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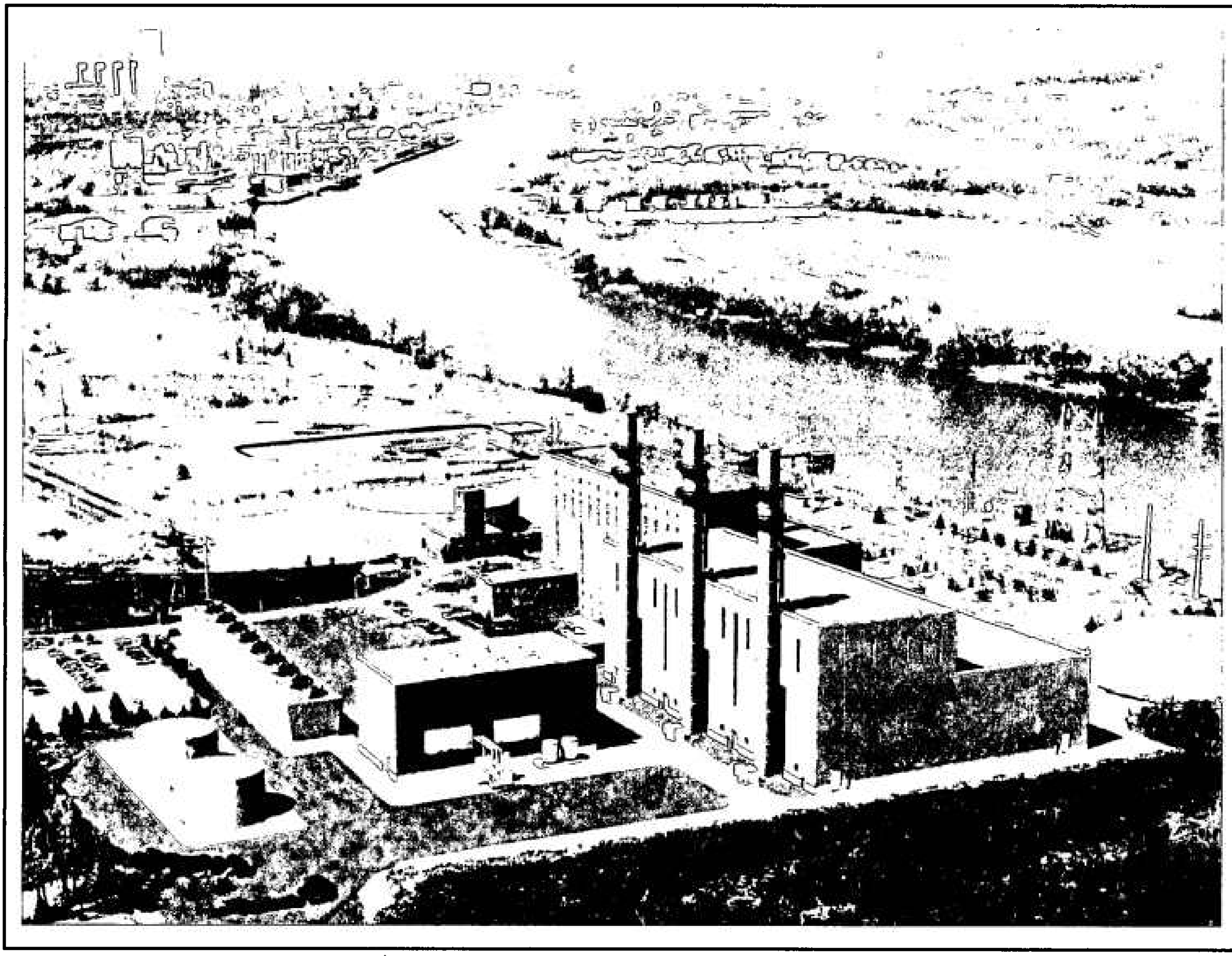


PSEG POWER NEW YORK INC.'S

Bethlehem Energy Center

Glenmont, New York

Supplement to Application for Certification of a Major Electric Generating Facility

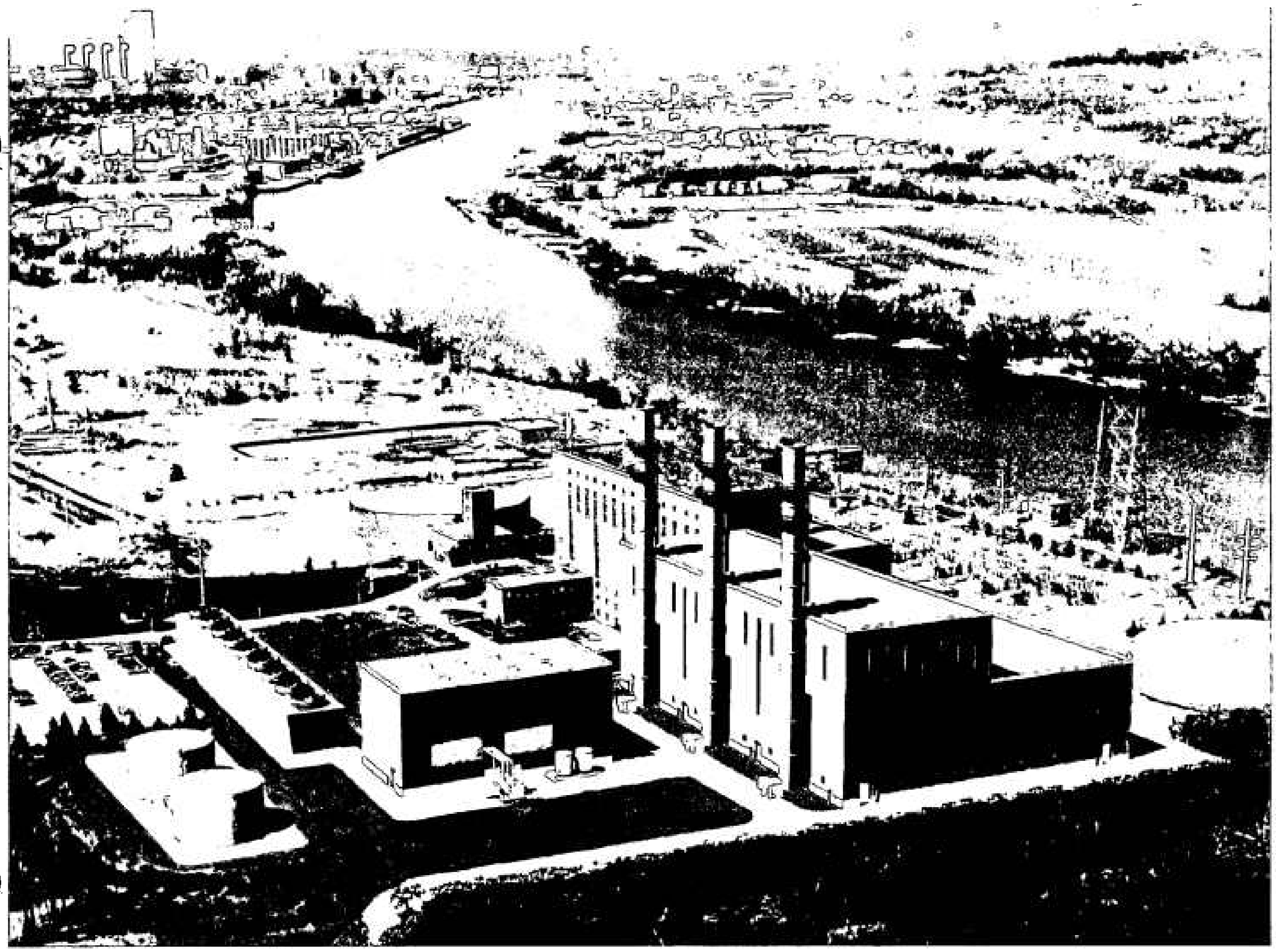
Under Article X of the
New York State Public Service Law
Case 97-F-2162

Volume 8 of 9
Appendix M.2

PSEG
Power New York Inc.

June, 2001

ENSR INTERNATIONAL



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ENSR INTERNATIONAL

ADDENDUM A.10
Alternative Cooling Systems Study

PSEG POWER NEW YORK INC.'S
Bethlehem Energy Center
SPDES Modification
DEC Number 4-0122-00044-00005

GLENMONT, NEW YORK 12077

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1.0 EXECUTIVE SUMMARY

1.1 Overview

This study presents a comprehensive analysis of cooling system alternatives applicable to the Bethlehem Energy Center (BEC), a 750-megawatt (MW), combined cycle power plant PSEG Power New York Inc. (PSEGNY) proposes to build at the site of the existing 400 MW Albany Steam Generating Station (ASGS or the Station) located on the western shore of the Hudson River in Bethlehem, NY. The retirement of the existing Station and replacement with BEC will result in significant air and water environmental improvements. The wet tower closed-loop cooling system proposed by PSEGNY will withdraw 98-99% less water than ASGS, which will greatly reduce the entrainment and impingement of aquatic organisms. The BEC provides a unique opportunity to retire an existing generation plant and redevelop the site with a state of the art facility that is needed to provide clean, efficient, reliable new generation for New York while significantly reducing environmental impacts. The BEC will:

- Provide 350 MW more electrical capacity while using less fuel.
- Provide significant environmental benefits that include a 97 - 98% reduction in emission rates of nitrogen oxides (NOx) and sulfur dioxide (SO_2).
- Dramatically reduce use of Hudson River water (by 98-99%) for cooling with consequent environmental improvements in terms of reduced effects on aquatic organisms.

This study assesses the quantitative and qualitative attributes of the proposed wet tower closed-loop cooling system to determine if any alternative provides additional protection of aquatic resources without creating significant undesirable effects or being wholly disproportionate in cost.

This Study concludes that the proposed cooling water intake structure satisfies best technology available (BTA) as applied in New York by the New York State Department of Environmental Conservation (NYSDEC). New York's view of how BTA determinations are made was set forth in recent decisions. For purposes of discussion, the following represents our understanding of New York's approach to these matters.

The federal Clean Water Act (CWA), as implemented by New York State regulations, requires that the location, design, construction and capacity of cooling water intake structures reflect BTA for minimizing adverse environmental impact. New York regulators have noted that court decisions have established that the determination of what constitutes BTA is a site specific issue of fact which depends upon a variety of factors including the cost and age of the facility, impacts to aquatic populations, the additional energy, if any, needed to support improved technology, and other relevant concepts. Accordingly, New York regulators impose conditions on a "case by case basis", consistent with the CWA.

The conclusion that the proposed wet tower cooling system meets the BTA test is supported by the specific location, design, construction and capacity of the proposed cooling water intake structure. In addition, this study documents the significant environmental improvements, in relation to economic costs, that would accrue from the proposed wet tower cooling system.

Concerning the location of cooling water intake structures, the 1976 EPA Development Document states that this factor can be the most important consideration. It recommends drawing water from main channels of large streams or from biologically deficient areas and avoiding important spawning areas, fish migration paths, shellfish beds and other areas where aquatic life may be concentrated. The proposed cooling water intake structure would involve modifications to an existing intake structure which is located outside the boundaries of areas designated as "Significant Coastal Fish and Wildlife Habitat Areas" by the New York State Department of State.

With regard to the BTA "design" requirement, the significantly reduced water withdrawal, relative to the existing permitted ASGS, coupled with the use of passive screens equipped with wedge wire mesh associated with the wet tower cooling system, would minimize entrainment and impingement of aquatic organisms in a cost effective manner.

With respect to "construction" of cooling water intake structures, the following factors were considered consistent with the 1976 EPA Development Document, p.145: (1) loss of potential habitat associated with the space occupied by the cooling water intake structure, (2) increased turbidity levels due to erosion of unprotected slopes around the excavations, (3) increased levels of turbidity from inadequately stabilized spoiled areas, and (4) filled aquatic areas associated with construction operations. Again, in the case at hand we are dealing with an existing permitted site with existing intake structures and thus avoiding disruptions associated with new construction. Disruptions associated with modifications to the existing intake structure would be small and of short duration.

BTA design features should reduce fish losses due to entrainment and impingement. There is no generally accepted intake design, which can be said to fulfill the requirements of Section 316(b) for all facilities. This case-by-case determination is made taking the individual site and associated factors into consideration. As demonstrated by the Study, the proposed wet tower cooling system is BTA for this location. Moreover, the design is predicated upon the retirement of the existing facility with its once through cooling system.

The proposed cooling water system is also consistent with the State's federally-approved water quality antidegradation policy as set forth in NYSDEC organization and delegation memorandum Number 85-40, dated September 9, 1985 since no lowering of water quality will occur.

Finally, it should be noted that this study analyzed the significant environmental considerations including visual and noise impacts associated with the various cooling system alternatives, and benefits that accrue from reuse of an existing industrial site.

The study has utilized conservative methodologies and assumptions throughout the analysis. As a result, some of the impacts, such as aquatic losses, are likely to be over-estimated. Likewise, estimates of the costs of cooling system alternatives were made using the most cost-effective, practical design PSEGNY could envision to avoid overstating the economic burden. This approach helps to ensure that decisions made using this information will protect the environment and the proposed wet tower cooling system represents BTA for this case.

1.2 The Project

PSEGNY acquired the existing station from Niagara Mohawk Power Corp. (Niagara Mohawk) in May 2000 with the purpose of operating the existing Station while exploring the possibility of moving forward with redevelopment plans initiated by Niagara Mohawk in 1998. The redevelopment of the site with the BEC utilizing the proposed wet tower cooling system provides a viable alternative to maintaining operation of the existing Station. PSEGNY has filed appropriate air and water permit applications for the new facility and will shortly file a supplement that will complete the Article X application for BEC submitted by Niagara Mohawk in 1998. Upon the construction and commercial operation of the proposed BEC, PSEGNY commits to retire the 50-year-old ASGS.

The existing ASGS is a 400 MW facility located along Route 144 on the western bank of the Hudson River (the River) approximately 1.5 miles south of the Albany City boundary. The City of Rensselaer is located on the eastern bank of the River directly opposite ASGS. Portions of the Town of East Greenbush lie directly opposite and across the River from the plant site.

The ASGS includes four identical steam units. Plant construction started in 1950. Two units went into operation in 1952 and other two units went into operation in 1953 and 1954. The ASGS was originally designed to burn coal and has since been modified to burn residual oil (1970) and natural gas (1981).

The ASGS uses a once-through cooling system to cool and condense steam that drives the electric generating turbines. When the ASGS is operating, water is withdrawn from the River and circulated through condensers – large heat exchangers. Steam is exhausted into the condensers, is cooled and condensed back to water, which is then pumped back into the boilers to repeat the steam/electric generating process. Steam does not come in contact with River water circulated through the condensers.

Water is withdrawn from the River, circulated through the condensers, and discharged back into the River in a continual process. The water is discharged back into the River at slightly higher temperatures and the resulting thermal plume is quickly dispersed by currents. Previous studies conducted at the facility demonstrated that the thermal plume does not adversely impact the River aquatic community.

PSEGNY's proposed BEC is a 750-MW, state-of-the-art combined cycle power plant that will use combustion turbines in conjunction with heat recovery steam generators and a new steam turbine. Natural gas will be the primary fuel and low-sulfur distillate oil will be used as a secondary fuel. This technology is the most efficient fossil-fueled electric generating technology currently available.

PSEGNY's proposed design for BEC includes the use of a closed loop cooling system with wet cooling towers. This system will reduce River water withdrawals by 98-99% and will be used in conjunction with state-of-the-art water intake technology employing wedge wire mesh screens. As documented in the SPDES permit application, this system will produce dramatic reductions in use of River water for cooling and dramatically reduce the number of organisms entrained or impinged by the ASGS.

1.3 The Study

This study was conducted to respond to a request for additional information on cooling system options made by various interested parties, including the New York State Department of Environmental Conservation (NYSDEC) and the New York State Department of Public Service (NYSDPS) and environmental organizations, when the BEC project was originally proposed by Niagara Mohawk. The study examines the specific and relevant facts, impacts and benefits associated with BEC to facilitate the necessary, case-by-case review and BTA determination performed by NYSDEC in issuing the SPDES permit.

PSEGNY intends to make this study available and to discuss its contents with regulators and interested individuals and organizations. This follows through on the commitment made to these stakeholders. The study supports the conclusion that a wet tower cooling system is the best choice for BEC. PSEGNY expects to continue the dialogue with interested parties on cooling system issues. This study will be a valuable resource as these discussions proceed.

The study evaluates the proposed wet tower cooling system and the various cooling system alternatives (i.e., once-through, wet/dry tower, and dry tower), and optional measures (i.e., the Gunderboom and holding tank). The study considered many factors including potential effect on system performance, air emissions, noise impacts, aesthetic impacts, aquatic impacts, and costs. In addition, quantifiable costs and benefits were compared in a cost/benefit analysis. Lastly, a holistic evaluation was completed of the quantifiable and non-quantifiable factors of the cooling system choices and was documented and summarized in Chapter 9, Conclusions.

The four basic cooling system configurations consist of:

- **A once-through cooling system** similar to the one now in use at ASGS. In a once-through system, water is withdrawn directly from a source, such as the River, and pumped into heat exchangers – called condensers, which condense steam exhausted from turbines back into water. The River water is pumped into tubes in the condenser, absorbs heat from steam that flows over the condenser tubes, and then is discharged back into the River. The water is discharged at a slightly higher temperature.

- **A closed loop system with wet cooling towers** as proposed by PSEGNY. In this system, water circulating through condenser tubes absorbs heat from steam and is then circulated to mechanical draft cooling towers where the water is cooled through contact with ambient air. The water is then sent back to the condenser to repeat the process. With mechanical draft cooling towers, visible water vapor plumes are sometimes formed above the towers. These plumes dissipate as they mix with ambient air. This system will reduce use of River water approximately 98-99% relative to the existing ASGS.

- **A closed loop system with wet/dry cooling towers** are mechanical draft cooling towers that incorporate features that, under specific ambient temperature and humidity conditions, can reduce the formation of water vapor plumes.

- **A closed loop system with dry cooling towers (air-cooled condenser)** uses finned-tubed steam/air heat exchangers directly to cool and condense steam. This system eliminates any significant evaporative water loss from the system and minimizes the Station's withdrawal of River water. Dry cooling towers, however, require significant additional capital cost and the towers are considerably larger both in height and area than evaporative towers.

At the suggestion of the staffs of NYSDEC and NYSDPS, the study also includes consideration of two modifications applicable to wet and wet/dry cooling tower systems. They are: 1) a Gunderboom system, which consists of a fine mesh screen designed to reduce the interaction of very small aquatic organisms with the cooling water intake, and 2) a water holding tank to allow daily sequenced pumping of River water to potentially reduce the entrainment of aquatic organisms. This provides a total of seven (7) alternatives to the proposed wet tower cooling system as described in Section 8.3.

1.4 Conclusions

Determination of BTA requires a specific case-by-case analysis. In this context it should be noted that the BEC project is an alternative to the continued operation of the ASGS. Major case-specific aspects of the BEC proposal include the commitment to retire an existing facility, redevelopment of an existing generation site, and reuse of existing infrastructure. The BEC plan, as proposed, will provide the best and most efficient use of existing resources as well as environmental benefits including protection of aquatic resources.

This study demonstrates that the wet tower cooling system is BTA for the BEC project. This conclusion is based upon many factors including the costs associated with each available alternative relative to quantifiable environmental benefits. The selection of the cooling system would have to be weighed against the option to continue operating the existing ASGS. While other alternatives may provide very small incremental reductions in the effects on aquatic life, the large additional costs of these alternatives outweigh the additional potential environmental benefits.

The BEC's employment of wedge wire screens coupled with the low volume makeup water requirements of the wet cooling tower will virtually eliminate the current impingement effects associated with ASGS and reduce the entrainment effects by about 98-99% as evaluated by various impact indicators that include estimated organism losses, equivalent adult numbers and biomass and conditional mortality rates (CMRs) to four relevant target fish species; river herring (alewife and blueback herring), American shad, white perch and striped bass.

For the wet tower cooling system operating at peak flow, the estimated annual loss of each of the four target species represent a fraction of one percent of the average annual commercial and recreational catch of each species in New York State. Actual losses are likely to be much less due to compounded conservative assumptions including: a) peak river water withdrawal will occur in the winter and not during the time of peak potential entrainment (i.e., late spring), and b) no compensatory response in the fish population to offset such potential losses was included in these impact indicator estimates.

As summarized in Chapter 9, the wet tower cooling system provides the best balance overall of the considerations including station performance, air emissions, aesthetics/visual impacts, noise, aquatics impacts, and costs.

2.0 DESCRIPTION OF COOLING ALTERNATIVES

The four basic cooling system configurations consist of:

- **A once-through cooling system** similar to the one now in use at ASGS. In a once-through system, water is withdrawn directly from a source, such as the River, and pumped into heat exchangers – called condensers, which condense steam exhausted from turbines back into water. The River water is pumped into tubes in the condenser, absorbs heat from steam that flows over the condenser tubes, and then is discharged back into the River. The water is discharged at a slightly higher temperature.

- **A closed loop system with wet cooling towers** as proposed by PSEGNY. In this system, water circulating through condenser tubes absorbs heat from steam and is then circulated to mechanical draft cooling towers where the water is cooled through contact with ambient air. The water is then sent back to the condenser to repeat the process. With mechanical draft cooling towers, visible water vapor plumes are sometimes formed above the towers. These plumes dissipate as they mix with ambient air. This system will reduce use of River water approximately 98-99% relative to the existing ASGS.

- **A closed loop system with wet/dry cooling towers** are mechanical draft cooling towers that incorporate features that, under specific ambient temperature and humidity conditions, can reduce the formation of water vapor plumes.

- **A closed loop system with dry cooling towers (air-cooled condenser)** uses finned-tubed steam/air heat exchangers directly to cool and condense steam. This system eliminates any significant evaporative water loss from the system and minimizes the Station's withdrawal of River water. Dry cooling towers, however, require significant additional capital cost and the towers are considerably larger both in height and area than evaporative towers.

At the suggestion of the staffs of NYSDEC and NYSDPS, the study also includes consideration of two modifications applicable to wet and wet/dry cooling tower systems. They are: 1) a Gunderboom system, which consists of a fine mesh screen designed to reduce the interaction of very small aquatic organisms with the cooling water intake, and 2) a water holding tank to allow daily sequenced pumping of River water to potentially reduce the entrainment of aquatic organisms. This provides a total of seven (7) alternatives to the proposed wet tower cooling system as described in Section 8.3.

More detailed descriptions of the various cooling alternatives are presented below.

2.1 Once-Through Cooling System

Approximately one-third of the output of a combined-cycle power plant is produced by a steam turbine-generator. In a steam turbine, a portion of the thermal energy in high-pressure and high-temperature steam is converted to shaft horsepower. In the case of the BEC, the steam entering the turbine will be at a pressure of 1,900 psig and a temperature of 1,050°F. As the steam travels from the inlet to the exhaust of the turbine, the steam expands and its pressure and temperature progressively decline as its thermal energy is converted to shaft horsepower. By the time the steam reaches the exhaust of the turbine, its absolute pressure will have typically been reduced to 2.0 inches of mercury, which is significantly below normal atmospheric pressure of 29.92 inches of mercury, and its temperature will have been reduced to approximately 110°F.

Once exhausted from the turbine, the steam must be condensed into water so that the water can be pumped back into the heat-recovery steam generators (HRSG), to be evaporated into steam once again. While the temperature and pressure of the steam will have been significantly reduced within the steam turbine, the steam nonetheless contains a significant amount of thermal energy in the form of latent heat of vaporization, or the thermal energy necessary for the phase change of water into steam. In order to change the steam back into water, this same amount of thermal energy must be transferred from the steam.

The process of transferring thermal energy from steam to condense the steam into water takes place in the plant's condensers. A condenser is a tube-and-shell heat exchanger in which cooling water, commonly referred to as circulating water, flows through tubes from one end of the condenser to the other, and steam flows around the outside of the tubes. Thermal energy is transferred from the steam to the cooling water because of the temperature difference between the two. In the process, the steam is condensed into water, and the temperature of the circulating water is increased.

In a once-through cooling system, circulating water is taken directly from a water body such as the River. In flowing through the condenser tubes and absorbing thermal energy from the steam, the circulating water is heated about 14.4°F above ambient water temperature. The heated water is then discharged back into the water body.

The steam turbine to be used in the BEC will exhaust at full load approximately 1,643,734 pounds of steam per hour to the condenser. The plant's condenser will require a circulating water flow of 224,026 gallons per minute of 66.6°F river water to condense this steam. An additional 11,791 gpm is required for cooling auxiliary plant equipment, thus the total river withdrawal rate under base conditions[1] is about 235,877 gpm for this cooling system (see Table 7-1 for complete river withdrawal totals).

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[1] Base conditions is the typical water withdrawal rate during gas firing of the BEC units.

If a once-through condenser-cooling system were to be used in the BEC, PSEGNY envisions the reuse of the Albany Steam Generating Station's existing shoreline intake and discharge structures. As in the existing ASGS, the raw water taken from the river would have to be screened to remove debris and fish. The Company further envisions the installation of new modified (Ristroph type) traveling water screens (through-flow or dual flow) with a low stress screen wash and organism return system to minimize mortality of fish impinged on the screens. Additionally, a tube-cleaning system would be installed to minimize the chemical and biological fouling of the condenser tubes, thus maintaining its heat exchange efficiency. The use of such a system minimizes the amount of chemicals that need to be added to the circulating water since mechanical cleaning is employed in lieu of chemical cleaning.

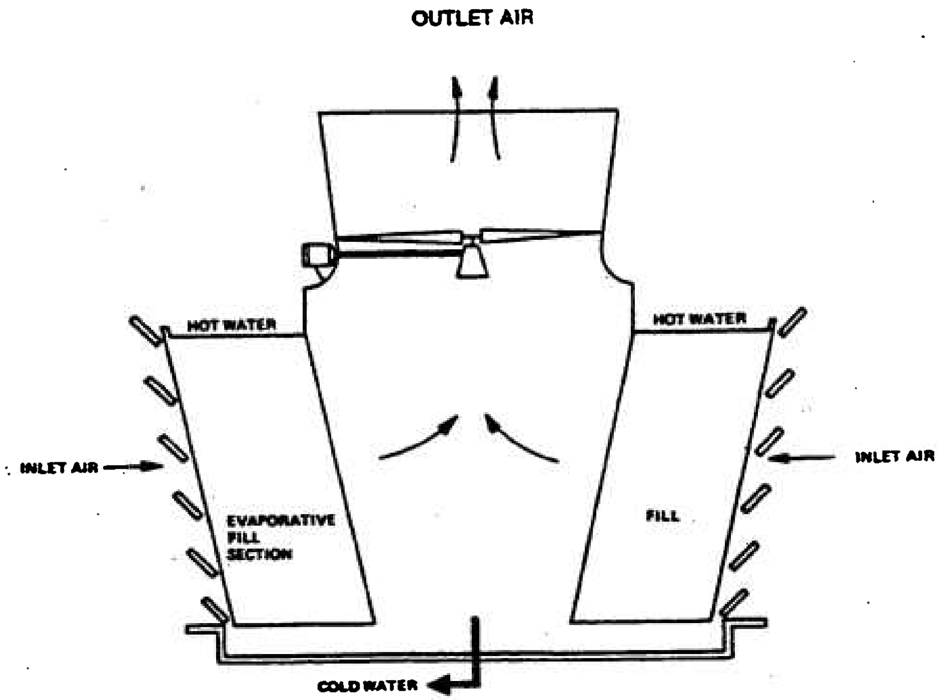
2.2 Closed-Loop Cooling System with Wet Cooling Towers

A system incorporating wet cooling towers would be similar to that originally proposed in Niagara Mohawk's Article X Application, with the exception that a new steam turbine generator and steam exhaust condenser would be installed. The increased thermal efficiency of this new equipment results in a design that allows a smaller wet cooling tower than proposed by Niagara Mohawk. As in a once-through cooling system, water circulating through condenser tubes would absorb heat from the steam exhausted from the plant's steam turbines. The circulating water would as a consequence be heated by about 19.3°F in the condenser.

Unlike the once-through cooling system, however, the circulating water discharged from the condensers would not be returned to the river. Instead, it would be sent to mechanical-draft cooling towers. In such towers, heated circulating water is cooled by being brought into direct contact with cooler ambient air. In the process, some water is evaporated into the air that flows through the cooling tower. Consequently, at high ambient-air humidity and low ambient-air temperatures, clearly visible plumes of condensed water droplets are formed.

A cross section of a conventional mechanical-draft cooling tower is shown in Figure 2-1. Cooling towers produce visible plumes because the ambient air that is drawn through the tower comes into direct contact with heated circulating water. The water is cooled partly through sensible heat transfer from the water to the air, in which heat is transferred solely because of the temperature difference between the water and air.

Figure 2-1 Cross-Section of Conventional Mechanical-Draft Cooling Tower



Source: Marley – Cooling Tower Fundamentals, 2nd Ed.

But much of the cooling occurs through latent heat transfer, in which some of the circulating water is evaporated into the air drawn through the cooling tower. In this process the air becomes fully saturated with moisture. The result is that the air exits an evaporative tower at 100% relative humidity and at a temperature above the ambient-air temperature. When this hot saturated air encounters the ambient air above the tower stack, it mixes with and is cooled by that ambient air. However, cool air cannot hold as much moisture as hot air. Depending on the temperature and humidity of the ambient air, some of the moisture in the air exiting the tower may condense into fine water droplets, forming a white plume above the tower. The plume eventually disappears as additional mixing of the cooling-tower plume and ambient air takes place, and the condensed water droplets are re-evaporated.

The size of the cooling tower, and the number and size of the fans, determines how much cooling water the tower can cool and how cool the water will become. These factors determine how efficiently the cooling water will remove the heat exhausted from the steam turbine in the condenser. Cooler water requires a larger cooling tower, but results in a smaller flow to maintain a given efficiency. A smaller flow results in a higher temperature rise of the water as it absorbs the heat from the steam exhausted from the steam turbine.

The circulating water that is evaporated into the air must be replaced with fresh water from the river. Moreover, the constant evaporation of circulating water concentrates solids in the water that remains in the closed-loop system, creating the need for water to be released, or blown down, from the system and replaced with fresh water to maintain solids concentrations at acceptable levels. Because of a need to keep suspended-solids levels in the circulating-water system below 75 milligrams per liter (mg/l), PSEGNY would plan to operate a closed-loop cooling system at four cycles of concentration. In other words, the blowdown rate would be maintained at approximately one-fourth of the evaporation rate. Therefore, even with a closed-loop system employing evaporative cooling towers, water volumes equivalent to the sum of the evaporation and the blowdown from the tower would still have to be withdrawn from the Hudson River. The volume of this make-up water is small in comparison to a once-through cooling system (approximately 3,277 and 5,923 gpm under base and peak conditions[2], respectively), and a passive wedge wire screen with 2-millimeter mesh will be used to filter the incoming water. This system is designed to further decrease the potential for biological entrainment. Compressed air is used to occasionally clear the screen of debris.

Since the cooling system is a closed one, the use of mechanical tube cleaning is not as effective. Hence, chemicals are added to the system to inhibit chemical and biological fouling of the condenser's tubular heat transfer surfaces. The type and concentration of chemicals are chosen to minimize the environmental effect of the residual chemicals blown down to the Hudson River. Since the chemicals are expensive, they account for a substantial portion of the plant's operating and maintenance expenditures.

2.3 Closed-Loop Cooling System with Wet/Dry (Hybrid) Cooling Towers

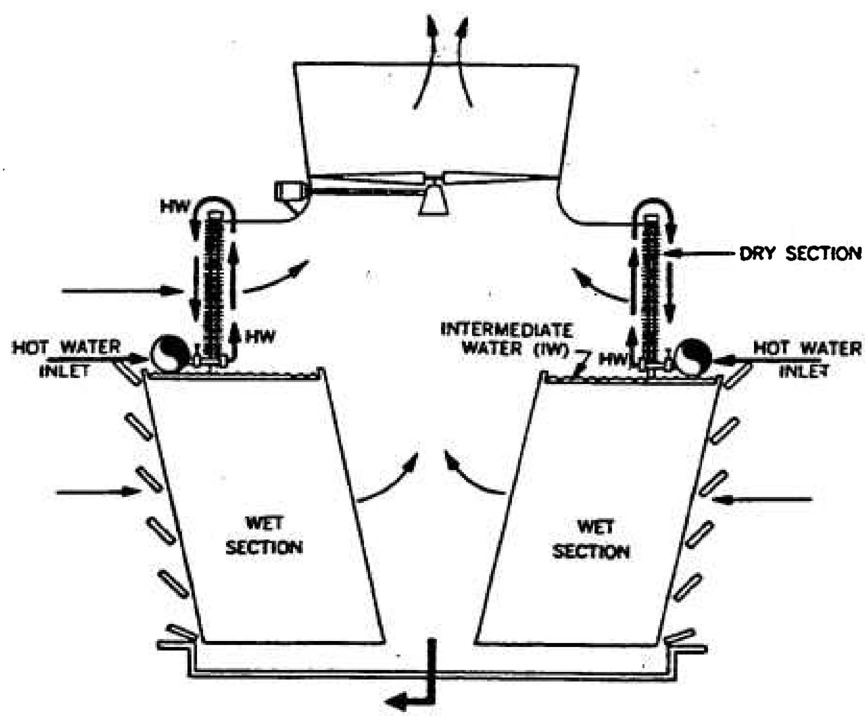
A hybrid tower incorporates finned-tube heat exchangers, or dry sections, and conventional evaporatively cooled, or wet, sections into configurations that utilize common air-moving equipment. The type of hybrid tower used as a basis for this study is more specifically referred to as a parallel air path, series water path, wet/dry (PPWD) cooling tower.

A parallel path wet/dry cooling tower reduces the frequency and magnitude of visible plumes by initially cooling the circulating water by sensible heat transfer in a finned-tube heat exchanger, in which water and air do not come into direct contact, and then cooling the water further in an evaporative heat exchanger. A cross section of a PPWD tower is shown in Figure 2-2. In this type of tower, finned tubes are arranged above the wet tower fill. Ambient air is drawn into the tower simultaneously through the finned-tube area and the tower-fill area. Hot circulating water flows first through the finned tubes, where it is cooled through sensible heat transfer only and no evaporation takes place. Consequently, the air drawn through this section of the tower is heated, but no moisture is added, with the result being that the air's relative humidity decreases. The circulating water is then distributed across the tower fill,

[2] Peak conditions will occur only when firing the units with low-sulfur distillate oil.

where the water is further cooled through both sensible and latent heat transfer as it drips through the fill. In this process the air drawn through this section of the tower is both heated and moisturized to 100% relative humidity. As this air is drawn upward through the tower it mixes with the subsaturated and heated air that was drawn through the dry section of the tower. Blending of these two air streams

Figure 2-2 Cross-Section of Parallel Air Path, Series Water Path, Wet/Dry Cooling Tower



Source: Marley – Cooling Tower Fundamentals, 2nd Ed.

results in a mixture that is heated above the ambient-air temperature, but that has a relative humidity less than 100%. When this air then mixes with ambient air above the tower stack, it is less likely to produce a mixture with a moisture content above saturation conditions. As a result, the size, duration and frequency of visible plumes is reduced. The addition of the dry section to the tower slightly reduces the volume of make-up water required for the wet/dry tower (approximately 5,660 gpm) over that required by the exclusively wet tower.

Any hybrid tower is designed to produce zero theoretical plume at a specific combination of ambient air temperature and relative humidity. At lower temperatures (relative humidity constant) or higher relative humidities (temperature constant) a plume will be formed, although the magnitude of the plume will be less than that of a plume from a strictly evaporative tower performing the same duty. Niagara Mohawk investigated systems incorporating hybrid towers with three different design points as a means of determining the sensitivity of tower costs to design temperature. An evaluation of the results of the Seasonal and Annual Cooling Tower Impact (SACTI) analysis performed for the Article X application suggested the following design points:

- Design Point A: 18°F, 93% RH
- Design Point B: 25°F, 93% RH
- Design Point C: 32°F, 93% RH

Design Point B corresponds to the temperature and relative humidity associated with the worst-case plume used in the application's visual-impact assessment. Design Points A and C were selected to bracket Design Point B for winter conditions.

For the new combined cycle installation proposed by PSEGNY, the design point of 19°F and 60% RH was selected as more realistic for the installation than those considered in Niagara Mohawk's Article X submittal. Cost comparisons and visible plume frequencies have been developed using this design point. This alternative would result in slightly less water withdrawal (3,033 and 5,661 gpm under base and peak conditions, respectively) than the wet cooling tower alternative. Wedge wire screens on the intake would be the same design as that proposed for the wet tower alternative.

Two cooling water intake options were evaluated in connection with the wet and hybrid cooling tower alternatives – the seasonal deployment of a fine-mesh barrier system (Gunderboom System) and the seasonal use of water storage tank that would permit the intake of make-up water during daily periods of low biological activity. Since no fish impingement is projected for the closed-loop cooling system alternatives, the two intake options would be used during the seasonal period when ichthyoplankton are present in the immediate vicinity of the intake structure. A brief description of each option is presented below:

<u>Intake Barrier System</u>: Gunderboom Incorporated (GI) has developed an intake barrier system termed the Marine/Aquatic Life Exclusion System (MLES™) that is designed to prevent the entrainment and impingement of ichthyoplankton and juvenile aquatic life at intake structures. According to Gunderboom Inc. literature the Gunderboom MLES™ fabric is manufactured as a mat of minute fibers and, as such, has no designated opening size; however, the Apparent Opening Size (AOS), as determined by sieve analysis, is approximately 20 microns. The maximum filtering capacity of the Gunderboom MLES™ is 5 gallons per minute per square foot (gpm/ft^2) of fabric; however, recent modifications to the fabric have increased the capacity to 15 to 20 gpm/ft^2 of fabric.

The incorporation of the Gunderboom MLES™ is an option for the BEC for the two evaporative tower cooling system alternatives. Based on experience at Lovett Generating Station, PSEGNY believes Gunderboom MLES™ can be an effective technology. For the purpose of this study, PSEGNY conducted a preliminary feasibility study to evaluate its applicability at BEC. Further, Gunderboom, Inc. conducted a site visit on 13 February 2001 and indicated that the deployment of a Gunderboom MLES™ at the cooling water intake structure was feasible. Before a Gunderboom MLES™ could be applied to BEC, a more detailed engineering evaluation would be required to ensure that no site-specific conditions exist that would jeopardize the reliability or effectiveness of the device.

The boom could be deployed around the cooling water intake structure (outboard of the passive screen units) during the seasonal period when ichthyoplankton are present in the vicinity of the plant (April through July) and, therefore, subject to entrainment. Based on BEC peak and base cooling water flows for the closed loop cooling system alternatives and using the 5 gpm/ft^2 of fabric filtering capacity, the Gunderboom MLES™ design for BEC would have 2000 ft^2 of filtering area. The 2000 ft^2 of filtering area would result in boom through mesh velocities of 0.007 fps under peak flow conditions and 0.004 fps under base flow conditions. Based on system developmental studies conducted at the Lovett Generating Station located on the Lower Hudson River Estuary (Mirant New York Incorporated 2001) a Gunderboom MLES™ for BEC would have a projected minimum effectiveness of 90% at reducing entrainment. Given the low velocities projected for a BEC boom, pressure relief holes in the upstream boom ply may not be required, but if they were incorporated the hole size would be no greater than 0.4-mm. An automated airburst cleaning system would be incorporated in the Gunderboom MLES™ to maintain the filtering capacity of the fabric. The airburst cleaning system has proven effective at maintaining boom filtering capacity at the Lovett Generating Station (LMS 2000).

BEC site assessment tasks that would be needed for Gunderboom, Inc. to design the boom and help determine the best method of boom deployment include: area bathymetric survey, velocity profiles, and sediment geotechnical conditions. Hudson River maximum tidal current velocities are higher in the vicinity of the Lovett Generating Station compared to the Hudson River in the BEC vicinity. The Lovett Gunderboom MLES™ evaluation program has resulted in a boom deployment and anchoring system (Figure 2-3) that effectively maintains the boom in place at the proper configuration to optimize the fabrics filtering capacity. A similar boom deployment technique could be used for a BEC Gunderboom, which would ensure that the BEC boom is not adversely impacted by ebb and flood current velocities. Boom deployment could be through the use of anchors, pile or a combination of the two depending on the bathymetry, velocity profiles, and sediment geotechnical conditions. If necessary, the area would be dredged to create the desired bottom contour, and any obstacles discovered in the site investigation that could adversely impact boom deployment would be removed.

The deployed boom would be visually examined every day and periodically examined by divers to ensure a complete seal with the bottom and sides and to ensure that the boom is in good working condition. Strain gauges and inside/outside water level gauges are incorporated into the boom to monitor stress and filtering capacity. These gauges will be electrically tied into the facility control room to ensure optimum operation of the boom over the deployment period. If boom failure is detected, the damaged section will be either repaired or replaced. During the period the boom is out of service for repairs or panel replacement the passive screens will provide adequate environmental protection. As noted in Chapter 7, ichthyoplankton entrainment is estimated to be very low at the passive screens and juvenile entrainment/impingement is not projected to occur. During the first and maybe the second seasonal period of boom deployment, a comprehensive ichthyoplankton monitoring program would be conducted to verify the effectiveness of the boom at limiting ichthyoplankton passage.

Clarification of NYSDEC's criteria for considering Gunderboom was received by PSEGNY at the end of December 2000. Winter weather conditions and insufficient time prevented providing responses to all requests made. This type of information is typically prepared in the design phase of the project in response to a permit condition. However, appropriate information to address these points will be developed and submitted to NYSDEC for evaluation during the permitting process. Specifically, consideration will be given to the following:

- A complete and detailed description of the configuration, facilities and structures of the Gunderboom MLES™ system. This description would include the design of the anchoring system proposed for the installation along with appropriate supporting information to ensure proper functioning (such as bottom cores and site specific studies) if an anchoring system is proposed.

- A maintenance plan that would ensure proper functioning of the Gunderboom. This would include descriptions of the maintenance and support systems for the Gunderboom, including operation of the airburst cleaning system.

- Drawings of the intake structure showing the location and design of the Gunderboom.

- A proposed entrainment monitoring program to monitor the effectiveness of the deployed boom including detection of boom failure and integrity of operation.

- A proposed contingency plan in the event that the Gunderboom malfunctions, is damaged, taken out of service for maintenance and/or repair, or is otherwise ineffective or fails to provide sufficient mitigation to continue satisfying BTA during the term of the SPDES permit.

