*

16.2 Information Provided in 2007

The 2007 Response evaluates the thermal discharge performance of Merrimack Station after a closed-loop conversion of both units, a closed-loop conversion of each unit individually, or the addition of 10-cell or 14-cell thermal discharge cooling towers (i.e., a "helper tower"). As discussed in response to Information Request #3, Section 4, the cooling water flow under each of these scenarios would be constant: the maximum condenser flowrates are 48,000 gpm at Unit 1 and 130,000 gpm at Unit 2.

16.3 Updated Analysis

Updated thermal discharge analyses of each cooling tower scenario are described in response to several information requests in the preceding sections. The updated analyses presented in response to Information Requests #6 and #8-10, Sections 7 and 9-11, were used to provide an estimate of the lowest thermal load discharge attainable by Merrimack Station after a conversion of one or both units to closed-loop cooling, as shown in Table 16-1. The updated analyses presented in response to Information Requests #13 and #14, Sections 14 and 15, were used to provide an estimate of the lowest thermal load discharge attainable by Merrimack Station after the addition of a 10-cell or 14-cell thermal discharge tower, as shown in Table 16-2. As discussed in response to Information Request #9, Section 10, the thermal analyses are based on empirical correlations, which are most accurate over the range of frequently occurring conditions and analysis utilizing outlier conditions will result in decrease accuracy.

To calculate the thermal load discharge at Merrimack Station under each cooling tower scenario, the maximum Station N10 - Station S4 temperature differential was determined on a daily, monthly, and yearly basis. The maximum temperature differentials estimated for each scenario were then multiplied by the corresponding daily, monthly, and yearly flow rates. It should be noted that the level of conservatism in the thermal discharge calculation increases as the length of time considered is extended, i.e., the highest hourly maximum temperature differential is applied to a daily flow rate, the highest daily maximum differential is applied to a monthly flowrate, and the highest monthly differential is applied to a yearly flowrate. Lower thermal load discharge would have been calculated if each corresponding hourly maximum differential and hourly flow rate were used and then summed over daily, monthly, and yearly periods. However, the more conservative method was used to ensure that reported thermal load discharge could be met. In addition, the added conservatism provides some margin to accommodate any error resulting from calculations using outlier conditions, as discussed above.

Cooling tower performance is estimated using ambient wet bulb temperature, cooling water flow rate, and cooling tower inlet temperature (as discussed in Section 14.2). The thermal performance of a once-through system utilizing the discharge cooling canal is estimated using ambient dry bulb temperature, condenser inlet temperature and Station power output (as discussed in Section 10.2). Since there is no direct correlation between, and significant variability within, the defining parameters of a given day, the most conservative approach was taken (i.e., the minimum river flow rates and maximum temperature differentials were used) to determine minimum thermal discharge from the Station.

The combined meteorological and river data set, described in response to Information Request #9, Section 10, was used in the updated thermal analyses. The data set and the calculated discharge temperatures used to determine thermal load discharge are provided in Attachment 2.

Table 16-1 Estimated Thermal Discharge after Conversion to Closed-Loop Cooling*

Month	Unit 1 & 2 Closed-Loop		Unit 1 Closed-Loop, Unit 2 Once-Through		Unit 1 Once-Through, Unit 2 Closed-Loop	
	(MBtu/day)	*(MBtu/month)*	*(MBtu/day)*	*(MBtu/month)*	*(MBtu/day)*	*(MBtu/month)*
January	N/A†	N/A†	N/A†	N/A†	N/A†	N/A†
February	N/A†	N/A†	N/A†	N/A†	N/A†	N/A†
March	176	5,443	8,496	263,378	7,034	218,066
April	222	6,645	8,806	264,176	7,670	230,097
May	199	6,156	9,404	291,527	6,117	189,621
June	135	4,058	22,108	663,242	6,896	206,875
July	105	3,260	16,580	513,994	6,340	196,541
August	109	3,388	29,021	899,639	10,809	335,082
September	146	4,389	30,404	912,124	11,884	356,505
October	192	5,941	18,523	574,218	7,155	221,794
November	205	6,155	11,765	352,964	7,623	228,698
December	188	5,839	9,723	301,403	7,421	230,058
Annual *(MBtu/year)*	80,848		11,097,509		4,337,479	

* *Estimated thermal discharge is conservatively calculated using the maximum temperature differential in a daily, monthly, and annual period*

† *N/A values indicates times when Merrimack River data was not recorded due to freezing conditions*

Table 16-2 Estimated Thermal Discharge after Addition of Thermal Discharge Tower*