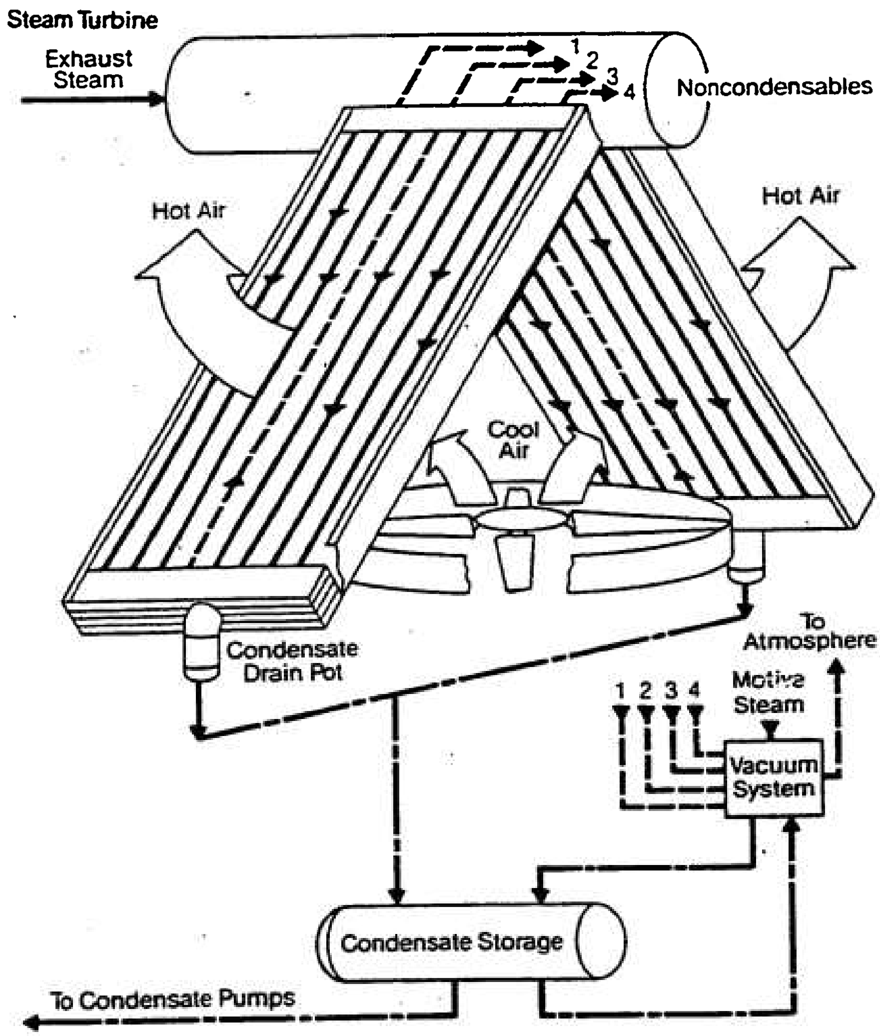
Daily Sequenced Pumping with Holding Tank: The evaluation of ichthyoplankton entrainment at Hudson River electric generating stations and other northeast facilities located on estuaries indicates that ichthyoplankton may be less abundant during the daylight hours compared to the period between dusk and dawn. Therefore the concept of collecting make-up (cooling) water from the River during the day for release from the holding tank during the nighttime period should result in a reduction in entrainment. When originally considered, this option would have utilized a 10-million gallon retired and converted residual oil tank for water storage. Plant design changes eliminated the availability of the tank for this purpose. However, because of the potential benefit, PSEGNY continued evaluation of this option with a new five million gallon holding tank and additional pumping capacity that would be provided for this purpose. The peak water withdrawal volume for the closed-loop cooling system is 5,923 gpm. Considering the dusk to dawn period as extending from 1800 hrs to 0600 hrs (12-hr period) the total volume of make-up water needed is approximately 4.26 million gallons. To obtain the water to meet the nighttime flow requirement, it is anticipated that the 5923 gpm-pumping rate would be doubled during a six-hour period bracketing mid-day or from 0900 hrs to 1500 hrs. It should be noted that doubling the intake flow rate would still result in passive screen through-mesh velocities less than 0.5 feet per second (fps).

2.4 Closed-Loop Cooling System with Dry Cooling Towers

A dry cooling tower consists entirely of finned-tube heat exchangers, thereby keeping water and air entirely segregated. A cross-sectional sketch of a typical dry cooling tower is shown in Figure 2-4. In the air-cooled arrangement for the new combined cycle installation, the exhaust steam condenser is eliminated. Rather, the steam exhausted from the turbine is ducted directly to a heat exchanger and cooled by ambient air blown by fans arrayed in multiple bays or segmented modules. In keeping the condensing steam and the cooling air segregated, there is no evaporation of water from the system. Therefore, there would be no visible plumes from the cooling tower. At the same time, however, all heat would be transferred from steam/water to air through sensible heat exchange, which is ordinarily less efficient than evaporative heat transfer. Consequently, a dry cooling tower is substantially larger than either an evaporative or a wet/dry tower designed for the same heat removal efficiency, as determined by the terminal-temperature difference (TTD), or difference between air entering the tower and condensed water leaving the tower. This difference is also commonly referred to as the tower approach temperature.

The river water withdrawal requirement for the dry cooling alternative is governed by make-up usage associated with the demineralized water system. As with all of the cooling system alternatives, the peak demineralized water make-up requirement is approximately 1,385 gpm during periods of distillate fuel operation when demineralized water is needed for cycle make-up and injection into the combustion turbines to control NOx emissions.

Figure 2-4 Profile of Typical Dry Cooling Tower



Source: Babcock & Wilcox – Steam: Its Generation and Use, 40th Ed.

With dry cooling towers, as ambient air temperatures rise, the rate at which the towers can transfer thermal energy from the steam to the air decreases. This means that the steam is condensed at a higher temperature, with an associated higher saturation pressure. Thus, steam-turbine backpressures would rise. As backpressures rise, the amount of energy that can be extracted from the steam in the form of mechanical work is diminished. Therefore, not only is the dry cooling tower expensive due to the size required to remove the heat from the steam, its use results in a decreased electrical dispatch capability in the warm summer months, precisely at the time when electricity is needed most.

3.0 PERFORMANCE

Each of the cooling options described in Section 2 provide different plant performance results in terms of net electrical output and energy-conversion efficiency (i.e., heat rate, which is a measure of the efficiency of the conversion from fuel to electricity – the higher the heat rate, the less efficient the process). These plant performance differences occur for two basic reasons: 1) each cooling option has different heat rejection capabilities that affect the steam turbine exhaust conditions (i.e., steam turbine backpressure) resulting in different electrical output of the steam turbine, and 2) each option requires different auxiliary power loads to operate support equipment such as pumps and fans. These ratings and efficiencies for each option are also sensitive to ambient conditions.

Detailed analyses, based on the selected General Electric 7FA combustion turbine, were performed to determine plant output and efficiency for the full range of ambient temperatures. These analyses included expected operating data of equipment received from equipment manufacturers of the different cooling options.

Figure 3-1 shows the net electrical output for each option over the range of expected ambient conditions. Figure 3-2 shows the corresponding plant efficiency in terms of net plant heat rate on a higher heating value basis. These figures illustrate how the different options affect performance. The shape of the curves is dictated by 1) equipment performance being highly dependent on ambient conditions, hence the overall plant performance is optimized for the annual average temperature condition and 2) a minimum net plant electrical output of 750 MW is desired throughout the year. At high ambient temperatures the combustion turbine output is reduced since the mass flow rate for the given combustion air volume is lower, resulting in lower combustion turbine electrical output and lower exhaust flows to the HRSGs. Therefore, the HRSGs are supplemental fired with natural gas burners to increase steam turbine output.

For the wet and wet/dry cooling towers, supplemental firing occurs at ambient temperatures above 78°F to maintain a net plant output of 750 MW. For the air-cooled condenser scenario, supplemental firing of the HRSGs would occur above approximately 70°F, while for the once through cooling scenario supplemental firing of the HRSGs would occur above approximately 83°F.

Figure 3-1 Cooling System Comparison Net Electrical Output vs. Ambient Temperature

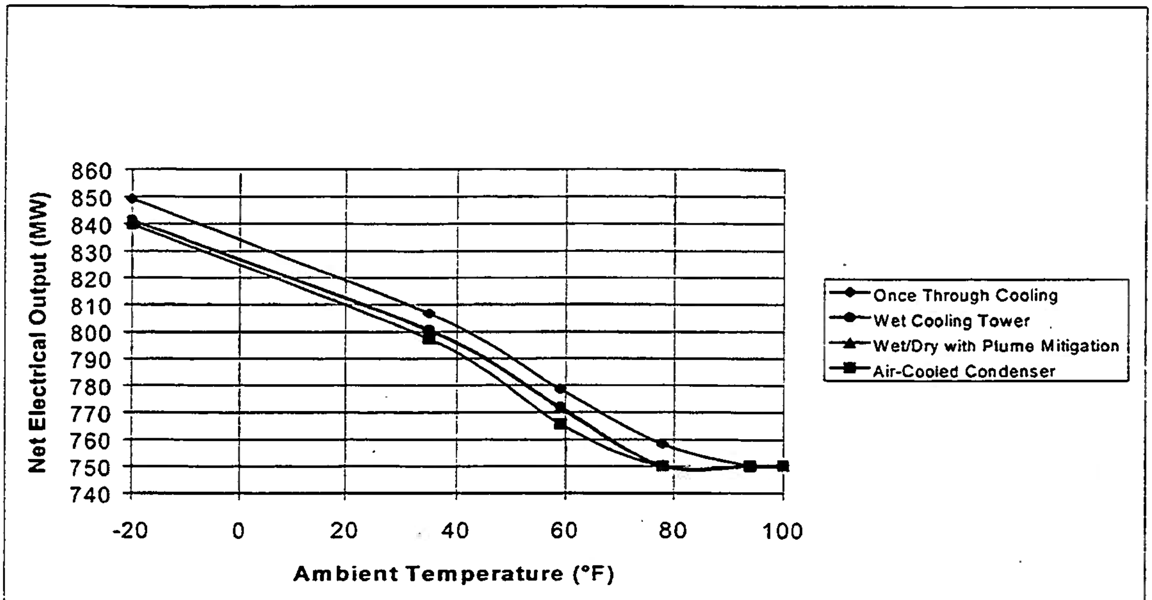
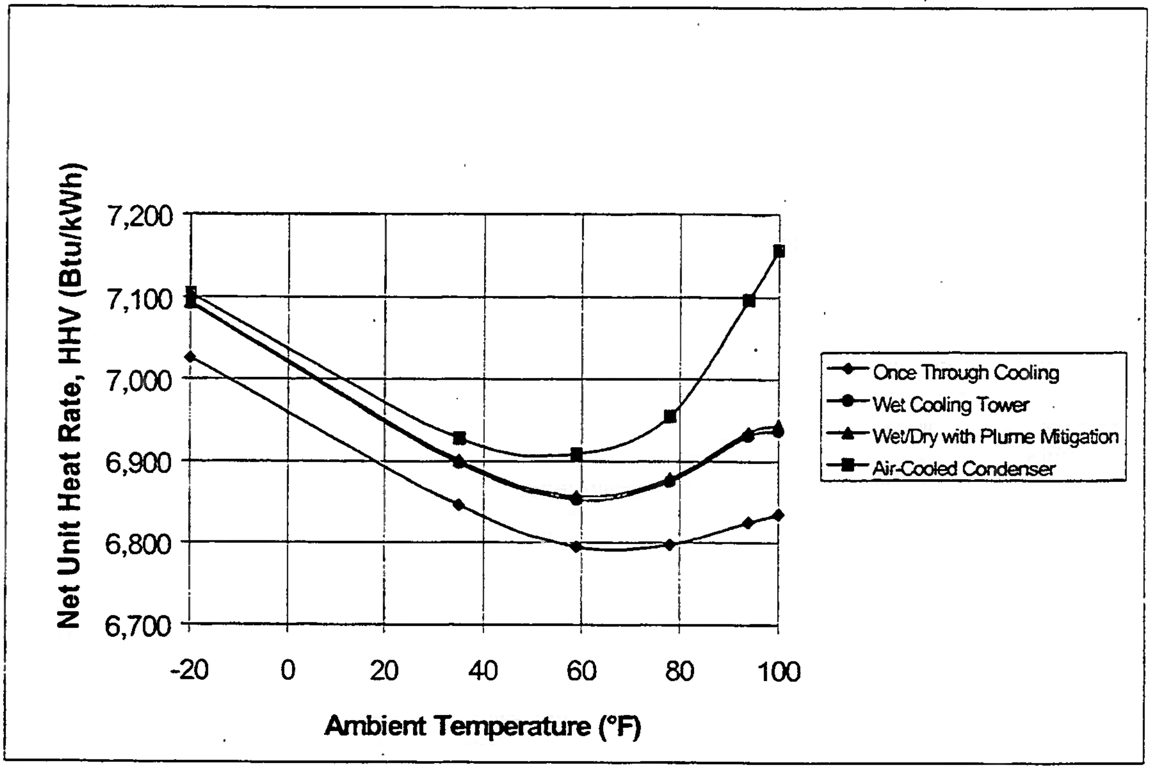


Figure 3-2 Cooling System Comparison Net Unit Heat Rate vs. Ambient Temperature



Therefore, the once through cooling system results in the best overall performance, having the most effective heat rejection characteristics during all seasons with the lowest auxiliary load and supplemental firing requirements. The wet cooling tower and wet/dry cooling tower with plume mitigation yield similar results. However, the wet/dry cooling tower requires additional auxiliary power, resulting in slightly poorer performance. Note that there are no appreciable differences in performance among the six wet and wet/dry cooling tower design points.

An air-cooled condenser with a 30°F approach, or terminal temperature difference at an annual average temperature, was selected to provide acceptable performance for most of the ambient air temperature ranges at a feasible cost. However, as is typical with air-cooled condensers the performance is significantly poorer, especially at the higher ambient temperatures. As illustrated in Figure 3-2, a comparison of plant performance between the wet and dry cooling alternatives for an ambient dry bulb condition of 78°F indicates that the net plant heat rate for the dry tower would be 1.16% poorer than the wet tower (6,955 Btu/kWh dry tower versus 6,875 Btu/kWh wet tower). For an ambient temperature of 94°F, a more typical summer condition, the net plant heat rate for the dry tower would be 2.40% poorer than the wet tower (7,097 Btu/kWh dry tower versus 6,931 Btu/kWh wet tower). Hence, the dry tower incurs a significant penalty during periods when energy is at its greatest demand.

4.0 EMISSIONS

4.1 Overview

4.1.1 Stack Emissions

This section discusses the projected stack emissions of several regulated pollutants, as well as other pollutants of interest that have been identified by active parties, and their emissions variability with respect to the type of cooling system used. The list of pollutants addressed in this section include sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), particulate matter 10 microns or less in size (PM_{10}), volatile organic compounds (VOC), ammonia (NH_3), and carbon dioxide (CO_2).

Stack emissions are discussed in detail in Section 4 of the BEC Air Permit Application. However, that discussion is limited to the proposed wet evaporative cooling tower option. Furthermore, the Air Permit Application includes an evaluation of the following operating conditions:

- three operating loads (100%, 75% and 50%);
- use of evaporative coolers in the summer (at ambient temperatures above approximately 78°F) to improve facility heat rate;
- two fuels (natural gas as the primary fuel and low sulfur distillate oil as the backup fuel); and
- supplementary duct firing with natural gas when the combustion turbines are operating at 100% load. (PSEGNY expects that duct firing would occur primarily in the summer when BEC's design electrical output of 750 MW (net) can not be achieved by the combustion turbine generators (CTGs) alone. Duct firing could also occur at other times when one or more of the CTGs are off line.)

In order to provide a more focused comparison of the impact of cooling system alternatives on stack emissions, this study is limited to the GE-7FA combustion turbine operating at 100% load. In addition, it was assumed that duct firing would occur at only when necessary to maintain BEC's electrical output at 750 MW (net) and only when the CTGs are firing natural gas. Following this approach results in annual emissions that are lower than the Project's potential-to-emit contained in the air permit application. Fixing the turbine design and operating load enables a more direct comparison of the impact of cooling system design on stack emissions. Nevertheless, even though the magnitude of emissions may be affected, it is expected that similar trends would be observed for any given operating load.

Stack emissions are presented on a gross basis, i.e., all values are total emissions and do not account for the decreases in emissions as a result of the future shutdown of the existing boilers at the Albany Steam Station. Emissions are expressed on both a total mass basis (tons/year or pounds/hour) and a unitized mass rate (pounds/megawatt-hour) for each cooling alternative. Expressing emissions both ways allows for a more complete evaluation of cooling system design impacts on emissions. Emissions are also presented on a seasonal basis.

4.1.2 Emissions Associated with Operation of the Wet and Wet/Dry Cooling Towers

The make-up water for the wet and wet/dry cooling towers may contain trace amounts of organic and inorganic compounds. These compounds may be present in the Hudson River (the source of the make-up water) or may be added as part of the treatment for biological, scale, deposits and corrosion control. The flow of the water through the cooling tower will release some of these compounds. Emission estimates for specific compounds are provided in pounds/hour and tons/year. It is important to note that, with the exception of the cooling tower additives, the cooling tower is not the only source of these compounds. The CTGs and duct burners are also sources of these compounds. As will be shown in Section 4.3.2, emissions of these compounds from the wet and wet/dry cooling tower are very small.

4.2 Methodology

4.2.1 Stack Emissions

The general method applied for emissions calculations is to calculate baseline emissions at design ambient air temperatures based on turbine performance data, known stack concentrations or, as a final resort, published emission factors. Turbine performance data is based on the GE-7FA turbine operating at 100% load firing natural gas at design ambient air temperatures of -20°F, 35°F, 59°F, 78°F, 94°F, and 100°F, as supplied by General Electric. Evaporative cooling and supplementary duct firing was also assumed for temperatures above 78°F. In addition, emissions were calculated for the combusting turbines firing distillate oil. The corresponding net electrical generation for each cooling system alternative was calculated based on combustion turbine performance data and steam turbine/condenser performance data. The net electric generation for each cooling system alternative is primarily affected by the ability to effectively condense steam (and maintain low condenser back pressure) and the amount of electricity consumed on-site (not available for sale). Net electrical generation at design ambient air conditions for each cooling system alternative is presented in Table 4-1.

Table 4-1 Net Electrical Generation (MW) with Three Turbines for Cooling System Alternatives

Fuel	Temp, °F	Evap Cooler/ Duct Firing	Once-Through	Wet Cooling Tower	Wet/Dry Cooling Tower	Dry Cooling Tower
Distillate Oil	-20	No/No	848.490	841.666	841.123	840.878
	35	No/No	821.534*	814.927	814.401*	814.164*
	59	No/No	ND	791.176	ND	ND
	100	No/No	ND	756.564	ND	ND
Natural Gas	-20	No/No	849.284	841.410	841.160	839.950
	35	No/No	806.714	800.673	800.323	797.269
	59	No/No	778.567	771.981	771.440	765.668
	78	Yes/No	758.344	749.936	749.410	743.204
	94	Yes/Yes	750.244	750.221	750.043	750.309
	100	Yes/Yes	750.401	750.029	750.188	750.456

* Approximated; ND indicates no data available

Historical temperature data for the Albany area were used to develop average seasonal net electrical generation. These data were interpolated from baseline design generation based on temperature differential and assuming distillate oil would be fired in the combustion turbines during the winter season. Seasonal electrical generation is presented in Table 4-2.

Table 4-2 Seasonal Net Electrical Generation (MW) with Three Turbines for Cooling System Alternatives

Season	Months	Once-Through	Wet Cooling Tower	Wet/Dry Cooling Tower	Dry Cooling Tower
Winter	Dec, Jan, Feb	826.45	819.24	819.28	819.04
Spring	Mar, Apr, May	794.89	786.72	786.25	781.98
Summer	Jun, Jul, Aug	777.43	761.31	760.61	755.06
Fall	Sep, Oct, Nov	790.51	781.66	781.16	776.50
Average	Jan-Dec	797.17	787.06	786.65	782.95

Emission rates for NOx, CO, and VOC will be minimized through the use of state-of-the-art-emissions controls.

- NOx – Use of dry low-NOx technology (natural gas firing) and water injection (low-sulfur distillate oil firing) in the combustion turbine generator (CTG) and selective catalytic reduction (SCR) in the heat recovery steam generator, will result in controlled emissions of 2 parts per million by volume, dry (ppmvd), corrected to 15 percent oxygen (15% O_2) for natural gas firing and 9 ppmvd @ 15% O_2 for low-sulfur distillate oil firing.

- CO and VOC – Use of an oxidation catalyst will reduce uncontrolled CO and VOC emissions by 80% and 30%, respectively.

The short-term CO emission rates contained in the air permit application are higher than the values used in this comparative analysis. The values in the air permit application were adjusted from the values used in this assessment to account for potential short-term peaks during transition between steady-state operating loads. The unadjusted values are more appropriate for the longer-term averages (seasonal/annual), which are the focus of this report. The PM_{10} emission rate accounts for both filterable and condensable particulate matter. The ammonia concentration is based on a maximum concentration of 5 ppmvd @ 15% O_2 ammonia slip resulting from SCR operation. The basis for the other emission rates is discussed in Section 4 of the Air Permit Application. Emission rates of other compounds will be minimized by using natural gas and low sulfur distillate fuel.

Emission rates for one turbine operating at base load with supplemental duct firing (at and above 78°F) are summarized in Table 4-3. Seasonal emissions were then calculated by interpolating the base data from Table 4-3 with respect to temperature and gross electrical output for the combustion turbine. Annual emissions were obtained by adding the seasonal emissions. The results are presented in Table 4-4. The only difference in the emission rates among the alternative cooling system designs is the result of the different amounts of duct firing necessary to maintain BEC's net electrical output at 750 MW (net).

Table 4-3 Emissions Rates (lbs/hr) for One Turbine Operating at Base Load

Temp. (°F)	Evap Cooler/ Duct Firing	Cooling System Alternative	NOx	SO_2	PM_{10}	CO	VOC	CO_2	NH_3
				Distillate oil Firing					
-20	No/No	All	74.1	85.6	67.5	14.2	5.6	344,748	15.3
35	No/No	All	70.3	81.3	65.9	13.8	5.4	327,760	14.5
59	No/No	All	67.6	78.1	64.6	13.1	5.2	314,555	13.9
100	Yes/No	All	64.2	74.2	63.1	12.3	1.9	298,911	13.2
				Natural Gas Firing					
-20	No/No	All	14.6	1.11	18.5	6.7	2.3	236,507	13.5
35	No/No	All	13.5	1.03	18.5	6.1	2.1	219,066	12.5
59	No/No	All	12.9	0.99	18.4	5.8	2.0	209,496	12.0
78	Yes/No	Once-through	12.9	0.96	18.5	5.6	1.9	204,273	11.7
78	Yes/No	Wet & Wet/Dry	12.6	0.96	18.5	5.7	2.0	204,404	11.7
78	Yes/No	Dry	12.6	0.97	18.7	6.0	2.2	206,661	11.7
94	Yes/Yes	Once-through	12.7	0.95	19.4	6.0	2.3	203,122	11.8
94	Yes/Yes	Wet & Wet/Dry	12.7	0.97	19.7	6.5	2.6	206,231	11.8
94	Yes/Yes	Dry	12.7	1.00	20.2	7.4	3.2	211,145	11.8
100	Yes/Yes	Once-through	12.7	0.97	19.6	6.2	2.4	202,672	11.8
100	Yes/Yes	Wet & Wet/Dry	12.7	0.97	19.9	6.7	2.7	205,630	11.8
100	Yes/Yes	Dry	12.7	1.00	20.6	7.8	3.5	212,149	11.8

Table 4-4 Seasonal/Annual Emissions for Three-Turbine Operation (tons)

Season	Cooling System Alternative	NO_x	SO_2	PM_{10}	CO	VOC	CO_2	NH_3
Winter	All	229.5	265.3	214.0	44.8	17.6	1,069,613	47.2
Spring	All	43.9	3.4	61.2	19.9	6.8	712,121	40.6
Summer	Once-through	42.4	3.2	61.3	19.1	6.6	685,640	39.2
	Wet	42.4	3.2	61.4	19.3	6.7	686,522	39.2
	Wet/Dry	42.4	3.2	61.4	19.3	6.7	686,522	39.2
	Dry	42.4	3.2	61.9	20.0	7.2	691,091	39.2
Fall	All	43.0	3.3	60.4	19.5	6.7	697,656	39.8
Annual	Once-through	358.8	275.2	397.0	103.4	37.6	3,164,914	166.8
	Wet	358.8	275.2	397.1	103.5	37.7	3,165,993	166.8
	Wet/Dry	358.8	275.2	397.1	103.5	37.7	3,165,993	166.8
	Dry	358.8	275.2	397.8	104.6	38.4	3,172,249	166.8

4.2.2 Wet and Wet/Dry Cooling Towers

Compounds present in the circulating water may be emitted as a constituent of the drift. Cooling tower drift consists of water droplets that are entrained in the airflow through the tower and carried out to the atmosphere. The drift droplets are created within the tower by mechanical impact forces with the tower fill material and air shearing which tend to produce large water droplets. Wet and wet/dry cooling towers are equipped with a series of screens that limit the amount of drift that escapes the tower. The design for the wet and wet/dry cooling towers includes efficient drift eliminators that will limit the drift rate to 0.0005 percent of the flow rate through the tower. Based on a water flow rate of 174,889 gallons/minute (gpm), the resultant drift rate is 0.874 gpm.

The droplets contain compounds that are present in the Hudson River (the source of the make-up water) or may be added as part of the treatment for biological, scale, deposits and corrosion control. Since the origin of these droplets is the cooling tower circulating water and the mechanism for droplet production is mechanical rather than evaporation and condensation, the concentration of solids and other non-volatile compounds in the drift droplets will be the same as the cooling tower circulating water. The concentration of these compounds in the recirculating water is equal to the concentration in the make-up water times the cycles of concentration. As discussed in Chapter 2, the design of the wet and wet/dry cooling towers assumes four cycles of concentration. Mass emission rates in pounds per hour for particulate matter (including trace metals) and compounds added to the circulating water for treatment were calculated as follows:

ER (lb/hr) = D (gal/min) x C (mg/l) x 3.785 (l/gal) x (gm/1000 mg) x (lb/453.6 gm) x (60 min/hr)

ER (lb/hr) = 0.000438 x C (mg/l)

Where:

ER is the emission rate (in grams/second)

D is the drift rate (0.874 gal/min)

C is the concentration of the trace metal in the circulating water (in milligrams per liter [mg/l]); for compounds present in the make-up water, C is equal to the concentration of the Hudson River water multiplied by 4 to account for the number of cycles of concentration; for compounds added to the circulating water for treatment, C is the concentration in the blowdown.

Concentrations of total dissolved solids and trace metal compounds in the make-up water were obtained from 21 samples of Hudson River water collected by the NYSDEC between April 18, 1997 and July 31, 2000 at the Station's water intake structure. The averages of the 21 samples were used to estimate emission rates from the cooling tower. Concentrations of compounds added to the circulating water for treatment were obtained from the Project's SPDES permit application. Table 4-5 contains a summary of the concentrations and estimated emission rates for these compounds. Annual emission rates for all compounds except Gluteraldehyde are based on the conservative assumption that the cooling tower operates continuously for 8,760 hours/year. The annual emission rate for this compound was estimated based on its expected dosage frequency (10 hours/day for one day/week).

Table 4-5 Estimated Emissions Associated with Drift from Wet and Wet/Dry Cooling Towers

Compound	Concentration (mg/l)[1]	Emission Rate (lb/hr)	Emission Rate (tons/yr)
Present in Make-up Water (Hudson River)			
Total solids	610.8	0.27	1.2
Cadmium	0.000364	0.00000016	0.00000070
Copper	0.01424	0.0000062	0.000027
Fluoride	0.000308	0.00000013	0.00000059
Lead	0.0076	0.0000033	0.000015
Manganese	0.01632	0.0000071	0.000031
Mercury	0.0004	0.00000018	0.00000077
Nickel	0.00484	0.0000021	0.0000093
Zinc	0.02828	0.000012	0.000054
Added to Circulating Water for Treatment			
BCDMH ("hydantoin")	9.6	0.0042	0.018
HEDP (Potassium salt)	1	0.00044	0.0019
Polyacrylate Copolymer	10	0.0044	0.019
Tetrapotassium Pyrophosphate	3.4	0.0015	0.0065
Sodium Polytriazoze	3	0.0013	0.0057
Potassium Hydroxide	7.3	0.0032	0.014
Potassium Phosphate	7.5	0.0033	0.014
EDTA Tetrasodium Salt	4	0.0018	0.0077
Gluteraldehyde	430	0.19	0.049

(1) Concentration in the cooling tower drift droplets (accounts for the tower operating at four cycles of concentration)

Additional sampling of Hudson River water conducted by Niagara Mohawk did not reveal the presence of any other compounds, including PCBs, above the detection level.

4.3 Results

4.3.1 Stack Emissions

The results of the analysis indicate that gross yearly emissions from the proposed plant are generally unaffected by the cooling system alternative ultimately selected. The reason for this is that plant emissions are produced by the combustion of fuel in the plant's gas turbines and, at temperatures above approximately 78°F, in the duct burners. The amount of duct firing necessary to maintain a plant electrical output of 750 MW (net) increases with higher temperatures (because of the natural de-rate of the combustion turbines at higher temperatures). In addition, the amount of duct firing increases with increasing on-site power requirements associated with the different cooling system alternatives. The primary reason for this result is that each cooling system option requires different amounts of power consumption on-site, which affects the net generation available for distribution (net generation is the gross amount of electricity produced minus the amount consumed on-site). As more electricity is consumed internally, less net electricity generation is obtained for each unit of fuel burned. The net effect is to increase the emissions per net megawatt of electricity generated. Results are presented in Table 4-6.

Table 4-6 Unitized Seasonal and Annual Average Emission Rates for Cooling System Alternatives (Lbs/Net MWH)

Cooling System	NO_x	SO_2	PM_{10}	CO	VOC	NH_3	CO_2
Winter							
Once Through	0.258	0.298	0.240	0.0503	0.0197	0.0530	1,200
Wet Cooling Tower	0.260	0.300	0.242	0.0507	0.0199	0.0534	1,211
Wet/Dry Cooling Tower	0.260	0.300	0.242	0.0507	0.0199	0.0534	1,211
Dry Cooling Tower	0.260	0.300	0.242	0.0508	0.0199	0.0534	1,211
Spring							
Once-through	0.0500	0.00382	0.0697	0.0227	0.00770	0.0462	810
Wet Cooling Tower	0.0505	0.00386	0.0704	0.0229	0.00780	0.0467	819
Wet/Dry Cooling Tower	0.0505	0.00386	0.0705	0.0229	0.00780	0.0467	819
Dry Cooling Tower	0.0508	0.00388	0.0709	0.0232	0.00794	0.0470	825
Summer							
Once-through	0.0493	0.00376	0.0714	0.0223	0.00767	0.0456	798
Wet Cooling Tower	0.0504	0.00385	0.0730	0.0229	0.00796	0.0466	816
Wet/Dry Cooling Tower	0.0504	0.00385	0.0731	0.0229	0.00797	0.0466	817
Dry Cooling Tower	0.0508	0.00391	0.0742	0.0240	0.00868	0.0470	829
Fall							
Once-through	0.0499	0.00381	0.0700	0.0226	0.00769	0.0461	808
Wet Cooling Tower	0.0504	0.00385	0.0709	0.0229	0.00779	0.0467	818
Wet/Dry Cooling Tower	0.0505	0.00386	0.0709	0.0229	0.00780	0.0467	818
Dry Cooling Tower	0.0508	0.00388	0.0714	0.0232	0.00798	0.0470	824
Annual Average							
Once-through	0.103	0.0788	0.1137	0.0296	0.01076	0.0478	906
Wet Cooling System	0.104	0.0798	0.1152	0.0300	0.01093	0.0484	918
Wet/Dry Cooling System	0.104	0.0799	0.1152	0.0301	0.01094	0.0484	919
Dry Cooling System	0.105	0.0803	0.1160	0.0305	0.01121	0.0486	925

Once-through cooling has the least internal power consumption and therefore the lowest emissions per net megawatt-hour. The wet cooling tower alternative increases internal power consumption due to the need for additional circulating water lift pumps and cooling tower fans. The addition of plume abatement to the cooling towers only marginally increases internal power consumption due to increased lift pump head and fan requirements. Finally, dry cooling towers represent the largest internal power consumption due to the increased number of fans. The overall impact is about 1 to 2.7%

increase in emissions per net MWH over those estimated for the proposed cooling system design (wet cooling tower) during the summer and about 1% increase annually, with the majority of the increase attributable to the higher power consumption and higher duct firing for the dry cooling tower.

4.3.2 Wet and Wet/Dry Cooling Tower Emissions

The once-through and dry cooling alternatives would not result in emissions associated with cooling tower operation. However, a review of Table 4-5 shows that emissions of total solids (particulates) and other compounds from the wet and wet/dry cooling tower are very small. A dispersion modeling analysis was conducted to estimate the annual ambient air quality concentrations associated with emissions from the proposed wet cooling tower. The Industrial Source Complex dispersion model was used to estimate ambient concentrations associated with operation of the 9-cell tower. The modeling approach was the same as used to estimate inhalable particulate matter (PM_{10}) concentrations for the tower as part of the air permit application. The maximum predicted annual average concentrations for the compounds listed in Table 4-5 are summarized in Table 4-7. Included in Table 4-7 are inhalation-based benchmark concentrations provided by the New York State Department of Health (NYSDOH) as well as annual guideline concentrations (AGCs) developed by the NYSDEC's as part of their air toxics policy (DAR-1). The NYSDEC and NYSDOH have developed these benchmark concentrations to evaluate whether air quality impact associated with a proposed emissions source is a potential health risk.

Table 4-7 Estimated Ambient Air Concentrations of Compounds Emitted from the Proposed Wet Cooling Tower

Compound	Annual Concentrations (μg/m³)			
	Project Cooling Tower(1)	NYSDEC AGC(2)	NYSDOH Risk-Based Air Concentration(3)	
			RfCs(4)	HBAC(5)
Total solids (as PM_{10})	0.092	50(6)	–	–
Cadmium	0.000000055	0.00005	0.02	0.0005
Copper	0.0000022	0.02	150	N/A(7)
Fluoride	0.000000047	0.41	0.08	N/A
Lead	0.0000012	0.75	1.5	N/A
Manganese	0.0000025	0.05	0.05	N/A
Mercury	0.000000061	0.3	0.3	N/A
Nickel	0.00000074	0.004	0.2	0.0042
Zinc	0.0000043	50	50	N/A
BCDMH ("hydantoin")	0.0015	ND(8)	ND	ND
HEDP (Potassium salt)	0.00015	ND	ND	ND
Polyacrylate Copolymer	0.0015	N/A	ND	ND
Tetrapotassium Pyrophosphate	0.00052	12	ND	ND
Sodium Polytriazoze	0.00045	ND	ND	ND
Potassium Hydroxide	0.0011	200	ND	ND
Potassium Phosphate	0.0011	ND	ND	ND
EDTA Tetrasodium Salt	0.00061	ND	ND	ND
Gluteraldehyde	0.0039	0.1	ND	ND

(1) Maximum predicted annual concentration, predicted to occur on northwestern BEC fence-line
(2) NYSDEC annual guideline concentration (NYSDEC DAR-1, Guidelines for the Control of Air Toxic Contaminants, 7/12/00)
(3) NYSDOH (July 27, 2000)
(4) Health Based Reference Concentrations (RfCs) to evaluate non-carcinogenic effects as presented in EPA's Integrated Risks Information (IRIS) database.
(5) Health Based Air Concentrations (HBAC) associated with a lifetime cancer risk of one-in-a-million for carcinogenic effects as presented in EPA's IRIS database.
(6) New York State and National Ambient Air Quality Standard
(7) N/A indicates "not applicable" (i.e., the NYSDOH does not consider this compound to be carcinogenic)
(8) ND indicates "no data" (i.e., the NYSDEC and/or the NYSDOH have not established benchmark concentrations for this compound)

The maximum annual concentrations listed in Table 4-7 are predicted to occur on the northwestern BEC fence-line. Predicted annual concentrations at all other areas are less than the values listed in Table 4-7. The results of the modeling analysis are also applicable to the wet/dry cooling tower. The maximum predicted concentrations of the compounds listed in Table 4-7 are well below the established health-based benchmarks established by the NYSDEC and NYSDOH. Therefore, emissions from the proposed wet cooling tower or the wet/dry cooling tower should not be significant factor in the selection of the cooling alternative.

5.0 NOISE

This chapter provides a comparison of estimated ambient sound impacts associated with alternative cooling systems at the BEC. Computer sound modeling was used to estimate ambient sound impacts at each of the six sensitive receptor locations that were identified in the Article X application.

Table 5-1 provides the octave band sound levels for the alternative cooling systems at a reference distance of 400-feet from the tower. The data presented in Table 5-1 was provided by Hamon Cooling Towers (Hamon 2000). A once-through system using the present Hudson River intake and discharge. This system would have sound emissions similar to the existing site and lower than the proposed projector any of the other closed loop cooling alternatives.

Table 5-1 400-Foot Sound Levels (dB) for Alternative Cooling Systems

Cooling System Alternative	Octave Band Center Frequencies (Hz)									A-Weighted
	31.5	63	125	250	500	1000	2000	4000	8000	
Once-through	0	0	0	0	0	0	0	0	0	0
Wet	76	72	70	64	62	59	55	52	45	64
Wet/Dry (Hybrid)	76	72	70	65	62	58	52	44	39	64
Dry (ACC)	79	75	72	64	62	60	51	45	37	65

The noise sound levels for the other major noise sources at the BEC (the gas turbines, building and ancillary equipment) are assumed to be the same for each of the cooling system alternatives.

The computer sound model used in this analysis is the same that was used to estimate the facility sound impact in support of the Article X application. The results of the modeling indicate that the project sound goals can be achieved at each of the six sensitive receptor locations for the *once-through*, *wet*, and *wet/dry* cooling options. The modeling indicates that sound produced by the *dry* cooling option will marginally exceed the project goals at the nearest residences north, east, and south of the BEC (Locations 1-3). Note that although Niagara Mohawk stipulated to a project design goal of CNR rank "C", the goal at locations 3 and 4 were adjusted to rank "B" to compensate for the existing low background sound levels at these locations.

Although all cooling system options can be designed to meet the project goals at the nearest sensitive receptors, the following observations should be noted:

- The *once-through* option results in total facility sound impacts in the middle and upper frequency ranges (above 500 Hz.) that are significantly below project goals at all six receptor locations. As such, the need for proposed facility sound mitigation (including gas turbine inlet, and building ventilation silencing) might be reduced while still achieving the project goals. Eliminating or reducing these controls may increase facility efficiency.

- Due to the elevation (144 feet) and the increased size of the dry cooling tower footprint, the dry tower option has a more significant acoustic impact than the evaporative tower options. Facility sound levels that are associated with the dry tower option are estimated to be approximately 2-3 dBA higher at all receptor locations. To further reduce dry cooling tower sound emissions would require operating the condenser fans at lower rotation speeds. This speed reduction would result in a reduced cooling capacity for the proposed tower design; as such, additional modules will be required to meet project design goals so that the dry cooling tower would be larger than described.

6.0 AESTHETICS

The following analysis identifies the visual setting in which the cooling tower will be located, describes the physical characteristics and dimensions of the cooling tower options (built structure and plume), and compares the qualitative difference in aesthetic impact between each of the alternatives.

6.1 Character and Visibility of the Bethlehem Energy Center Project

The various cooling tower options are but one component of the larger BEC Project. The aesthetic impact of alternative cooling systems is integrally linked to the visual elements of the overall project and must be evaluated within this context. The following provides a brief description of the character and potential visibility of the BEC.

6.1.1 Project Description

The BEC site is dominated by the existing industrial structures that comprise the ASGS. Major structures existing on site include a two-tier powerhouse (225 ft wide by 300 ft long by 165 ft high) with four steel stacks located on top of the building (336 ft high relative to ground level), three 10-million gallon residual oil storage tanks, two 1-million gallon diesel oil storage tanks, an electrical switchyard and ancillary equipment, coal unloading and handling buildings, an oil tanker and barge unloading dock, and wastewater treatment building and settling ponds. The existing ASGS is a large-scale industrial facility that is a highly dominant visual feature within foreground and middleground views. Figure 6-1 illustrates the character of the existing ASGS site.

6.1.2 Project Visibility

Viewshed analysis and extensive windshield survey indicates that the views of the existing ASGS are highly limited by intervening landform and vegetation. Unobstructed views were found from locations along the Hudson River to the north and south of the project site, major transportation routes in the City of Albany (I-787 and the Dunn Memorial Bridge), south facing windows in high-rise buildings in the City of Albany (including the 41st floor observation deck in the Corning Tower), Route 9J in the Town of East Greenbush, and River Road (NYS Route 144) in the vicinity of the BEC. Views of the existing ASGS from upland locations are rare due to intervening landform and vegetation. Views from the Papscanee Island Nature Preserve are generally limited to waterfront locations. Trailside views from within the preserve are substantially screened by foreground vegetation.

Viewshed and windshield analysis indicates that the periodic vapor plume emitted from the existing stacks of the ASGS is currently visible from a larger geographic area than existing ASGS structures. Potential plume visibility is dependent on plume size and wind direction. However, views of the vapor plume remain relatively rare due to intervening landform and vegetation.

Given similar height and location, the structures and periodic vapor plumes of the proposed BEC are expected to be visible from the same viewshed area as the existing structures and plume of the ASGS.

6.1.3 Project Setting

In order to evaluate the potential visual impact of each cooling tower alternative, it is first necessary to understand the visual setting in which the cooling tower would be located. The following description of the visual character of the regional landscape establishes the baseline condition from which the qualitative differences in cooling tower options can be measured.

6.1.3.1 Landscape Zones

The visual setting of the study region can be divided into areas of unique patterns and visual composition; areas with common characteristics of landform, water resources, vegetation, land use, and land use intensity. Within the BEC study area, six distinct landscape zones were defined. These zones, their general landscape character, use and visual quality are as follows:

Urban Zone – The downtown areas of the Cities of Albany and Rensselaer includes areas of high-density commercial, residential and industrial uses. Built structures and streets dominate this zone. Buildings are typically 2 to 4 stories tall. However, high-rise office towers in excess of 20 stories are common in downtown Albany, with the 41-story Corning Tower being the tallest structure in the city. These areas include some street trees, but they are not generally large. Buildings in the downtown area of Albany are a mix of old and new. Outside of the Albany downtown and in the City of Rensselaer buildings tend to be older. Many structures are very well maintained or restored while others are in various states of disrepair or alteration. Views are generally short distance and focused along streets (which are typically arranged in a grid/block pattern). Scenic/recreational opportunities are generally associated with small urban parks, although the Corning Preserve provides recreational open space along the Hudson River in Albany.

The urban zone contains the highest population density within the study area. The vast majority of potential viewers that may be impacted by the proposed BEC are those who live, work, or are traveling through the urban areas of the Cities of Albany and Rensselaer. Although occasional views of the Hudson River are available, views within the urban zone are generally focused inward toward streets and adjacent buildings. Structures, background topography, and trees generally block distant views from ground level and lower story locations. Distant views may be possible, from south facing windows of high-rise structures and from major transportation routes, including Interstate 787 and the Dunn Memorial Bridge.

Views found within the urban zone may be considered to be of low to moderate visual quality depending on the character and composition of built and natural features within view. Most views in the direction of the proposed BEC from the urban zone are already impacted adversely by existing intensive urban and industrial land uses within the field of view.

<u>Waterfront Zone</u> – This zone includes the Hudson River coastal area and can be divided into two sub-areas: the industrial zone of the Ports of Albany and Rensselaer and adjacent industrial uses, and the rural zone to the south of the industrial areas.

The northern portion of the waterfront zone on both the east and west bank of the Hudson River is characterized by heavy industrial uses. The 350± acre Port of Albany industrial area, located approximately one-mile to the north of the BEC site in the City of Albany, includes more than 50 petroleum storage tanks as well as refinery structures, sewage treatment plant, bulk material storage silos, outdoor bulk material stockpiles, warehouses, truck terminals, and associated large scale heavy industrial and port facilities. The Conrail Kenwood Railyard is located immediately adjacent to the Port of Albany industrial complex. The 200± acre Port of Rensselaer industrial area, located across the Hudson River opposite the Port of Albany in the City of Rensselaer, includes more than 70 petroleum storage tanks as well as warehouses, stockpiles and similar industrial port facilities. The Citgo Oil Terminal borders the BEC site to the south. This property is comprised of approximately 40 petroleum product storage tanks, petroleum loading/unloading structures and equipment, and other associated industrial infrastructure. The Air Products product storage facility and truck terminal is also located south of the BEC site on the west side of River Road. The Agway industrial facility borders the project site to the north and the IPT Oil Terminal is located directly across the Hudson River to the east. The river shoreline in this area is characterized by industrial uses including docks, bulkheads and stabilized banks. A navigable channel is maintained within the Hudson River for commercial and recreational vessels.

Views found within the industrial areas of the waterfront zone may be considered to be of low visual quality due to the presence of existing industrial and urban land uses. Views of existing petroleum storage tanks, storage warehouses and silos, truck terminals, rail yards and large-scale heavy industrial and port facilities are common and combine to substantially reduce the aesthetic quality the waterfront area.

To the south of the industrial area, the river is generally characterized by wooded shorelines comprised of mature deciduous growth, second growth woodland, successional scrubland, wetland species, occasional low islands, and extensive tidal flats. Rural residential development along, and inland from, the river shoreline is common along the east bank of the Hudson River.

In addition to providing water access to industries located along its banks, the Hudson River is a major recreational resource in the area. The northern portion of the 192-acre Papscanee Island Nature Preserve is located approximately 0.5 mile to the southeast of the BEC site on the east side of the Hudson River, in the Town of East Greenbush. This is a passive recreation area, including bird watching, picnicking, hiking and cross-country skiing.

Views from certain undeveloped areas along the Hudson River and surrounding lowlands may be considered to be of moderate to high visual quality due to the natural character of the river, particularly within the Papscanee Island Nature Preserve. Land-side views within these areas are generally contained by dense vegetation, although extended views are available from shoreline areas, and from the river itself. However, the quality of such views is somewhat diminished by existing waterfront residential structures found along the west bank of the river, as well as views of the existing ASGS facilities.

<u>Valley Hills</u> – This zone includes the forested valley walls to the east and west of the Hudson River. This area is characterized by dissected; rolling topography that is primarily wooded, but includes occasional open fields, pastures, and hedgerows. Very low density rural homes (a mix of old and new) and accessory structures (barns, garages, etc.) are scattered throughout. This area includes some agricultural land and farms, but the dominant land use is undeveloped woodland. Views are primarily short distance, typically contained by foreground vegetation and surrounding hillsides. Longer distance views occasionally extend across adjacent yards and small open fields. More distant views are available from open hillsides, but are not common. Such views are generally blocked or partially screened by foreground vegetation or intervening hills.

Views found within the valley hills landscape unit may be considered to be of moderate to high visual quality. Views of the existing ASGS and periodic vapor plume from this zone are rare due to intervening landform and vegetation

<u>Open Uplands</u> - This zone comprises a relatively level or gently sloping topography creating an upland plateau 150 to 250 feet above the Hudson River, primarily to the west. Land cover is a mix of active agriculture, open fields, and scrubland, with occasional woodlots. Very low-density rural residences are

scattered throughout this unit. Properties are generally well maintained, although occasional poorly maintained residential properties and outdoor storage lots are also found. Viewpoints located in this unit often have long distance views across open fields and over wooded valley hills.

Views found within the open uplands landscape zone may be considered to be of moderate to high visual quality. Views of the ASGS and periodic vapor plume from this zone are rare due to intervening landform and vegetation.

<u>Suburban Residential</u> - Moderate to high density suburban residential areas are located in Delmar (3 miles to the west-northwest), East Greenbush (2-3 miles to the east), and Castleton-on-Hudson (4-5 miles to the south). Expanding pockets of moderate to high-density suburban residential areas are scattered throughout the region. Buildings generally consist of single-family homes. These homes are typically in good condition and well cared for. The homes are also setback relatively far from the road and have well defined front and side yards. Trees and landscaping are typically present in the yards, but tree size, species, and age are highly variable. Occasional long distance views are available along road axes or across open yards, but the presence of adjacent structures and trees limit most views.

Views found within the suburban residential zone may be considered to be of low to moderate visual quality. Views of the ASGS and periodic vapor plume from suburban residential areas are rare due to intervening landform and vegetation.

<u>Highway Commercial</u> - This zone occurs along portions of the major highways within the study area and along certain local roads on the edges of the Cities of Albany and Rensselaer. Examples include sections of U.S. Routes 9/20 in East Greenbush and 9W in Bethlehem where adjacent land use is dominated by various commercial enterprises including restaurants, automobile sales and repair, convenience stores, and shopping centers. The type and arrangement of land use in this zone is highly influenced by the automobile. Cars and pavement typically dominate foreground views. There is little consistency in building size, style, or layout, and many of the smaller businesses are not well maintained. Some of the structures are vacant. Views in these areas are primarily directed along the road corridor itself, with medium and distant views blocked by vegetation and frontage development. The presence of diverse signage systems, poorly maintained structures, traffic congestion, and/or the lack of consistent architectural style creates visual clutter that detracts from the character of the surrounding landscape.

Views found within the highway commercial zone may be considered to be of low visual quality. Views of the ASGS and periodic vapor plume from highway commercial corridors are rare due to intervening landform and vegetation.

6.1.4 Existing Vapor Plumes

Vapor plumes are common visual elements in the local landscape. Depending on atmospheric conditions and generating source, vapor plumes of varying magnitude can be observed emanating from numerous existing facilities within the vicinity of the BEC, including industrial facilities located in the Ports of Albany and Rensselaer as well as commercial HVAC systems throughout the Cites of Albany and Rensselaer. Notable sources of commonly visible vapor plumes include the existing Albany Steam Station in Bethlehem, the BASF and Coastal Power facilities in Rensselaer, Air Products in Bethlehem, Blue Circle Cement in Ravena, and General Electric Plastics in Selkirk.

6.2 Visual Character of Cooling System Options

Each of the cooling options investigated requires a different amount of space and structural configuration for the equipment involved. Table 6-1 summarizes the dimensional characteristics for each of the four cooling-tower options.

Table 6-1 Dimensions of BEC Cooling Tower Options

Option	Once-Through Cooling	Wet Cooling Tower	Wet/Dry Cooling Tower	Dry Cooling Tower
No. of Bays or Cells	NA	9 Cells	12 Cells	42 (6 X 7)
No. of Rows	NA	1	1	6
Length (feet)	NA	486	504	318
Width each Row (feet)	NA	48	42	41
Total Width (feet)	NA	48	42	247
Total Area (acres)	NA	0.54	0.49	1.81
Height (feet)	NA	47	69	144

6.2.1 Once-through Cooling

Once-through cooling requires no external cooling tower structure. As such this alternative would result in no additional visual impact. Figure 6-2 illustrates the visual character of the BEC utilizing the once-through cooling option.

will be screened by the existing and proposed BEC structures, if not screened by intervening landform and vegetation.

6.2.4 Closed-Loop Cooling System with Dry Cooling Towers

The dry cooling tower is quite different in form and scale than either the wet or wet/dry towers. The dry cooling tower comprised of bundles of finned tube heat exchangers configured in an A-frame arrangement connected to a steam inlet and an outlet condensate header. These A-frame units are mounted above a linear series of cooling fans. To meet the cooling requirements of the BEC, the dry cooling tower must include six parallel rows of A-frame structures measuring approximately 318 feet long by 41 feet wide by 64 feet high each. This configuration results in an overall footprint measuring approximately 318 feet by 247 feet (1.8 acres).

Air-cooled condensers require sufficient open space below the fan deck to admit necessary air volume. To meet the cooling requirements of the BEC, the fan deck must be elevated 80 feet above grade. The fan deck will be supported by concrete and/or structural steel support framework. However, the open space area below the fans can have no other impediments to air flow. The A-frame structures extend an additional 64 feet above the fan deck, for a total structure height of 144 feet above grade – 19 feet taller than the proposed powerhouse building. Above the fan deck, the A-frame structures may be enclosed with architectural cladding on four sides. Figure 6-5 illustrates the visual character of the dry cooling tower alternative.

6.3 Cooling Tower Plumes

6.3.1 Plume Frequency and Duration

This section presents information regarding the frequencies of occurrence and duration of cooling tower plumes for the wet cooling tower and wet/dry cooling tower designs. There are no cooling tower plumes associated with the once-through or dry cooling tower options.

As discussed in Section **2.2**, whether a visible plume is present above the tower is dependent on the amount of moisture leaving the tower, the ambient dry bulb temperature, and the amount of moisture in the ambient air (expressed as relative humidity). For a given tower design, a relationship between ambient dry bulb temperature and relative humidity can be established that defines the ambient conditions under which a visible plume can be seen.

The frequencies of occurrence of visible plumes for the proposed wet cooling tower and the alternative wet/dry cooling tower are shown in Table 6-2 and Table 6-3. The data in these tables have been estimated based on two sets of meteorological data:

- The Interpower data (September 1998 – August 1989) used by the SACTI model in the Article X application (ENSR, 1998), and
- Albany County Airport data (1993-1997).

Table 6-2 Predicted Frequencies of Visible Plume for Wet Cooling Tower (No Abatement) During Daylight Hours

Hour of Day	Average Seasonal/Annual Frequencies (%) of Visible Plumes									
	Winter		Spring		Summer		Fall		Annual	
	Albany	Interpower	Albany	Interpower	Albany	Interpower	Albany	Interpower	Albany	Interpower
5	93.6	85.2	66.4	77.3	50.5	85.4	74.0	65.3	71.0	78.3
6	94.0	87.5	68.1	65.9	53.6	56.3	74.0	65.8	72.3	68.8
7	93.8	87.4	63.8	46.6	37.4	38.3	74.4	63.9	67.2	58.9
8	93.3	83.9	52.8	34.1	15.5	29.6	67.0	56.3	56.9	50.8
9	92.2	78.6	41.0	22.4	7.4	8.9	52.6	28.4	48.0	34.4
10	91.3	64.7	31.5	18.4	4.4	6.5	37.7	21.2	41.0	27.5
11	85.0	53.6	25.0	15.5	3.7	4.9	22.9	12.7	33.9	21.5
12	75.1	48.8	20.9	12.0	2.6	7.5	18.8	10.7	29.1	19.6
13	63.3	42.4	16.3	8.2	2.0	6.3	13.7	13.0	23.6	17.4
14	54.8	41.6	15.0	9.2	2.8	8.8	12.2	11.4	21.0	17.6
15	54.4	38.6	15.0	8.1	2.2	8.4	13.0	11.1	21.0	16.4
16	51.3	42.7	14.1	8.0	3.3	8.2	14.1	16.2	20.6	18.7
17	55.2	52.9	14.3	11.2	2.4	13.1	16.1	19.5	21.8	24.0
18	63.0	60.7	16.3	20.2	3.1	20.5	21.2	27.6	25.7	32.1
19	72.9	72.4	18.6	27.0	3.5	25.0	26.4	44.0	30.1	41.9
20	79.3	74.2	23.1	34.8	4.4	40.0	34.3	54.5	35.0	50.7
Avg.	75.8	63.5	31.4	26.3	12.4	19.9	35.8	32.9	38.7	36.4

Notes:

1. Daylight hours = 0500-2000
2. Meteorological data: Albany County Airport (1993-1997) and Interpower (September 1988 – August 1989)

Table 6-3 Predicted Frequencies of Visible Plume for Wet/Dry Cooling Tower (19°F/60% RH Design) During Daylight Hours

Hour of Day	Average Seasonal/Annual Frequencies (%) of Visible Plumes									
	Winter		Spring		Summer		Fall		Annual	
	Albany	Interpower	Albany	Interpower	Albany	Interpower	Albany	Interpower	Albany	Interpower
5	65.0	55.7	33.1	43.2	19.8	62.5	38.5	46.7	39.0	50.8
6	65.6	55.7	35.4	36.4	22.0	33.3	36.1	43.4	39.7	43.3
7	68.5	56.3	32.2	26.1	10.7	18.3	37.4	34.7	37.1	35.2
8	69.8	54.0	24.0	12.9	3.7	15.5	34.4	28.2	32.8	28.3
9	68.0	47.6	17.0	8.2	1.3	1.3	21.4	13.4	26.7	18.1
10	60.7	35.3	12.0	8.0	0.7	1.3	12.6	10.6	21.3	14.3
11	50.7	27.4	9.1	3.6	1.1	2.5	5.9	4.2	16.5	9.7
12	39.6	17.9	6.8	2.4	0.2	5.0	4.2	4.0	12.6	7.5
13	31.3	27.1	5.2	2.4	0.2	2.5	4.2	5.8	10.2	9.7
14	26.6	21.3	4.3	0.0	0.2	5.0	3.3	4.3	8.6	8.0
15	24.0	20.5	4.8	0.0	0.4	3.6	3.1	4.2	8.0	7.3
16	22.9	23.6	4.6	1.1	0.7	2.4	2.6	6.8	7.6	8.6
17	25.7	20.7	4.1	4.5	0.7	6.0	3.5	6.5	8.4	9.5
18	29.3	23.6	5.4	11.2	0.7	10.3	4.2	9.2	9.8	13.9
19	35.0	26.4	7.6	11.2	1.1	14.5	5.3	18.7	12.2	17.7
20	40.0	38.2	8.7	11.2	0.9	26.7	7.7	22.1	14.2	24.5
Avg.	45.2	34.5	13.4	11.5	4.0	11.1	14.1	16.6	19.1	18.8

Notes:

1. Daylight hours = 0500-2000
2. Meteorological data: Albany County Airport (1993-1997) and Interpower (September 1988 - August 1989)

The Interpower meteorological data was used in the SACTI modeling analysis because it was demonstrated to be more representative of conditions within the Hudson River Valley than data measured at the Albany County Airport. Data from Albany County Airport were used in this analysis for comparative purposes only.

Table 6-2 and Table 6-3 summarize the expected seasonal and annual frequencies of occurrence of visible plumes for the wet and wet/dry tower designs and two sets of meteorological data. Note that the Interpower data covers a one-year period and only the daylight hours (assumed to be 0500-2000 hours). The Albany County Airport data covers a five-year period and all 24-hours per day; however, only data during daylight hours were used in this analysis.

The data show that on an annual basis, visible plumes are expected to occur 36%-39% of the time (no abatement), and 19% of the time (26°F/60% RH abatement design) on an annual basis during daylight hours. The data in Table 6-2 and Table 6-3 show that the highest frequencies of visible plumes during daylight hours for the two cases evaluated are expected to occur during the winter season (64%-76% [no abatement]; 35%-45% [26°F/60% RH abatement design]). A further review of the data in the tables indicates that the frequencies of occurrence of visible plumes are expected to be the highest during the morning (generally between 0500 and 0900 hours).

Table 6-4 and Table 6-5 show the seasonal and annual durations of visible plumes for the two cooling tower cases evaluated. Data are presented based on Albany County Airport meteorological data only (the data in and Table 6-2 and Table 6-3 showed that the frequencies of occurrence of visible plumes during the winter were the highest using Albany County Airport data). The data in the first column (Visible Plume Hours/Day) are the total number of hours per day the plume was visible. The data in the next four columns are the expected number of days in each season that there are 0, at least 1, at least 2, etc. hours per day of visible plume. For example, on average, there would be only 1.6 days during the winter season when there would be no visible plume during daylight hours for the wet cooling tower design. Similarly, Table 6-5 shows that there would be only 17 days during the winter season when there would be no visible plume during daylight hours for the wet/dry cooling tower design.

Table 6-4 Predicted Duration of Visible Plume for Wet Cooling Tower (No Abatement) During Daylight Hours

Visible Plume Hours/Day	Average Number of Days Per Season/Year				
	Winter	Spring	Summer	Fall	Annual
0	1.6	18.6	33.4	12.4	66.0
≥ 1	88.6	73.4	58.6	78.6	299.2
≥ 2	87.8	67.8	49.4	73.8	278.8
≥ 3	86.8	61.2	35.2	70.0	253.2
≥ 4	85.8	51.0	17.2	63.2	217.2
≥ 5	84.6	40.0	7.0	52.8	184.4

≥ 6	83.4	32.8	4.0	39.4	159.6
≥ 7	81.2	27.0	2.6	29.8	140.6
≥ 8	76.2	20.2	2.4	24.2	123.0
≥ 9	69.6	16.8	1.4	19.2	107.0
≥ 10	62.6	14.8	1.2	15.6	94.2
≥ 11	58.2	13.2	1.0	12.6	85.0
≥ 12	54.2	11.0	0.8	11.0	77.0
≥ 13	49.2	9.6	0.4	9.2	68.4
≥ 14	44.8	8.4	0.4	7.4	61.0
≥ 15	41.8	7.4	0.4	6.6	56.2
16	37.4	6.6	0.4	5.8	50.2

Notes:
1. **Data are for daylight hours (0500 - 2000) only**
2. **Meteorological data: Albany County Airport, 1993-1997**

Table 6-5 Predicted Duration of Visible Plume for Wet/Dry Cooling Tower (19°F/60% RH Design) During Daylight Hours

Visible Plume Hours/Day	Average Number of Days Per Season/Year				
	Winter	Spring	Summer	Fall	Annual
0	17.0	49.6	64.0	43.6	174.2
≥ 1	73.2	42.4	28.0	47.4	191.0
≥ 2	69.6	37.4	16.8	37.8	161.6
≥ 3	66.6	31.0	8.2	32.4	138.2
≥ 4	64.4	23.0	3.2	26.8	117.4
≥ 5	58.6	16.2	0.8	19.0	94.6
≥ 6	53.6	11.4	0.4	11.6	77.0
≥ 7	46.0	8.4	0.4	6.6	61.4
≥ 8	38.0	6.4	0.4	5.2	50.0
≥ 9	33.8	4.8	0.4	3.8	42.8
≥ 10	29.4	4.4	0.2	3.0	37.0
≥ 11	25.6	3.4	0.2	2.4	31.6
≥ 12	22.8	2.4	0.0	2.0	27.2
≥ 13	20.8	2.0	0.0	1.6	24.4
≥ 14	18.4	1.4	0.0	1.4	21.2
≥ 15	16.0	1.2	0.0	1.4	18.6
16	14.2	1.0	0.0	1.4	16.6

Notes:
1. **Data are for daylight hours (0500 - 2000) only**
2. **Meteorological data: Albany County Airport, 1993-1997**

6.3.2 Plume Dimension

The SACTI model provided information regarding the length and width of elevated plumes for the wet cooling tower with no abatement. For the purposes of the visible plume assessment, the SACTI model was applied with hourly meteorological data for daytime hours excluding hours with observed precipiation (as recorded at Albany Airport) and 100% relative humidity. The SACTI model is not capable of simulating plumes for wet/dry cooling towers. As such, a quantitative comparison of plume dimensions between the wet and wet/dry towers is not provided in this report.

6.3.2.1 Closed-Loop Cooling System with Wet Tower (No Abatement)

Visible vapor plume lengths and frequencies predicted by the SACTI model are summarized in Table 6-6. The frequency distribution of plume length indicates that a visible plume will extend to 500 meters or more from the plant about 9% of the year during daylight hours. Conversely, this implies that 91% of the time the plume will extend 400 meters or less from the plant. The results in Table 6-6 also indicate that visible plumes will extend no more than 100 meters from the plant about 50% of the time. Given the closest distance to the property boundary from the cooling tower is approximately 100 meters, more than 50% of the time that visible plumes are predicted they will remain over PSEGNY property. Longer plumes are expected during colder weather. The frequency of plumes at least 500 meters long ranges from about 8% to 19% in spring, fall, and winter compared to less than 1% in summer.

The SACTI model predicted some long plumes, 5000 meters or greater, in the spring, fall, and winter, though they were very infrequent (0.1% in the spring, 0.9% in the fall, and 0.8% in the winter). These longer plumes are predicted during cold conditions (temperature of about near freezing or colder) and high relative humidity (86 - 89%). The maximum plume length predicted by SACTI was 6,526 meters, which was predicted to occur in fall and winter, for plume trajectories toward the east- southeast (ESE) and east (E). The total frequency of the longest visible plume is 0.09% of all hours analyzed or 3 hours/year (i.e., all daylight hours excluding hours of precipitation and 100% relative humidity = a total 3,395 hours; 3,395 hours/year x 0.09/100 = 3 hours/year).

Visible vapor plume heights and frequencies predicted by the SACTI model are summarized in Table 6-7. These calculations show that for about 87 percent of all hours, the plume rise will be limited to 200 meters or less. Higher visible plumes are predicted to occur more frequently during colder months.

Table 6-6 Summary of Cooling Tower Plume Length Calculations

	Frequency Distribution of Plume Length (%)[1]				
Plume Length (meters)	Spring	Summer	Fall	Winter	Annual
100 m	46.22	22.01	51.61	85.98	49.66
200 m	33.58	11.39	36.87	73.15	37.11
300 m	18.27	5.64	20.43	49.34	22.24
400 m	13.84	3.10	15.05	36.51	16.26
500 m	7.75	0.66	10.45	19.44	8.98
1,000 m	6.73	0.44	8.76	15.87	7.48
2,000 m	6.73	0.44	7.99	14.95	7.13
3,000 m	6.73	0.44	7.99	14.95	7.13
4,000 m	2.21	0.00	2.30	4.63	2.18
5,000 m	0.09	0.00	0.92	0.79	0.38
6,526 m[2]	0.00	0.00	0.15	0.26	0.09
10,000 m					

(1) Percent of time (total hours) plume was at least this long over all wind directions.
(2) 6,526 meters was the longest calculated plume.

Table 6-7 Summary of Cooling Tower Plume Height Calculations

	Frequency Distribution of Plume Height (%)(1)				
Plume Height (meters) (2)	Spring	Summer	Fall	Winter	Annual
10	100.00	100.00	100.00	100.00	100.00
20	98.06	99.11	99.85	99.87	99.09
30	81.64	83.96	84.64	97.49	86.36
40	47.97	34.96	53.92	86.77	54.29
50	41.51	18.58	45.31	80.42	44.80
60	39.76	17.37	43.78	76.85	42.83
70	38.93	16.70	42.71	76.85	42.18
80	38.10	16.04	41.63	76.19	41.38
90	28.87	9.07	33.49	69.05	33.43
100	28.87	9.07	33.49	69.05	33.43
200	11.44	2.32	12.90	27.91	12.96
300	6.73	0.44	7.99	14.95	7.13
400	6.73	0.44	7.99	14.95	7.13
500	6.73	0.44	7.99	14.95	7.13
600	6.73	0.44	7.99	14.95	7.13
700	6.73	0.44	7.99	14.95	7.13
800	2.12	0.00	1.54	4.10	1.89
900	0.00	0.00	0.00	0.00	0.00
1,000	0.00	0.00	0.00	0.00	0.00

(1) Percent of time (total hours) plume was at least this high over all wind directions.
(2) Height above tower (add 15 meters for height above ground).

To identify a reasonable "worst-case" visible plume for photo simulation analysis, the SACTI visible plume predictions were ranked from shortest to longest and the predicted frequencies were summed to identify the 90th percentile in terms of plume length. The dimensions of the 90th percentile plume for simulation are:

- Length = 1,335 feet from the center of the cooling tower block
- Height = 612 feet from the top of the cooling tower "stacks" (659 feet above the ground) at a downwind distance of 1,335 feet
- Radius = 172 feet (from plume centerline to the top of the visible plume at a downwind distance of 1,335 feet

The meteorological conditions associated with visible plume are an ambient temperature of 31°F and a relative humidity of 79 percent. This plume is predicted to occur 34 hours per year.

To identify an "average" visible plume for photo simulation analysis, the SACTI visible plume predictions were ranked from shortest to longest to identify the 50th percentile in terms of plume length. The dimensions of the 50th percentile plume for simulation are:

- Length = 141 feet from the center of the cooling tower block
- Height = 107 feet from the top of the cooling tower "stacks" (659 feet above the ground) at a downwind distance of 141 feet
- Radius = 64 feet (from plume centerline to the top of the visible plume at a downwind distance of 141 feet

Under meteorological conditions favorable to plume formation the visible plume would be somewhat dense in composition and appear nearly white in color with a billowing cloud-like form. On clear days, the vapor plume will display a varying shadowed texture similar in appearance to common cloud formations. The vapor plume would often be at a relatively low altitude and thus appear more visually distinct than natural cloud formations, particularly when viewed against background landscape. Under atmospheric conditions less conducive to plume formation the vapor plume would appear smaller in scale and more transparent with less distinct shadowing and textural contrast. At other times little or no vapor plume formation would be visible at all. The color and texture of the vapor plume would tend to blend with background sky conditions, particularly on overcast days. Figure 6-6 illustrates the character of the BEC under the wet cooling alternative from the Papscanee Island Nature Preserve when no plume is visible. Figure 6-7 illustrates the character and magnitude of the wet cooling alternative from the same location under an "average" visible plume condition. Figure 6-8 illustrates the character and magnitude of the wet cooling alternative under the "worst-case" winter cooling tower plume.

be approximately 22 feet taller, the scale of both alternatives would be subordinate to adjacent powerhouse structures and would be substantially screened from local and distant off-site views by intervening on-site structures and vegetation, if not off-site landform and vegetation.

The principal difference between the wet and wet/dry cooling tower alternatives would be the frequency, duration and scale of a visible vapor plume. A visible plume would be expected to form approximately 36%-39% of annual daylight hours when operating a wet cooling system without abatement. Similarly, a visible plume would be expected to form approximately 19% of the time under the wet/dry cooling tower alternative assuming a 19°F/60% RH abatement design.

The SACTI model provided information regarding the length, width and height of elevated plumes for the wet cooling tower with no abatement. Since this model is not capable of simulating plumes for wet/dry cooling towers, a quantitative comparison of plume dimensions between the wet and wet/dry towers cannot be provided. In an unabated condition, the frequency distribution of the SACTI model indicates that a visible vapor plume would extend to 500 meters or more from the plant about 9% of the year during daylight hours. This implies that 91% of the time the plume will extend 400 meters or less from the plant. The visible plumes will extend no more than 100 meters from the plant about 50% of the time. Given the closest distance to the property boundary from the cooling tower is approximately 100 meters, more than 50% of the time that visible plumes are predicted, they will remain over PSEGNY property. During 87 percent of all annual daylight hours, the plume centerline height would be limited to 200 meters or less. The "average" (50^{th} percentile) visible cooling tower plume would have a length of approximately 43 meters, a centerline height of 32.7 meters above ground and a radius of 19.6 meters, and would remain on the BEC site.

The "worst-case" cooling tower plume would be visible from a somewhat larger geographic area than the BEC structures. Therefore, areas that do not currently view some portion of the ASGS structures may periodically view a cooling tower plume. Depending on atmospheric conditions and the fuel type being burned, such visibility may be concurrent with visibility of a vapor plume emitted from the combustion turbine stacks. More common smaller plumes will be visible from a smaller geographic area. Potential plume visibility is dependent on plume size and wind direction. However, views of the vapor plume will be relatively rare in upland areas (valley hills, open upland, suburban residential and highway commercial landscape zones), due to intervening landform and vegetation.

Plumes emitted from the wet/dry tower option may be less dense than a plume from a tower without abatement. In addition, the visible plume from a wet/dry tower would not extend as far downwind or as high above the tower resulting in a smaller viewshed area.

The dry cooling tower will maintain a more visually complex industrial character than either the wet or wet/dry cooling tower options, with a complicated framework steel supports and large scale ductwork and piping. Moreover, the dry cooling tower is substantially larger in scale, making the cooling tower more visible from off-site locations and increasing the overall dominance of the BEC complex on the landscape. From viewing locations to the east, the existing and proposed powerhouses will substantially screen the dry cooling tower from view. However, portions of the cooling tower would be visible above the powerhouses from points to the east, including the Hudson River and riverfront locations within the Papscanee Island Nature Preserve.

The dry cooling tower would emit no visible vapor plume and would create no visual impact in this regard.

6.4.2 Compatibility with Regional Landscape

The overall impact of the cooling tower options is measured by compatibility (or incompatibility) with the setting in which the facility is viewed. Viewshed analysis and windshield survey indicates that the BEC (and periodic cooling tower plume) would be visible from locations along the Hudson River, major transportation routes in the City of Albany (I-787 and the Dunn Memorial Bridge), south facing windows of high-rise buildings in the City of Albany (including the 41st floor observation deck in the Corning Tower), Route 9J in the Town of East Greenbush, and River Road (NYS Route 144) in the vicinity of the BEC. Views of the facility structures and cooling tower vapor plume from upland locations (valley hills, open upland, suburban residential and highway commercial landscape zones) are rare due to intervening landform and vegetation. Views from the Papscanee Island Nature Preserve are generally limited to waterfront locations. Trailside views from within the preserve are substantially screened by foreground vegetation.

The majority of locations that will view the BEC are located within the urban or waterfront landscape zones. From these locations, existing urban and heavy industrial views dominate the foreground landscape, adversely affecting the aesthetic quality of the view. From viewing locations that are not currently affected by significant urban or industrial uses, such as NYS Route 9J and the waterfront areas of the Papscanee Island Nature Preserve, the existing ASGS remains a dominant industrial feature within view. As such, all cooling tower structures will be completely consistent in character with the industrial setting in which they are viewed. However, the large scale of the dry tower alternative would heighten the perceived scale of the BEC.

The visible vapor plume of the wet and wet/dry cooling tower options would be similarly consistent in aesthetic character. Under atmospheric conditions conducive to plume formation, numerous vapor plumes are likely to be visible throughout the Ports of Albany and Rensselaer, and surrounding urban areas. Moreover, a cooling tower plume may be emitted concurrently with a vapor plume from the combustion turbine stacks at the BEC. Although potentially large in dimension, any increase in visual impact resulting from a cooling tower plume is expected to be slight when viewed within the context of the surrounding urban and industrial setting.

7.0 WATER AND AQUATICS

7.1 Water Usage

Table 7-1 summarizes the base and peak water flow rates for the various BEC cooling system alternatives. Base and peak flows are provided for the river water withdrawal and cooling tower blowdown. Table 7-2 compares the water withdrawal volumes and approach velocities for the various cooling system alternatives to base flow conditions at ASGS. Both tables clearly illustrate that the proposed BEC will substantially reduce water withdrawal volumes (about 98-99%) and approach velocities (about 90-95%) when compared to ASGS.

Base flow water usage is based on design flow withdrawal requirements for operation of all generating units during gas firing. Peak flow water usage is based on design flow requirements for operation of all generating units during distillate oil firing. Both base and peak flow water requirements assume continuous (i.e., 24-hr) plant operation at maximum design-load operating capacity (i.e., all three combustion turbine-generators operating). However, projected BEC operation is load-following, (i.e., operating on a schedule to meet daily power demand). Thus, potential impact estimates are considered most conservative (i.e., worse-case); overestimating actual water usage and water withdrawal impacts.

Cooling water usage at the existing ASGS is based on actual average plant operations (333,886 gpm). Actual permitted water withdrawal is slightly larger (352,083 gpm).

For the wet/dry-cooling tower with plume mitigation, losses due to evaporation, makeup and system blowdown flows are approximately 7% less on an annual average basis than for the proposed wet cooling tower. Since the dry cooling tower is virtually a closed system with no losses, makeup water requirements are minimal and blowdown is only necessary from the steam cycle.

Table 7-1 Water Usage Summary for Alternative Cooling Systems

Cooling System Type	Bethlehem Energy Center Condenser Cooling System Alternatives Flow Requirements (gpm)			
	Once-Through Cooling	Wet Cooling Tower	Wet/Dry Tower with Plume Mitigation	Dry Cooling Tower
Base Water Withdrawal	235,877 (1)	3,277	3,033 (2)	57
Peak Water Withdrawal	238,705	5,923	5,661	1,385
Base Blowdown	0	796	735	0
Peak Blowdown	0	1,125	1,060	0

Notes:

1. Includes 1,500 gpm for occasional screen wash flows.
2. Based on evaporation estimates from cooling tower manufacturers.

Base and peak BEC wet cooling tower withdrawals (3,277 and 5,923 gpm or 7.3 and 13.2 cubic feet per second [cfs]) represent about 0.27 and 0.48%, respectively, of the Hudson River (River) freshwater flow (based on the one in ten year seven consecutive day freshwater flow (7-Q_{10}) of 2,730 cfs at USGS Green Island Station for the period 1946 to 1998). This limited water withdrawal is expected to have minimal impact on flow, water levels, current patterns or aquatic resources in the River. While these impacts are expected to be minimal, the potential impact of water withdrawal due to the entrainment and impingement of aquatic organisms were still evaluated for each of the different BEC condenser cooling system alternatives.

7.2 Impingement

7.2.1 Factors Affecting Impingement

Aquatic organisms and debris present in the vicinity of water intake structures may become carried in the water that is withdrawn for process/cooling needs. Intake structures are typically equipped with a screening system to prevent debris and fish from entering the cooling system. Impingement refers to those organisms that are blocked (entrapped) by the screening system and are held in contact with the screening media.

Factors that might affect impingement include the volume and velocity of the water withdrawn, the type of screening system and the density, distribution and the period of occurrence of the organisms in the vicinity of the intake structure. Barnthouse and Van Winkle (1988) analyzed Hudson River impingement and noted that there was a rough correlation between river abundance and the numbers impinged. Condenser cooling water volumes for each BEC cooling system alternative are summarized in Table 7-1. Table 7-2 shows the reduction in base water make-up volumes and calculated screen face velocities for the cooling system alternatives compared to the existing ASGS.

Table 7-2 Water Withdrawal Volumes and Approach Velocities for Alternative Cooling Systems

Cooling System Alternative	Plant Operation	Water Withdrawal Volume		Approach Velocity	
		GPM	% Reduction	ft/sec	% Reduction
Existing Albany Steam Generating Station (four units, once-through)	Base[1]	333,886	–	1.230^{2}	–
BEC Once-Through	Base	235,877	29.4	0.869^{2}	29.3
	Peak	238,705	28.5	0.879^{2}	28.5
BEC Wet Cooling Tower	Base	3,277	99.0	0.065^{3}	94.7
	Peak	5,923	98.2	0.118^{3}	90.4
BEC Wet/Dry Cooling Tower	Base	3,033	99.1	0.060^{3}	95.1
	Peak	5,661	98.3	0.112^{3}	90.9
BEC Dry Tower	Base	57	99.9	0.001^{3}	99.9
	Peak	1,385	99.6	0.028^{3}	97.7

[1] Typical flow during full, four-unit operation. This is less than the permitted flow of 352,083 gpm.

[2] Approach velocity calculation based on an intake open area of 604.8 ft^2

[3] Approach velocity calculation based on passive screen surface area of 112.3 ft^2 equipped with 2.0 mm wedge wire mesh (effective open area value of 0.532)

Different screening systems would be used at the BEC depending on the selection of once-through condenser cooling or closed-loop condenser cooling systems. For a typical once-through cooling system (such as the system in operation at the ASGS), two sets of screens are used for screening of intake water: fixed (bar) screens to remove large debris, and traveling screens to remove smaller material. Bar screens usually have a vertical opening of approximately 2.75-in., and traveling screens are typically sized to be about one-half the opening of the condenser tubes – typically 0.38-in square mesh is used as the screening media in traveling screens. The existing ASGS uses a vertical traveling screen (VTS) system to remove smaller material. If the BEC were to use a once-through cooling system, the existing screen system would be modified to use modified (fish-survival enhancements [Ristroph type]) through-flow or dual-flow traveling screens and a low stress screen-wash/organism-return system to minimize mortality of impinged organisms. The fixed bar screens would be required to prevent larger debris from entering the intake structure.

As shown in Table 7-1, closed loop cooling systems (i.e., wet, wet/dry, and dry cooling towers) would require substantially less water to be withdrawn from the Hudson River. Because of this lower volume, the vertical traveling screens would be replaced with a smaller surface area passive screen system. A passive (or fixed) screen system consisting of two screen units equipped with 2.0-millimeter (mm) wedge wire mesh would be installed outboard of the existing cooling water intake structure. Two separate passive screen operating scenarios could be employed at the BEC; the first scenario would use only one of the two passive screen units with the other maintained as a back-up unit or during cleaning, the second scenario would use both passive screen units simultaneously. The single screen unit option would result in screen mesh velocities well below 0.5 fps; however, the advantage of the two-screen unit scenario is the lower through screen velocities (about 0.1 fps). An operating option would be to use the two-screen option during periods when ichthyoplankton are in the area and the one screen option during the remainder of the year. A separate pipe would convey the cooling tower make-up water, therefore, there would be no need for the existing bar screens and intake tunnels.

7.2.2 Hudson River Aquatic Populations

The following section is presented in order to put the impingement and entrainment recorded and projected at the ASGS and BEC into perspective related to the Hudson River Estuary as a dynamic ecosystem. The impingement and entrainment information for ASGS is limited to twelve and one surveys, respectively. Therefore, it was thought to be important to present relevant impingement and entrainment information for the Lower Hudson River Estuary generating stations even though the closest station to ASGS is over 120 rkm down estuary. Comparisons of this nature are obviously qualitative in nature because of the natural differences in the abundance and distribution of aquatic organisms at the two locations potentially attributable to water quality, habitat and numerous other factors.

7.2.2.1 General Information on Electric Generating Stations Along Lower Hudson River

A total of six electric generating stations are located along the Lower Hudson River Estuary (Troy Dam to the George Washington Bridge); of these six generating stations located along the banks of the Hudson River estuary, three stations, ASGS (river kilometer [RKM] 229.0), Danskammer Point Generating Station (RKM 107.0), and the Lovett Generating Station (RKM 67.0), are similar in generation capacity, screening system design, and cooling water withdrawal volumes. The three generating stations have been in operation since the early 1950s, while the other three stations (Roseton, Indian Point and Bowline Point) began commercial operation during the early to mid 1970s. All six stations employ once-through condenser cooling water systems, i.e., water withdrawal from the Hudson River through an intake structure, passage through the condensers, and return of the same volume of water to the Hudson River. Some general information on Hudson River electric generating stations is presented in Appendix A.1, Table A.1-1.

Fish impingement information based on collections from the intake traveling screens at the Lovett, Danskammer Point, and ASGS is presented in Appendix A.1, Table A.1-2. A general discussion of Hudson River fish population dynamics based primarily on the information collected at the cooling water intakes of the estuarine located generating stations including the ASGS is presented below.

7.2.2.2 General History

A 25-year record of fishery statistics exists for the Hudson River estuary. A continuous record of traveling screen impingement exists from the five lower estuary generating facilities. In addition, there is limited information on ichthyoplankton entrainment. The intake collection information documents abundance patterns, seasonal migration/distribution patterns, reproduction times and locations, and population age class composition. In addition to plant sampling information, sampling information is available for the entire estuary covering the same time period and documenting distribution patterns, reproduction/nursery areas, and population age class composition. Overall, the longterm Hudson River fishery abundance information for the freshwater zone, which includes the ASGS/BEC location, suggests that the yearling and older fish community have exhibited considerable year-to-year variability with no long term trend apparent (HRDEIS 1999).

The following trends in the longterm abundance of fish in the lower Hudson River is based on the 25-year record (1973-1997) at the Danskammer Point Generating Station (Normandeau Associates, 1999). The average annual impingement at Danskammer Point is 309,577 fish ranging from a low of 178,155 individuals recorded in 1978 to a high of 1,027,304 individuals recorded in 1973 (Table A.1-2). White perch represents the dominant species impinged at the mid-estuary located facility accounting for 45.8% of the longterm average and ranging from a low of 52,240 recorded in 1978 to a high of 243,465 recorded in 1984. River herring (alewife, blueback herring) represent the second most abundant taxonomic group of fish impinged accounting for 9.3% of the longterm average, with a range of 6,217 recorded in 1986 to 100,111 recorded in 1975.

The annual estimated impingement data presented in Table A.1-2 illustrates the high degree of variability that is noted in the annual abundance patterns of Hudson River fish populations, especially anadromous and estuarine migrant populations. The Hudson River aquatic populations have been subject to condenser cooling water withdrawal impacts from six generating stations, with once-through cooling water systems, for approximately 40 years. Over this time period population levels of the major fish species present in the river have varied; however, in general a healthy, viable and diverse resource is present in the estuary.

7.2.2.3 Herring

Various species of herring (e.g., alewife and blueback herring) constitute the dominant fish species entrained at Hudson River power stations, including the ASGS. Herring also represent a substantial percentage of the total fish impingement at all Hudson River generating stations located in the estuarine section, with the percent contribution to the overall annual estimate lowest at the downriver stations and the greatest contribution noted at the mid- and upriver stations. For the two reasons listed above the herring are discussed here and then later in this chapter when comparing the BEC cooling system alternatives.

Herring are anadromous species that migrate to low salinity/freshwater sections of east-coast estuaries to spawn in the spring. Following spawning, the adults leave the estuary. After hatching, herring young reside in the estuary until the early fall when, as juveniles, they leave the estuary for nearshore coastal waters. Based on monitoring and fish passage programs conducted at Mohawk River locks and dams, a large percentage of the juvenile herring (primarily blueback herring) population that pass the ASGS during the late summer and fall probably originate in the Mohawk River (Ross 1999).

Sexually mature herring have high fecundity and relatively high natural mortality at each lifestage from eggs through adult. A daily instantaneous total natural mortality rate of 0.2211 (daily finite mortality rate of 0.1884) was reported by Ichthyological Associates, Inc. (IA 1979) for larval blueback herring, and Richkus and DiNardo (1984) report a juvenile natural mortality rate of 75% (m = 0.03307/day) over a six-week period prior to emigration from a pond in Rhode Island. The reproductive strategy to account for this high natural mortality is high fecundity or the production of large numbers of eggs, which under normal conditions result in an adequate number of adults to maintain the population. Over the years this strategy has resulted in substantial annual variability in Hudson River herring abundance. However, over the period from 1979 through 1997, there were slight increasing and decreasing trends in the juvenile index of blueback herring and alewife, respectively, based on the Fall Shoals Surveys (HRDEIS 1999).

7.2.2.4 Albany Steam Generating Station Impingement

The occurrence of fish species impinged monthly at the ASGS during four annual and eight seasonal sampling programs is presented in Table A.1-3 in Appendix A.1. In total, 58 species of fish representing 22 families have been identified among fish collected from the ASGS traveling screens. The majority of the fish species collected are non-migratory freshwater species, but the species that numerically dominate impingement collections are migratory species. The lowest number of fish species was collected during the winter months and the greatest number of species was present during the spring and early summer period. Blueback herring and white perch are the dominant species collected, and represents 45 and 19% of the average total estimated impingement, respectively. At the ASGS impingement of blueback herring demonstrates two annual peaks – a small spring peak that is attributable to upriver migration of adults, and a large fall peak of juveniles that migrate downstream from upriver spawning and nursery waters. The size of the fall peak is primarily dependent on seasonal reproduction success in the Mohawk River drainage coupled with the ability of the juveniles to bypass the numerous Mohawk River locks and dams.

Annual impingement estimates for the four 12-month monitoring programs conducted at ASGS range from a low of 242,139 fish (April 1984-March 1985) to a high of 518,385 fish (October 1982-September 1983) (Table A.1-2). The average annual impingement at the ASGS accounting for average monthly operating conditions (cooling water flow) and based on the results of the four annual programs and several seasonal monitoring programs is presented in Table A.1-3. The estimated annual average number of fish impinged on the ASGS intake traveling screens is 311,636 fish. Estimated monthly impingement was greatest during the months of October and May, with 73,651 and 67,988 fish, respectively. The lowest average monthly impingement was recorded in February with 910 fish estimated impinged.

7.2.3 Estimated Impingement Rates for BEC Alternative Cooling Systems

The low volume of make-up water required for each of the identified closed loop condenser cooling water alternatives (see Table 7-2) combined with the use of a passive intake screen system is expected to result in virtually no fish impingement at the BEC.

For the single steam turbine BEC with a once-through condenser cooling water system, the average volume of cooling water withdrawn from the Hudson River would be 29% less than required by the four unit ASGS; therefore impingement is projected to be at least 29% lower. (NOTE: The lower intake velocity for the single steam turbine facility [see Table 7-2] would result in lower organism entrainment and subsequent impingement on the modified intake traveling screens.) In addition, the BEC with a once-through cooling water system would have modified (either through-flow or dual-flow) traveling screens, which, by design, decrease the stress to impinged organisms and allows for substantially higher post-impingement survival. Post-impingement survival values (percent survival by species) for conventional and modified (BEC) traveling screens are presented in Table A.1-4. (NOTE: Table A.1-4 incorporates preliminary post-impingement survival data recently collected at the Dunkirk Steam Station located on Lake Erie in Dunkirk, NY.) Estimated impingement for the BEC with a once-through cooling system is presented in Table A.1-5. Also presented in Table A.1-5 is the estimated number of specimens of each species that would survive impingement and be returned alive to the Hudson River. The total estimated annual number of fish impinged for the BEC is 223,898 (compared to 311, 636 for the existing ASGS). The total estimated post-impingement mortality for the BEC is 142,593 fish compared to 260,750 for the existing ASGS.

7.2.4 Summary

Each of the BEC cooling water system alternatives results in reduced impacts to aquatic organisms as compared to the existing ASGS that is equipped with a once-through cooling water system and conventional vertical traveling screens. The once-through cooling water system for the BEC would reduce impingement impacts by approximately 40% through a combination of reduced impingement and higher post-impingement survival. For the three closed-loop cooling water system alternatives there would be virtually no impingement of fish species at the BEC due to lower water withdrawal volumes, reduced intake velocities, and use of passive screens.

7.3 Entrainment

7.3.1 Introduction

Entrainment refers to the process where an aquatic organism is drawn into a water intake and is of such a size that it passes through the mesh opening of the intake screening system. Organisms entrained at a cooling water intake are typically subject to mechanical, pressure, temperature and chemical stresses as they pass through the system.