Month	10-Cell Thermal Discharge Tower		14- Cell Thermal Discharge Tower	
	(MBtu/day)	*(MBtu/month)*	*(MBtu/day)*	*(MBtu/month)*
January	N/A†	N/A†	N/A†	N/A†
February	N/A†	N/A†	N/A†	N/A†
March	9,522	295,172	9,037	280,151
April	9,444	283,305	9,195	275,843
May	9,231	286,156	8,882	275,348
June	27,037	811,097	21,286	638,578
July	18,938	587,076	14,946	463,321
August	26,590	824,286	20,640	639,855
September	28,453	853,575	23,600	707,991
October	25,363	786,264	22,117	685,614
November	16,487	494,600	15,769	473,066
December	12,315	381,757	11,181	346,616
Annual *(MBtu/year)*	10,385,166		8,613,885	

* *Estimated thermal discharge is conservatively calculated using the maximum temperature differential in a daily, monthly, and annual period*

† *N/A values indicates times when Merrimack River data was not recorded due to freezing conditions*

The volume of water that would be withdrawn from and discharged to the Merrimack River under each cooling tower scenario is described in response to Information Requests #5 and #13-14, Sections 6 and 14-15, and shown in Table 16-3.

The condenser cooling water flow required for each cooling tower scenario was provided in the 2007 Response, as discussed in Section 16.2. The calculated hourly cooling tower water inlet temperatures and cooling tower water outlet temperatures are provided in Attachment 2, with the combined meteorological and river data set. The monthly average cooling tower water inlet and outlet temperatures are shown in Table 16-4.

Table 16-3 Estimated Merrimack River Water Intake and Discharge

Station Configuration		Intake Flow			Discharge Flow		
		Cooling Tower Makeup [MGD]	*Once-Through Flow [MGD]*	Combined Total [MGD]	*Cooling Tower Blowdown [MGD]*	*Once-Through Flow [MGD]*	Combined Total [MGD]
Unit 1 & 2 Once-Through	*U1*		*69.12*	256.32		*69.12*	256.32
	U2		*187.20*			*187.20*	
Unit 1 & 2 Closed-Loop	*U1*	*1.77*		5.98	*0.35*		1.19
	U2	*4.21*			*0.84*		
Unit 1 Closed-Loop Unit 2 Once-Through	*U1*	*1.77*		188.97	*0.35*		187.55
	U2		*187.20*			*187.20*	
Unit 1 Once-Through Unit 2 Closed-Loop	*U1*		*69.12*	73.33		*69.12*	69.96
	U2	*4.21*			*0.84*		
10-Cell Thermal Discharge Tower	*U1*		*69.12*	256.32		*69.12*	256.32
	U2		*187.20*			*187.20*	
14-Cell Thermal Discharge Tower	*U1*		*69.12*	256.32		*69.12*	256.32
	U2		*187.20*			*187.20*	

Table 16-4 Estimated Cooling Tower Inlet and Outlet Temperatures

Month	Unit 1 & 2 Closed-Loop		10-Cell Discharge Tower		14-Cell Discharge Tower	
	Inlet (°F)	Outlet (°F)	Inlet (°F)	Outlet (°F)	Inlet (°F)	Outlet (°F)
January	N/A†	N/A†	N/A†	N/A†	N/A†	N/A†
February	N/A†	N/A†	N/A†	N/A†	N/A†	N/A†
March	62.9	54.3	62.9	56.3	62.9	54.3
April	69.0	58.0	69.0	60.5	69.0	58.0
May	77.9	64.9	77.9	67.9	77.9	64.9
June	90.7	74.0	90.7	77.5	90.7	74.0
July	99.8	79.0	99.8	83.2	99.8	79.0
August	99.6	78.5	99.6	82.7	99.6	78.5
September	91.6	73.4	91.6	77.3	91.6	73.4
October	76.7	62.8	76.7	66.0	76.7	62.8
November	66.4	55.4	66.4	58.0	66.4	55.4
December	61.7	51.3	61.7	53.7	61.7	51.3

† *N/A values indicates times when Merrimack River data was not recorded due to freezing conditions*

17 References

17.1 American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE). ASHRAE Fundamentals. 2001 Edition.

17.2 Stephen S. Perkins, Office of Ecosystem Protect, Environmental Protection Agency. Letter to William H. Smagula, Public Service of Hew Hampshire, Information Request for NPDES Permit Re-issuance NPDES Permit No: NH0001465. January 2010.

17.3 Public Service of New Hampshire, Enercon Services, Inc, and Normandeau Associates. Response to the United States Environmental Protection Agency CWA § 308 Letter, PSNH Merrimack Station Units #1 and #2, Bow, New Hampshire. November 2007.

17.4 SPX Cooling Technologies. Cooling Tower Fundamentals. Second Edition. 2006.