The following sections present the estimated entrainment for the ASGS and projected entrainment for the BEC cooling system alternatives. The entrainment estimates are based on monitoring studies conducted at the ASGS (LMS 1984) and longitudinal river ichthyoplankton surveys (LRS) that have been conducted for the Hudson River Utilities sponsored studies covering the past 25 years (HRDEIS 1999). A brief discussion and comparison of the ASGS monitoring studies and the LRS data is provided in Appendix A.2.

Based on the data available, four target species were selected to estimate annual entrainment mortality rates at the ASGS and the proposed BEC: river herring (alewife and blueback herring), American shad, striped bass and white perch. The river herring and white perch were selected as target species because they have historically been collected as the dominant species in entrainment samples at ASGS and in the LRS (LMS 1984, HRDEIS 1999). Although the early life stages of American shad have been collected in low numbers in entrainment samples at ASGS they were included as a target species because of their commercial/recreational importance and their high abundance in the regions of the LRS in which ASGS/BEC is located. Striped bass were not collected in entrainment samples at ASGS but are the third most abundant species collected in the LRS.

Annual entrainment losses were estimated for each cooling system alternative under both base and peak cooling water flow requirements. Entrainment losses were also estimated for two operational modifications to the wet evaporative and hybrid tower alternatives (i.e., a sequenced pumping schedule and an intake barrier system).

Annual entrainment estimates for both base and peak water usage requirements assumed continuous station operation (i.e., maximum design load for 24-hrs each day); however, projected BEC operation would be load-following (i.e., operating on a schedule to meet daily power demand). While oil firing operations may occur during any portion of the year, oil firing and peak water withdrawal requirements are currently projected to occur only during winter months (e.g., December – March), when air temperatures and fuel demands dictate oil-firing operation for maximum station efficiency. Gas-firing (i.e., base water withdrawal usage) would likely predominate station operation during the remainder of the year (April – November), including the period of greatest potential for entrainment impacts (April – June). Therefore, entrainment estimates are considered most conservative (i.e., worse-case); overestimating actual water usage and water withdrawal impacts. The method used to estimate entrainment mortality rates, as well as the results of modeling efforts to estimate the effect of annual entrainment losses are provided in the following subsections and in Appendix A.2.

7.3.2 Estimated Entrainment for BEC Cooling System Alternatives

The total number of fish eggs, larvae, and juveniles estimated entrained at the ASGS during 1983 (LMS 1984), and entrainment estimates for the alternative BEC cooling water systems based on a percent reduction of base and peak flow rates are presented in Table 7-3. For estimated entrainment calculations, all eggs, yolk-sac larvae and post yolk-sac larvae were considered vulnerable to entrainment for the closed-loop cooling system alternatives, regardless of life stage and size. Juveniles were not considered vulnerable to entrainment for the closed-loop cooling system alternatives based on the use of 2-mm wedge wire mesh cylindrical passive screens. The passive wedge wire screens with 2.0 mm slot width proposed for installation at BEC with a closed-loop cooling system assure that through-slot velocity does not exceed 0.3 ft/sec under both peak (i.e., distillate oil firing) or base (i.e., gas firing) water withdrawal conditions (see Table 7-2). Intake screens of this design, combined with low intake velocity (< 0.5 ft/sec), have been demonstrated to reduce entrainment of fish eggs and larvae (as well as effectively eliminate impingement of larger fish) (Browne et al. 1981, Hanson 1981, Weisberg et al. 1987). Wedge wire screen exclusion efficiencies have been calculated for several species based on larval length; and applied in entrainment loss estimates at other water withdrawal intakes (ERC 1995). Based on these studies, entrainment loss estimates presented here are considered conservative (i.e., overestimated) because it is likely that the 2.0-mm wedge wire screens will also exclude some larvae.

Table 7-3 Estimated Entrainment Rates Based on ASGS 1983 Data

Cooling System Alternative	Total Estimated Abundance by Lifestage			
	Eggs	Yolk-Sac Larvae	Post Yolk-Sac Larvae	Juvenile
ASGS Four Unit Once-through	4.2×10^8	4.6×10^8	2.1×10^8	1.3×10^5
BEC Once-through – Peak	3.0×10^8	3.3×10^8	1.5×10^8	9.3×10^4
BEC Once-through – Base	3.0×10^8	3.3×10^8	1.5×10^8	9.2×10^4
BEC Wet – Peak	7.5×10^6	8.2×10^6	3.7×10^6	NA
BEC Wet – Alt. Pump Schedule – Peak	5.6×10^6	6.1×10^6	2.8×10^6	NA
BEC Wet – Intake Barrier System – Peak	7.5×10^5	8.2×10^5	3.7×10^5	NA
BEC Wet – Base	4.1×10^6	4.5×10^6	2.1×10^6	NA
BEC Wet – Alt. Pump Schedule – Base	3.1×10^6	3.4×10^6	1.5×10^6	NA
BEC Wet – Intake Barrier System – Base	4.1×10^5	4.5×10^5	2.1×10^5	NA
BEC Wet/Dry – Peak	7.1×10^6	7.8×10^6	3.6×10^6	NA
BEC Wet/Dry – Alt. Pump Schedule – Peak	5.3×10^6	5.8×10^6	2.7×10^6	NA
BEC Wet/Dry – Intake Barrier System – Peak	7.1×10^5	7.8×10^5	3.6×10^5	NA
BEC Wet/Dry – Base	3.8×10^6	4.2×10^6	1.9×10^6	NA
BEC Wet/Dry – Alt. Pump Schedule – Base	2.9×10^6	3.1×10^6	1.4×10^6	NA
BEC Wet/Dry – Intake Barrier System – Base	3.8×10^5	4.2×10^5	1.9×10^5	NA
BEC Dry – Peak	1.7×10^6	1.9×10^6	8.6×10^5	NA
BEC Dry – Base	7.2×10^4	7.9×10^4	3.6×10^4	NA

Notes:

NA – Not applicable: Juveniles are not considered vulnerable to entrainment for the closed-loop cooling system alternatives based on the use of 2-mm wedge wire mesh cylindrical passive screens.

Abundance estimates for BEC cooling system alternatives are based on the percent reduction of flow for each alternative. Estimated abundance for the alternative pump schedule and intake barrier system options assumes an additional 25% and 90% reduction in entrainment, respectively.

Entrainment rates for the existing ASGS are based on entrainment monitoring that was conducted at the ASGS during April through September 1983 (LMS 1984). This period corresponds to the historical seasonal period of ichthyoplankton presence in the Hudson River estuary. Circulating water flow during the period when entrained organisms were collected averaged about 95% of the peak design flow for ASGS. During the six-month sampling program, eggs and larvae of river herring (alewife and blueback herring), American shad, white perch, and minnows and carp (Cyprinidae) were collected. River herring dominated the entrainment monitoring collections, representing approximately 95 percent of the total number of eggs collected (LMS 1984). White perch eggs were the second most dominant species collected, representing approximately 4.5 percent of the total number of eggs collected, with the eggs of American shad, minnows and other Cyprinidae accounting for the remaining 0.5 percent.

River herring comprised about 98 percent of the larvae collected while white perch and other species were each about 1 percent of the entrainment collections.

Of the target species selected, only the early life stages of river herring and white perch were collected in entrainment samples in sufficient number to allow for an annual entrainment estimate. Average weekly sample densities during April through September were applied to base and peak cooling water intake flows to estimate annual entrainment (see Appendix A.2). The estimated annual entrainment for river herring and white perch based on entrainment sampling densities and base and peak cooling water flow for the existing ASGS and the proposed BEC cooling water system alternatives is summarized in Table 7-4.

Entrainment at the ASGS and the proposed BEC was also estimated using LRS ichthyoplankton density data from the Albany region. Average weekly egg and larval densities in the Albany region were applied to the base and peak cooling water intake flows at the ASGS and the proposed BEC cooling system alternatives, similar to CEMR and ETM entrainment impact models (see Section 7.3.3 and Appendix A.2). The estimated annual entrainment numbers for each cooling water system alternative is summarized in Table 7-4 and Table 7-5.

Table 7-4 Summary of Estimated Annual Entrainment (numbers) for Target Species Based on ASGS Data

Cooling System Alternative	Lifestage	River Herring	American Shad	Striped Bass	White Perch	All Species
Existing Albany Steam Station	Egg	3.90E+08	NC	NC	2.07E+07	4.10E+08
	Yolksac larvae	2.70E+07	NC	NC	4.46E+06	3.15E+07
	Post Yolksac larvae	6.35E+08	NC	NC	5.55E+06	6.40E+08
	Juvenile	0.00E+00	NC	NC	0.00E+00	0.00E+00
	Total	1.05E+09	--	--	3.07E+07	1.08E+09
BEC Once-Through Cooling - Peak Flow	Egg	2.79E+08	NC	NC	1.48E+07	2.93E+08
	Yolksac larvae	1.93E+07	NC	NC	3.19E+06	2.25E+07
	Post Yolksac larvae	4.54E+08	NC	NC	3.96E+06	4.58E+08
	Juvenile	0.00E+00	NC	NC	0.00E+00	0.00E+00
	Total	7.52E+08	--	--	2.19E+07	7.74E+08
BEC Once-Through Cooling - Base Flow	Egg	2.75E+08	NC	NC	1.46E+07	2.90E+08
	Yolksac larvae	1.91E+07	NC	NC	3.15E+06	2.22E+07
	Post Yolksac larvae	4.49E+08	NC	NC	3.92E+06	4.52E+08
	Juvenile	0.00E+00	NC	NC	0.00E+00	0.00E+00
	Total	7.43E+08	--	--	2.17E+07	7.65E+08
BEC Wet - Peak Flow	Egg	6.91E+06	NC	NC	3.67E+05	7.28E+06
	Yolksac larvae	4.79E+05	NC	NC	7.90E+04	5.58E+05
	Post Yolksac larvae	1.13E+07	NC	NC	9.84E+04	1.14E+07
	Juvenile	NA	NC	NC	NA	NA
	Total	1.87E+07	--	--	5.44E+05	1.92E+07
BEC Wet Alt. Pump Sched - Peak Flow	Egg	6.91E+06	NC	NC	3.67E+05	7.28E+06
	Yolksac larvae	3.57E+05	NC	NC	7.76E+04	4.34E+05
	Post Yolksac larvae	8.91E+06	NC	NC	9.60E+04	9.01E+06
	Juvenile	NA	NC	NC	NA	NA
	Total	1.62E+07	--	--	5.41E+05	1.67E+07
BEC Wet Intake Barrier Sys - Peak Flow	Egg	5.53E+06	NC	NC	2.94E+05	5.82E+06
	Yolksac larvae	3.83E+05	NC	NC	6.32E+04	4.46E+05
	Post Yolksac larvae	9.01E+06	NC	NC	7.87E+04	9.09E+06
	Juvenile	NA	NC	NC	NA	NA
	Total	1.49E+07	--	--	4.36E+05	1.54E+07
BEC Wet - Base Flow	Egg	3.83E+06	NC	NC	2.03E+05	4.03E+06
	Yolksac larvae	2.65E+05	NC	NC	4.37E+04	3.09E+05
	Post Yolksac larvae	6.23E+06	NC	NC	5.44E+04	6.29E+06
	Juvenile	NA	NC	NC	NA	NA
	Total	1.03E+07	--	--	3.01E+05	1.06E+07
BEC Wet Alt. Pump Sched - Base Flow	Egg	3.83E+06	NC	NC	2.03E+05	4.03E+06
	Yolksac larvae	1.97E+05	NC	NC	4.29E+04	2.40E+05
	Post Yolksac larvae	4.93E+06	NC	NC	5.31E+04	4.98E+06
	Juvenile	NA	NC	NC	NA	NA

Cooling System Alternative	Lifestage	River Herring	American Shad	Striped Bass	White Perch	All Species
	Total	8.95E+06	–	–	2.99E+05	9.25E+06
BEC Wet Intake Barrier Sys - Base Flow	Egg	3.44E+06	NC	NC	1.83E+05	3.63E+06
	Yolksac larvae	2.38E+05	NC	NC	3.94E+04	2.78E+05
	Post Yolksac larvae	5.61E+06	NC	NC	4.90E+04	5.66E+06
	Juvenile	NA	NC	NC	NA	NA
	Total	9.29E+06	–	–	2.71E+05	9.56E+06
BEC Wet/Dry - Peak Flow	Egg	6.61E+06	NC	NC	3.51E+05	6.96E+06
	Yolksac larvae	4.58E+05	NC	NC	7.55E+04	5.33E+05
	Post Yolksac larvae	1.08E+07	NC	NC	9.40E+04	1.09E+07
	Juvenile	NA	NC	NC	NA	NA
	Total	1.78E+07	–	–	5.20E+05	1.84E+07
BEC Wet/Dry Alt. Pump Sched - Peak Flow	Egg	6.61E+06	NC	NC	3.51E+05	6.96E+06
	Yolksac larvae	3.41E+05	NC	NC	7.42E+04	4.15E+05
	Post Yolksac larvae	8.51E+06	NC	NC	9.18E+04	8.61E+06
	Juvenile	NA	NC	NC	NA	NA
	Total	1.55E+07	–	–	5.17E+05	1.60E+07
BEC Wet/Dry Intake Barrier Sys - Peak Flow	Egg	5.29E+06	NC	NC	2.81E+05	5.57E+06
	Yolksac larvae	3.66E+05	NC	NC	6.04E+04	4.27E+05
	Post Yolksac larvae	8.61E+06	NC	NC	7.52E+04	8.69E+06
	Juvenile	NA	NC	NC	NA	NA
	Total	1.43E+07	–	–	4.16E+05	1.47E+07
BEC Wet/Dry - Base Flow	Egg	3.54E+06	NC	NC	1.88E+05	3.73E+06
	Yolksac larvae	2.45E+05	NC	NC	4.05E+04	2.86E+05
	Post Yolksac larvae	5.77E+06	NC	NC	5.04E+04	5.82E+06
	Juvenile	NA	NC	NC	NA	NA
	Total	9.55E+06	–	–	2.79E+05	9.83E+06
BEC Wet/Dry Alt. Pump Sched - Base Flow	Egg	3.54E+06	NC	NC	1.88E+05	3.73E+06
	Yolksac larvae	1.83E+05	NC	NC	3.97E+04	2.22E+05
	Post Yolksac larvae	4.56E+06	NC	NC	4.92E+04	4.61E+06
	Juvenile	NA	NC	NC	NA	NA
	Total	8.29E+06	–	–	2.77E+05	8.56E+06
BEC Wet/Dry Intake Barrier Sys - Base Flow	Egg	3.19E+06	NC	NC	1.69E+05	3.36E+06
	Yolksac larvae	2.21E+05	NC	NC	3.64E+04	2.57E+05
	Post Yolksac larvae	5.19E+06	NC	NC	4.53E+04	5.24E+06
	Juvenile	NA	NC	NC	NA	NA
	Total	8.60E+06	–	–	2.51E+05	8.85E+06
BEC Dry - Peak Flow	Egg	1.62E+06	NC	NC	8.58E+04	1.70E+06
	Yolksac larvae	1.12E+05	NC	NC	1.85E+04	1.30E+05
	Post Yolksac larvae	2.63E+06	NC	NC	2.30E+04	2.66E+06
	Juvenile	NA	NC	NC	NA	NA
	Total	4.36E+06	–	–	1.27E+05	4.49E+06
BEC Dry - Base Flow	Egg	6.66E+04	NC	NC	3.54E+03	7.01E+04
	Yolksac larvae	4.61E+03	NC	NC	7.61E+02	5.37E+03

Cooling System Alternative	Lifestage	River Herring	American Shad	Striped Bass	White Perch	All Species
	Post Yolksac larvae	1.08E+05	NC	NC	9.48E+02	1.09E+05
	Juvenile	NA	NC	NC	NA	NA
	Total	1.80E+05	--	--	5.24E+03	1.85E+05

Note(s): Entrainment estimates based on ASGS 1983 Entrainment Monitoring Survey
NC - None collected (little or none collected during 1983 entrainment sampling program)
NA - Not applicable (Juveniles are not considered vulnerable to entrainment based on the use of 2.0-mm mesh passive screens)

Table 7-5 Summary of Estimated Annual Entrainment (numbers) for Target Species Based on LRS Data

Cooling System Alternative	Lifestage	River Herring	American Shad	Striped Bass	White Perch	All Species
Existing Albany Steam Station	Egg	1.84E+10	6.88E+07	5.46E+06	6.10E+08	1.91E+10
	Yolksac larvae	7.83E+09	2.44E+07	2.32E+06	7.92E+08	8.65E+09
	Post Yolksac larvae	1.16E+08	1.53E+07	2.62E+05	1.83E+07	1.50E+08
	Juvenile	1.20E+06	5.29E+07	1.21E+05	7.84E+06	6.21E+07
	Total	2.64E+10	1.61E+08	8.17E+06	1.43E+09	2.80E+10
BEC Once-Through Cooling - Peak Flow	Egg	1.32E+10	4.92E+07	3.90E+06	4.36E+08	1.37E+10
	Yolksac larvae	5.60E+09	1.74E+07	1.66E+06	5.66E+08	6.18E+09
	Post Yolksac larvae	8.33E+07	1.09E+07	1.87E+05	1.31E+07	1.07E+08
	Juvenile	8.60E+05	3.79E+07	8.65E+04	5.60E+06	4.44E+07
	Total	1.88E+10	1.15E+08	5.84E+06	1.02E+09	2.00E+10
BEC Once-Through Cooling - Base Flow	Egg	1.30E+10	4.86E+07	3.86E+06	4.31E+08	1.35E+10
	Yolksac larvae	5.53E+09	1.72E+07	1.64E+06	5.59E+08	6.11E+09
	Post Yolksac larvae	8.23E+07	1.08E+07	1.85E+05	1.29E+07	1.06E+08
	Juvenile	8.50E+05	3.74E+07	8.55E+04	5.54E+06	4.39E+07
	Total	1.86E+10	1.14E+08	5.77E+06	1.01E+09	1.98E+10
BEC Wet - Peak Flow	Egg	3.27E+08	1.22E+06	9.69E+04	1.08E+07	3.39E+08
	Yolksac larvae	1.39E+08	4.33E+05	4.12E+04	1.40E+07	1.53E+08
	Post Yolksac larvae	2.07E+06	2.71E+05	4.64E+03	3.24E+05	2.67E+06
	Juvenile	NA	NA	NA	NA	NA
	Total	4.68E+08	1.92E+06	1.43E+05	2.52E+07	4.95E+08
BEC Wet Alt. Pump Sched - Peak Flow	Egg	3.27E+08	1.22E+06	9.69E+04	1.08E+07	3.39E+08
	Yolksac larvae	1.03E+08	3.47E+05	4.05E+04	1.38E+07	1.18E+08
	Post Yolksac larvae	1.63E+06	2.55E+05	5.23E+03	3.16E+05	2.21E+06
	Juvenile	NA	NA	NA	NA	NA
	Total	4.32E+08	1.82E+06	1.43E+05	2.49E+07	4.59E+08
BEC Wet Intake Barrier Sys - Peak Flow	Egg	2.94E+08	1.10E+06	8.72E+04	9.75E+06	3.05E+08
	Yolksac larvae	1.25E+08	3.89E+05	3.71E+04	1.26E+07	1.38E+08
	Post Yolksac larvae	1.86E+06	2.44E+05	4.18E+03	2.92E+05	2.40E+06
	Juvenile	NA	NA	NA	NA	NA
	Total	4.21E+08	1.73E+06	1.28E+05	2.27E+07	4.45E+08
BEC Wet - Base Flow	Egg	1.81E+08	6.75E+05	5.36E+04	5.99E+06	1.87E+08
	Yolksac larvae	7.68E+07	2.39E+05	2.28E+04	7.77E+06	8.49E+07
	Post Yolksac larvae	1.14E+06	1.50E+05	2.57E+03	1.79E+05	1.47E+06
	Juvenile	NA	NA	NA	NA	NA
	Total	2.59E+08	1.06E+06	7.90E+04	1.39E+07	2.74E+08
BEC Wet Alt. Pump Sched - Base Flow	Egg	1.81E+08	6.75E+05	5.36E+04	5.99E+06	1.87E+08
	Yolksac larvae	5.72E+07	1.92E+05	2.24E+04	7.63E+06	6.51E+07
	Post Yolksac larvae	9.04E+05	1.41E+05	2.89E+03	1.75E+05	1.22E+06

Cooling System Alternative	Lifestage	River Herring	American Shad	Striped Bass	White Perch	All Species
	Juvenile	NA	NA	NA	NA	NA
	Total	2.39E+08	1.01E+06	7.89E+04	1.38E+07	2.54E+08
BEC Wet Intake Barrier Sys - Base Flow	Egg	1.63E+08	6.08E+05	4.82E+04	5.39E+06	1.69E+08
	Yolksac larvae	6.92E+07	2.15E+05	2.05E+04	7.00E+06	7.64E+07
	Post Yolksac larvae	1.03E+06	1.35E+05	2.31E+03	1.61E+05	1.33E+06
	Juvenile	NA	NA	NA	NA	NA
	Total	2.33E+08	9.58E+05	7.11E+04	1.25E+07	2.46E+08
BEC Wet/Dry - Peak Flow	Egg	3.12E+08	1.17E+06	9.26E+04	1.04E+07	3.24E+08
	Yolksac larvae	1.33E+08	4.14E+05	3.94E+04	1.34E+07	1.47E+08
	Post Yolksac larvae	1.97E+06	2.59E+05	4.44E+03	3.10E+05	2.55E+06
	Juvenile	NA	NA	NA	NA	NA
	Total	4.47E+08	1.84E+06	1.36E+05	2.41E+07	4.73E+08
BEC Wet/Dry Alt. Pump Sched - Peak Flow	Egg	3.12E+08	1.17E+06	9.26E+04	1.04E+07	3.24E+08
	Yolksac larvae	9.89E+07	3.32E+05	3.87E+04	1.32E+07	1.12E+08
	Post Yolksac larvae	1.56E+06	2.43E+05	5.00E+03	3.02E+05	2.11E+06
	Juvenile	NA	NA	NA	NA	NA
	Total	4.13E+08	1.74E+06	1.36E+05	2.38E+07	4.38E+08
BEC Wet/Dry Intake Barrier Sys - Peak Flow	Egg	2.81E+08	1.05E+06	8.33E+04	9.32E+06	2.91E+08
	Yolksac larvae	1.19E+08	3.72E+05	3.54E+04	1.21E+07	1.32E+08
	Post Yolksac larvae	1.78E+06	2.33E+05	3.99E+03	2.79E+05	2.29E+06
	Juvenile	NA	NA	NA	NA	NA
	Total	4.02E+08	1.66E+06	1.23E+05	2.17E+07	4.26E+08
BEC Wet/Dry - Base Flow	Egg	1.67E+08	6.25E+05	4.96E+04	5.55E+06	1.73E+08
	Yolksac larvae	7.11E+07	2.22E+05	2.11E+04	7.19E+06	7.86E+07
	Post Yolksac larvae	1.06E+06	1.39E+05	2.38E+03	1.66E+05	1.36E+06
	Juvenile	NA	NA	NA	NA	NA
	Total	2.39E+08	9.85E+05	7.31E+04	1.29E+07	2.53E+08
BEC Wet/Dry Alt. Pump Sched - Base Flow	Egg	1.67E+08	6.25E+05	4.96E+04	5.55E+06	1.73E+08
	Yolksac larvae	5.30E+07	1.78E+05	2.07E+04	7.06E+06	6.02E+07
	Post Yolksac larvae	8.37E+05	1.30E+05	2.68E+03	1.62E+05	1.13E+06
	Juvenile	NA	NA	NA	NA	NA
	Total	2.21E+08	9.34E+05	7.30E+04	1.28E+07	2.35E+08
BEC Wet/Dry Intake Barrier Sys - Base Flow	Egg	1.51E+08	5.63E+05	4.46E+04	4.99E+06	1.56E+08
	Yolksac larvae	6.40E+07	1.99E+05	1.90E+04	6.47E+06	7.07E+07
	Post Yolksac larvae	9.52E+05	1.25E+05	2.14E+03	1.49E+05	1.23E+06
	Juvenile	NA	NA	NA	NA	NA
	Total	2.15E+08	8.87E+05	6.58E+04	1.16E+07	2.28E+08
BEC Dry - Peak Flow	Egg	7.64E+07	2.85E+05	2.27E+04	2.53E+06	7.92E+07
	Yolksac larvae	3.25E+07	1.01E+05	9.63E+03	3.29E+06	3.59E+07
	Post Yolksac larvae	4.83E+05	6.33E+04	1.09E+03	7.58E+04	6.23E+05
	Juvenile	NA	NA	NA	NA	NA

Cooling System Alternative	Lifestage	River Herring	American Shad	Striped Bass	White Perch	All Species
	Total	1.09E+08	4.50E+05	3.34E+04	5.89E+06	1.16E+08
BEC Dry - Base Flow	Egg	3.15E+06	1.18E+04	9.33E+02	1.04E+05	3.26E+06
	Yolksac larvae	1.34E+06	4.17E+03	3.97E+02	1.35E+05	1.48E+06
	Post Yolksac larvae	1.99E+04	2.61E+03	4.47E+01	3.12E+03	2.57E+04
	Juvenile	NA	NA	NA	NA	NA
	Total	4.50E+06	1.85E+04	1.37E+03	2.43E+05	4.77E+06

Note(s): Entrainment estimates based on Hudson River Estuary Monitoring Program Icthyoplankton Survey
River herring 1980-95; American shad 1978, 1980-95; striped bass 1975-95; white perch 1975, 1977-95
NA - Not applicable (Juveniles are not considered vulnerable to entrainment based on the use of 2.0-mm mesh passive screens)

7.3.3 CMR Methodology for Estimating Entrainment Mortality

7.3.3.1 Overview

The effects of power plant cooling systems on aquatic populations may be estimated using mathematical models. These models typically use population data such as size, density and distribution of a species within the subject water body, and incorporate biological data such as hatching rates and time spent in the larval stage, to describe the population dynamics of a particular species. When combined with data about plant operations, such as water intake rates and discharge temperatures, the effect of a power station on aquatic populations may be estimated.

One common measure of a plant's effect on fish populations is the conditional mortality rate (CMR). The CMR is defined as the fraction of some initial population that would be lost due to power plant operations in the absence of all other causes of mortality. The CMR (m) may be calculated as follows:

$$m = 1 - \frac{\text{Number alive at time } T_1 \text{ with plant mortality}}{\text{Number alive at time } T_1 \text{ without plant mortality}}$$

For example, a CMR of 2 percent for white perch in a given year means that 2 percent of the white perch population that was present in the source water body was killed due to power plant operations. The concept of conditional mortality forms the basis of several assessment models including the Conditional Entrainment Mortality Rate (CEMR) model and the Empirical Transport Model (ETM).

The purpose of this analysis is to examine the CMR calculated for the ASGS using the CEMR model and the ETM to present the results of CMR modeling for the BEC using the calculation technique (ETM) employed recently for a similar study associated with the proposed Athens Generating Project.

CMR modeling was done for the existing four-unit operation as well as for the various BEC cooling system alternatives. Four representative target species within the Albany region (RKM 201-246) of the Hudson River were selected for this analysis: river herring (*Alosa aestivalis* and *A. pseudoharengus*), American shad (*A. sapidissima*), striped bass (*Morone saxatilis*), and white perch (*M. americana*).

Two sets of calculations are provided for each species for the once-through cooling systems. The first, identified as the 100% mortality, conservatively assumes that all of the species that are entrained do not survive. The second, identified as the estimated mortality, estimates the fraction of those entrained species that are lost due to plant operating factors. CMR estimates for closed-loop cooling system alternatives assume 100% mortality.

7.3.3.2 Description of CEMR and ETM Models

A brief discussion of the CEMR model and ETM that have been used to estimate entrainment mortality rates is presented below.

<u>Conditional Entrainment Mortality Rate (CEMR)</u>

Cooling water in the discharge canal is sampled to identify the number of organisms that are being entrained in the system. The CEMR then relates sampling data for each species to the estimated stock of that same species and life stage in the water body that supplies the plant. Based on this data, the fraction of a particular species that are lost due to plant entrainment may be estimated.

<u>Empirical Transport Model (ETM)</u>

This type of model is also designed to estimate entrainment loss, i.e., the probability that a fish will die from passage through the cooling water system of a power plant. By describing a series of possible conditions in the form of probabilities, losses due to entrainment in a plant's cooling water system may be estimated. The mathematical arguments below are among those used in the formulation of an ETM.

- The probability that a fish will be resident in the portion of the river affected by a power plant,
- The probability that a fish will be in the near-field area of the plant's water intake structure, and
- The probability that a fish will pass through the intake screens and ultimately die from plant passage.

Information about plant operations, such as average daily water flow and thermal characteristics, is also included in the model specification.

7.3.3.3 Impact Assessment by Species

Data on populations of aquatic species in the Hudson River were obtained from Longitudinal River Surveys (LRS) that were conducted for the Hudson River Utilities during the period 1975-1995. Table 7-6 summarizes the average annual CMR values for each cooling system alternative under both base (i.e., gas firing) and peak (i.e., oil distillate firing) operating conditions. The following subsections discuss the individual results for each of the target species.

Table 7-6 Average Annual CMR Values for Target Species

	Species			
Cooling System Alternative	**River Herring**	**American Shad**	**Striped Bass**	**White Perch**
Albany Steam Station Once-through	16.52%	22.69%	0.22%	3.31%
Albany Steam Station Once-through – CEMR	18.69%	26.45%	0.61%	1.91%
BEC Once-Through – Peak	13.55%	18.45%	0.26%	2.79%
BEC Once-Through – Base	13.43%	18.28%	0.26%	2.76%
BEC Wet – Peak	0.32%	0.53%	< 0.01%	0.05%
BEC Wet – Alt. Pump Schedule – Peak	0.27%	0.47%	< 0.01%	0.05%
BEC Wet – Intake Barrier Sys. – Peak	0.03%	0.05%	< 0.01%	0.01%
BEC Wet – Base	0.18%	0.29%	< 0.01%	0.03%
BEC Wet – Alt. Pump Schedule – Base	0.15%	0.26%	< 0.01%	0.03%
BEC Wet – Intake Barrier Sys. – Base	0.02%	0.03%	< 0.01%	< 0.01%
BEC Wet/Dry – Peak	0.31%	0.50%	< 0.01%	0.05%
BEC Wet/Dry – Alt. Pump Sched. – Peak	0.26%	0.45%	< 0.01%	0.05%
BEC Wet/Dry – Intake Barrier Sys. – Peak	0.03%	0.05%	< 0.01%	0.01%
BEC Wet/Dry – Base	0.17%	0.27%	< 0.01%	0.03%
BEC Wet/Dry – Alt. Pump Sched. – Base	0.14%	0.24%	< 0.01%	0.03%
BEC Wet/Dry – Intake Barrier Sys. – Base	0.02%	0.03%	< 0.01%	< 0.01%
BEC Dry – Peak	0.08%	0.12%	< 0.01%	0.01%
BEC Dry – Base	< 0.01%	0.01%	< 0.01%	< 0.01%

Note(s): All models assume 100% mortality, Empirical Transport Model (ETM) used in all CMR estimates except as noted

7.3.3.4 River Herring

The incubation period for river herring is 6 days at 15°C, which is close to the average ambient temperature during the spring spawning period. Yolk-sac larvae average 2.5-mm total length (TL) at hatching. Transition to the post yolk-sac stage occurs at about 5.1 mm TL (Mullen et al. 1986). Transformation to the juvenile stage is complete at 20 mm TL (Jones et al. 1978). At the temperature Assumed for incubation (15°C), the entire larval stage duration using Houde's (1989) model is 51.8 days and the average daily growth rate is 0.34 mm/day. Using this relationship, the following life stage durations were input to the model: eggs – 6 days; yolk-sac larvae – 7.7 days; and post yolk-sac larvae – 44.1 days. The estimated intervals for juveniles to outgrow vulnerability to entrainment for the existing ASGS and the BEC project with once-through cooling are 29.6 and 44.4 days, respectively. (NOTE: This calculation is based on a screen mesh size of 0.38 x 0.38-inch for the existing ASGS, and a screen slot mesh size of 0.25 x 0.50-inch for the BEC. If once-through cooling were employed at the BEC, the actual screen mesh size would be 0.125 x 0.50-inch. This would result in a small decrease in the duration of vulnerability compared to the existing ASGS.) Based on the use of 2.0-mm mesh passive screens, juveniles are not considered vulnerable to entrainment for the closed-loop cooling alternatives.

Table A.2-9 in Appendix A.2 shows the annual CMRs calculated for each of the alternatives under peak flow conditions using the ETM as well as those using the CEMR for the ASGS. (Note CMRs using the ETM could be calculated only for those years during which river herring were recorded in the longitudinal river ichthyoplankton survey [LRS] samples). Since an unmeasured proportion of river herring spawning occurs outside the River proper, in tributaries and in the Mohawk River, the LRS sampling of early life stages within the River may underestimate the true abundance (i.e., population size, HRDEIS 1999) and result in overestimated CMRs. For the ASGS, CMRs calculated using the ETM ranged from 5.66% to 32.31% (100% mortality) and from 5.20% to 29.51% during 1980-1995. The CEMR values computed for the ASGS existing operations were higher than those computed using the ETM during 1984-1985 and 1987-1992. The CMRs decrease considerably with each of the BEC alternatives. CMRs were lowest for BEC with either wet or wet/dry cooling towers with an intake barrier system also in place (0.03% for both alternatives).

Table A.2-10 in Appendix A.2 shows the annual CMRs calculated for each of the alternatives under base flow conditions. All CMR values for each of the BEC closed-loop cooling system alternatives under base flow conditions are less than 0.2%; and approximately 50 percent less than those for peak flow conditions. CMRs for BEC with either wet or wet/dry cooling towers with an intake barrier system are 0.02%.

7.3.3.5 American Shad

The incubation period for American shad is 6 days at 17°C, which is close to the average ambient temperature during the spring spawning period (LMS 1988). Yolk-sac larvae are 5.7 mm TL at hatching and transition to the post yolk-sac stage occurs at about 12.2 mm TL. The juvenile stage begins once the larvae reach 27-mm TL (Jones et al. 1978). At the temperature assumed for incubation (17°C), the entire larval stage duration using Houde's (1989) model is 45 days and the average daily growth rate is 0.47 mm/day. Using this relationship, the following life stage durations were input to the model: eggs – 6 days; yolk-sac larvae – 13.7 days; and post yolk-sac larvae – 31.3 days. The intervals estimated for juveniles to outgrow vulnerability to entrainment for the existing the ASGS and the BEC project with once-through cooling are 6.3 and 16.9 days, respectively. Based on the use of 2.0-mm mesh passive screens, juveniles are not considered vulnerable to entrainment for the closed-loop cooling alternatives.

Table A.2-11 in Appendix A.2 shows the annual CMRs calculated for each of the alternatives under peak flow condition using the ETM as well as those using the CEMR for the ASGS. (Note CMRs using the ETM could be calculated only for those years during which American shad were recorded in the LRS samples). Due to the proximity of the Troy Dam and its effect on tidal flow, it is likely that the entrainment mortality estimates for the ASGS are biased high (HRDEIS 1999). For the existing ASGS, CMRs calculated using the ETM ranged from 3.65% to 46.22% (100% mortality) and from 3.10% to 40.61% during 1978-1995. The CMRs decreased considerably with each of the BEC alternatives, averaging 18.45% and 9.01% for the BEC project with once-through cooling (100% mortality and estimated mortality, respectively), 0.53% for the BEC project with wet cooling towers, 0.50% for the BEC project with wet/dry cooling towers, and 0.12% for the BEC project with dry cooling towers. Using an alternative pump schedule with wet or wet/dry cooling towers reduces annual CMRs by approximately 11%; while installation of an intake barrier system reduces annual CMRs to 0.05%.

Table A.2-12 in Appendix A.2 shows the annual CMRs calculated for each of the alternatives under base flow conditions. All CMR values for each of the BEC closed-loop cooling system alternatives under base flow conditions are less than 0.3%. The CMRs decrease considerably compared to peak flow conditions with each of the BEC alternatives. CMRs were lowest for BEC with either wet or wet/dry cooling towers with an intake barrier system also in place (0.03% for both alternatives) and for BEC with dry cooling towers in place (0.01%).

7.3.3.6 Striped Bass

The incubation period for striped bass is 2.6 days at 15°C, which is close to the average ambient temperature during the spring spawning period (Fay et al. 1983). Yolk-sac larvae are 2 mm TL at hatching and the post yolk-sac larval stage begins at about 6 mm TL (Hardy 1978). Transition to the juvenile stage occurs at 25 mm TL (Fay et al. 1983). At the temperature assumed for incubation (15°C), the entire larval stage duration using Houde's (1989) model is 51.8 days and the average daily growth rate is 0.44 mm/day. Using this relationship, the following life stage durations were input to the model: eggs – 2.6 days; yolk-sac larvae – 9 days; and post yolk-sac larvae – 42.8 days. The intervals estimated for juveniles to outgrow vulnerability to entrainment for the existing ASGS and the BEC project with once-through cooling are 11.3 and 22.5 days, respectively. Based on the use of 2.0-mm mesh passive screens, juveniles are not considered vulnerable to entrainment for the closed-loop cooling alternatives.

Table A.2-13 shows the annual CMRs calculated for each of the alternatives under peak water withdrawal requirements (i.e., oil distillate firing) using the ETM as well as those using the CEMR for the ASGS. For the existing ASGS, CMRs calculated using the ETM ranged from <0.01% to 1.15% (100% mortality) and from <0.01% to 0.49% (estimated mortality) during 1975-1995. Due to the longer entrainment interval for the BEC project with once-through cooling, CMR values were slightly higher for some years and averaged 0.26% (100% mortality). The CMRs decreased considerably with each of the remaining BEC alternatives, averaging 0.05% for BEC project with once-through cooling (estimated mortality), and <0.01% for the BEC project with each closed-loop cooling system alternative. The CEMR values computed for the ASGS existing operations were higher than those computed using the ETM during 1975-1985 and 1987-1994.

Table A.2-14 in Appendix A.2 shows the annual CMRs calculated for each of the alternatives under base (i.e., gas firing) water withdrawal conditions. All CMR values for each of the BEC closed-loop cooling system alternatives under base flow conditions are less than 0.01%.

7.3.3.7 White Perch

The incubation period for white perch is 2.9 days at 15°C, which is close to the average ambient temperature during the spring spawning period (LMS 1988). Yolk-sac larvae are 1.7 mm TL at hatching and transition to the post yolk-sac larval stage occurs at 3.9 mm TL (Hardy 1978). The juvenile stage begins at 20 mm TL (EA EST 1995; Hardy 1978). At the temperature assumed for incubation (15°C), the entire larval stage duration using Houde's (1989) model is 51.8 days and the average daily growth rate is 0.35 mm/day. Using this relationship, the following life stage durations were input to the model: eggs – 2.9 days; yolk-sac larvae – 6.2 days; post yolk-sac larvae – 45.6 days. The intervals estimated for juveniles to outgrow vulnerability to entrainment for the existing ASGS and the BEC project with once-through cooling are 28.3 and 42.5 days, respectively. Based on the use of 2.0-mm mesh passive screens, juveniles are not considered vulnerable to entrainment for the closed-loop cooling alternatives.

Table A.2-15 shows the annual CMRs calculated for each of the alternatives using the ETM as well as those using the CEMR for the ASGS. (Note CMRs using the ETM could be calculated only for those years during which white perch were recorded in the LRS samples). For the ASGS, CMRs calculated using the ETM ranged from 0.87% to 9.33% (100% mortality) and from 0.78% to 6.37% (estimated mortality) during 1975-1995. The CMRs decreased considerably with each of the BEC alternatives, averaging 2.79% and 0.98% for the BEC project with once-through cooling (100% mortality and estimated mortality, respectively) and 0.05% for the BEC project with wet and wet/dry cooling towers. CMRs for the BEC project with dry cooling towers and wet or wet/dry cooling towers with an intake barrier system were 0.01%.

Table A.2-16 in Appendix A.2 shows the annual CMRs calculated for each of the alternatives under base (i.e., gas firing) water withdrawal conditions. All CMR values for each of the BEC closed-loop cooling system alternatives under base flow conditions are less than 0.01%.

7.3.3.8 Summary

Reductions in water withdrawal for the BEC cooling system alternatives compared to the existing ASGS are projected to result in a substantial reduction in the numbers of organisms entrained and a corresponding reduction in the potential impact of entrainment losses on river-wide aquatic resources. Average annual CMR values for each of the four target species are less than 0.3% under base (i.e., gas firing) operating conditions and less than 0.6% under peak (i.e., oil distillate firing) conditions for BEC closed-loop cooling system alternatives. Estimated entrainment and CMR model estimates are highly conservative, assuming continuous (24-hr) station operation. The use of a 2.0-mm mesh passive screen system for the alternative closed-cycle cooling system alternatives and additional intake technology considerations (e.g., fine-mesh barrier system) at the BEC are projected to result in further reductions in entrainment and potential impacts. Results of the modeling for the four target species demonstrate that, regardless of the cooling technology selected, the impact of the BEC on aquatic species would be significantly less than that observed with operation of the ASGS.

7.3.4 Equivalent Adult Analysis

Although there may be mortality associated with entrainment, the natural mortality rates for early life stages of fish are generally high. Natural mortality rates are typically very high for eggs, but decline progressively as the fish matures to adulthood. The impact of removal of a given number of eggs, larvae and juveniles on the overall population can be put into perspective through the use of equivalent adult analysis. This analysis method estimates the number of adults that would be lost as a result of entrainment of younger life stages, while accounting for natural mortality.

Estimated entrainment losses for each target species and life stage were used to calculate the equivalent number of adults lost for the ASGS and for the proposed BEC cooling system alternatives. Entrainment estimates using both ASGS entrainment monitoring data and LRS data were used to estimate equivalent adult losses. A summary of the estimated number and estimated biomass of equivalent adults lost is provided in Table 7-7 through Table 7-10. Results of the equivalent adult analysis from either a numeric or biomass perspective for the four target species demonstrate that, regardless of the cooling technology selected, the impact of the BEC on aquatic species would be significantly less than that observed with operation of the ASGS.

Table 7-7 Summary of Equivalent Adults (numbers lost) for Target Species Based on ASGS Data

Cooling System Alternative	Total Plant Flow (m3/day)	River Herring	American Shad	Striped Bass	White Perch
Existing Albany Steam Station	1,820,010	84,777	NA	NA	29,939
BEC Once-Through Cooling - Peak Flow	1,301,179	60,609	NA	NA	21,405
BEC Once-Through Cooling - Base Flow	1,285,764	59,891	NA	NA	21,151
BEC Wet - Peak Flow	32,286	1,504	NA	NA	531
BEC Wet Alt. Pump Sched - Peak Flow	32,286	1,207	NA	NA	519
BEC Wet Intake Barrier Sys - Peak Flow	32,286	150	NA	NA	53
BEC Wet - Base Flow	17,863	832	NA	NA	294
BEC Wet Alt. Pump Sched - Base Flow	17,863	668	NA	NA	287
BEC Wet Intake Barrier Sys - Base Flow	17,863	83	NA	NA	29
BEC Wet/Dry - Peak Flow	30,858	1,437	NA	NA	508
BEC Wet/Dry Alt. Pump Sched - Peak Flow	30,858	1,154	NA	NA	496
BEC Wet/Dry Intake Barrier Sys - Peak Flow	30,858	144	NA	NA	51
BEC Wet/Dry - Base Flow	16,533	770	NA	NA	272
BEC Wet/Dry Alt. Pump Sched - Base Flow	16,533	618	NA	NA	266
BEC Wet/Dry Intake Barrier Sys - Base Flow	16,533	77	NA	NA	27
BEC Dry - Peak Flow	7,550	475	NA	NA	124
BEC Dry - Base Flow	311	20	NA	NA	5

Note(s): Entrainment estimates based on Albany Steam Generating Station 1983 Entrainment Monitoring Survey
NA - Not applicable (little or none collected during 1983 entrainment sampling program)
Estimates assume 100% entrainment mortality

Table 7-8 Summary of Equivalent Adults (lbs lost) for Target Species Based on ASGS Data

Cooling System Alternative	Total Plant Flow (m3/day)	River Herring	American Shad	Striped Bass	White Perch
Existing Albany Steam Station	1,820,010	31,589	NA	NA	1,696
BEC Once-Through Cooling - Peak Flow	1,301,179	22,584	NA	NA	1,213
BEC Once-Through Cooling - Base Flow	1,285,764	22,317	NA	NA	1,198
BEC Wet - Peak Flow	32,286	560	NA	NA	30
BEC Wet Alt. Pump Sched - Peak Flow	32,286	450	NA	NA	29
BEC Wet Intake Barrier Sys - Peak Flow	32,286	56	NA	NA	3
BEC Wet - Base Flow	17,863	310	NA	NA	17
BEC Wet Alt. Pump Sched - Base Flow	17,863	249	NA	NA	16
BEC Wet Intake Barrier Sys - Base Flow	17,863	31	NA	NA	2
BEC Wet/Dry - Peak Flow	30,858	536	NA	NA	29
BEC Wet/Dry Alt. Pump Sched - Peak Flow	30,858	430	NA	NA	28
BEC Wet/Dry Intake Barrier Sys - Peak Flow	30,858	54	NA	NA	3
BEC Wet/Dry - Base Flow	16,533	287	NA	NA	15
BEC Wet/Dry Alt. Pump Sched - Base Flow	16,533	230	NA	NA	15
BEC Wet/Dry Intake Barrier Sys - Base Flow	16,533	29	NA	NA	2
BEC Dry - Peak Flow	7,550	177	NA	NA	7
BEC Dry - Base Flow	311	7	NA	NA	0

Note(s): Entrainment estimates based on Albany Steam Generating Station 1983 Entrainment Monitoring Survey
NA - Not applicable (little or none collected during 1983 entrainment sampling program)
Estimates assume 100% entrainment mortality

Table 7-9 Summary of Equivalent Adults (numbers lost) for Target Species Based on LRS Data

Cooling System Alternative	Total Plant Flow (m3/day)	River Herring	American Shad	Striped Bass	White Perch
Existing Albany Steam Station	1,820,010	399,657	726,867	1,202	1,565,637
BEC Once-Through Cooling - Peak Flow	1,301,179	285,726	519,659	860	1,119,320
BEC Once-Through Cooling - Base Flow	1,285,764	282,341	513,503	849	1,106,060
BEC Wet - Peak Flow	32,286	7,074	262	1	10,208
BEC Wet Alt. Pump Sched - Peak Flow	32,286	6,324	239	1	10,023
BEC Wet Intake Barrier Sys - Peak Flow	32,286	707	26	0	1,021
BEC Wet - Base Flow	17,863	7,074	262	1	10,208
BEC Wet Alt. Pump Sched - Base Flow	17,863	3,499	132	0	5,545
BEC Wet Intake Barrier Sys - Base Flow	17,863	391	14	0	565
BEC Wet/Dry - Peak Flow	30,858	6,761	250	1	9,757
BEC Wet/Dry Alt. Pump Sched - Peak Flow	30,858	6,045	228	1	9,579
BEC Wet/Dry Intake Barrier Sys - Peak Flow	30,858	676	25	0	976
BEC Wet/Dry - Base Flow	16,533	3,623	134	0	5,228
BEC Wet/Dry Alt. Pump Sched - Base Flow	16,533	3,239	122	0	5,132
BEC Wet/Dry Intake Barrier Sys - Base Flow	16,533	676	13	0	523
BEC Dry - Peak Flow	7,550	1,654	61	0	2,387
BEC Dry - Base Flow	311	68	3	0	98

Note(s):Entrainment estimates based on Hudson River Estuary Monitoring Program Icthyoplankton Survey
River herring 1980-95; American shad 1978, 1980-95; striped bass 1975-95; white perch 1975, 1977-95
Estimates assume 100% entrainment mortality

Table 7-10 Summary of Equivalent Adults (lbs lost) for Target Species Based on LRS Data

Cooling System Alternative	Total Plant Flow (m3/day)	River Herring	American Shad	Striped Bass	White Perch
Existing Albany Steam Station	1,820,010	148,920	2,776,714	6,919	88,706
BEC Once-Through Cooling - Peak Flow	1,301,179	106,468	1,985,155	4,947	63,418
BEC Once-Through Cooling - Base Flow	1,285,764	105,206	1,961,637	4,888	62,667
BEC Wet - Peak Flow	32,286	2,636	1,000	4	578
BEC Wet Alt. Pump Sched - Peak Flow	32,286	2,357	913	4	568
BEC Wet Intake Barrier Sys - Peak Flow	32,286	264	100	0	58
BEC Wet - Base Flow	17,863	1,458	553	2	320
BEC Wet Alt. Pump Sched - Base Flow	17,863	1,304	505	2	314
BEC Wet Intake Barrier Sys - Base Flow	17,863	146	55	0	32
BEC Wet/Dry - Peak Flow	30,858	2,519	955	4	553
BEC Wet/Dry Alt. Pump Sched - Peak Flow	30,858	2,252	873	4	543
BEC Wet/Dry Intake Barrier Sys - Peak Flow	30,858	252	96	0	55
BEC Wet/Dry - Base Flow	16,533	1,350	512	2	296
BEC Wet/Dry Alt. Pump Sched - Base Flow	16,533	1,207	467	2	291
BEC Wet/Dry Intake Barrier Sys - Base Flow	16,533	135	51	0	30
BEC Dry - Peak Flow	7,550	616	234	1	135
BEC Dry - Base Flow	311	25	10	0	6

Note(s): Entrainment estimates based on Hudson River Estuary Monitoring Program Icthyoplankton Survey
River herring 1980-95; American shad 1978, 1980-95; striped bass 1975-95; white perch 1975, 1977-95
Estimates assume 100% entrainment mortality

7.3.5 Estimated Pounds Lost to the Fishery

Another approach for placing the potential entrainment fish losses at the BEC in perspective was to provide estimates of pounds lost to the commercial/recreational fishery as a result of the operation of the ASGS and for the proposed BEC cooling system alternatives. The method simply involves multiplying the estimates of pounds taken in the commercial/recreational fishery for each species by the CMR calculated for the ASGS and different BEC cooling system alternatives (see Section 7.3.3).

The method was employed for the Athens Project on the River (Englert 1999) and was characterized as conservative (i.e., overestimating) because it does not take into account the possible density dependent response of the population that can reduce the effect on the fishery and the resultant CMR estimate. The estimated pounds lost to the fishery data were obtained from the National Marine Fisheries Service (NMFS) website. NYSDEC has previously indicated that the method is sound and conservative but believes there are some biases and uncertainties in the NMFS data (Englert 1999). A summary of the estimated pounds lost to the commercial and recreational fishery is provided in Table 7-11 and Table 7-12. Results of the estimated pounds lost to the fishery for the four target species demonstrate that, regardless of the cooling technology selected, the impact of the BEC on aquatic species would be significantly less than that observed with operation of the ASGS.

Table 7-11 Average Annual Estimated Loss (lbs) to New York State Commercial Landings

Cooling System Alternative	River Herring	American Shad	Striped Bass	White Perch
Existing Albany Steam Station	5,092	101,027	946	2,017
Existing Albany Steam Station - CEMR	2,760	115,413	2,405	1,105
BEC Once-Through Cooling - Peak Flow	4,428	82,594	1,118	1,732
BEC Once-Through Cooling - Base Flow	4,389	81,830	1,107	1,716
BEC Wet Cooling Tower - Peak Flow	68	2,332	6	31
BEC Wet Cooling Tower and Alternative Pump Schedule - Peak Flow	55	2,070	6	31
BEC Wet Cooling Tower and Intake Barrier System - Peak Flow	7	234	1	3
BEC Wet Cooling Tower - Base Flow	38	1,294	3	17
BEC Wet Cooling Tower and Alternative Pump Schedule - Base Flow	30	1,148	3	17
BEC Wet Cooling Tower and Intake Barrier System - Base Flow	4	130	0	2
BEC Wet/Dry Cooling Tower - Peak Flow	65	2,229	5	30
BEC Wet/Dry Cooling Tower and Alternative Pump Schedule - Peak Flow	52	1,979	5	29
BEC Wet/Dry Cooling Tower and Intake Barrier System - Peak Flow	6	223	1	3
BEC Wet/Dry Cooling Tower - Base Flow	35	1,198	3	16
BEC Wet/Dry Cooling Tower and Alternative Pump Schedule - Base Flow	28	1,063	3	16
BEC Wet/Dry Cooling Tower and Intake Barrier System - Base Flow	3	120	0	2
BEC Dry Cooling Tower - Peak Flow	16	548	1	7
BEC Dry Cooling Tower - Base Flow	1	23	0	0

Note(s): All alternatives assume 100% mortality, Empirical Transport Model (ETM) used in all CMR estimates except as noted

Annual losses based on estimated annual CMR values and annual NYS Landings

Table 7-12 Average Annual Estimated Loss (lbs) to New York State Recreational Landings

Cooling System Alternative	River Herring	American Shad	Striped Bass	White Perch
Existing Albany Steam Station	6,021	128,577	2,745	145
Existing Albany Steam Station - CEMR	6,914	146,886	5,528	90
BEC Once-Through Cooling - Peak Flow	4,888	105,117	3,593	114
BEC Once-Through Cooling - Base Flow	4,844	104,145	3,559	113
BEC Wet Cooling Tower - Peak Flow	118	2,968	5	3
BEC Wet Cooling Tower and Alternative Pump Schedule - Peak Flow	100	2,634	5	3
BEC Wet Cooling Tower and Intake Barrier System - Peak Flow	12	297	0	0
BEC Wet Cooling Tower - Base Flow	66	1,646	3	2
BEC Wet Cooling Tower and Alternative Pump Schedule - Base Flow	55	1,461	3	2
BEC Wet Cooling Tower and Intake Barrier System - Base Flow	7	165	0	0
BEC Wet/Dry Cooling Tower - Peak Flow	113	2,837	5	3
BEC Wet/Dry Cooling Tower and Alternative Pump Schedule - Peak Flow	95	2,518	5	3
BEC Wet/Dry Cooling Tower and Intake Barrier System - Peak Flow	11	284	0	0
BEC Wet/Dry Cooling Tower - Base Flow	61	1,524	2	1
BEC Wet/Dry Cooling Tower and Alternative Pump Schedule - Base Flow	51	1,353	3	1
BEC Wet/Dry Cooling Tower and Intake Barrier System - Base Flow	6	153	0	0
BEC Dry Cooling Tower – Peak Flow	28	697	1	1
BEC Dry Cooling Tower – Base Flow	1	29	0	0

Note(s): All alternatives assume 100% mortality, Empirical Transport Model (ETM) used in all CMR estimates except as noted
Annual losses based on estimated annual CMR values and annual NYS Landings. Annual American shad landings based on a percentage of commercial landings.

8.0 INCREMENTAL COSTS AND BENEFITS RELATIVE TO PROPOSED COOLING SYSTEM

PSEGNY proposes to install a closed-cycle cooling system with wet towers and wedge wire screens for the proposed BEC. This chapter evaluates the incremental costs and benefits of alternatives to this proposed cooling system. The results are based on detailed technical, cost and biological effectiveness information developed in Chapters 4 and 7, and Appendices A through D.

8.1 Methodology for Evaluating Incremental Costs and Benefits

This section provides background on the evaluation of incremental costs and benefits. The background includes an overview of the analysis of incremental costs and benefits and descriptions of the types of costs and benefits included in this analysis.

8.1.1 Overview of the Analysis of Incremental Costs and Benefits Relative to Wet Tower Alternative

Evaluation of incremental costs and benefits is an approach for providing information to decision makers faced with the task of comparing alternative projects or policies. The approach involves systematic enumeration of additional benefits and costs that would accrue to members of society if an alternative to the baseline project or policy is undertaken. The baseline represents a benchmark against which alternatives are compared. This approach provides an *ex ante* perspective; alternatives are evaluated in advance to aid in deciding whether one of the proposed alternatives should be undertaken.

The rationale for evaluating the incremental costs and benefits of alternative project or policies—such as alternative cooling water systems at BEC—is to allow society's resources to be put to their most valuable use. The most general approach to comparing alternatives is to perform a cost-benefit analysis that compares the total costs and benefits relative to the "do nothing" alternative. In some contexts, however, such a comparison is infeasible or complicated by additional factors. Since the proposed BEC requires a cooling system, there is no apparent "do nothing" alternative against which to compare cooling system alternatives. Consequently, the analysis uses the proposed cooling system as a baseline for comparison. In evaluating other alternatives, the basic principle is to select the alternative that produces the greatest net incremental benefits (i.e., incremental benefits minus incremental costs). It is possible that all alternatives produce net incremental benefits that are negative. In that case, the higher value alternative is the baseline alternative.

Evaluation of incremental costs and benefits requires the careful enumeration of the monetary value of different impacts resulting from BTA alternatives. These impacts are typically separated into costs (negative impacts) and benefits (positive effects), although the two categories are closely related. The costs included in cost-benefit assessments should reflect costs to society as a whole, rather than transfers from one group to another. EPA Cost-Benefit Guidelines define social cost as follows:

> The total social cost is the sum of the opportunity costs incurred by society because of a new regulatory policy; the opportunity costs are the value of the goods and services lost by society resulting from the use of resources to comply with and implement the regulation, and the reduction in output. (U.S. Environmental Protection Agency 2000, p. 113)

This definition is consistent with guidelines from the Office of Management and Budget (1996) and standard economic theory as described in economic texts (e.g., Stokey and Zeckhauser 1978 and Nas 1996).

EPA guidelines describe five basic components of total social costs (U.S. Environmental Protection Agency 2000, p.113-4):

- Real-resource compliance costs (including unpriced resources);
- Government regulatory costs;
- Social welfare losses (i.e., deadweight welfare losses resulting from changes in prices to consumers)[3];
- Transitional costs[4]; and
- Indirect costs (e.g., affects on product quality, productivity, and innovation).

The most significant component of the total costs for regulatory requirements typically is the value of the real-resource compliance costs. The EPA Cost-Benefit Guidelines, for example, state: "The largest fraction of direct social costs arises from the real-resource costs due to the new regulation. These new compliance costs arise from the installation, operation, and maintenance of new capital equipment, or are a results of changes in the production process that raise the price of producing the good." (U.S. Environmental Protection Agency 2000, p.119)

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[3] "These are the losses in consumer and producer surpluses associated with the rise in price (or decreases in output) of goods and services that occurs as a result of an environmental policy." (U.S. Environmental Protection Agency 2000, p. 114)

[4] "These include the value of resources that are displaced because of regulation-induced reductions in production, and the price real-resource costs of reallocating those resources." (U.S. Environmental Protection Agency 2000, p. 114)

The benefits included in cost-benefit assessments should reflect benefits to society. Estimates of environmental benefits reflect social benefits when they are based on the willingness to pay (WTP) of individuals who receive the increased environmental services (e.g. recreational fishing services). The EPA guidelines, for example, state that "The benefits of a policy are the sum total of each affected individual's WTP [willingness-to-pay] for the policy" (U.S. Environmental Protection Agency 2000, p.61). WTP represents the value of a good or service in monetary terms (i.e., the amount the individual is "willing-to-pay" in dollar terms). The current EPA Cost-Benefit Guidelines for benefits assessment summarize this approach as follows:

> The willingness to trade off compensation for goods or services can be measured either as *willingness to pay* (WTP) or *willingness to accept* (WTA). Economists generally express WTP and WTA in monetary terms. In the case of an environmental policy, willingness to pay is the maximum amount of money an individual would voluntarily exchange to obtain an improvement (or avoid a decrement) in the environmental effects of concern. (U.S. Environmental Protection Agency 2000, p. 60, emphasis in original)

EPA notes that: "In practice, WTP is generally used to value benefits because it is often easier to measure and estimate." (U.S. Environmental Protection Agency 2000, p. 61) This approach to measuring benefits is consistent with Office of Management guidelines (1996) and standard economic texts (e.g., Stokey and Zeckhauser 1978, Tietenberg 1996 and Nas 1996).

8.1.2 Types of Costs and Benefits Considered in this Study

The costs in this study represent the social costs of cooling system alternatives. The following are the three major components of the cost of cooling system alternatives evaluated in this study:

1. *Capital costs.* Capital costs are the one-time costs of construction and installation of cooling system equipment. Capital costs are private real resource costs.

2. *Operating and Maintenance (O&M) Costs.* Operating and maintenance (O&M) costs are changes in the operation and maintenance costs of BEC due to cooling system alternatives. O&M costs are private real resource costs.

3. *Costs Associated with Power Impacts.* Implementation of cooling systems would result in impacts to power generation at BEC. The impacts would result in social costs due to increases in fuel and operations and maintenance costs as a result of the power impacts.

These cost categories correspond to the real-resource compliance costs of the proposed action. These estimates do not include government regulatory costs, social welfare losses, transitional costs, and indirect costs, since these costs were judged not to be significant for the cooling system alternatives at BEC. To the degree that these costs are important, the social costs estimates may understate the actual social costs of cooling systems.

The benefits quantified in this study consist of commercial and recreational fishing benefits due to cooling system alternatives relative to the proposed wet tower cooling system. The additional fish are measured in terms of increases in fishery catch (weight) for each of four species – American shad, river herring, striped bass, and white perch. Appendix A provides details on the estimation of changes in catch for each species. Increases in commercial and recreational fishery catch are valued by developing estimates of the willingness-to-pay for commercial and recreational fish, expressed in dollars per pound.

Some of the alternatives would have adverse environmental effects that are not considered quantitatively in the cost-benefit analysis. These include noise and aesthetic impacts. Noise impacts are discussed in Chapter 5, and aesthetic impacts, including plume and tower visibility impacts, are discussed in Chapter 6. The values of these effects are not calculated due to lack of necessary information to make reliable estimates.

8.1.3 Estimation of Incremental Costs and Benefits Relative to Wet Tower Alternative

The incremental costs and benefits reported in this chapter are estimated relative to the proposed cooling system, which includes closed-cycle cooling with wet towers and wedge wire screens. For each alternative, incremental costs associated with each cost category are estimated by taking the difference between the costs with the alternative cooling system and the costs with the proposed (baseline) system. Incremental benefits are estimated similarly. The costs and benefits associated with each alternative, including the proposed Wet Tower alternative, are presented in detailed form in Appendix C (Costs) and Appendix D (Benefits).

8.2 Outline of Chapter 8

The remainder of the chapter is organized as follows. Section 8.3 provides brief overviews of the selected alternatives. Section 8.4 presents the incremental cost estimates for these alternatives. Section 8.5 provides estimates of the incremental benefits. Section 8.6 provides incremental cost-benefit comparisons. Section 8.7 considers the sensitivity of results to alternative assumptions and omitted effects. Appendix B provides additional information on the methodologies and results. Appendix C provides detailed total costs, and Appendix D provides detailed total benefits.

The estimates of the costs and benefits of cooling system alternatives in this chapter are based upon sound economic principles and methodologies. The cost estimates are based upon detailed technical and economic information on annual real-resource costs and other costs related to each alternative as well as a sound economic methodology to aggregate the annual values into estimates of the present value of costs for each alternative. The benefit estimates are based upon detailed information on the additional fish protected by each alternative as well as on detailed estimates of the values of additional fish caught by commercial and recreational fishermen. As with the costs, the annual benefit values are aggregated into estimates of the present value of the benefits for each alternative using sound economic principles. All of the procedures described in this chapter reflect sound cost-benefit methodology.

8.3 Overview of Cooling System Alternatives Considered for Application at BEC

This section provides an overview of the alternative cooling systems for which detailed incremental cost and benefit information are developed. These incremental costs are estimated relative to the Wet Tower alternative, which would install a closed-cycle cooling system using wet cooling towers and a wedge wire screen. The closed-cycled cooling systems considered in this analysis employ three different types of tower: Wet Towers, Wet/Dry (Hybrid) Towers, and Dry Towers. Full descriptions and discussions of each cooling tower option are provided in Chapter 2.

Each of the alternatives considered in this study are described briefly below.

1. *Once Through.* This alternative would employ a once-through cooling system with modified fine-mesh traveling screens.

2. *Wet Towers with Seasonal Gunderboom.* This alternative would install a closed-cycle cooling system using wet cooling towers, a wedge wire screen, and a seasonally employed Gunderboom.

3. *Wet Towers with Holding Tank.* This alternative would install a closed-cycle cooling system using wet cooling towers and a wedge wire screen. Intake water during biologically active periods would be supplied by a water tank, which would be filled during periods of low biological activity.

4. *Wet/Dry Towers.* This alternative would install a closed-cycle cooling system using wet/dry (hybrid) cooling towers with a wedge wire screen.

5. *Wet/Dry Towers with Seasonal Gunderboom.* This alternative would install a a closed-cycle cooling system using wet/dry (hybrid) cooling towers, a wedge wire screen, and a seasonally employed Gunderboom.

6. *Wet/Dry Towers with Holding Tank.* This alternative would install a closed-cycle cooling system using wet/dry cooling towers and a wedge wire screen. Intake water during biologically active periods would be supplied by a water tank, which would be filled during periods of low biological activity.

7. *Dry Cooling Towers.* This alternative would install a closed-cycle cooling system using dry cooling towers with a wedge wire screen.

8.4 Incremental Costs of Cooling System Alternatives Relative to Wet Tower Alternative

This section presents the incremental costs of the alternatives evaluated in this study. The first subsection provides an overview of the methodology used to estimate costs. The following subsections provide methodology and results for the major cost categories. The final subsection reports the total incremental costs of the alternatives.

8.4.1 Overview of Cost Methodology

Incremental costs are measured as the present value of additional resource costs and other relevant costs related to each of the alternatives. As discussed above, this study develops estimates for three major categories of cost:

Construction costs;

Operating and maintenance (O&M) costs; and

Costs associated with power impacts at BEC.

Construction costs include the costs of installing equipment. Operating and maintenance (O&M) costs include the annual costs of operating and maintaining equipment once it has been installed as well as any change in O&M costs for the facility as a whole. Power costs are the result of changes in continuing operation that lead to increased power requirements or reduced generation efficiency. The dollar value of the impacts relate to increased fuel consumption and changes in air emissions that would result from each alternative.

Incremental costs are developed as estimates of the changes in resource costs or other costs incurred in each year due to each alternative relative to the proposed cooling system. Total incremental costs are calculated as the present value of annual costs as of January 1, 2002, the date at which construction of the alternatives is assumed to begin. BEC is assumed to have a 25-year lifetime starting from 2003, the year in which power is first generated. The inflation-adjusted discount rate used in the analysis is 7 percent, based upon recommendations by the Office of Management and Budget (OMB 1996). All costs are in January 2000 dollars.[5]

8.4.2 Incremental Construction Costs Relative to Wet Tower Alternative

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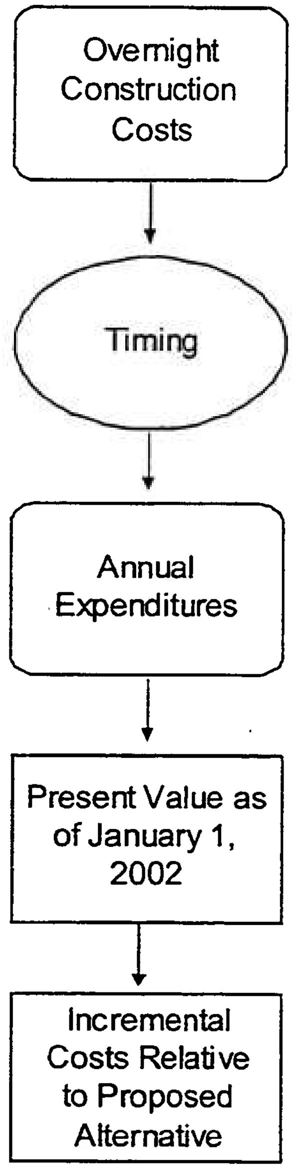
[5] The distinction of year 2000 dollars deals with the adjustment of dollars for inflation to account for the fact that the value of a dollar (generally) declines over time. This is not to be confused with the time value of money, or the fact that money can earn interest over time, which is accounted for by using discount rates to calculate present values as of January 1, 2002.

Construction costs consist of the capital, labor, and materials costs associated with the construction and installation of the alternatives.

8.4.2.1 Methodology

Figure 8-1 illustrates the methodology used to estimate incremental construction costs. Appendix B provides detailed estimates of the overnight capital costs required to develop each of the alternatives. Overnight capital costs are engineering estimates of the cost of installing the necessary structures and modifications using year 2000 prices for materials, equipment and labor. These cost estimates assume the modifications can be completed immediately (i.e. "overnight").

Figure 8-1 Methodology for Incremental Construction Costs Relative to Wet Tower Alternative



The actual timing of the expenditures, however, affects their present value. Incurring expenditures later lowers their present value, since a return could be gained in financial markets during the interim. The time required to complete construction of the alternatives is 18 months for all alternatives. The overnight cost estimates and the information regarding the timing of costs are used to develop estimates of the annual expenditures associated with the capital costs of construction for each of the eight alternatives. These annual values are provided in Appendix C. Annual costs are translated into present values using a real discount rate of 7 percent.

8.4.2.2 Results

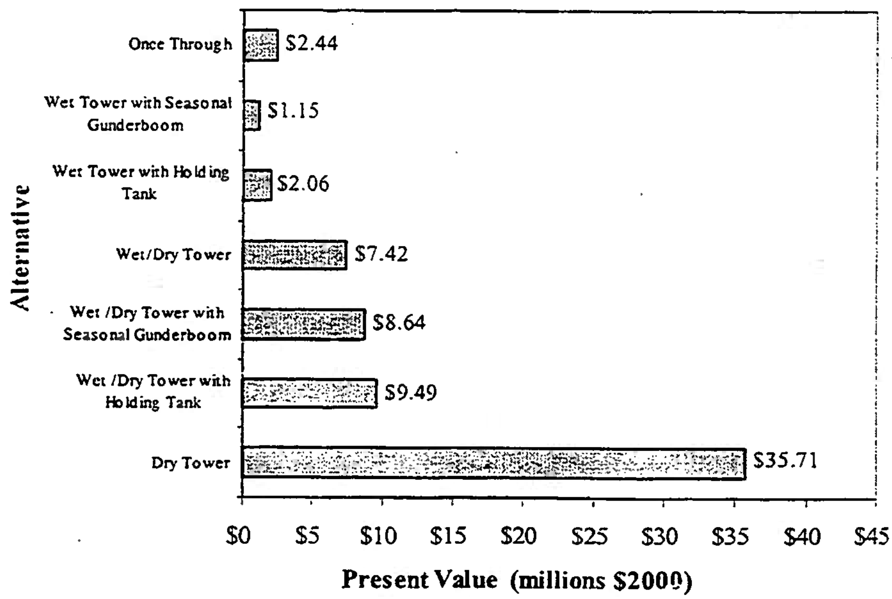
The present values of the estimated incremental construction costs for each of the seven alternatives are provided in Table 8-1 and shown graphically in Figure 8-2. The incremental construction costs for the alternatives differ substantially. The Wet Tower with Seasonal Gunderboom has the lowest incremental construction cost of $1.15 million. The Dry Tower is the most expensive relative to the Wet Tower, with an incremental construction cost of $35.71 million. The other cooling tower alternatives have incremental construction costs ranging from $2.06 million to $9.49 million.

Table 8-1 Incremental Construction Costs of Cooling System Alternatives Relative to Wet Tower Alternative

Alternative	Present Value of Construction Costs (millions of year 2000 $)
Once Through	$ 2.44
Wet Tower with Seasonal Gunderboom	$ 1.15
Wet Tower with Holding Tank	$ 2.06
Wet/Dry Tower	$ 7.42
Wet/Dry Tower with Seasonal Gunderboom	$ 8.64
Wet/Dry Tower with Holding Tank	$ 9.49
Dry Tower	$35.71

Note: All values are present values as of January 1, 2002, in millions of 2000 dollars.
Source: NERA calculations as explained in text.

Figure 8-2 Incremental Construction Costs of Cooling System Alternatives Relative to Wet Tower Alternative



Notes: All values are present values as of January 1, 2002, in millions of January 2000 dollars.
Source: NERA calculations as explained in text.

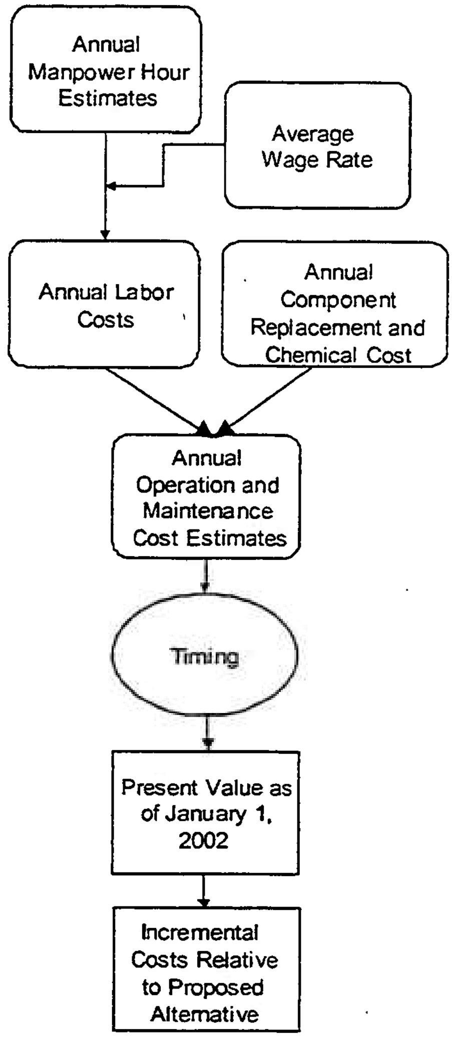
8.4.3 Incremental Operating and Maintenance Cost Relative to Wet Tower Alternative

Many of the alternatives proposed for BEC involve the installation of equipment that requires continuous care to function properly. Maintaining this equipment entails O&M costs. In addition, installation of the alternatives can change the O&M costs for the facility as a whole.

8.4.3.1 Methodology

As seen in Figure 1-3, which illustrates the methodology used to calculate the present value of incremental O&M costs, O&M costs are broken into two categories: annual labor costs and other operating and maintenance costs, including annual component replacement and chemical treatment costs. Appendix B provides detailed information for each of these cost categories. Annual labor costs are estimated by multiplying an estimate average wage rate by estimates of additional annual manpower hours for each alternative.

Figure 8-3 Methodology for Incremental Operating and Maintenance Costs Relative to Wet Tower Alternative



Appendix C provides estimates of the annual total O&M costs for each of the alternatives during the period 2002 to 2028. Annual O&M costs begin in July 2003 because BEC is assumed to be operational 1.5 years after initial construction. Annual costs are translated into present values using a real discount rate of 7 percent (OMB 1996).

8.4.3.2 Results

Table 8-2 provides the present value of estimated incremental O&M costs for the cooling system alternatives. These results are shown graphically in Figure 8-4. As with the construction costs, these costs vary considerably across the various alternatives, although the general level of incremental O&M costs is substantially lower than the incremental construction costs.

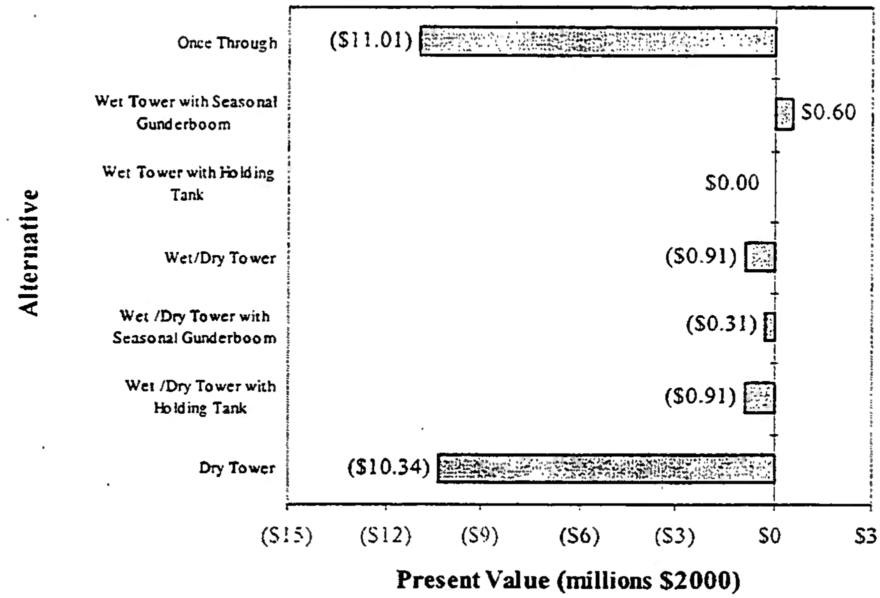
Table 8-2 Incremental Operating and Maintenance Costs of Cooling System Alternatives Relative to Wet Tower Alternative

Alternative	Present Value of O&M Costs (millions of year 2000 $)
Once Through	($11.01)
Wet Tower with Seasonal Gunderboom	$ 0.60
Wet Tower with Holding Tank	$ 0.00
Wet/Dry Tower	($ 0.91)
Wet/Dry Tower with Seasonal Gunderboom	($ 0.31)
Wet/Dry Tower with Holding Tank	($ 0.91)
Dry Tower	($10.34)

Note: All values are present values as of January 1, 2002, in millions of January 2000 dollars. Parentheses indicate negative values.
Source: NERA calculations as explained in text.

The present value of the incremental O&M costs relative to the Wet Tower alternative differ significantly, with most alternatives incurring an incremental O&M savings (i.e. negative costs) and some incurring O&M costs. Alternatives with incremental O&M savings have O&M costs that are lower than the O&M costs of the Wet Tower alternative. The Once Through, Dry Tower, and all Wet/Dry Tower alternatives have incremental savings; the largest incremental savings is $11.01 million for the Once Through alternative. The addition of the Seasonal Gunderboom to the Wet Towers results in incremental O&M costs of $0.60 million. The Holding Tanks have no incremental O&M costs.

Figure 8-4 Incremental Operating and Maintenance Costs of Cooling System Alternatives Relative to Wet Tower Alternative



Notes: All values are present values as of January 1, 2002, in millions of January 2000 dollars.
Parentheses indicate negative values.
Source: NERA calculations as explained in text.

8.4.4 Incremental Power Costs Relative to Wet Tower Alternative

Cooling system alternatives can lead to power impacts at BEC. The social cost of these impacts is one of the elements of the social costs of the alternatives. The power costs consist of two components: (1) energy costs from power impacts at BEC, and (2) air costs from changes in emissions at BEC. Energy costs are the social costs of increased power requirements and reduced generation efficiency at BEC. Air costs are the social cost of changes in air emissions resulting from power impacts at BEC. These costs result from both auxiliary power requirements and heat rate penalties due to implementation of cooling system alternatives.

Detailed information on the costs associated with energy and air emissions is provided in Appendix B. This appendix includes the methodologies and values used in estimating the costs associated with power impacts at BEC.

8.4.4.1 Methodology

Cooling system alternatives can cause power impacts at BEC through two basic mechanisms:

1. *Increased auxiliary power requirements.* Auxiliary power requirements reflect the additional in-plant power requirements due to the alternatives. These additional power requirements would increase fuel use at BEC.

2. *Performance (heat rate) Penalties.* Cooling system alternatives may reduce BEC's power generation efficiency. For example, closed-cycle cooling systems create higher cooling water temperatures that in turn cause higher turbine backpressure. The heat rate penalties increase the quantity of fuel required to generate the same quantity of energy.

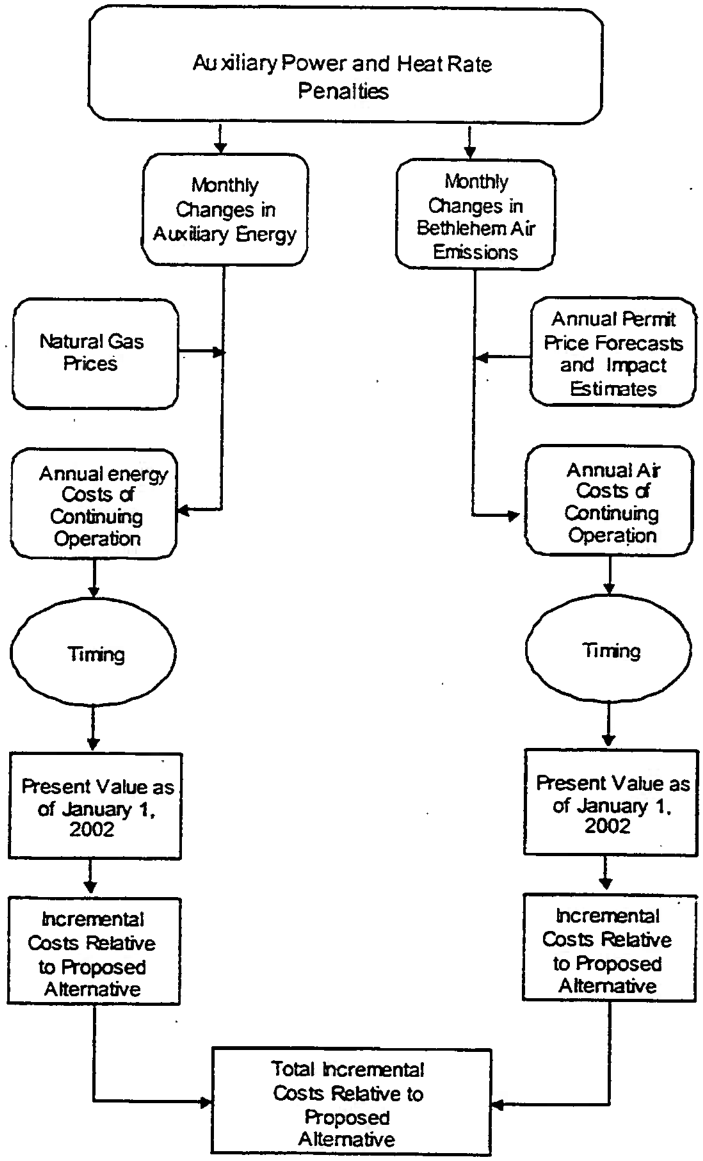
Each of these operating impacts increases the quantity of fuel used by BEC and increases the social cost of providing electricity.

The energy costs of cooling system alternatives are estimated by multiplying the change in natural gas consumption by the market price for natural gas. The change in natural gas consumption reflects monthly estimates of auxiliary power loads and heat rate penalties. Natural gas prices reflect seasonal price variations and forecasted changes in future gas prices. Auxiliary power loads also result in additional variable O&M costs that are included in power costs. Appendix B provides further details on methodologies and data.

The air costs of cooling system alternatives are based on changes in NO_X and CO_2 emissions. The cost associated with each emission is estimated by multiplying the quantity of increases in air emissions by the marginal social cost of those emissions. Emissions increases are based on changes in natural gas consumption due to auxiliary power loads and heat rate penalties. Marginai social costs are based on either the cost of emissions permits or estimates of the marginal impact associated with emissions. Appendix B provides further details.

Figure 8-5 summarizes the methodology used to calculate the incremental costs associated with power impacts at BEC. Total monthly power costs are estimated by summing energy and air costs in each month. Annual power costs are estimated by adding power costs across months. Appendix C provides detailed annual calculations. The present value of power costs is estimated using a discount rate of 7 percent. The incremental costs presented in this chapter are estimated by taking the difference between incremental power costs for each alternative relative to the Wet Tower alternative.

Figure 8-5 Methodology for Incremental Costs Associated with Power Impacts Relative to Wet Tower Alternative



8.4.4.2 Results

Estimates of the incremental power costs are provided in Table 8-3 and shown graphically in Figure 1-6. The Once Through alternative results in an incremental energy savings of $3.60 million. All Wet/Dry

Tower alternatives and Dry Tower alternative have incremental power costs ranging from $1.45 to $1.52 million. The addition of Gunderboom or Holding Tanks to the Wet Tower result in no incremental power costs.[6]

Incremental air costs are significantly lower than incremental energy costs. The Once Through alternative would result in an incremental savings of $1.47 million. The Wet/Dry Tower alternatives and Dry Tower Alternative would result in incremental costs of $0.59 to $0.66 million. Total incremental power costs for the cooling towers range from a savings of $5.07 million for the Once Through alternative alternatives to a cost of $2.18 million for the Dry Tower.

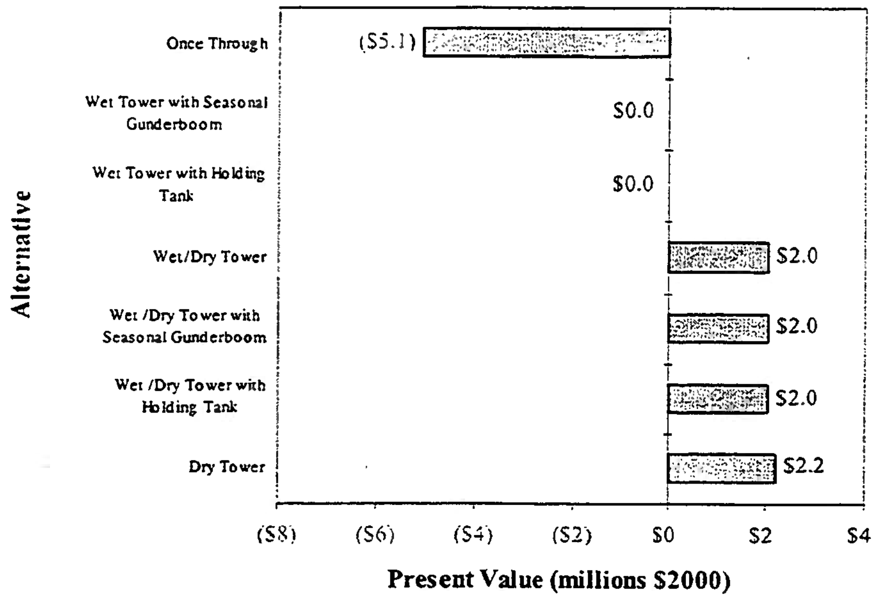
Table 8-3 Incremental Costs Associated with Power Impacts from Cooling System Alternatives Relative to Wet Tower Alternative

Alternative	Present Value of Incremental Power Costs (millions of year 2000 $)		
	Air	Energy	Total Power
Once Through	($1.47)	($3.60)	($5.07)
Wet Tower with Seasonal Gunderboom	$0.00	$0.00	$0.00
Wet Tower with Holding Tank	$0.00	$0.00	$0.00
Wet/Dry Tower	$0.59	$1.45	$2.04
Wet/Dry Tower with Seasonal Gunderboom	$0.59	$1.45	$2.04
Wet/Dry Tower with Holding Tank	$0.59	$1.45	$2.04
Dry Tower	$0.66	$1.52	$2.18

Note: All values are present values as of January 1, 2002, in millions of January 2000 dollars. Parentheses indicate negative values.
Source: NERA calculations as explained in text.

[6] The Holding Tank alternative may result in additional power costs, although these would be limited compared to other power impacts. Consequently, these are not estimated.

Figure 8-6 Incremental Costs Associated with Power Impacts From Cooling System Alternatives Relative to Wet Tower Alternative



Notes: All values are present values as of January 1, 2002, in millions of January 2000 dollars. Parentheses indicate negative values.
Source: NERA calculations as explained in text.

8.4.5 Total Incremental Costs of Alternatives Relative to Wet Tower Alternative

Combining the various cost components produces estimates of the incremental total costs of each alternative, expressed as the total present value of incremental costs as of January 1, 2002. These costs are listed in Table 8-4 and shown graphically in Figure 8-7.

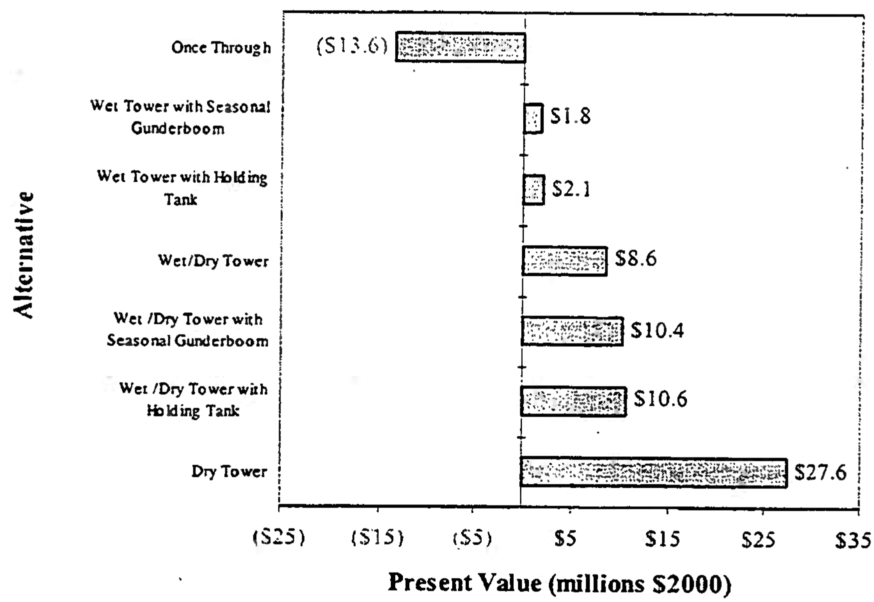
Table 8-4 Incremental Total Costs of Cooling System Alternatives Relative to Wet Tower Alternative

Alternative	Present Value of Incremental Total Cost (millions of year 2000 $)			
	Construction	O&M	Power	Total
Once Through	$ 2.44	($11.01)	($5.07)	($13.63)
Wet Tower with Seasonal Gunderboom	$ 1.15	$ 0.60	$0.00	$ 1.75
Wet Tower with Holding Tank	$ 2.06	$ 0.00	$0.00	$ 2.06
Wet/Dry Tower	$ 7.42	($ 0.91)	$2.04	$ 8.55
Wet/Dry Tower with Seasonal Gunderboom	$ 8.64	($ 0.31)	$2.04	$ 10.37
Wet/Dry Tower with Holding Tank	$ 9.49	($ 0.91)	$2.04	$ 10.61
Dry Tower	$35.71	($10.34)	$2.18	$ 27.56

Note: All values are present values as of January 1, 2002, in millions of January 2000 dollars. Parentheses indicate negative values.
Source: NERA calculations as explained in text.

The incremental costs of the alternatives relative to the Wet Tower alternative differ significantly. The Once Through alternative results in a $13.63 million incremental savings. All other alternatives results in incremental costs, ranging from $1.75 million for the Wet Tower with Gunderboom to $27.56 million for the Dry Tower alternative.

Figure 8-7 Total Incremental Costs of Cooling System Alternatives Relative to Wet Tower Alternative



Notes: All values are present values as of January 1, 2002, in millions of January 2000 dollars. Parentheses indicate negative values.
Source: NERA calculations as explained in text.

8.5 Incremental Benefits of Cooling System Alternatives Relative to Wet Tower Alternative

This section provides estimates of the incremental benefits associated with each cooling system alternative. As with the cost estimates, the benefit estimates are expressed as present values as of January 1, 2002 in January 2000 dollars.

The first subsection provides an overview of the overall incremental benefits methodology; the focus is on estimating the incremental benefits of changes in the commercial and recreational catch from implementation of each alternative relative to the Wet Tower alternative. The second subsection summarizes the methodology used to estimate increases in the projected commercial and recreational catch for each species. The third and fourth subsections provide estimates of the dollar values of benefits for commercial and recreational catch, respectively. The final subsection reports the total benefits of each alternative.

8.5.1 Overview of Methodology

Figure 8-8 illustrates the methodology to develop estimates of the incremental benefits for each alternative. The methodology consists of a series of steps to develop estimates of the annual benefits to commercial and recreational fishermen and to calculate the present value of these annual benefits over the life of the station.

1. *Additional pounds to the commercial and recreational fisheries.* Determine the change in commercial/recreational landings weight (pounds) for each species.
2. *Wholesale commercial values.* Determine the wholesale prices used to value species caught by commercial fishermen.
3. *Recreational values.* Determine the value that recreational fishermen would place on additional fish catch.
4. *Benefits from increases in catch.* Use the quantities (from Steps 1) and values (from Steps 2 and 3) to calculate the annual benefits of changes in commercial and recreational catch.
5. *Present value of benefits.* Aggregate the annual benefits over BEC's remaining lifetime using the same discount rate used to calculate the present value of costs.
6. *Incremental Benefits.* Incremental benefits of each alternative are estimated by taking the difference between each alternative's benefits and the benefits of the Wet Tower alternative.

This methodology produces estimates of the present value of incremental benefits for each of the alternatives as of January 1, 2002. These incremental benefit estimates can be compared directly to the incremental cost estimates developed in the previous section.

8.5.2 Changes in Commercial and Recreational Catch

Benefits estimates are based on increases in potential catch to commercial and recreational fisheries. The increases in catch to commercial and recreational fisheries are based on conditional mortality rates (CMRs) for the BEC facility, estimates of recreational and commercial landings, and the biological effectiveness of cooling system alternatives. Increases in catch are estimated for four species: American shad, white perch, river herring, and striped bass. These four species represent the major species impinged and entrained at BEC. In fact, there is some evidence that some of these species are not impinged or entrained at BEC at all.[7] Appendix A provides further details on the methodology used to estimate changes in commercial and recreational catch.

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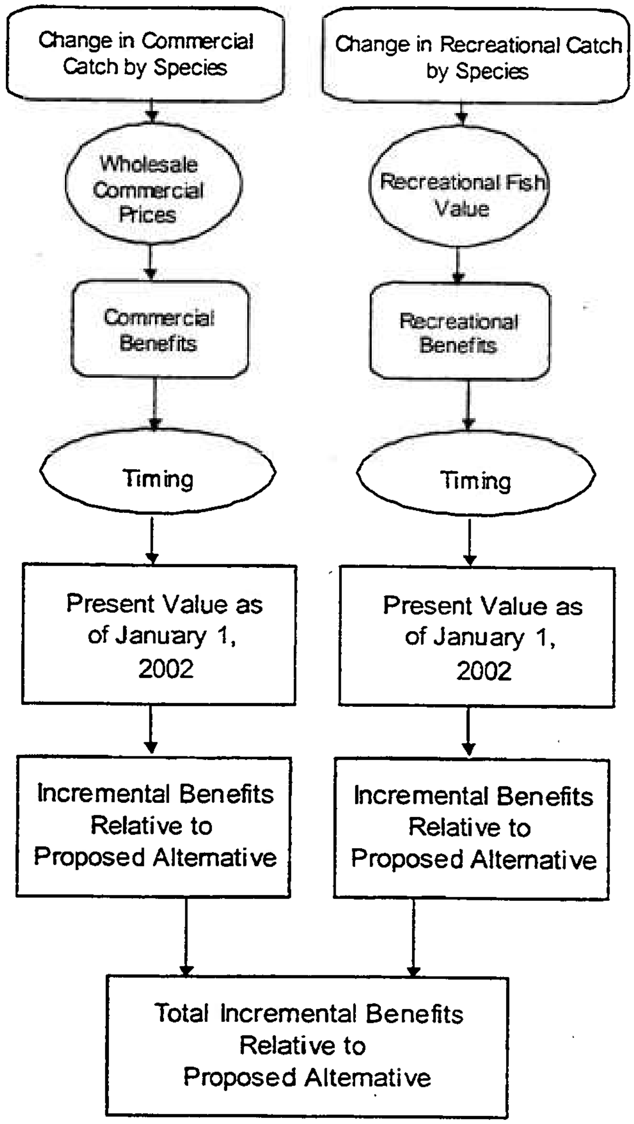
[7] Intake sampling at the ASGS indicated white perch and river herring losses, and few if any American shad or striped bass losses (Albany Steam Generating Station 1983 Entrainment Monitoring Survey 1984).

Figure 8-8 Methodology for Incremental Benefits Relative to Wet Tower Alternative



Appendix D provides estimates of the changes in commercial and recreational catch for each species due to the cooling system alternatives. Tables D-2 through D-9 provide estimates of the weight of commercial/recreational fish saved for each alternative. These estimates are based on the change in catch relative to current operations of the ASGS.

The magnitude of fish gains varies considerably for the different alternatives. In addition, the patterns of protection differ by species within a given alternative. This intra-alternative variation is due predominantly to the differing population concentration of fish species and the relative effectiveness of alternatives with respect to specific types of fish. Variations in the effectiveness of alternatives on various species are reflected in the Tables D-2 to D-9.

8.5.3 Commercial Fishing Benefits

This section develops estimates of the commercial fishing benefits for each of the alternatives.

8.5.3.1 Commercial Fish Prices

Appendix B provides the data and methodology used to estimate commercial fish values in this study. The values are based upon wholesale prices at the Fulton Fish Market in New York City as reported by the National Marine Fisheries Service (NMFS). The commercial prices used in this study are average values over the last nine years of available data (1990-1998). Table 8-5 shows the commercial values for each of the species. The commercial values range from $0.16 per pound for river herring to $2.98 per pound for striped bass.

As discussed in Appendix B, the wholesale prices provide upper bound estimates of the social value of additional commercial catch. The estimates assume that commercial fishermen spend no additional resources catching the additional fish. However, some increase in resources devoted to commercial catch (e.g., more commercial boats) typically accompanies any increase in stocks in open-access fisheries. The theory of open-access fisheries (explained in more detail in Appendix B) suggests the additional effort may significantly reduce the value of additional commercial catch (see, e.g., Anderson 1986). Indeed, for valuable species for which there is considerable commercial competition, the increased resources put in place could completely eliminate the benefits from the increased commercial catch. The estimates in this study ignore these considerations.

Table 8-5 Average Wholesale Commercial Prices for Species Considered

Species	Dollars per Pound[a]
American Shad	$0.69
River Herring [b,c]	$0.16
Striped Bass	$2.98
White Perch	$1.13

[a] Average of Fulton Fish Market Prices over the period 1990-1998 for White Perch and Stripped Bass and over the period 1990-1997 for all other species, in January 2000 dollars
[b] The river herring category includes alewife and blueback herring.
[c] River herring prices are calculated by multiplying ex-vessel prices by the average ratio of wholesale to ex-vessel prices for other species
Source: Appendix B.

8.5.3.2 Incremental Commercial Fishing Benefits Relative to Wet Tower Alternative

Table 8-6 shows estimates of the incremental commercial benefits relative to the Wet Tower alternative for each of the alternatives. Incremental commercial benefits are measured as the difference between the present value of benefits of an alternative and the Wet Tower alternative over the period from the year the alternative takes effect to the scheduled shutdown of the BEC units in the year 2028. Detailed commercial benefits by year are provided in Appendix D. The alternatives are listed in the same order as in the cost analyses in the previous section. The incremental commercial fishing benefits are shown graphically in Figure 8-9.

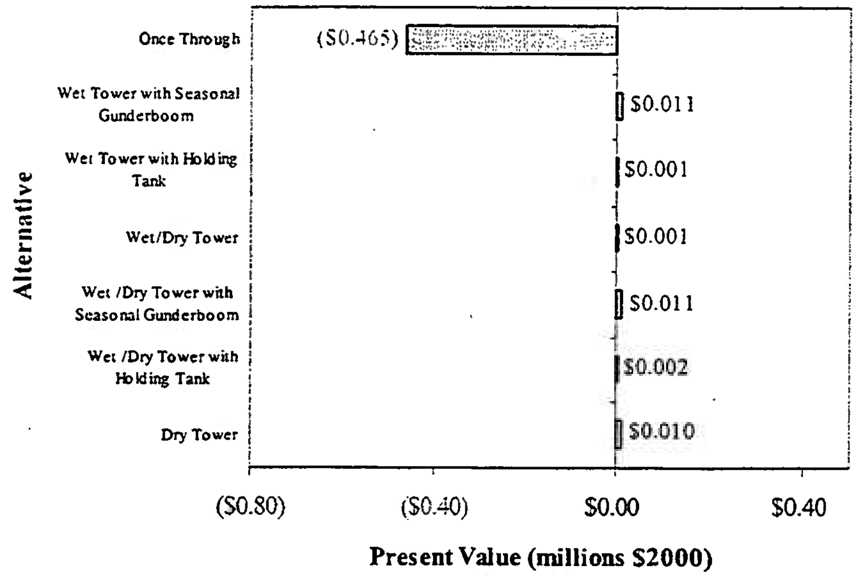
Incremental commercial fishing benefits vary across alternatives The Once Through alternative results in a negative benefit (i.e., incremental cost) of $465,000. All other alternatives result in incremental benefits ranging from about $1,000 for the Wet Tower with Holding Tank and Wet/Dry Tower to $11,000 for the Wet Tower with Seasonal Gunderboom and Wet/Dry Tower with Seasonal Gunderboom. The majority of benefits can be attributed to the reduction in losses of American Shad.

Table 8-6 Incremental Commercial Fishing Benefits of Cooling System Alternatives Relative to Wet Tower Alternative

Alternative	Present Value of Incremental Commercial Benefits (millions of year 2000 $)
Once Through	($0.465)
Wet Tower Seasonal Gunderboom	$ 0.011
Wet Tower with Holding Tank	$ 0.001
Wet/Dry Tower	$ 0.001
Wet/Dry Tower with Seasonal Gunderboom	$ 0.011
Wet/Dry Tower with Holding Tank	$ 0.002
Dry Tower	$ 0.010

Note: All values are present values as of January 1, 2002, in millions of January 2000 dollars. Parentheses indicate negative values.
Source: NERA calculations as explained in text.

Figure 8-9 Incremental Commercial Fishing Benefits of Cooling System Alternatives Relative to Wet Tower Alternative



Note: All values are present values as of January 1, 2002, in millions of January 2000 dollars. Parentheses indicate negative values.
Source: NERA calculations as explained in text.

8.5.4 Incremental Recreational Fishing Benefits

This section considers the incremental benefits to recreational fishermen from the cooling system alternatives at BEC.

8.5.4.1 Recreational Fish Values

Appendix B develops the estimate of the value that recreational fishermen would place on additional catch, which is equal to \$3.88 per pound. The value is based upon a detailed assessment of the empirical literature on the value that recreational fishermen place on additional catch. The marginal value reflects the catch per trip (i.e., pounds per trip) for recreational fishing in New York State. As explained in Appendix B, this detailed assessment provides an economically sound basis for estimating the benefits of additional recreational catch due to cooling system alternatives at BEC.

8.5.4.2 Incremental Recreational Fishing Benefits Relative to Wet Tower Alternatives

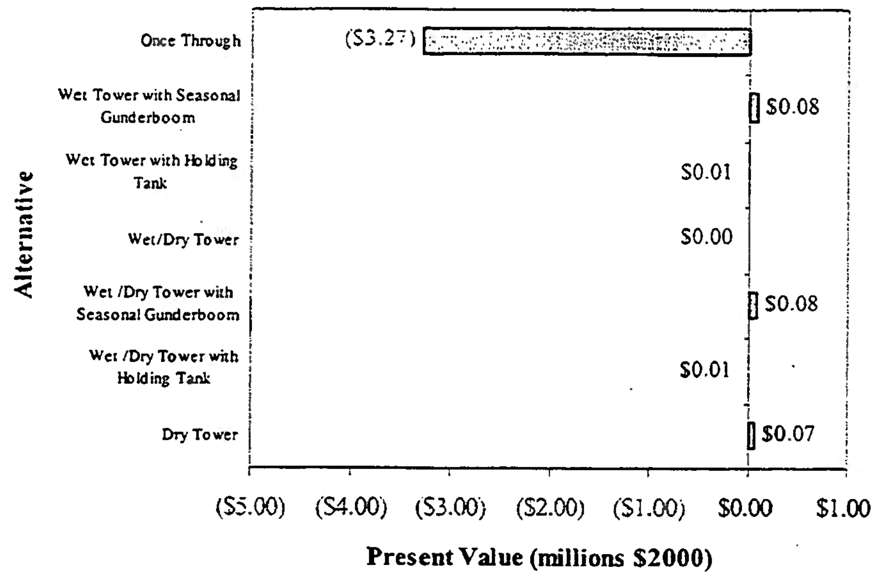
Table 8-7 shows estimates of the incremental recreational benefits for each of the alternatives relative to the Wet Tower Alternative. As with incremental commercial benefits, incremental recreational benefits are measured as the difference between the present value of an alternative's benefits and the Wet Tower benefits over the period from when the alternative would be implemented to the scheduled closure of the BEC units in the year 2028 (detailed recreational benefit estimates by year are provided in Appendix D). The incremental recreational fishing estimates are shown graphically in Figure 8-10.

Table 8-7 Recreational Fishing Benefits of Cooling System Alternatives Relative to Wet Tower Alternative

Alternative	Present Value of Incremental Recreational Benefits (millions of year $2000)
Once Through	($3.273)
Wet Tower Seasonal Gunderboom	$ 0.082
Wet Tower with Holding Tank	$ 0.010
Wet/Dry Tower	$ 0.004
Wet/Dry Tower with Seasonal Gunderboom	$ 0.083
Wet/Dry Tower with Holding Tank	$ 0.014
Dry Tower	$ 0.070

Note: All values are present values as of January 1, 2002, in millions of January 2000 dollars. Parentheses indicate negative values.
Source: NERA calculations as explained in text.

Figure 8-10 Recreational Fishing Benefits of Cooling System Alternatives Relative to Wet Tower Alternative



Notes: All values are present values as of January 1, 2002, in millions of January 2000 dollars. Parentheses indicate negative values.
Source: NERA calculations as explained in text.

Incremental recreational fishing benefits vary across alternatives. The Once Through alternative results in an incremental cost (i.e., negative benefit) of $3.27 million. All other alternatives result in incremental benefits ranging from $4,000 for the Wet/Dry Tower to $83,000 for the Wet/Dry Tower with Gunderboom. As with commercial benefits, most recreational benefits are attributed to reduction in losses of American Shad.

8.5.5 Total Incremental Benefits of Alternatives Relative to Wet Tower Alternative

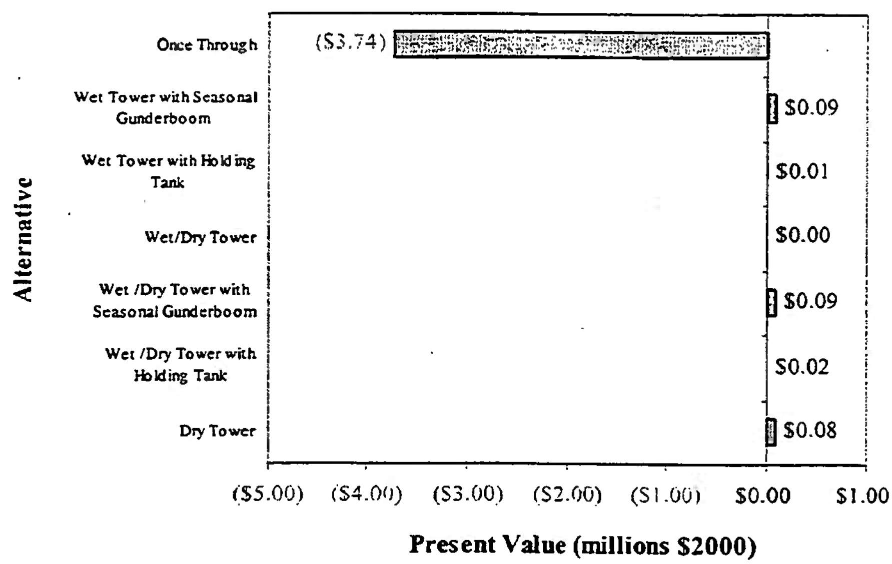
Total incremental benefits are equal to the sum of incremental commercial and incremental recreational benefits. Table 8-8 lists total incremental benefit estimates for all alternatives. Figure 8-11 shows the total incremental benefit results graphically.

Table 8-8 Incremental Total Benefits of Cooling System Alternatives Relative to Wet Tower Alternative

Alternative	Present Value of Incremental Total Benefits (millions of year 2000 $)
Once Through	($3.738)
Wet Tower Seasonal Gunderboom	$ 0.094
Wet Tower with Holding Tank	$ 0.012
Wet/Dry Tower	$ 0.005
Wet/Dry Tower with Seasonal Gunderboom	$ 0.094
Wet/Dry Tower with Holding Tank	$ 0.016
Dry Tower	$ 0.080

Note: All values are present values as of January 1, 2002, in millions of 2000 dollars. Parentheses indicate negative values.
Source: NERA calculations as explained in text.

Figure 8-11 Incremental Total Benefits of Cooling System Alternatives Relative to Wet Tower Alternative



Notes: All values are present values as of January 1, 2002, in millions of January 2000 dollars. Parentheses indicate negative values.
Source: NERA calculations as explained in text.

Incremental total benefits of cooling systems vary across alternatives. The Once Through alternative has an incremental cost (i.e., negative benefit) of $3.74 million. All other alternative results in incremental benefits ranging from $5,000 for the Wet/Dry Tower alternative to $94 thousand for two alternatives: the Wet Tower with Seasonal Gunderboom and the Wet/Dry Tower with Seasonal Gunderboom.

8.6 Total Incremental Costs and Benefits of Cooling System Alternatives Relative to Wet Tower Alternative

Table 8-9 summarizes the estimates of total incremental costs and benefits for each of the cooling system alternatives. The first two columns show estimates of total incremental costs and benefits. The third column shows estimates of the incremental net benefits (i.e., benefits minus costs). Figure 8-12 provides a graphical summary of the incremental net benefits.

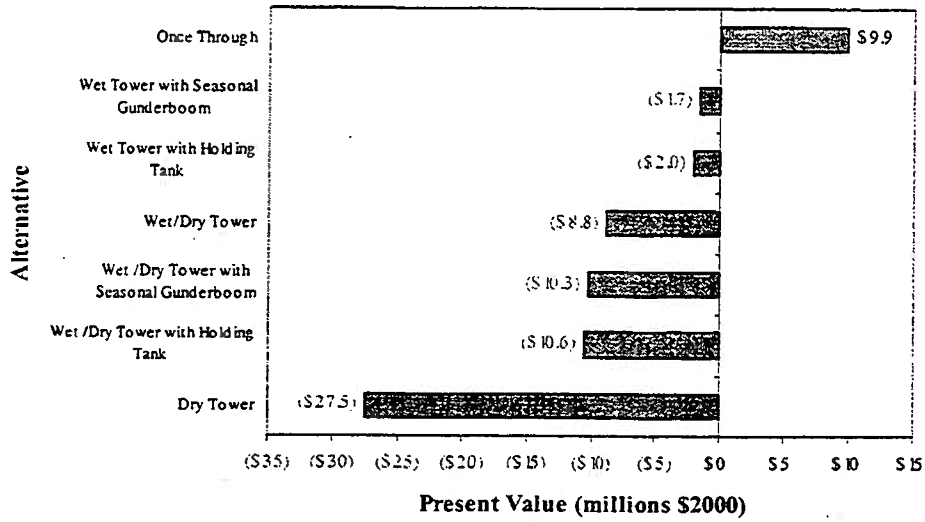
All closed-cycle cooling systems result in negative incremental net benefits (i.e., incremental costs) ranging from $1.66 million for the Wet Tower with Seasonal Gunderboom alternative to $27.48 million for the Dry Tower alternative. The Once Through alternative results in positive incremental benefits of $9.89 million.

Table 8-9 Incremental Total Costs and Benefits for Cooling System Alternatives Relative to Wet Tower Alternative

Alternative	Present Value (millions of year 2000 $)		
	Incremental Total Costs	Incremental Total Benefits	Incremental Net Benefits
Once Through	($13.63)	($3.74)	$ 9.89
Wet Tower Seasonal Gunderboom	$ 1.75	$0.09	($ 1.66)
Wet Tower with Holding Tank	$ 2.06	$0.01	($ 2.05)
Wet/Dry Tower	$ 8.55	$0.00	($ 8.55)
Wet/Dry Tower with Seasonal Gunderboom	$ 10.37	$0.09	($10.28)
Wet/Dry Tower with Holding Tank	$ 10.61	$0.02	($10.60)
Dry Tower	$ 27.56	$0.08	($27.48)

Note: All values are present values as of January 1, 2002, in millions of 2000 dollars. Parentheses indicate negative values.
Source: NERA calculations as explained in text.

Figure 8-12 Incremental Net Benefits of Cooling System Alternatives Relative to Wet Tower Alternative



Notes: All values are present values as of January 1, 2002, in millions of January 2000 dollars. Parentheses indicate negative values.
Source: NERA calculations as explained in text.

8.6.1 Incremental Costs and Benefits for Non-Dominated Alternatives Relative to Wet Tower Alternative

This section uses the incremental cost and benefit results in the previous section to develop information on a smaller set of alternatives that are not dominated by other alternatives. An alternative is "dominated" if another alternative produces equal or greater incremental benefits at lower incremental costs.

8.6.1.1 Reasons for Considering Only Non-Dominated Alternatives

From a cost-benefit perspective, it would not be sensible to select an alternative that was dominated by another alternative. By selecting the other alternative, one would be able to achieve at least as many incremental benefits at lower incremental costs.

The full set of seven alternatives includes many that are dominated by another alternative. For example, the Wet Towers with Holding Tank results in more incremental costs than the Wet Towers with Seasonal Gunderboom ($2.06 million versus $1.75 million) but generates smaller incremental benefits ($1,000 versus $9,000). The Wet Towers with Seasonal Gunderboom thus dominates the Wet

Towers with Holding Tank; one would not choose an alternative that has greater incremental costs and produces smaller incremental benefits.

8.6.1.2 Incremental Costs and Benefits of More Costly Non-Dominated Alternatives Relative to Wet Tower Alternative

Table 8-10 shows the more costly non-dominated alternatives. The more costly non-dominated alternatives include:

- Wet Tower with Seasonal Gunderboom, and
- Wet/Dry Tower with Seasonal Gunderboom.

We have focused on the more costly non-dominated alternatives because these represent potentially more stringent alternatives to the proposed cooling system. Many of the more costly technologies are dominated by less costly technologies that provide greater benefits at lower cost. The Dry Tower alternative, for example, is the most expensive alternative, although two of the alternatives (Wet Tower with Seasonal Gunderboom and Wet/Dry Tower with Seasonal Gunderboom) provide greater incremental benefits at a lower incremental cost.

Comparison of the incremental costs and benefits provides information on the incremental benefits gained from utilizing increasingly costly technologies. For example, the Wet Tower with Season Gunderboom alternative has incremental costs of $1.75 million, while the incremental benefits are about $94,000; the ratio of the incremental costs to incremental benefits is about 19. For the Wet/Dry Tower with Season Gunderboom alternative, incremental costs are $10.37 million and incremental benefits are also about $94,000; in this case, the ratio of these incremental costs to incremental benefits is about 110. These results suggest that the neither alternative is warranted from a cost-benefit perspective, since the incremental costs far exceed the incremental benefits gained by more costly alternatives than the proposed Wet Tower alternative.

Table 8-10 Incremental Costs and Benefits of Non-Dominated Technologies Relative to Wet Tower Alternative

Alternative	Present Value (millions of 2000 $)		
	Incremental Total Costs	Incremental Total Benefits	Incremental Net Benefits
Once Through	($13.63)	($3.7381)	$ 9.89
Wet Tower with Seasonal Gunderboom	$ 1.75	$ 0.0938	($ 1.66)
Wet/Dry Tower with Seasonal Gunderboom	$ 10.37	$ 0.0942	($10.28)

Note: All values are present values as of January 1, 2002, in millions of 2000 dollars. Parentheses indicate negative benefits.
Source: NERA calculations as explained in text.

8.7 Sensitivity Analyses for Cooling System Alternatives

The incremental cost and benefit calculations are based upon some assumptions that cannot be quantified, but whose qualitative effects can be assessed. This section summarizes these factors and their implications for the incremental cost and benefit results. It also provides quantitative estimates of incremental costs and benefits for the alternatives using different discount rates.

8.7.1 Impacts Not Quantitatively Assessed

As noted in Section 8.1, several categories of cost included in the EPA Guidelines as potential categories were not quantified—government regulatory costs, social welfare losses, transitional costs, and indirect costs—because we anticipated that they are likely to be relatively small. Other categories of costs that are excluded include the following:

- Private costs of obtaining the 316(b) permit;
- Disposal of waste materials (relevant for some technological options);
- Air emissions other than CO_2 and NO_X;
- Noise impacts associated with cooling towers (Chapter 5 provides further details); and
- Aesthetic impacts associated with cooling towers and cooling tower plumes (Chapter 6 provides further details).

We expect that these costs are likely to be small relative to the total costs of the various technologies.

In addition to these omitted categories of costs, the analyses do not take into account some factors that might change the biological or economic values used in the analyses. Perhaps the most important factors that are excluded are two biological relationships:

1. Natural biological compensation, which would reduce the effects of losses at BEC and thus reduce the gains from cooling system alternatives; and

2. Lags in adult fish production, i.e., the delay between fish protection and the development of fish large enough to be caught commercially or recreationally.

Both factors would tend to reduce the estimated fish protection benefits, since the effects would either decrease the fish gains or delay the time when benefits are received. With regard to economic factors, the values of recreational or commercial catch might change over time (in real terms). Since the changes might be positive or negative, omitting these potential changes should not change our estimates of the likely fish protection benefits.

8.7.2 Results Using Alternative Discount Rates

This section provides quantitative estimates of incremental costs and benefits for the alternatives using different discount rates. The above results are based upon a real discount rate of 7 percent, which is the discount rate recommended in OMB guidelines (OMB 1996). To test the sensitivity of the results to the discount rate, we calculate incremental costs and benefits for two other discount rates: 3 percent and 10 percent.

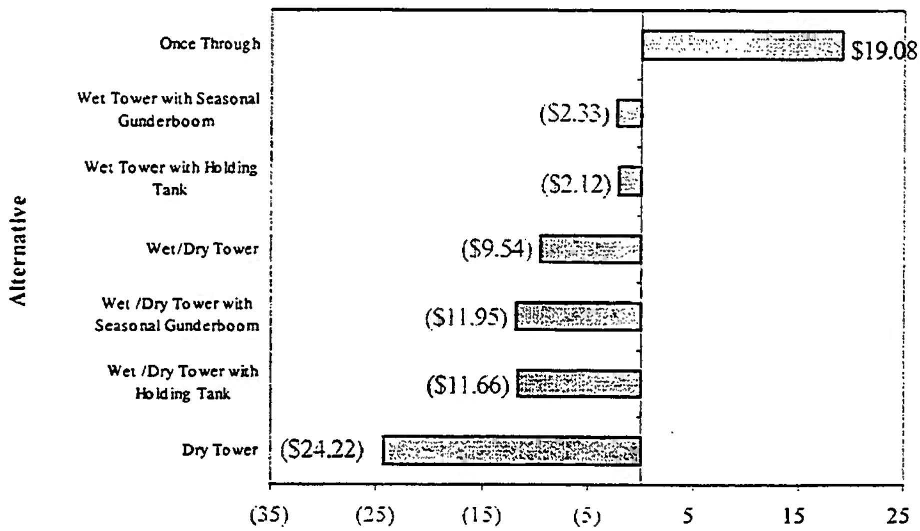
Table 8-11 lists the results of these sensitivity analyses. Figure 8-13 and Figure 8-14 show the incremental net benefits under 3 percent and 10 percent discount rate assumptions, respectively. Incremental costs and benefits both decrease as the discount rate is increased. The net benefits (i.e., benefits minus costs) also decrease as the discount rate increases. The basic results, however, are not sensitive to the changes in discount rate. All incremental net benefits are negative except for the Once Through alternative, meaning that incremental costs exceed incremental benefits relative to the Wet Tower alternative.

Table 8-11 Incremental Total Costs and Benefits for Alternative Discount Rates of Cooling System Alternatives Relative to Wet Tower Alternative[a]

Alternative	Present Value (millions of year 2000 $)		
	Incremental Total Costs	Incremental Total Benefits	Incremental Net Benefits
3 Percent Discount Rate for Cost Benefits			
Once Through	($22.82)	($3.74)	$ 19.08
Wet Tower Seasonal Gunderboom	$ 2.42	$ 0.09	($ 2.33)
Wet Tower Holding Tank	$ 2.13	$ 0.01	($ 2.12)
Wet/Dry Tower	$ 9.54	$ 0.00	($ 9.54)
Wet/Dry Tower with Seasonal Gunderboom	$ 12.05	$ 0.09	($11.95)
Wet/Dry Tower with Holding Tank	$ 11.67	$ 0.02	($11.66)
Dry Tower	$ 24.30	$ 0.08	($24.22)
10 Percent Discount Rate for Cost Benefits			
Once Through	($ 9.67)	($3.74)	$ 5.93
Wet Tower Seasonal Gunderboom	$ 1.46	$ 0.09	($ 1.36)
Wet Tower Holding Tank	$ 2.01	$ 0.01	($ 2.00)
Wet/Dry Tower	$ 8.06	$ 0.00	($ 8.05)
Wet/Dry Tower with Seasonal Gunderboom	$ 9.57	$ 0.09	($ 9.48)
Wet/Dry Tower with Holding Tank	$10.07	$ 0.02	($10.05)
Dry Tower	$28.65	$ 0.08	($28.57)

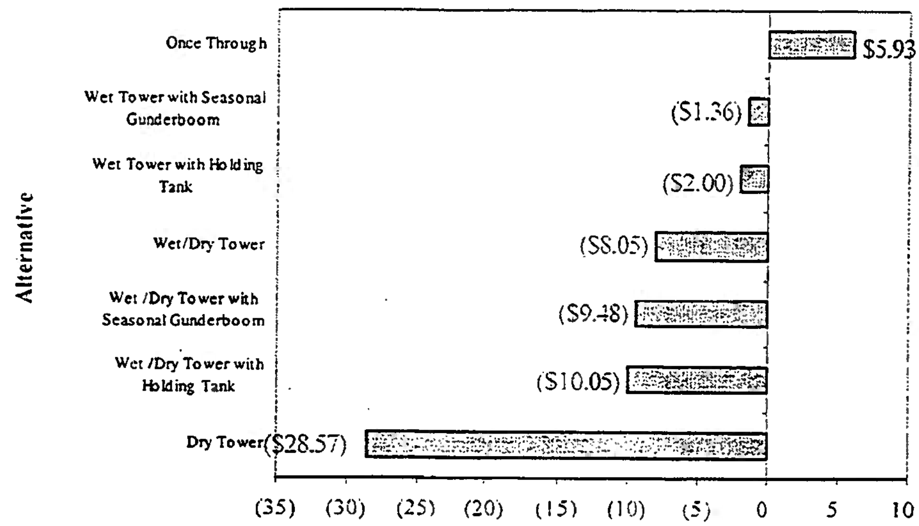
a All values are present values as of January 1, 2002, in millions of January 2000 dollars. Parentheses indicate negative values.
Source: NERA calculations as explained in text.

Figure 8-13 Sensitivity Analysis with a 3 Percent Discount Rate of Incremental Net Benefits of Cooling System Alternatives Relative to Wet Tower Alternative



Notes: Parentheses indicate negative values.
Source: NERA calculations as explained in text.

Figure 8-14 Sensitivity Analysis with a 10 Percent Discount Rate of Incremental Net Benefits of Cooling System Alternatives Relative to Wet Tower Alternative



Notes: Parentheses indicate negative values.
Source: NERA calculations as explained in text.

9.0 CONCLUSIONS

Overall Assessment

This Study concludes that the wet tower cooling system is the best choice for BEC and should be selected as BTA. The evaluation indicates that the wet tower cooling system will significantly reduce the loss of aquatic organisms compared to the existing Station's cooling water system. While other alternatives may provide very small additional reductions in aquatic effects, the additional costs of these alternatives outweigh the additional potential environmental gains. The selection of the cooling system would have to be weighed against the option to continue operating the existing ASGS. The wet tower cooling system with passive wedge wire screens is the most appropriate technology for the BEC because it provides the best balance of performance, air emissions, aesthetics/visual, noise, environmental protection, and cost factors.

The once-through cooling alternative would provide maximum thermal efficiency and minimum visual effects. However, this alternative would require the withdrawal of significantly more Hudson River water (about 40 to 70 times more) than the wet tower cooling tower and have more effect on aquatic biota.

The wet/dry and dry tower alternatives would use less river water than the wet tower. However, the wet tower cooling system offers the advantages of being more efficient than the dry tower alternative, less intrusive to nearby properties from noise and visual perspectives, and provides the most significant environmental benefits particularly relative to the incremental improvements and corresponding incremental costs associated with the other alternatives.

Performance

An analysis of the performance of the proposed wet tower cooling system and the three other cooling system alternatives (i.e., once-through, wet/dry tower, and dry tower) indicates that the once-through cooling water system has the best overall thermal performance (i.e., most effective heat rejection characteristics with lowest auxiliary load requirements). The wet/dry and dry cooling tower alternatives require additional auxiliary power compared to the wet tower. Additionally, both the wet/dry and the dry tower alternatives have lower performance. In fact, the dry tower performance is reduced by about 166 Btu/kWh at 94 F. This is roughly 2.4% less efficient, and requires approximately 2.5% more fuel with corresponding increases in emissions for the same kWh of electricity produced with the wet tower cooling system at higher ambient temperatures (≥ 94 F).

The once-through cooling system has the lowest internal power consumption of the alternatives and therefore the lowest emissions per net megawatt-hour. By contrast, dry towers represent the largest internal power consumption due to the number of fans. The overall effect is about a 1 to 2.7% increase in emissions per megawatt hour as compared to the other alternatives.

Noise

Ambient sound impacts associated with the alternative cooling systems were evaluated. The results of the computer model indicate that all of the alternatives, except the dry cooling tower can meet the stipulated sound levels. The dry tower alternative would marginally exceed the stipulated sound levels by approximately 2-3 decibels at all receptor locations. Lowering condenser fan rotation speed, or adjusting the design of the fan blades and / or tower stacks could reduce sound levels associated with the operation of the dry tower. However, this may necessitate the installation of additional cooling tower modules to compensate for lost capacity and therefore the dry tower would be larger than described in this study.

Aesthetics

The qualitative difference in aesthetic impact was evaluated by comparing the physical characteristics and dimensions of the cooling tower structures and plumes. Given similar height and location, the structures and periodic vapor plumes of the proposed BEC are expected to be visible from the same area as the existing structures and plume of the ASGS. A dry cooling tower, that would have a footprint of close to 2.0 acres in size and 144 feet high, would be the most visually dominant element of the project and be quite imposing on the immediate vicinity of the project site. This visual impact would be most adverse along River Road.

The once-through cooling system requires no external structure, will not emit a visible vapor plume, and results in no visual impact. The principal difference between the wet and wet/dry towers would be the frequency, duration and scale of the visible vapor plume. However, for the vast majority of the time the vapor plume associated with the wet tower would remain over the project site and any visual impact would be slight considering the urban and industrial setting and existence of other plumes. The dry cooling tower would not emit any vapor plume.

Aquatic Impacts

One of the substantial benefits of the proposed BEC Project is the reduction in the effects on aquatic biota compared to the existing ASGS. The wet tower cooling system will significantly reduce water use from current levels.

When BEC is complete the volume of water withdrawn from the Hudson River will be reduced from a typical flow of approximately 334,000 gallons per minute (gpm) to base and peak flows of 3,277 and 5,923 gpm, respectively, or by about 98 to 99%. Furthermore, the peak BEC withdrawal flow (5,923 gpm or 13.2 cfs) would only represent about 0.48% of the freshwater inflow to the River under low summer/fall flow conditions. This limited water withdrawal is expected to have minimal effect on flow volumes, water levels, current patterns or aquatic resources in the River.

The current ASGS conventional traveling screens with intake velocities of about 1.2 feet per second (fps) would be replaced by a submerged intake passive screen system that uses a static cylindrical screen with 2mm wedge wire mesh slot openings to maximize open area that will reduce the intake velocity to approximately 0.12 fps.

The BEC's employment of wedge wire screens coupled with the low volume makeup water requirements for the wet cooling tower will virtually eliminate the current impingement effects associated with ASGS and reduce the entrainment effects by about 98-99% as evaluated by various indicators that include estimated organism losses, equivalent adult numbers and biomass and conditional mortality rates (CMRs) to four relevant target fish species; river herring (alewife and blueback herring), American shad, white perch and striped bass.

For the wet tower cooling system operating at peak flow, the estimated annual loss of each of the four target species represent a small fraction of one percent of the average annual commercial and recreational catch of each species in New York State. Actual losses are likely to be much less for two reasons: peak flow will typically occur in the winter and not during the time of peak entrainment potential (i.e., late spring), and no compensatory response in the fish population to offset such losses was included in these impact indicator estimates.

<u>**Costs and Benefits**</u>

Seven alternatives to minimize aquatic impacts were evaluated and compared to the proposed wet tower cooling system[8] with regard to potential biological effectiveness, engineering practicality, and costs. The seven alternatives include 1) a new BEC once-through cooling water system, 2) wet cooling tower and intake barrier system (Gunderboom), 3) wet cooling tower with a holding tank, 4) wet/dry cooling tower, 5) wet/dry cooling tower and Gunderboom, 6) wet/dry cooling tower with a holding tank, and 7) dry cooling tower. The alternatives were selected for detailed evaluation considering, the location, design, construction, and capacity of the intake structure. Additionally, each alternative was assessed as to whether the costs of further reductions would impose an impracticable or unbearable economic burden, and/or would be out of proportion to the anticipated environmental gains.

A detailed incremental cost analysis of the seven alternatives was performed. Incremental costs include construction, operation and maintenance (O&M) expenses, the value of power losses, and the

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[8] All closed cycle cooling alternatives would include the installation of a passive screen system equipped with 2mm wedge wire mesh.

cost savings attributable to potential reductions in commercial and recreational fishery losses. The incremental total present value costs of all alternatives range from a cost savings of approximately $13.6 million for the once-through system to a cost of approximately $27.6 million for the dry tower.

In contrast, the total potential savings to the commercial/recreational fisheries range from an incremental cost of about $3.7 million for the once-through alternative to incremental benefits of about $94 thousand for the wet or wet/dry towers with a seasonal Gunderboom.

In terms of quantifiable costs and benefits, the once-through cooling system results in positive incremental total benefits of about $9.9 million, while all closed cycle systems result in total incremental costs ranging from about $1.7 million for the wet cooling tower with Gunderboom to about $27.5 million for the dry tower alternative.

Summary

After considering all practicable alternate cooling water intake technologies available to minimize potential adverse environmental impact, this Study concludes that the wet tower cooling system discussed herein constitutes BTA given that the other practicable alternatives are wholly disproportionate to any environmental benefits which might be conferred by such measures. The wet tower cooling system represents a 98-99% reduction in losses of aquatic organisms as compared to the ASGS. Accordingly, any potential additional reductions in losses to aquatic organisms are very small in comparison and the effect of any such additional reductions would be virtually impossible to detect at a population level. Based on compounded conservative assumptions (see Appendix A), the estimated Conditional Mortality Rates for the target species associated with wet tower cooling system range from a fraction of one percent to essentially zero (see Table 7-6).

As detailed in the body of this Study, the once-through, wet towers with holding tank, wet/dry towers, wet/dry towers with holding tank, and dry cooling towers alternatives are not BTA because wet towers with seasonal Gunderboom and wet/dry towers with season Gunderboom provide greater environmental benefits at less cost. In addition, there are qualitative factors (e.g., aesthetics, noise, energy conservation), which favor the wet tower cooling system.

The once through alternative compares less favorably to the wet tower cooling system from a BTA perspective since it provides considerably less environmental benefits at a higher capital construction cost. The once through cooling system alternative has a significantly higher flow and is not equipped with wedge wire screens. Accordingly, impingement and entrainment estimates are significantly higher. The higher aquatic losses coupled with construction costs higher than that for the wet tower cooling system (because of the extensive underground piping required), make this alternative unattractive.

The wet towers with holding tank alternative compares less favorably to the wet towers cooling system from a BTA perspective in that the marginal additional reduction in aquatic effects is wholly disproportionate to the additional costs of this alternative. Moreover, the wet tower with holding tank alternative results in more incremental costs than the Wet Tower with Seasonal Gunderboom alternative, but generates smaller incremental benefits. The actual effectiveness of the holding tank as a mitigation measure is not clear.

The wet/dry towers alternative compares less favorably to the wet tower cooling system from a BTA perspective in that marginal additional reduction in aquatic effects is likewise wholly disproportionate to the additional costs of this alternative. This alternative would require a slightly taller structure than the wet tower cooling system.

The wet/dry towers with holding tank alternative compares less favorably to the wet tower cooling system from a BTA perspective in that the marginal additional reduction in aquatic effects is likewise wholly disproportionate to the additional costs of this alternative. The wet/dry towers with holding tank alternative results in more incremental costs than the wet/dry tower with seasonal Gunderboom alternative, but generates smaller incremental benefits. In addition, the holding tank creates an additional visual impact. Moreover, as previously mentioned, the actual effectiveness of the holding tank as a mitigation measure is not clear.

The dry cooling towers alternative compares less favorably to the wet tower cooling system from a BTA perspective in that the marginal additional reduction in aquatic effects is likewise wholly disproportionate to the dramatic additional costs of this alternative. In addition, the shear size of the structure negatively affects the visual impact and aesthetics. The dry cooling tower is somewhat noisier than the wet tower cooling system. Moreover, this alternative is significantly less energy efficient, uses more fuel, and generates greater air emissions.

The wet towers with seasonal Gunderboom and wet/dry towers with seasonal Gunderboom alternatives are superior to the once through, wet towers with holding tank, wet/dry towers, wet/dry towers with holding tank, and dry cooling tower alternatives, but compare less favorably to the wet tower cooling system.

The wet towers with seasonal Gunderboom alternative does not constitute BTA relative to the wet tower cooling system given that the marginal additional reduction in aquatic effects is wholly disproportionate to the additional costs of this alternative. Specifically, the incremental costs associated with this alternative as compared with the wet tower cooling system are 19 times the quantifiable incremental benefits associated with the reduced loss of fish. Moreover, as discussed in Chapter 7, the Study's conclusions in this regard are predicated upon compounded conservative assumptions that overestimate the potential loss of aquatic organisms.

Likewise, the wet/dry towers with seasonal Gunderboom alternative does not constitute BTA relative to the wet towers cooling system given that the marginal additional reduction in aquatic effects is wholly disproportionate to the additional costs of this alternative. Specifically, the incremental costs associated with this alternative as compared with the wet tower cooling system are 110 times the quantifiable incremental benefits associated with the reduced loss of fish. Moreover, as discussed in Chapter 7, the Study's conclusions in this regard are predicated upon compounded conservative assumptions that overestimate the potential loss of aquatic organisms. In particular, the methodologies employed in the assessment do not take into account density dependent mechanisms (compensation) exhibited by fish populations.

On a qualitative basis, the wet tower cooling system compares favorably as a whole with all other alternatives. Specifically, the wet tower cooling system would provide less noise than every other alternative except once-through. With regard to aesthetics, the wet tower cooling system would create less visual impact than the existing structures or those associated with wet towers with holding tank or dry cooling towers. Any visual impact to nearby properties resulting from a cooling tower plume is expected to be slight when viewed within the context of the surrounding urban and industrial setting. Finally from an energy conservation standpoint the wet tower cooling system compares favorably with every other alternative, except once-through.

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Appendix 1

APPENDIX A

IMPINGEMENT AND ENTRAINMENT SUPPORTING INFORMATION

APPENDIX A.1

IMPINGEMENT DATA

Table A.1-1 Hudson River Power Plant Information

Generating Station	River Mile	Number of Units	MWe Per Plant	Maximum Cooling Water Withdrawal Volume (cfs)	Cooling System Type	Installed Technology
Albany Steam Generating Station	142.3	4	400	744.2	Once-through. One intake and discharge structure.	
Danskammer Point Generating Station	66.5	4	491	704.0	Once-through. One intake structure and three discharge pipes.	Shoreline intake structure leading to canal. Conventional through-flow traveling screens.
Roseton Generating Station	65.9	2	1,200	1428.1	Once-through. One intake structure and one offshore diffuser discharge pipe.	Shoreline intake structure. Six conventional through-flow traveling screens and two modified dual-flow traveling screens.
Indian Point Nuclear Generating Station	42.9	2	1,929	1939.0	Once-through. Separate intake bays and one shoreline discharge structure.	Shoreline intake structure. Both units have modified through-flow traveling screens and low stress fish return system.
Lovett Generating Station	41.6	3	462.5	604.9	Once-through. Three separate shoreline intake openings, with two shoreline discharge structures and one offshore discharge pipe.	Shoreline intake structure. Conventional through-flow traveling screens. Currently evaluating a barrier system capable of excluding ichthyoplankton.
Bowline Point Generating Station	37.3	2	1,202	1711.2	Once-through. One intake structure and two separate offshore diffuser discharge pipes.	Shoreline intake structure located on an embayment. Conventional through-flow traveling screens and low stress fish return system. Seasonal (fall-spring) deployment of 0.38-in. barrier net to mitigate impingement.

Source: Hutchison, Jr., J. B. 1988. Technical description of Hudson River electricity generating stations. Pages 113-117. In: Barnthouse, Klauda, Vaughan, and Kendall [eds.], Science, Law, and Hudson River Power Plants. American Fisheries Society Monograph 4.

Table A.1-2 Total and Selected Species Estimated Impingement at Representative Hudson River Power Plants

YEAR	LOVETT GENERATING STATION (HUDSON RIVER km 67) Total Fish	Blueback herring	White perch	Spottail shiner	Alewife	American shad	[illegible] Total Fish	Blueback herring	White perch	Spottail shiner	Alewife	American shad	ALBANY STEAM GENERATING STATION (Hudson River km 229) Total Fish	Blueback herring	White perch	Spottail shiner	Alewife	American shad
1973	182,159	9,042	61,061	8,260	8,723		1,027,304	29,234	110,545	18,137	148,912	1,266						
1974	167,179	13,760	87,323	3,491	3,525		330,786	13,339	84,253	9,872	31,379	2,444	342,461	100,723	60,086	51,889	38,257	11,840
1975	136,178	7,409	62,635	3,462	4,922		323,874	100,111	98,230	9,856	29,755	2,456	312,719	144,093	49,529	39,442	12,768	32,569
1976	80,611	384	48,139	3,351	573		248,258	14,176	117,738	14,279	9,920	2,011						
1977	114,880	777	80,980	2,109	1,939		296,947	30,098	140,835	21,547	24,833	2,800						
1978	45,832	1,709	28,636	952	1,320		178,155	40,628	62,240	8,856	24,343	3,624						
1979	90,021	3,818	57,732	1,959	1,076		194,879	26,397	79,089	15,170	10,841	4,201						
1980	113,139	4,347	79,131	2,404	457		342,363	19,615	175,056	15,756	33,740	11,502						
1981	119,569	558	94,372	284	663		258,371	6,583	139,865	13,783	18,086	4,828						
1982	66,990	2,820	35,645	544	263		337,976	9,980	221,359	12,686	16,085	3,306						
1983	62,756	587	33,400	1,040	210		442,392	23,266	226,752	17,668	26,205	18,814	518,385	287,213	168,875	10,329	27,172	2,101
1984	28,677	1,169	13,830	965	147		433,174	40,390	243,485	15,715	21,132	14,426	242,139	79,023	109,305	13,845	17,208	3,012
1985	30,750	848	8,009	860	683		343,824	62,182	117,682	13,889	32,812	11,832						
1986	42,107	459	26,933	953	527		225,885	6,217	167,880	19,842	8,460	2,179						
1987	17,203	870	9,798	292	101		417,387	42,879	233,444	37,702	22,393	2,911						
1988	42,118	316	24,244	307	140		348,490	58,149	148,803	12,035	12,843	7,094						
1989	70,377	304	35,459	921	259		288,595	9,588	167,897	28,595	3,893	4,848						
1990	33,090	263	19,481	1,185	327		299,128	30,743	187,977	14,622	4,530	2,212						
1991	32,369	713	8,203	534	149		458,872	89,471	138,101	20,856	27,570	13,848						
1992	20,830	500	11,866	120	1,086		194,771	12,334	112,707	11,973	8,010	6,198						
1993	16,281	99	9,625	158	119		330,259	26,355	135,887	11,149	18,561	5,756						
1994	31,609	124	19,915	61	218		200,390	14,799	88,688	8,884	23,864	12,056						
1995	47,620	895	18,731	286	164		304,842	18,277	118,059	20,234	14,775	3,195						
1996	30,808	209	18,859	174	258	133	301,815	8,740	153,148	28,140	7,143	5,021						
1997							337,054	11,922	98,350	13,488	20,255	7,506						
Average	87,106	2,124	37,591	1,361	1,160		309,577	28,922	141,803	16,399	18,785	6,294	353,926	152,743	96,949	28,826	23,851	12,331
Minimum	16,281	99	8,203	61	101		178,155	6,217	52,240	8,856	3,893	1,266	242,483	79,023	49,529	10,329	12,768	2,101
Maximum	182,159	13,760	94,372	8,260	8,723		1,027,304	100,111	243,485	37,702	148,912	18,814	518,385	287,213	168,875	51,889	38,257	32,569

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Table A.1-3 Albany Steam Generating Station Estimated Annual Average Impingement

Family	Species	Month												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Acipenseridae	Atlantic sturgeon	0	0	0	0	0	1	0	0	0	0	0	1	2
	Shortnose sturgeon	11	0	0	4	2	0	6	6	8	3	0	0	40
Anguillidae	American eel	33	41	103	2646	815	229	194	141	336	1777	495	95	6904
Bothidae	Summer flounder	0	0	0	0	0	0	1	0	0	0	0	0	1
Catostomidae	White sucker	6	0	4	59	49	5	4	0	3	10	15	4	159
Centrarchidae	Black crappie	10	9	22	32	61	3	3	0	9	19	27	25	220
	Bluegill	2	1	5	127	2621	54	7	5	143	83	113	53	3213
	Largemouth bass	1	0	0	0	2	0	2	1	1	11	27	6	52
	Longear sunfish	0	0	0	0	2	0	0	0	0	0	0	0	2
	Pumpkinseed	40	5	27	171	412	83	38	26	96	180	62	20	1160
	Redbreast sunfish	0	0	0	0	20	14	6	3	5	24	3	0	75
	Rock bass	1	0	8	48	88	50	15	4	14	12	32	6	280
	Smallmouth bass	11	0	0	14	7	1	2	1	1	13	3	1	52
	White crappie	33	1	0	11287	9794	2017	410	51	77	785	1018	366	25840
Clupeidae	Alewife	0	7	0	2532	9982	171	407	948	2649	1681	82	0	18458
	American shad	0	0	0	7	26	15	2433	3390	4804	986	118	0	11779
	Blueback herring	0	0	0	534	14717	2809	501	1225	42310	58652	19889	394	141033
	Gizzard shad	1539	6	27	18	282	11	0	17	43	629	992	971	4535
	AW/BBH	0	0	0	0	6	17	44	0	0	0	0	0	67
Cyprinidae	Bluntnose minnow	0	0	0	22	7	0	0	0	0	0	0	0	29
	Carp	11	0	2	2	5	1	2	2	20	16	11	5	76
	Common shiner	0	0	0	2	0	0	0	0	0	1	0	0	4
	Creek chub	0	0	0	2	1	0	0	0	0	0	0	0	3
	Emerald shiner	4	2	26	29	18	1	1	0	1	1	5	1	90
	Fallfish	0	0	0	0	0	1	0	0	0	0	0	0	1

Family	Species	Month												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Cyprinidae (Cont'd)	Golden shiner	38	30	67	165	116	19	14	13	26	16	29	54	585
	Goldfish	15	16	67	60	24	3	1	1	0	7	74	56	324
	Rosyface shiner	0	0	0	0	0	0	0	0	0	1	1	4	6
	Silvery minnow	4	10	47	350	168	5	1	1	5	5	3	3	603
	Spotfin shiner	1	1	32	1199	0	0	0	0	0	0	0	0	1233
	Spottail shiner	910	697	1557	5598	4669	853	630	931	2541	617	1994	1991	22988
	UID shiner	0	0	0	8	8	0	0	0	0	0	0	0	16
Cyprinodontidae	Banded killifish	24	0	0	10	19	11	7	3	2	7	0	11	92
	Mummichog	0	0	0	0	0	0	1	0	1	0	0	1	3
Engraulidae	Bay anchovy	0	0	0	0	5	288	26	3	0	0	0	0	321
Esocidae	Chain pickerel	0	0	0	0	2	1	0	0	0	0	0	0	3
	Northern pike	0	0	0	0	1	0	0	0	0	0	0	0	1
	Redfin pickerel	2	4	16	2	1	0	2	2	1	1	1	1	33
Gadidae	Atlantic tomcod	65	12	11	2	3	80	45	6	1	12	21	117	377
Gasterosteidae	Fourspine stickleback	0	0	0	2	0	0	0	0	0	0	0	0	2
	Threespine stickleback	0	0	0	2	0	0	0	0	0	0	0	0	2
Ictaluridae	Brown bullhead	4	10	15	49	75	23	11	100	4	9	29	29	359
	Channel catfish	0	0	0	0	0	3	2	8	0	0	0	0	13
	Tadpole madtom	0	0	0	0	2	0	0	0	0	0	0	0	2
	White catfish	0	10	5	36	68	86	210	391	431	394	593	7	2229
	Yellow bullhead	0	0	0	0	0	0	0	0	3	7	5	8	25
Osmeridae	Rainbow smelt	0	0	105	29	9	6	2	1	0	0	0	0	151
Percichthyidae	Striped bass	58	0	8	8	266	795	735	1080	980	327	109	252	4618
	White bass	0	0	0	0	0	0	0	0	0	1	0	11	12
	White perch	41	36	148	6548	22717	7847	2504	1637	6083	7313	4778	90	59741
Percicidae	Logperch	0	0	0	0	0	0	0	0	0	3	0	0	3
	Tessellated darter	0	0	26	1154	563	43	23	16	22	37	43	29	1957
	Walleye	0	0	0	2	1	0	0	0	0	0	0	0	3
	Yellow perch	30	10	31	828	319	86	11	4	5	7	26	54	1411

Family	Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
		Month												
Percopsidae	Trout-perch	2	2	1	34	20	5	1	3	5	2	0	0	75
Petromyzontidae	Lamprey spp.	0	0	0	0	0	0	0	0	0	0	0	1	1
Salmonidae	Brown trout	0	0	0	0	2	1	0	0	2	1	1	0	7
Sciaenidae	Freshwater drum	0	0	0	0	0	0	0	1	0	0	0	0	1
Soleidae	Hogchoker	0	0	0	2	5	129	89	73	9	1	0	0	309
Umbridae	Central mudminnow	0	0	2	36	8	0	0	0	0	0	7	1	55
TOTAL SPECIES		26	20	25	39	43	36	36	33	34	38	32	33	58
TOTAL ABUNDANCE		2896	910	2362	33660	67988	15767	8391	10094	60641	73651	30606	4668	311636

Source: LMS, 1998a

Table A.1-4 Post-Impingement Survival Values for Conventinoal and Modified (Ristroph Type) Traveling Screens

Family	Species	Percent Survival (%)	
		Conventional	Ristroph Type
Acipenseridae	Atlantic sturgeon	60	80
	Shortnose sturgeon	60	80
Anguillidae	American eel	70	95
Bothidae	Summer flounder	70	95
Catostomidae	White sucker	50	70
Centrarchidae	Black crappie	30	40
	Bluegill	80	80
	Largemouth bass	75	90
	Longear sunfish	70	80
	Pumpkinseed	75	80
	Redbreast sunfish	70	80
	Rock bass	70	80
	Smallmouth bass	75	90
	White crappie	30	40
Clupeidae	Alewife	0	10
	American shad	0	10
	Blueback herring	0	10
	Gizzard shad	5	10
	AW/BBH	0	10
Cyprinidae	Bluntnose minnow	50	90
	Carp	50	80
	Common shiner	50	90
	Creek chub	50	90
	Emerald shiner	50	90
	Fallfish	50	90
	Golden shiner	45	90
	Goldfish	50	80
	Rosyface shiner	50	90
	Silvery minnow	50	90
	Spotfin shiner	50	90
	Spottail shiner	50	90
	UID shiner	50	90
Cyprinodontidae	Banded killifish	85	90
	Mummichog	85	90
Engraulidae	Bay anchovy	0	80
Esocidae	Chain pickerel	70	90
	Northern pike	70	90
	Redfin pickerel	70	90
Gadidae	Atlantic tomcod	10	70
Gasterosteidae	Fourspine stickleback	70	90
	Threespine stickleback	70	90

Family	Species	Percent Survival (%)	
		Conventional	Ristroph Type
Ictaluridae	Brown bullhead	65	90
	Channel catfish	70	90
	Tadpole madtom	70	90
	White catfish	75	90
	Yellow bullhead	70	90
Osmeridae	Rainbow smelt	0	85
Percichthyidae	Striped bass	25	70
	White bass	25	70
	White perch	25	70
Percicidae	Logperch	65	80
	Tessellated darter	90	100
	Walleye	65	80
	Yellow perch	65	80
Percopsidae	Trout-perch	15	20
Petromyzontidae	Lamprey spp.	70	95
Salmonidae	Brown trout	60	80
Sciaenidae	Freshwater drum	20	25
Soleidae	Hogchoker	90	95
Umbridae	Central mudminnow	60	80

[1]Post-impingement survival estimates incorporate preliminary information from modified dual-flow screen study conducted by NMPC at the Dunkirk Steam Station.

[2]Albany Steam Station (existing).

[3]Bethlehem Energy Center (alternative once-through cooling system).

Source: LMS, 1998a

Table A.1-5 Estimated Annual Impingement and Post-Impingement Survival Albany Steam Generating Station and the Bethlehem Energy Center: Once-Through Condenser Cooling Water System Alternative

Species	Albany Steam Generating Station			Bethlehem Energy Center		
	Total Impingement	Post-Impingement Survival	Post-Impingement Mortality	Total Impingement	Post-Impingement Survival	Post-Impingement Mortality
Atlantic sturgeon	2	1	1	1	1	0
Shortnose sturgeon	40	24	16	29	23	6
American eel	6,904	4,833	2,071	4,973	4,726	247
Summer flounder	1	1	0	1	1	0
White sucker	159	80	79	115	80	35
Black crappie	220	66	154	158	63	95
Bluegill	3,213	2,570	643	2,314	1,851	463
Largemouth bass	52	39	13	37	33	4
Longear sunfish	2	1	1	1	1	0
Pumpkinseed	1,160	870	290	836	669	167
Redbreast sunfish	75	53	22	54	43	11
Rock bass	280	196	84	202	162	40
Smallmouth bass	52	39	13	37	33	4
White crappie	25,840	7,752	18,088	18,612	7,445	11,167
Alewife	18,458	0	18,458	13,295	1,329	11,966
American shad	11,779	0	11,779	8,484	848	7,636
Blueback herring	141,033	0	141,033	101,583	10,159	91,424
Gizzard shad	4,535	227	4,308	3,266	327	2,939
AW/BBH	67	0	67	48	5	43
Bluntnose minnow	29	15	14	21	19	2
Carp	76	38	38	55	44	11
Common shiner	4	2	2	3	3	0
Creek chub	3	2	1	2	2	0
Emerald shiner	90	81	9	65	58	7
Fallfish	1	1	0	1	1	0
Golden shiner	585	263	322	421	379	42
Goldfish	324	162	162	233	186	47
Rosyface shiner	6	3	3	4	4	0
Silvery minnow	603	302	301	434	391	43
Spotfin shiner	1,233	617	616	888	800	88
Spottail shiner	22,988	11,494	11,494	16,558	14,902	1,656
UID shiner	16	8	8	12	11	1
Banded killifish	92	78	14	66	59	7
Mummichog	3	3	0	2	2	0
Bay anchovy	321	0	321	231	185	46
Chain pickerel	3	2	1	2	2	0
Northern pike	1	1	0	1	1	0
Redfin pickerel	33	23	10	24	22	2
Atlantic tomcod	377	38	339	204	143	61
Fourspine stickleback	2	1	1	2	2	0
Threespine						

Species	Albany Steam Generating Station			Bethlehem Energy Center		
	Total Impingement	Post-Impingement Survival	Post-Impingement Mortality	Total Impingement	Post-Impingement Survival	Post-Impingement Mortality
stickleback	2	1	1	2	2	0
Brown bullhead	359	233	126	194	175	19
Channel catfish	13	9	4	7	6	1
Tadpole madtom	2	1	1	2	2	0
White catfish	2,229	1,672	557	1,204	1,084	120
Yellow bullhead	25	18	7	14	13	1
Rainbow smelt	151	0	151	81	69	12
Striped bass	4,618	1,155	3,463	3,326	2,328	998
White bass	12	3	9	9	6	3
White perch	59,741	14,935	44,806	43,030	30,120	12,910
Logperch	3	2	1	2	2	0
Tessellated darter	1,957	1,761	196	1,410	1,410	0
Walleye	3	2	1	2	2	0
Yellow perch	1,411	917	494	1,016	812	204
Trout-perch	75	11	64	54	11	43
Lamprey spp.	1	1	0	1	1	0
Brown trout	7	4	3	5	4	1
Freshwater drum	1	0	1	1	0	1
Hogchoker	309	278	31	223	211	12
Central mudminnow	55	33	22	40	32	8
Total	**311,636**	**50,886**	**260,750**	**223,898**	**81,305**	**142,593**

APPENDIX A.2

ENTRAINMENT INFORMATION

APPENDIX A.2

ENTRAINMENT INFORMATION

A.2.1 Icthyoplankton Density and Entrainment Monitoring Study Data

Species composition and density of icthyoplankton in the vicinity of the proposed BEC is provided by both river sampling and entrainment monitoring studies conducted at Albany Steam Station during 1975 and 1983, respectively; and by the longitudinal river ichthyoplankton surveys (LRS) that have been conducted for the Hudson River Estuary Monitoring Program since 1975.

Icthyoplankton sampling at river stations in the vicinity of Albany Steam Station during 1975 indicated that river herring (*Alosa* spp.) eggs and larvae dominated the icthyoplankton community, with peak egg abundance in mid-May (LMS 1975). White perch larvae were found to be abundant during the mid-summer period, and larvae of Centrarchidae and Cyprinidae were also common, although found in low abundance, during the summer.

Entrainment studies at Albany Steam Station during 1983 found that river herring comprised 98% of all entrained eggs and 99% of all entrained larvae (LMS, 1984). Only "occasional" American shad larvae were collected, and striped bass were not identified in any entrainment samples. Weekly mean entrainment abundance at the Albany Steam Generating Station during 1983 is shown in Table A.2-1. The total number of river herring and white perch specimens entrained at Albany Steam Station (weekly mean abundance in no./1000m^3 adjusted for weekly plant flow) from April through September 1983 are listed below:

TAXA	Eggs	Yolk Sac Larvae	Post Yolk Sac Larvae	Juveniles
River herring	4.00×10^8	4.52×10^8	2.08×10^8	1.28×10^5
White perch	1.95×10^7	8.10×10^6	1.59×10^6	0

Icthyoplankton species composition and relative abundance information is also available for the Albany region of the Hudson River from the LRS sampling program. River herring eggs and larvae generally dominate icthyoplankton samples collected in the Albany region, with peak abundance occurring in May (EA 1998). Average annual egg density varies, ranging from a high of 1935 eggs/ cubic meter in 1986 to a low of <0.01 eggs/ cubic meter in 1981 (Table A.2-2). American shad eggs and larvae are also abundant in Albany region LRS samples from mid-May to early June, in relatively less densities. White perch eggs and larvae are also present in the Albany region, although in relatively less densities than river herring; while striped bass eggs and larvae are rarely found north of RM 110 (EA 1998).

Average annual icthyoplankton density data from the LRS provides an estimate of the average icthyoplankton density for the entire Albany region, from Hudson River Mile (RM) 125 to 152, encompassing a volume of approximately 71,149,105 cubic meters. Many entrainment assessment models (e.g., CEMR, ETM) rely on the LRS average regional densities to calculate spatial icthyoplankton distributions and relative regional abundance estimates. However icthyoplankton density within the Albany region can vary considerably and many of the LRS Albany region sampling stations, particularly during those years prior to 1990, were located in the lower portion of the Albany region, south of the Albany Steam Generating Station.

Based on a direct comparison of icthyoplankton density data collected during the 1983 ASGS monitoring survey and the 1983 LRS, LRS data may overestimate the density of river herring eggs and larvae and under estimate the density of river herring post-yolk sac larvae near the ASGS (Table A.2-3). The LRS may likely also overestimate the numbers of white perch, striped bass and American shad larvae in the vicinity of the Albany Steam Generating Station. Few, if any, American shad and no striped bass eggs or larvae were collected in entrainment samples during the 1983 monitoring survey; however, based on the 1983 LRS data and spatial distribution estimates, over 45% of American shad eggs and over 54% of American shad yolk-sac larvae in the Hudson River occurred in the Albany Region.

A historical comparison of icthyoplankton density data from the LRS indicates that 1983 was not atypical. Excluding the notably abundant 1986 and 1987 Year Classes from comparison, 1983 egg and larval densities were at or near the long-term average for most of the target species and lifestages (Figures A.2-1 through A.2-4).

Daily mean entrainment abundance during 1984 at the Roseton and Danskammer Generating Stations (located in the Newburgh Bay area of the Hudson River at RKM 106 and RKM 107, respectively) is shown in Tables A.2-4 and A.2-5 (LMS, 1985) for comparison.

A.2.2 Hourly Entrainment Density and Alternative Pump Schedule

Day-night differences in icthyoplankton density within the water column have been investigated by several authors (McFadden 1977; Loesch et al. 1982). Studies have found that most larval fish (yolk sac and post- yolk sac lifestages) tend to congregate near the bottom of the water column during the day and disperse into the water column at night. Corresponding day-night differences in entrainment densities have been investigated at several intake structures, with varying results.

Average hourly entrainment densities at the Albany Steam Station were estimated to evaluate alternative pump schedules as an optional means of reducing entrainment losses using a closed-loop cooling system. Entrainment monitoring surveys conducted at the Albany Steam Station during 1983 provided only daily estimates of entrainment density (i.e., sample data was composited over a 24-hr period); however, hourly entrainment sampling was conducted at the Roseton and Danskammer Generating Stations during May through July 1987. These data were used to estimate the hourly distribution of yolk sac and post- yolk sac larvae of target species entrained at the proposed BEC.

The hourly entrainment percent distribution of river herring, American shad, striped bass and white perch at the Roseton and Danskammer Generating Stations is shown in Figures A-2.5 through A-2.8. Average daily yolk sac and post- yolk sac densities at the Albany Steam Station were adjusted based on the average hourly distribution of target species at the Roseton and Danskammer Generating Stations. The average hourly distribution for both stations is provided in Table A-2.6.

Several alternative pump schedules were evaluated as an additional option for the proposed BEC with closed-loop cooling systems using either wet or wet/dry cooling towers. Pump schedules were based on the average daily flow requirements for wet and wet/dry cooling tower alternatives, pump capacity, storage tank capacity and intake velocities. Pump schedules were varied to minimize entrainment of river herring, the primary species collected during entrainment monitoring surveys at ASGS. Pump schedules were varied to minimize plant flow (i.e., pumping) during periods of highest icthyoplankton densities and maximize pumping rates during periods of lowest densities. A summary of the alternative pump schedules evaluated is provided in Table A.2-7. Estimated entrainment impacts were calculated based on the schedule providing the largest percent reduction of river herring yolk-sac and post yolk-sac larvae (Table A.2-8).

A.2.3 Intake Barrier System

Effectiveness of an intake barrier system at reducing entrainment impacts was evaluated for closed-looped cooling system alternatives (i.e., wet and wet/dry cooling towers) for the proposed BEC. Gunderboom Incorporated has developed a barrier system termed the Marine/Aquatic Life Exclusion System (MLES) that is designed to prevent the entrainment and impingement of ichthyoplankton and juvenile aquatic life at intake structures. The Gunderboom MLES would be deployed and maintained around the cooling water intake structure from April through July.

Effectiveness of the intake barrier system was considered 90% (i.e., the intake barrier system would exclude 90% of the fish eggs and larvae of all target species from entrainment). Effectiveness was based on recent studies conducted at the Lovett Generating Station **(LMS 2000)**. Average annual egg, yolk sac and post- yolk sac larval entrainment estimates (i.e., losses) for wet and wet/dry cooling tower alternatives were directly adjusted to reflect the intake barrier system.

A.2.4 Conditional Mortality Rates

The conditional mortality rates (CMR) for the Albany Steam Station and the BEC project alternative cooling systems are summarized in Tables A.2-9 through A.2-16 for the four target species (river herring, American shad, striped bass, and white perch). CMRs for the Albany Steam Generating Station were calculated using the Conditional Entrainment Mortality Rate (CEMR) and Empirical Transport Model (ETM) methodologies. CMRs for the BEC project alternative cooling systems were calculated using the ETM methodology only (the ETM methodology does not require absolute estimates of the number of organisms). In addition, two estimates were provided for the ETM and

CEMR methodologies for the once-through cooling systems. The first estimate assumes that all of the four species and lifestages that are entrained into the plant are killed (100% mortality). The second estimate is based on a calculated mortality rate due to plant operations. CEMR estimates for the Albany Steam Station (100% Mortality) are as reported in the HRDEIS (1999).

A.2.4.1 Conditional Entrainment Mortality Rate (CEMR)

The conditional entrainment mortality rate (CEMR) method relates estimates of the actual number of fish entrained at the plant and the fraction of entrained organisms killed by plant passage to estimates of the standing crop of the same species and life stage in the river. The number of organisms entrained is determined based on sampling of the cooling water in the discharge canal. The CEMR method uses daily empirical data on the total number of organisms killed at the plant and the total number of organisms present in the river during the same period. Thus the CEMR requires direct estimates of the density of organisms in the water being withdrawn. The model formulation for the CEMR is:

$$m = \sum_{c} R_c \left(1 - \prod_{s} \prod_{d} \left(1 - Z_{c,s,d} E_{p,s,d} \right) \right)$$

where:

m = conditional mortality rate

R_c = the relative size of daily cohort c

$Z_{c,s,d}$= the proportion of day d spent in life stage s by cohort c, where $d = c$ + age in days

$E_{p,s,d}$= the fraction of the riverwide abundance of life stage s killed by entrainment on day d

A.2.4.2 Empirical Transport Model (ETM)

The empirical transport model (ETM) is designed to simulate the temporal-spatial movement of a population by partitioning time and space into segments and using the observed field data to estimate the relative proportion of the river population in each segment. The model is specified as a series of summed probabilities to calculate entrainment loss; i.e., a fish will die from entrainment given its probabilities of being in the segment of the river vulnerable to power plant withdrawal, of being in the near-field area of the intake, of being passed through the intake screens, and of dying from plant passage. Since the ETM formulation is based on the spatial distributions of the organisms, it does not require estimates of the absolute number of organisms in the river or of the numbers entrained, but it does require estimates of the fraction of organisms in the river that are likely to be entrained, the fraction of organisms that do not survive plant passage, and the water withdrawal rates at the plant. The model formulation used in this analysis is an enhanced version of the Type II ETM:

$$m_{si} = 1 - \left(D_{ski}{}^{(-E_{ski} \cdot t)} + \left(1 - D_{ski}\right)\right)$$

where:

m_{si} = conditional mortality rate for life stage *s* during year *i*

D_{ski} = proportion of total standing crop of life stage *s* individuals in region *k* during year *i*

E_{ski} = instantaneous entrainment mortality rate of life stage *s* in region *k* during year *i*

t = life stage duration in days

and

$$E_{ski} = \frac{V_d \cdot F_{ski}}{V_T}$$

where:

V_d = daily volume (m^3) of water withdrawn by the plant

V_T = total volume (m^3) of study region *k*

F_{ski} = entrainment vulnerability factor of life stage *s* in region *k* during year *i*

and

$$F_{ski} = f_{ski} \cdot W_{ski}$$

where:

f_{ski} = fraction of life stage *s* individuals lost due to plant passage (combined mechanical and thermal mortality) in region *k* during year *i*

W_{ski} = ratio of the average power plant intake concentration to average regional concentration of life stage *s* individuals in region *k* during year *i*

The assumptions associated with the development of the ETM are that:

1. The data used to establish spatial and temporal distributions are accurate.

2. Organisms move instantaneously among regions of the water body between time steps and do not move among regions within each time step.

3. Parameter values specifying organisms distributions are based on the entire standing crop of each entrainable length interval. This assumption results in an overestimate since larger larvae are not susceptible to entrainment and the Albany region represents only a percentage of the entire river population.

4. The natural mortality rate of a given length interval of organisms is the same in all regions of the water body during the entire time that the length interval is present within the entrainment period.

5. Natural mortality rates are independent of population density (i.e., it is assumed that no compensatory mechanisms are operative that could offset the plant impact, although these mechanisms have been shown to occur in fish populations).

6. For a given time length interval, organisms have a fixed spatial distribution that is derived directly from field data.

7. Spawning takes place on a weekly basis with all of the spawn of a given week occurring instantaneously at the start of a week.

<u>Model Input Parameters</u>

Plant Operation Data

Daily water temperatures recorded at Poughkeepsie Water Works (T_{PWW}), located about 105 km downstream, were used to estimate intake and discharge temperatures for the Albany Steam Station. The following relationship was used to estimate intake temperature (T_A) at the Albany Steam Station (from Wells and Young 1992):

$$T_A = -1.805 + 1.068\ T_{PWW} \quad (n = 245,\ r^2 = 0.927)$$

Discharge temperatures (T_D) at Albany Steam Station were estimated using the following relationship (from HRDEIS, 1993):

$$T_D = 6.72447 + 0.868815\ T_{PWW}$$

The transit time at Albany Steam Station was calculated to be 1.67 minutes based on estimates of a 450-ft discharge canal and an average velocity in the canal of 4.5-ft/sec. The plant flow rates used in the ETM model for existing Albany Steam Station operations and for each of the various BEC alternatives are as follows:

1) Albany Steam Station existing four unit operation with once-through cooling water system using 9.5-mm (0.38-in.) mesh screens, total plant flow = 334,000 gpm (1,820,631 m^3/day).

2) BEC proposed operation with once-through cooling water system using 6.4- x 12.7-mm (0.25- x 0.50-in.) slot mesh screens, total plant base flow = 235,877 gpm (1,285,764 m^3/day) and total plant peak flow = 238,705 gpm (1,301,179 m^3/day) (NOTE: Projected mesh size of installed screens is 3.2 x 12.7-mm [0.125 x 0.50-inch] should this cooling system be selected.)

3) BEC proposed operation with closed-cycle wet cooling tower system using 2.0-mm (0.08-in.) mesh passive screens, total plant base flow = 3,277 gpm (17,863 m^3/day) and total plant peak flow = 5,923 gpm (32,286 m^3/day).

4) BEC proposed operation with closed-cycle wet/dry cooling tower system using plume abatement and 2.0-mm mesh passive screens, total plant base flow = 3,033 gpm (16,533 m^3/day) and total plant peak flow = 5,661 gpm (30,858 m^3/day).

5) BEC proposed operation with closed-cycle dry cooling tower system using 2.0-mm mesh passive screens, total plant base flow = 57 gpm (311 m^3/day) and total plant peak flow = 1,385 gpm (7,550 m^3/day).

Study Region Volume

The geographic regions and associated volumes of water used as physical input parameters in the CMR model were consistent with the sampling design of the Hudson River Estuary Monitoring Program (1975-1995 Year Class Reports prepared for the Hudson River Utilities). The regions used for the purposes of this analysis extended from the Federal Dam at Troy (RKM 246) to the George Washington Bridge (RKM 19):

Geographic Region	River Kilometers	Regional Volume (m^3)
Yonkers	19-39	229,420,288
Tappan Zee	39-55	321,811,465
Croton-Haverstraw	55-63	147,736,754
Indian Point	63-76	208,336,266
West Point	76-90	207,455,769
Cornwall	90-100	139,791,019
Poughkeepsie	100-124	298,133,444
Hyde Park	124-138	165,484,666
Kingston	138-151	141,469,879
Saugerties	151-172	176,295,711
Catskill	172-201	160,731,743
Albany	201-246	71,149,105
TOTAL	227	2,267,816,109

For the purposes of this analysis, it was assumed that the plant only withdraws water from the Albany region which has an estimated volume of 71,149,105 m^3.

Spatial Distributions

The spatial distributions (D-factors, e.g., D_{ski}) of each species were estimated by year (1975-1995) from standing crop data derived from the longitudinal river ichthyoplankton surveys (LRS) that were conducted in the 12 geographic regions for the Hudson River Estuary Monitoring Program. The fractional distribution for each susceptible life stage of each species was calculated from the product of the regional density, i.e., the Albany regional density, and the volume of that region. The fraction of the river-wide standing crop within the Albany region was computed by dividing the Albany standing crop by the river-wide standing crop estimate. Thus the spatial distribution value for a given species and life stage represents the estimated proportion of that species' life stage present in the Albany region relative to the other regions of the river during year *i*, such that the sum of D_{ski} over all twelve regions is equal to 1.0 for that species and life stage during the given year. For example, a D-factor value of 0.1455 for American shad juveniles during 1980 means that an estimated 14.55% of the entire American shad juvenile population in the Hudson River from the Yonkers region to the Albany region (RKM 19-246) occurred in the Albany region (RKM 201-246) during that year. The D-factors used in the ETM model were calculated for each year and are shown in Table A.2-17.

Entrainment Mortality

The entrainment mortality factor (f_{ski}) represents an estimate of the fraction of entrained organisms that will be lost as a result of passage through the condenser cooling system. During passage, entrained organisms are vulnerable to abrupt changes in velocity, temperature, and pressure, as well as physical abrasion, which may affect their survival. Thus total entrainment mortality results from a combination of mechanical and thermal effects and may be estimated as:

$$f_{ski} = 1 - \left[(1 - M_T) \cdot (1 - M_M)\right]$$

where:

M_T = thermal mortality component

M_M = mechanical mortality component

Entrainment mortality was assumed to be 100% for all species and life stages to provide the most conservative CMR estimates for existing Albany Steam Station operations and for each of the BEC alternatives.

Representative entrainment mortality was also computed for existing Albany Steam Station operations and for the BEC alternative with a once-through cooling system to obtain a better understanding of BEC impacts. The calculation technique and input parameters are the same as that used in the 1993 submittal of the Draft Environment Impact Statement for State Pollutant Discharge Elimination System Permits for the Hudson River Utilities (HRDEIS, 1993). A double hinged line model based on exposure temperature (discharge temperature and exposure duration) was used to estimate the thermal mortality (M_T) component as follows:

$$M_T = \begin{cases} 0 \; if \; T_D \langle X_1 \\ 1 \; if \; T_D \rangle X_2 \\ M_T^{\bullet} \; otherwise \end{cases}$$

and

$$M_T^{\bullet} = \left[\frac{1}{X_2 - X_1}\right] \cdot (T_D - X_1)$$

where:

$M_T^{\bullet}$ = thermal mortality rate for a given species

T_D = discharge temperature (°C)

X_1 = lower temperature boundary (°C)

X_2 = upper temperature boundary (°C)

Boundary values were estimated for striped bass using a nonlinear regression from experimental data (Kellogg et al., 1984; HRU, 1992) as:

$$X_1 = a1 + (b1 \cdot T_A) + (c1 \cdot \log_{10}(t_i))$$
$$X_2 = a2 + (b2 \cdot T_A) + (c2 \cdot \log_{10}(t_i))$$

where:

T_A = intake temperature

t_i = transit time through unit *i*

The coefficients used for each life stage are summarized in Table A.2-18. The striped bass equations were also used for white perch with the exception of the YSL life stage, where thermal mortality was estimated using an equation from LMS (1988):

$$M_T = 0.9915 - [(0.07205 \cdot T_D \cdot \log_{10}(t_i)) + (0.01451 \cdot T_D \cdot T_A) + (3.293 \cdot \log_{10}(t_i)) - (0.5921 \cdot T_A)]$$

Boundary values for river herring and American shad are as follows:

Lifestage	Temperature (°C)	
	X_1	X_2
Yolk Sac larvae (YSL)	33.5	38.0
Post Yolk-Sac Larvae (PYS)	29.8	32.9
Juveniles (JUV)	29.8	32.9

For YSL and PYS, the average TL_{95} thermal tolerance limit for alewife at 10 minutes of exposure was used for X_1, and the average TL_5 limit was used for X_2, both reported in EA (1978a). Juvenile boundary values were set equal to those for PYS, and 100% thermal mortality was assumed for eggs.

Mechanical mortality values (M_M) for existing Albany Steam Station operations were estimated based on empirical entrainment survival studies used in the HRDEIS (1993). Mechanical mortality values for the BEC once-through alternative were estimated based on values used for Public Service Electric and Gas Company's 1999 §316(b) Demonstration (PSEG, 1999). These values are shown in Table A.2-19.

Total entrainment mortality (f_{ski}) was calculated by week for each year and then averaged by year for input to the ETM. Tables A.2-20 and A.2-21 show the annual instantaneous entrainment mortality rates (E_{ski}) computed by species and life stage for Albany Steam Generating Station existing operations and for the BEC once-through alternative.

Entrainment Interval

The entrainment interval (i.e., life stage duration, t) may be defined as the length of time required for an organism to grow through the entrainable life stages. This interval includes the duration of the spawning period and is dependent on an organism's growth rate and ambient water temperature. Incubation periods were derived from values provided in the literature. Each species' growth duration to maximum entrainable size was computed by using a physical growth model from Houde (1989) that was designed to estimate the average daily growth rate from hatching to the end of the post yolk-sac larval stage. This model is estimated by specifying stage duration (D) as a function of temperature (T):

$$D = 952.5\, T^{-1.0752}$$

The hatch length of each species is subtracted from the length at which transition to the juvenile stage occurs. This is then divided by the stage duration (D) to obtain an average daily growth rate. Using this relationship, the durations (in days) to the end of each larval stage and to each maximum entrainable size were computed. The maximum entrainable sizes for each target species were determined both for existing operations and for the proposed alternatives.

The maximum entrainable size for existing Albany Steam Generating Station operations was estimated from entrainment length frequencies at the Roseton and Danskammer Point Generating Stations (EA, 1978b, 1980; EA EST, 1988; LMS, 1985) to be 30 mm total length (TL). A maximum entrainable size of 35 mm TL based on BEC once-through system alternative operations (6.4- x 12.7-mm mesh slot screens) was estimated from entrainment length frequencies at the Salem Generating Station after the addition of 6.4- x 12.7-mm mesh slot screens (PSEG, 1999) to be 35 mm TL. A maximum entrainable size of 20 mm TL is estimated for the BEC closed-cycle system alternative operations (with 2.0-mm wedge-wire mesh screens); this is the same TL that was employed for the Athens Generating Project

(LMS, 1998). The passive wedge-wire screens with 2.0 mm slot width proposed for installation at BEC with a closed-loop cooling system assure that through-slot velocity does not exceed 0.5 ft/sec under both peak (i.e., distillate oil firing) or base (i.e., gas firing) water withdrawal conditions. Intake screens of this design, combined with low intake velocity (< 0.5 ft/sec), have been demonstrated to reduce entrainment of fish eggs and larvae (as well as effectively eliminate impingement of larger fish) (Browne et al. 1981, Hanson 1981, Weisberg et al. 1987). Wedge wire screen exclusion efficiencies have been calculated for several species based on larval length; and applied in entrainment loss estimates (ERC 1995). Based on these studies, a maximum entrainable size of 20 mm TL is a conservative estimate because it is likely that some larvae and eggs < 20 mm in size will also be excluded by the 2.0-mm wedge-wire screens.

W-ratio

The W-ratio represents a measure of the abundance of organisms in power plant intake water relative to their average abundance in a theoretical cross-section of the river located in front of the power plant. A conservative (i.e., overestimating) W-ratio of 1.0 was assumed for all species and operating scenarios.

A.2.5 Equivalent Adult Analysis

Although there may be mortality associated with entrainment, the natural mortality rates for early life stages of fish are generally high. Natural mortality rates are typically very high for eggs, but decline progressively as the fish matures to adulthood. The impact of removal of a given number of eggs, larvae and juveniles on the overall population can be put into perspective through the use of equivalent adult analysis. This analysis method estimates the number of spawning adults that would be lost as a result of entrainment of younger life stages at a generating facility, while accounting for natural mortality.

An evaluation of impacts to aquatic resources due to entrainment was accomplished by estimating the equivalent adults lost annually for each target species and each operating alternative. The equivalent adult method uses life stage-specific survival rates to convert estimates of loss for each life stage to an equivalent number lost at some later life stage according to the following equation:

$$N_k = \sum_{i}^{k} \left(S_i \times N_i \right)$$

where

N_k = Equivalent number of organisms at age (k)

S_i = Total survival from life stage (i) to age (k)

N_i = Number of life stage (i) lost to entrainment.

The equivalent adult method requires estimates of life stage-specific total mortality rate for each life stage potentially entrained and for all subsequent life stages up to age (k) to estimate total survival. It is assumed that the fish population is at replacement level, such that the number of recruits just offsets adult mortality and the population neither increases nor decreases. The life stage survival values for age 0+ impinged fish were partitioned over a twelve month period such that the equivalent adult estimates were weighed by monthly occurrence. Life stages-specific total mortality rates for each target species is provided in Table A.2-22.

A.2.6 Economic Impact to New York State Fisheries

Entrainment fish losses at the BEC were equated to their equivalent pounds lost to the commercial and recreational fishery as a result of the operation of the Albany Steam Generating Station and for the proposed BEC cooling system alternatives. The method simply involves multiplying the estimates of pounds taken in the commercial/ recreational fishery for each species by the CMR calculated for the ASGS and different BEC cooling system alternatives (see Section 8.3.3). The method was employed for the Athens Project on the River (Englert 1999) and was characterized as conservative (i.e., overestimating) because it does not take into account the possible density dependent response of the population that can reduce the effect on the fishery and the resultant CMR estimate. previously indicated that the method is sound and conservative but believes there are some biases and uncertainties in the NMFS data.

New York State commercial and recreational landings data were obtained from the National Marine Fisheries Service (NMFS) for the same period as CMR values were estimated (1975-1995), when available. NMFS commercial landings data (annual pounds) were available for all four target species. Recreational landings data (total catch; includes harvested and catch-and-release) were available for river herring (annual number), striped bass (annual pounds) and white perch (annual number). Annual losses (pounds) to recreational landings for river herring and white perch were estimated using an individual fish weight of 0.75 and 0.32 lb, respectively. Individual fish weights were estimated using species life-history information (i.e., length-weight-growth) and an estimated average age of five years.

Table A.2-1 Weekly Mean Entrainment Abundance (No./1000 m^3) at the Albany Steam Generating Station during 1983

Date	River Herring				White Perch			
	Eggs	YSL	PYS	JUV	Eggs	YSL	PYS	JUV
3-9 Apr	0	0	0	0	0	0	0	0
10-16 Apr	0	0	0	0	0	0	0	0
17-23 Apr	8	0	0	0	0	0	0	0
24-30 Apr	4	0	0	0	0	0	0	0
1-7 May	11707	0	0	0	96	0	0	0
8-14 May	688	0	0	0	52	0	0	0
15-21 May	8176	7	58	0	138	25	4	0
22-28 May	8566	999	28224	0	168	54	65	0
29 May - 4 Jun	889	349	4183	0	302	14	11	0
5-11 Jun	309	615	6228	0	683	242	124	0
12-18 Jun	211	88	4546	0	99	15	49	0
19-25 Jun	23	62	4804	0	59	0	25	0
26 Jun - 2 Jul	0	0	898	2	27	0	80	0
2-9 Jul	12	0	344	0	0	0	48	0
10-16 Jul	0	0	448	0	0	0	19	0
17-23 Jul	0	0	63	0	0	0	10	0
24-30 Jul	0	0	22	0	0	0	0	0
31 Jul - 6 Aug	0	0	12	0	0	0	0	0
7-13 Aug	0	0	0	0	0	0	0	0
14-20 Aug	0	0	0	0	0	0	0	0
21-27 Aug	0	0	0	0	0	0	0	0
28 Aug - 3 Sep	0	0	0	0	0	0	0	0
4-10 Sep	0	0	0	0	0	0	0	0
11-17 Sep	0	0	0	0	0	0	0	0
18-24 Sep	0	0	0	0	0	0	0	0
25-30 Sep	0	0	0	0	0	0	0	0

Notes:

YSL – Yolk Sac Larvae; PYS – Post Yolk Sac Larvae; JUV - Juveniles

Table A.2-2 Average Icthyoplankton Density (no/cubic meter) of Target Species from the LRS (Albany region)

Year	River Herring				American shad				Striped bass				White perch			
	Eggs	YSL	PYSL	JUV	Eggs	YSL	PYSL	JUV	Eggs	YSL	PYSL	JUV	Eggs	YSL	PYSL	JUV
1975									< 0.01	< 0.01	0.00	0.01	0.01	0.01	0.01	0.00
1976									0.01	< 0.01	0.00	0.00				
1977									< 0.01	< 0.01	< 0.01	< 0.01	0.02	0.05	0.01	
1978					0.03	0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.00	0.11	0.08	0.02	< 0.01
1979									< 0.01	< 0.01	< 0.01	0.00	0.14	0.06	0.10	0.61
1980	1.93	1.37	3.51		0.43	0.45	0.17	2.61	0.00	0.01	< 0.01	0.00	0.29	0.16	0.11	<0.00
1981	0.00	0.00	0.00		0.92	0.19	0.08	2.79	< 0.01	< 0.01	0.01	< 0.01	0.17	0.17	0.33	<0.00
1982	4.74	0.93	0.58	0.01	0.18	0.46	0.05	< 0.01	< 0.01	< 0.01	< 0.01	0.00	3.83	0.17	0.03	0.00
1983	42.65	1.69	0.65	< 0.01	1.13	0.28	0.03	< 0.01	< 0.01	< 0.01	0.00	0.00	0.88	0.12	0.34	0.00
1984	5.35	0.09	0.55	< 0.01	0.62	0.04	< 0.01	< 0.01	< 0.01	0.00	< 0.01	0.00	0.16	0.03	0.02	0.00
1985	0.91	0.28	0.23	0.04			0.04	0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.03	0.01	0.42	<0.00
1986	1935.23	509.59	0.53	< 0.01			0.10	< 0.01	0.69	0.29	< 0.01	0.00	68.23	79.81	0.02	0.00
1987	76.84	342.61	0.80	0.02			0.05	< 0.01	0.08	0.04	< 0.01	< 0.01	10.90	29.13	0.10	<0.00
1988	1.07	0.31	0.44	0.00	0.74	0.14	0.11	0.02	< 0.01	< 0.01	< 0.01	0.00	0.16	0.03	0.04	<0.00
1989	3.80	0.51	0.37	0.01	0.99	0.13	0.07	< 0.01	< 0.01	< 0.01	< 0.01	0.00	0.19	0.05	0.01	0.00
1990	15.67	1.44	0.84	0.02	0.59	0.38	0.21	0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.54	0.05	0.05	<0.00
1991	1.53	0.30	0.45	< 0.01	0.23	0.10	0.06	0.01	< 0.01	< 0.01	0.01	< 0.01	0.04	0.02	0.06	<0.00
1992	6.63	2.28	1.66	0.01	0.18	0.24	0.56	0.05	0.01	< 0.01	< 0.01	0.00	0.61	0.14	0.49	0.00
1993	0.22	0.23	0.71	0.00	0.18	0.02	0.06	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.08	0.04	0.05	0.00
1994	0.39	0.65	1.38	< 0.01	0.53	0.05	0.09	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.15	0.09	0.19	0.00
1995	0.25	0.08	0.40	< 0.01	0.05	0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.05	0.04	0.04	0.00
AVG	131.08	53.90	0.82	0.01	0.48	0.18	0.10	0.32	0.04	0.02	< 0.01	< 0.01	4.33	5.51	0.12	0.03
1983	42.65	1.69	0.65	< 0.01	1.13	0.28	0.03	0.00	0.00	< 0.01	0.00	0.00	0.88	0.12	0.34	0.00

Note: River herring were not processed in LRS collections prior to 1980; American shad were not reported during 1979 in LRS collections, and no eggs or larvae were collected from 1985 to 1987; White perch were not reported in LRS collections during 1976, and no juvenile estimates were made for the LRS during 1977.

YSL – Yolksac Larvae, PYS – Post Yolksac Larvae, JUV – Juveniles, LRS – Longitudinal River Survey

Table A.2-3 Average Weekly Icthyoplankton Density (no/cubic meter) of Target Species from ASGS and LRS (Albany region), May – July 1983

Species	Week	Eggs		Yolksac Larvae		Post Yolksac Larvae		Juvenile	
		LRS	ASGS	LRS	ASGS	LRS	ASGS	LRS	ASGS
Alosa spp.	1	1.86	11.71	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.20	0.69	0.09	0.00	0.01	0.00	0.00	0.00
	3	403.64	8.18	0.06	0.01	0.00	0.06	0.00	0.00
	4	5.22	8.57	11.76	1.00	0.00	28.22	0.00	0.00
	5	12.00	0.89	1.24	0.35	0.26	4.18	0.00	0.00
	6	0.73	0.31	2.63	0.62	0.12	6.23	0.00	0.00
	7	2.55	0.21	1.06	0.09	0.40	4.55	0.00	0.00
	8	0.36	0.02	0.10	0.06	2.60	4.80	0.00	0.00
	9	0.00	0.00	0.00	0.00	2.66	0.90	< 0.01	0.00
	10	0.00	0.01	0.00	0.00	0.43	0.34	0.00	0.00
	AVG	42.65	3.06	1.69	0.21	0.65	4.93	< 0.01	0.00
American shad	1	0.20	NA	0.00	NA	0.00	NA	0.00	NA
	2	0.34	NA	0.00	NA	0.00	NA	0.00	NA
	3	7.56	NA	0.01	NA	0.00	NA	0.00	NA
	4	2.22	NA	0.34	NA	0.16	NA	0.00	NA
	5	0.85	NA	0.47	NA	0.02	NA	0.00	NA
	6	0.07	NA	1.74	NA	0.01	NA	0.00	NA
	7	0.06	NA	0.30	NA	0.01	NA	0.00	NA
	8	0.00	NA	0.00	NA	0.01	NA	0.00	NA
	9	0.00	NA	0.00	NA	0.10	NA	< 0.01	NA
	10	0.00	NA	0.00	NA	< 0.01	NA	0.00	NA
	AVG	1.13	–	0.28	–	0.03	–	< 0.01	–
Striped bass	1	0.00	NA	0.00	NA	0.00	NA	0.00	NA
	2	0.00	NA	0.00	NA	0.00	NA	0.00	NA
	3	< 0.01	NA	0.00	NA	0.00	NA	0.00	NA
	4	0.00	NA	< 0.01	NA	0.00	NA	0.00	NA
	5	< 0.01	NA	0.00	NA	0.00	NA	0.00	NA
	6	< 0.01	NA	0.00	NA	0.00	NA	0.00	NA
	7	0.01	NA	0.00	NA	0.00	NA	0.00	NA
	8	0.00	NA	< 0.01	NA	0.00	NA	0.00	NA
	9	0.00	NA	0.00	NA	0.00	NA	0.00	NA
	10	0.00	NA	0.00	NA	0.00	NA	0.00	NA
	AVG	< 0.01	–	< 0.01	–	0.00	–	0.00	–
White perch	1	0.34	0.10	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.02	0.05	0.01	0.00	0.00	0.00	0.00	0.00
	3	4.24	0.14	0.02	0.02	0.00	0.00	0.00	0.00
	4	0.39	0.17	0.31	0.05	0.00	0.07	0.00	0.00
	5	1.56	0.30	0.01	0.01	0.00	0.01	0.00	0.00
	6	0.18	0.68	0.41	0.24	0.00	0.12	0.00	0.00
	7	1.75	0.10	0.29	0.01	0.00	0.05	0.00	0.00
	8	0.33	0.06	0.15	0.00	0.10	0.02	0.00	0.00
	9	0.00	0.03	0.01	0.00	1.22	0.08	0.00	0.00
	10	0.00	0.00	< 0.01	0.00	2.08	0.05	0.00	0.00
	AVG	0.88	0.16	0.12	0.03	0.34	0.04	0.00	0.00

Note(s): LRS – Longitudinal River Survey, ASGS – Albany Steam Generating Station, NA – Not applicable (only "occasional" American shad larvae were collected and no striped bass were identified in any entrainment samples)

Table A.2-4 Daily Mean Entrainment Abundance (No./1000 m^3) at the Roseton Generating Station During 1984

Date	River Herring				American Shad				Striped Bass				White Perch			
	Eggs	YSL	PYS	JUV	Eggs	YSL	PYS	JUV	Eggs	YSL	PYS	JUV	Eggs	YSL	PYS	JUV
1-May	289.93	4.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.02	0.00	0.00	0.00
8-May	254.66	8.62	6.65	0.00	0.67	0.00	0.00	0.00	2.01	0.00	0.00	0.00	61.56	1.98	0.00	0.00
15-May	69.02	6.04	46.86	0.00	1.35	3.35	0.00	0.00	0.67	0.00	0.00	0.00	89.30	60.37	10.06	0.00
18-May	3.37	25.54	257.20	0.00	0.67	11.42	0.00	0.00	2.02	0.00	0.00	0.00	82.05	114.30	22.33	0.00
22-May	104.78	22.04	261.96	0.00	0.00	1.33	5.34	0.00	0.00	0.67	0.00	0.00	121.46	28.67	65.45	0.00
23-May	84.09	16.60	226.89	0.00	0.00	9.23	15.24	0.00	1.34	0.00	0.00	0.00	59.35	53.84	45.68	0.00
24-May	92.46	7.32	231.92	0.00	0.00	1.97	11.33	0.00	0.00	0.00	0.00	0.00	76.46	35.16	40.57	0.00
25-May	18.65	0.64	138.51	0.00	0.00	0.00	4.62	0.00	0.65	0.00	0.00	0.00	50.36	15.24	33.85	0.00
26-May	27.49	4.66	296.01	0.00	0.00	0.66	2.01	0.00	0.00	0.00	0.00	0.00	55.42	23.38	58.79	0.00
27-May	9.31	4.04	254.76	0.00	0.00	0.67	10.03	0.00	0.67	0.00	0.00	0.00	100.31	28.84	28.75	0.00
28-May	2.64	9.99	358.59	0.00	0.00	0.00	6.02	0.00	0.00	1.34	0.00	0.00	123.86	37.13	12.65	0.00
29-May	2.04	22.94	223.50	0.00	0.00	1.34	8.01	0.00	6.73	6.80	0.00	0.00	112.72	58.79	18.78	0.00
30-May	15.11	427.58	3367.25	0.00	0.00	21.84	127.78	0.00	1.34	0.67	0.00	0.00	89.51	89.43	158.14	0.00
31-May	2.70	678.35	12972.80	0.00	0.00	60.04	127.91	0.00	0.00	0.00	0.00	0.00	108.46	29.76	53.05	0.00
mean	69.73	88.50	1331.64	0.00	0.19	7.99	22.74	0.00	1.10	0.68	0.00	0.00	81.77	41.21	39.15	0.00
1-Jun	23.75	249.52	4527.93	0.00	0.00	79.90	125.12	0.00	0.68	0.00	0.00	0.00	60.19	4.66	1.35	0.00
5-Jun	6.69	14.10	842.31	0.00	0.00	8.69	8.70	0.00	0.00	0.67	0.00	0.00	105.59	6.69	6.69	0.00
6-Jun	6.71	11.36	501.35	0.00	0.00	7.37	12.67	0.00	2.70	0.68	0.00	0.00	144.23	7.33	3.34	0.00
7-Jun	5.37	35.98	290.36	0.00	0.00	4.03	13.39	0.00	2.00	0.00	0.00	0.00	189.75	3.31	0.66	0.00
8-Jun	27.27	39.94	149.50	0.00	0.00	2.66	22.56	0.00	6.64	5.30	0.00	0.00	276.34	6.66	3.99	0.00
12-Jun	0.66	2.64	113.91	0.00	0.00	0.00	3.31	0.00	9.26	41.67	2.00	0.00	101.29	14.51	24.48	0.00
13-Jun	1.35	2.66	148.78	0.00	0.00	0.00	0.66	0.00	8.07	58.20	17.47	0.00	115.87	24.75	87.17	0.00
14-Jun	0.00	3.31	112.73	0.00	0.00	0.00	0.00	0.00	2.67	23.34	18.70	0.00	84.49	11.98	65.75	0.00
15-Jun	0.67	0.66	89.76	0.00	0.00	0.67	0.66	0.00	0.67	86.44	86.48	0.00	36.97	13.94	73.16	0.00
19-Jun	0.00	1.39	44.21	0.00	0.00	0.00	0.69	0.00	0.00	2.06	160.15	0.00	33.73	2.77	91.54	0.00
20-Jun	0.00	0.00	71.11	0.00	0.00	0.00	0.00	0.00	0.00	4.66	226.32	0.00	33.86	1.33	167.54	0.00
21-Jun	0.00	2.61	84.06	0.00	0.00	0.00	0.66	0.00	0.00	4.61	188.40	0.00	57.93	3.32	119.88	0.00
22-Jun	0.00	0.66	22.61	0.00	0.00	0.00	0.68	0.00	0.00	6.67	290.93	0.00	40.60	0.66	251.65	0.00
23-Jun	0.00	0.00	14.02	0.00	0.00	0.00	0.00	0.00	0.00	6.06	163.99	0.00	56.33	2.01	360.23	0.00
24-Jun	0.00	0.00	37.79	0.00	0.00	0.00	0.00	0.00	0.00	2.76	87.34	0.00	62.79	2.68	292.04	0.00
25-Jun	0.00	0.00	22.84	0.00	0.00	0.00	1.32	0.00	0.00	6.02	61.37	0.00	15.53	3.96	281.76	0.00
26-Jun	0.00	0.00	39.22	0.00	0.00	0.00	1.30	0.00	0.00	1.35	43.75	0.00	34.46	1.34	172.61	0.00
27-Jun	0.00	0.00	64.03	0.00	0.00	0.00	0.00	0.00	0.00	2.70	25.43	0.00	29.19	1.99	234.97	0.00
28-Jun	0.00	0.00	55.70	0.00	0.00	0.00	0.00	0.00	0.00	0.66	29.20	0.00	32.53	0.67	154.50	0.00

Date	River Herring				American Shad				Striped Bass				White Perch			
	Eggs	YSL	PYS	JUV	Eggs	YSL	PYS	JUV	Eggs	YSL	PYS	JUV	Eggs	YSL	PYS	JUV
29-Jun	0.00	0.00	75.51	0.00	0.00	0.00	1.38	0.00	0.00	0.68	21.46	0.00	26.36	0.70	169.79	0.00
mean	3.62	18.24	365.39	0.00	0.00	5.17	9.66	0.00	1.63	13.36	71.15	0.00	76.90	5.76	128.16	0.00
3-Jul	0.00	0.00	44.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.33	0.00	0.00	0.00	62.84	0.00
10-Jul	0.00	0.00	72.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.37	0.66	0.00	0.00	28.93	0.00
17-Jul	0.00	0.00	1.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.33	1.98	0.00	0.00	11.80	0.00
24-Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.66	0.00	0.00	12.00	0.00

Notes:

YSL – Yolk Sac Larvae; PYS – Post Yolk Sac Larvae; JUV – Juveniles

Table A.2-5 Daily Mean Entrainment Abundance (No./1000 m^3) at the Danskammer Generating Station During 1984

Date	River Herring				American Shad				Striped Bass				White Perch			
	Eggs	YSL	PYS	JUV	Eggs	YSL	PYS	JUV	Eggs	YSL	PYS	JUV	Eggs	YSL	PYS	JUV
1-May	2608.70	8.62	0.66	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	77.38	0.00	0.00	0.00
8-May	945.24	17.42	6.01	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	780.88	8.00	0.00	0.00
15-May	377.67	18.53	45.60	0.00	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	331.19	110.85	3.29	0.00
17-May	185.69	61.01	408.97	0.00	1.32	10.63	1.33	0.00	3.98	0.00	0.00	0.00	680.12	163.97	10.64	0.00
19-May	20.53	18.51	376.18	0.00	0.00	4.63	2.67	0.00	0.00	0.00	0.00	0.00	168.65	64.92	17.14	0.00
21-May	2167.52	27.99	350.47	0.00	0.00	4.68	11.32	0.00	1.34	0.67	0.00	0.00	368.07	50.07	34.02	0.00
23-May	2760.43	23.82	475.56	0.00	0.00	5.95	70.25	0.00	0.00	0.66	0.00	0.00	1274.11	61.09	126.96	0.00
25-May	494.46	4.00	448.43	0.00	0.00	2.66	34.60	0.00	2.64	2.00	0.00	0.00	893.59	66.90	45.13	0.00
27-May	142.99	30.78	507.41	0.00	0.67	2.02	22.71	0.00	2.01	4.02	0.00	0.00	355.42	64.89	19.38	0.00
29-May	251.13	60.62	206.80	0.00	0.00	0.00	23.24	0.00	3.34	6.66	0.00	0.00	1038.21	82.50	15.94	0.00
31-May	341.43	1292.52	13134.29	0.00	0.00	48.29	187.23	0.00	1.37	0.69	0.00	0.00	4686.10	47.48	39.86	0.00
mean	935.98	142.17	1450.94	0.00	0.24	7.47	32.12	0.00	1.40	1.34	0.00	0.00	968.52	65.52	28.40	0.00
2-Jun	143.30	240.53	7364.25	0.00	1.31	29.85	164.66	0.00	0.67	0.00	0.00	0.00	405.13	12.06	0.00	0.00
4-Jun	79.68	53.05	3223.10	0.00	0.00	13.43	36.94	0.00	2.03	2.01	0.00	0.00	476.93	14.11	4.03	0.00
6-Jun	63.28	18.84	753.23	0.00	0.67	1.33	9.36	0.00	2.02	4.02	0.00	0.00	487.99	33.02	2.01	0.00
8-Jun	113.40	73.92	296.99	0.00	0.00	2.65	26.65	0.00	11.37	11.97	0.00	0.00	580.78	15.47	2.71	0.00
10-Jun	86.17	17.31	75.98	0.00	0.00	0.00	4.66	0.00	5.28	17.85	0.00	0.00	495.59	22.00	4.68	0.00
12-Jun	27.22	4.63	131.35	0.00	0.00	0.00	2.02	0.00	38.89	30.75	9.42	0.00	283.10	31.90	25.99	0.00
14-Jun	3.33	4.67	114.31	0.00	0.00	0.00	0.00	0.00	13.38	26.00	11.33	0.00	242.21	28.04	54.24	0.00
16-Jun	0.00	0.67	160.34	0.00	0.00	0.00	0.00	0.00	6.71	20.71	65.06	0.00	275.03	19.46	159.41	0.00
18-Jun	3.37	0.67	64.68	0.00	0.00	0.00	0.65	0.00	1.32	20.69	386.77	0.00	155.03	19.99	137.80	0.00
20-Jun	2.65	1.33	113.04	0.00	0.00	0.00	0.65	0.00	0.00	21.98	123.92	0.00	76.61	4.66	154.68	0.00
22-Jun	17.86	0.00	22.69	0.00	0.00	0.00	0.00	0.00	0.67	1.34	406.25	0.00	44.26	3.98	362.10	0.00
26-Jun	0.67	0.66	87.93	0.00	0.00	0.00	1.34	0.00	3.32	6.66	58.70	0.00	50.15	8.02	169.57	0.00
mean	45.08	34.69	1033.99	0.00	0.17	3.94	20.58	0.00	7.14	13.67	88.45	0.00	297.73	17.73	89.77	0.00
3-Jul	0.00	0.00	64.23	0.00	0.00	0.00	0.67	0.00	0.00	0.00	5.35	0.00	1.33	0.00	58.80	0.00
10-Jul	0.00	0.00	60.43	2.01	0.00	0.00	0.67	0.00	0.00	0.00	6.02	0.66	0.00	0.00	55.63	0.00
17-Jul	0.00	0.00	4.00	1.34	0.00	0.00	0.00	0.66	0.00	0.00	0.67	4.00	0.00	0.00	48.21	2.68
24-Jul	0.00	0.00	0.66	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.64	0.00	0.00	31.37	10.71

Notes:

YSL – Yolk Sac Larvae; PYS – Post Yolk Sac Larvae; JUV – Juveniles

Table A.2-6. Icthyoplankton Distribution (%) at Roseton and Danskammer based on Average Hourly Entrainment Density, May Through July 1987

Species	Life Stage	Station	Hour																							
			9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00
Alosa	YSL	Roseton	4.91	5.07	4.52	6.18	4.10	4.07	6.23	4.03	2.17	1.79	2.58	4.14	4.84	2.66	4.12	6.03	3.68	2.68	2.98	3.69	3.45	3.44	5.51	7.15
		Dansk.	4.42	6.43	4.24	7.58	2.88	1.92	2.88	0.58	0.75	2.10	5.08	2.72	6.48	2.05	2.63	5.26	5.24	3.22	4.61	3.28	2.62	8.65	7.88	6.50
		Average	4.66	5.75	4.38	6.88	3.49	3.00	4.55	2.30	1.46	1.94	3.83	3.43	5.66	2.36	3.38	5.65	4.46	2.95	3.79	3.48	3.04	6.04	6.69	6.83
	PYSL	Roseton	6.12	6.47	7.42	5.98	4.32	2.86	2.89	2.71	2.86	3.41	3.22	4.02	3.95	4.58	4.81	3.96	3.92	3.73	3.99	3.79	3.85	3.36	3.73	4.06
		Dansk.	6.25	4.65	4.13	3.37	3.37	2.31	1.94	2.31	3.88	3.51	5.41	3.86	4.35	2.90	3.73	3.69	4.34	4.46	3.59	4.31	4.17	4.96	7.15	7.36
		Average	6.19	5.56	5.77	4.68	3.84	2.58	2.42	2.51	3.37	3.46	4.32	3.94	4.15	3.74	4.27	3.83	4.13	4.09	3.79	4.05	4.01	4.16	5.44	5.71
	JUV	Roseton	2.96	3.56	2.51	3.70	1.42	1.65	0.82	1.30	4.70	6.37	2.86	3.52	4.39	3.72	5.92	4.36	11.28	3.88	8.27	8.34	6.87	2.82	2.33	2.44
		Dansk.	10.86	6.29	8.60	1.49	1.33	1.71	0.67	1.88	4.16	2.86	4.37	3.55	6.77	8.33	1.55	6.81	3.56	2.49	4.51	2.25	3.14	2.52	2.42	7.87
		Average	6.91	4.93	5.55	2.59	1.37	1.68	0.75	1.59	4.43	4.61	3.62	3.53	5.58	6.02	3.74	5.58	7.42	3.19	6.39	5.29	5.01	2.67	2.37	5.16
Am. shad	YSL	Roseton	0.00	0.00	19.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.24	0.00	39.18	0.00	0.00	0.00	20.87	0.00	0.00	0.00	0.00	0.00
		Dansk.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Average	0.00	0.00	9.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.12	0.00	19.59	0.00	0.00	0.00	10.43	0.00	0.00	0.00	0.00	0.00
	PYSL	Roseton	5.28	5.01	7.67	8.47	2.22	1.62	2.20	4.36	2.18	7.14	3.80	3.11	8.40	6.90	3.99	3.22	3.19	3.84	2.67	2.73	4.37	1.60	3.29	2.77
		Dansk.	4.96	5.09	3.24	1.44	1.44	3.11	5.52	3.01	3.10	5.29	5.44	5.59	11.49	6.17	2.33	3.98	0.78	2.37	2.28	2.30	4.55	4.00	5.85	6.66
		Average	5.12	5.05	5.46	4.95	1.83	2.36	3.86	3.69	2.64	6.22	4.62	4.35	9.95	6.53	3.16	3.60	1.98	3.10	2.48	2.52	4.46	2.80	4.57	4.71
	JUV	Roseton	7.20	17.31	8.89	7.14	0.00	0.00	0.00	0.00	0.00	3.17	0.00	7.21	7.33	7.35	3.04	0.00	3.03	25.13	0.00	0.00	0.00	3.19	0.00	0.00
		Dansk.	13.41	10.56	21.63	3.21	0.00	0.00	3.38	3.25	0.00	3.19	0.00	16.95	0.00	0.00	0.00	21.15	0.00	0.00	0.00	0.00	3.24	0.00	0.00	0.00
		Average	10.31	13.94	15.26	5.18	0.00	0.00	1.69	1.63	0.00	3.18	0.00	12.08	3.66	3.68	1.52	10.58	1.51	12.57	0.00	0.00	1.62	1.60	0.00	0.00
S. Bass	YSL	Roseton	0.70	1.72	1.76	2.66	2.73	3.50	6.65	6.53	5.29	3.87	2.75	3.08	3.06	5.50	4.77	6.39	5.92	5.88	5.57	5.18	5.37	4.42	4.41	2.28
		Dansk.	3.74	2.92	2.61	2.51	2.87	2.54	2.94	3.49	7.68	7.40	5.62	1.94	2.11	3.16	4.15	2.95	2.76	2.86	3.67	5.44	7.47	6.58	7.17	5.42
		Average	2.22	2.32	2.18	2.60	2.80	3.02	4.79	5.01	6.49	5.64	4.18	2.51	2.59	4.33	4.46	4.67	4.34	4.37	4.62	5.31	6.42	5.50	5.79	3.85
	PYSL	Roseton	1.35	2.20	2.40	2.46	3.48	4.36	5.62	5.76	4.46	3.83	2.51	2.90	3.43	5.46	5.37	7.02	6.99	5.74	5.03	4.99	4.47	3.97	4.04	2.18
		Dansk.	5.29	3.52	3.10	0.00	3.34	3.21	4.75	2.75	6.75	6.29	5.01	2.22	1.80	2.63	3.87	3.42	2.80	3.79	4.43	4.70	6.15	5.50	8.24	6.44
		Average	3.32	2.86	2.75	1.23	3.41	3.79	5.18	4.26	5.60	5.06	3.76	2.56	2.61	4.05	4.62	5.22	4.89	4.76	4.73	4.84	5.31	4.73	6.14	4.31
	JUV	Roseton	3.58	2.42	4.03	4.65	2.54	2.15	3.36	3.10	2.85	2.77	2.53	3.27	3.82	4.43	4.95	6.49	7.91	6.14	6.77	8.24	5.51	4.07	2.85	1.37
		Dansk.	4.95	5.58	3.95	1.46	2.11	3.58	4.82	4.15	4.07	2.67	2.46	2.02	3.59	3.11	5.98	7.58	7.17	6.74	6.06	3.52	4.92	2.07	2.82	4.61
		Average	4.26	4.00	3.99	3.16	2.32	2.86	4.09	3.62	3.46	2.72	2.50	2.64	3.71	3.77	5.47	7.03	7.54	6.44	6.41	5.88	5.22	3.07	2.84	2.99
W. Perch	YSL	Roseton	4.57	3.93	4.03	3.78	3.09	4.38	4.94	3.61	2.87	4.19	4.61	2.87	4.64	4.55	4.33	4.25	4.05	4.32	4.63	3.14	5.65	4.69	3.51	5.36
		Dansk.	2.11	3.45	4.56	7.48	3.34	4.45	7.16	1.82	4.04	5.10	7.32	4.14	1.82	2.48	3.24	2.31	3.23	3.80	3.39	5.21	3.75	7.50	3.82	4.50
		Average	3.34	3.69	4.29	5.63	3.22	4.41	6.05	2.71	3.46	4.64	5.97	3.51	3.23	3.52	3.79	3.28	3.64	4.06	4.01	4.18	4.70	6.09	3.66	4.93
	PYSL	Roseton	3.33	3.06	3.96	3.92	3.64	3.80	5.59	3.17	3.26	3.86	4.29	3.27	5.79	4.10	4.72	5.80	4.43	4.69	4.74	4.46	5.09	4.04	2.75	4.24
		Dansk.	2.41	3.39	4.77	0.16	6.53	3.99	4.34	2.44	3.45	5.51	6.56	7.23	2.11	2.49	3.19	2.59	4.42	4.26	3.55	5.99	4.61	8.09	4.04	3.87
		Average	2.87	3.22	4.36	2.04	5.08	3.89	4.97	2.80	3.35	4.69	5.43	5.25	3.95	3.30	3.96	4.20	4.43	4.48	4.14	5.23	4.85	6.07	3.39	4.06
	JUV	Roseton	1.37	1.74	1.01	3.01	1.30	4.54	3.44	3.77	5.00	3.11	1.92	1.85	4.41	4.21	5.27	7.68	8.87	7.08	4.98	11.34	5.91	3.61	2.42	2.15
		Dansk.	0.88	3.15	2.72	3.04	1.83	3.96	2.76	5.38	8.02	5.47	1.58	1.55	2.39	4.92	3.46	1.84	11.16	6.37	5.58	8.76	8.87	3.15	1.41	1.74
		Average	1.12	2.45	1.87	3.03	1.56	4.25	3.10	4.57	6.51	4.29	1.75	1.70	3.40	4.57	4.37	4.76	10.01	6.73	5.28	10.05	7.39	3.38	1.91	1.94

Note(s): YSL – Yolksac larvae, PYSL – Post Yolksac larvae, JUV – Juvenile, Hour – Start

Table A.2-7 Daily Sequenced Pumping – Alternative Pump Schedules and Hourly Flow

Alternative Schedule No.	Start Hour																							
	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00
1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2				XX	XX	XX	XX	XX	XX	X	X	X	X	X	X	X	X	X	X	X	X			
3						XXX	XXX	XXX	XXX	X	X	X	X	X	X	X	X	X	X	X	X			
4						XXX	XXX	XXX	XXX					XXX	XXX	XXX	XXX							
5				XX	XX	XX	XX	XX	XX						XX	XX	XX	XX	XX	XX				
6					XX	XX	XX	XX	XX	XX						XX	XX	XX	XX	XX	XX			
7						XXX	XXX	XXX	XXX	XXX			X	X	X	X	X	X	X	X	X			

Note(s):

Alternative Schedule No. 1 is considered "base case" (i.e., no variation in pumping schedule)
X – Average hourly flow for each cooling tower alternative; Hourly flow based on the average daily flow requirements for wet and wet/dry cooling tower alternatives

Average daily flow for BEC with Wet Cooling Towers – Peak Flow = 8.5 million gallons (32,286 cubic meters), Average hourly flow = 355,380 gallons (1345 cubic meters)
Average daily flow for BEC with Wet Cooling Towers – Base Flow = 4.7 million gallons (17, 863 cubic meters), Average hourly flow = 196,620 gallons (744 cubic meters)
Average daily flow for BEC with Wet/Dry Cooling Towers – Peak Flow = 8.2 million gallons (30,858 cubic meters), Average hourly flow = 339,660 gallons (1286 cubic meters)
Average daily flow for BEC with Wet/Dry Cooling Towers – Base Flow = 4.4 million gallons (16,533 cubic meters), Average hourly flow = 181,980 gallons (688 cubic meters)

Table A.2-8 Percent (%) Reduction in Larval Entrainment Based on Several Alternative Pump Schedules

Alternative Schedule	Lifestage	Species			
		River herring	American shad	Striped bass	White perch
1	YSL	--	--	--	--
	PYSL	--	--	--	--
2	YSL	12.7	19.7	0.5	0.5
	PYSL	13.4	8.4	0.6	1.8
3	YSL	22.1	19.7	1.6	1.6
	PYSL	19.6	9.4	-8.9	1.1
4	YSL	18.5	-17.5	7.4	7.4
	PYSL	19.5	16.5	-12.8	7.3
5	YSL	9.2	-20.1	3.1	3.1
	PYSL	12.9	27.7	-5.1	2.9
6	YSL	19.8	58.3	3.3	3.3
	PYSL	15.9	22.5	-14.1	-4.2
7	YSL	25.5	19.7	1.8	1.8
	PYSL	20.9	5.9	-12.7	2.4

Note(s):

YSL – Yolk sac larvae; PYSL – Post Yolk sac larvae

Alternative Schedule No. 1 is considered "base case" (i.e., no variation in pumping schedule). Negative (-) reductions indicate a possible increase in tentrainment for that species and lifestage based on the hourly pumping sequence.

Table A.2-9 Annual CMR Values for River Herring – Peak Flow

Year	Albany Steam Generating Station				Proposed Bethlehem Energy Center								
	ETM		CEMR		ETM								
	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Wet Coo'ing Tower	Wet Cooling w/ Alt. Pump Schedule	Wet Cooling w/ Intake Barrier System	Wet/Dry Cooling Tower	Wet/Dry Cooling w/ Alt. Pump Schedule	Wet/Dry Cooling w/ Intake Barrier System	Dry Cooling Tower
1975	-	-	22.03%	18.57%	-	-	-	-	-	-	-	-	-
1976	-	-	23.59%	19.78%	-	-	-	-	-	-	-	-	-
1977	-	-	21.25%	17.58%	-	-	-	-	-	-	-	-	-
1978	-	-	25.39%	20.85%	-	-	-	-	-	-	-	-	-
1979	-	-	21.42%	18.34%	-	-	-	-	-	-	-	-	-
1980	29.90%	26.63%	22.24%	18.58%	25.54%	11.21%	0.62%	0.51%	0.06%	0.59%	0.48%	0.06%	0.14%
1981	-	-	8.19%	6.59%	-	-	-		-	-		-	-
1982	11.12%	9.49%	4.28%	3.48%	9.88%	3.89%	0.13%	0.11%	0.01%	0.13%	0.10%	0.01%	0.03%
1983	15.71%	14.48%	9.58%	8.26%	11.81%	9.68%	0.32%	0.28%	0.03%	0.31%	0.27%	0.03%	0.08%
1984	5.66%	5.20%	18.73%	16.57%	4.51%	2.66%	0.11%	0.10%	0.01%	0.11%	0.09%	0.01%	0.03%
1985	11.36%	9.91%	13.25%	11.02%	9.35%	5.34%	0.18%	0.15%	0.02%	0.17%	0.14%	0.02%	0.04%
1986	8.25%	7.35%	4.68%	3.83%	6.28%	4.44%	0.17%	0.14%	0.02%	0.16%	0.13%	0.02%	0.04%
1987	24.81%	21.35%	31.35%	23.98%	21.84%	8.34%	0.40%	0.31%	0.04%	0.38%	0.30%	0.04%	0.09%
1988	8.61%	7.71%	19.36%	16.01%	6.54%	4.33%	0.19%	0.16%	0.02%	0.19%	0.16%	0.02%	0.05%
1989	16.50%	14.75%	27.96%	23.49%	13.11%	8.69%	0.30%	0.26%	0.03%	0.29%	0.25%	0.03%	0.07%
1990	21.70%	19.74%	24.79%	20.86%	17.40%	11.18%	0.43%	0.37%	0.04%	0.41%	0.36%	0.04%	0.10%
1991	16.37%	14.38%	21.37%	17.80%	12.95%	7.97%	0.33%	0.27%	0.03%	0.31%	0.26%	0.03%	0.08%
1992	32.31%	29.51%	41.55%	35.74%	25.80%	16.20%	0.77%	0.65%	0.08%	0.74%	0.62%	0.07%	0.18%
1993	10.01%	9.05%	10.15%	8.21%	7.80%	4.12%	0.25%	0.21%	0.02%	0.24%	0.20%	0.02%	0.06%
1994	22.30%	19.43%	14.73%	11.95%	19.39%	6.87%	0.42%	0.34%	0.04%	0.40%	0.32%	0.04%	0.10%
1995	13.16%	11.75%	6.68%	5.44%	11.04%	5.32%	0.24%	0.20%	0.02%	0.23%	0.19%	0.02%	0.06%
avg	16.52%	14.71%	18.69%	15.57%	13.55%	7.35%	0.32%	0.27%	0.03%	0.31%	0.26%	0.03%	0.08%

Notes:
ETM – Empirical Transport Model; CEMR – Conditional Entrainment Mortality Rate; Alternative cooling systems and intake options assume 100% mortality unless otherwise noted

Table A.2-10 Annual CMR Values for River Herring – Base Flow

	Albany Steam Generating Station				Proposed Bethlehem Energy Center								
	ETM		CEMR		ETM								
Year	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Wet Cooling Tower	Wet Cooling w/ Alt. Pump Schedule	Wet Cooling w/ Intake Barrier System	Wet/Dry Cooling Tower	Wet/Dry Cooling w/ Alt. Pump Schedule	Wet/Dry Cooling w/ Intake Barrier System	Dry Cooling Tower
1975	-	-	22.03%	18.57%	-	-		-	-	-	-	-	-
1976	-	-	23.59%	19.78%	-	-	-	-	-	-	-	-	-
1977	-	-	21.25%	17.58%	-	-	-	-	-	-	-	-	-
1978	-	-	25.39%	20.85%	-	-	-	-	-	-	-	-	-
1979	-	-	21.42%	18.34%	-	-	-	-	-	-	-	-	-
1980	29.90%	26.63%	22.24%	18.58%	25.34%	11.09%	0.34%	0.28%	0.03%	0.32%	0.26%	0.03%	0.01%
1981	-	-	8.19%	6.59%	-	-	-	-	-	-	-	-	-
1982	11.12%	9.49%	4.28%	3.48%	9.80%	3.85%	0.07%	0.06%	0.01%	0.07%	0.05%	0.01%	< 0.01%
1983	15.71%	14.48%	9.58%	8.26%	11.68%	9.57%	0.18%	0.16%	0.02%	0.16%	0.15%	0.02%	< 0.01%
1984	5.66%	5.20%	18.73%	16.57%	4.46%	2.63%	0.06%	0.05%	0.01%	0.06%	0.05%	0.01%	< 0.01%
1985	11.36%	9.91%	13.25%	11.02%	9.26%	5.28%	0.10%	0.08%	0.01%	0.09%	0.07%	0.01%	< 0.01%
1986	8.25%	7.35%	4.68%	3.83%	6.22%	4.39%	0.09%	0.08%	0.01%	0.09%	0.07%	0.01%	< 0.01%
1987	24.81%	21.35%	31.35%	23.98%	21.66%	8.25%	0.22%	0.17%	0.02%	0.21%	0.16%	0.02%	< 0.01%
1988	8.61%	7.71%	19.36%	16.01%	6.47%	4.28%	0.11%	0.09%	0.01%	0.10%	0.08%	0.01%	< 0.01%
1989	16.50%	14.75%	27.96%	23.49%	12.98%	8.60%	0.17%	0.14%	0.02%	0.16%	0.13%	0.02%	< 0.01%
1990	21.70%	19.74%	24.79%	20.86%	17.24%	11.06%	0.24%	0.21%	0.02%	0.22%	0.19%	0.02%	< 0.01%
1991	16.37%	14.38%	21.37%	17.80%	12.82%	7.88%	0.18%	0.15%	0.02%	0.17%	0.14%	0.02%	< 0.01%
1992	32.31%	29.51%	41.55%	35.74%	25.58%	16.03%	0.43%	0.36%	0.04%	0.40%	0.34%	0.04%	0.01%
1993	10.01%	9.05%	10.15%	8.21%	7.73%	4.08%	0.14%	0.11%	0.01%	0.13%	0.11%	0.01%	< 0.01%
1994	22.30%	19.43%	14.73%	11.95%	19.23%	6.79%	0.23%	0.19%	0.02%	0.22%	0.17%	0.02%	< 0.01%
1995	13.16%	11.75%	6.68%	5.44%	10.95%	5.26%	0.13%	0.11%	0.01%	0.12%	0.10%	0.01%	< 0.01%
avg	16.52%	14.71%	18.69%	15.57%	13.43%	7.27%	0.18%	0.15%	0.02%	0.17%	0.14%	0.02%	< 0.01%

Notes:
ETM – Empirical Transport Model; CEMR – Conditional Entrainment Mortality Rate; Alternative cooling systems and intake options assume 100% mortality unless otherwise noted

Table A.2-11 Annual CMR Values for American shad – Peak Flow

Year	Albany Steam Generating Station				Proposed Bethlehem Energy Center								
	ETM		CEMR		ETM								
	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Wet Cooling Tower	Wet Cooling w/ Alt. Pump Schedule	Wet Cooling w/ Intake Barrier System	Wet/Dry Cooling Tower	Wet/Dry Cooling w/ Alt. Pump Schedule	Wet/Dry Cooling w/ Intake Barrier System	Dry Cooling Tower
1975	-	-	36.57%	30.91%	-	-	-	-	-	-	-	-	-
1976	-	-	37.08%	31.36%	-	-	-	-	-	-	-	-	-
1977	-	-	3.38%	2.98%	-	-	-	-	-	-	-	-	-
1978	13.27%	11.60%	18.09%	14.90%	10.89%	5.20%	0.29%	0.26%	0.03%	0.27%	0.24%	0.03%	0.07%
1979	-	-	31.72%	26.61%	-	-	-	-	-	-		-	-
1980	41.76%	37.01%	42.26%	35.99%	34.29%	18.07%	1.01%	0.89%	0.10%	0.96%	0.85%	0.10%	0.24%
1981	27.17%	24.48%	15.64%	13.29%	21.83%	13.37%	0.59%	0.53%	0.06%	0.57%	0.51%	0.06%	0.14%
1982	25.20%	21.44%	1< 0.01%	8.17%	19.88%	9.43%	0.54%	0.45%	0.05%	0.52%	0.43%	0.05%	0.13%
1983	22.72%	19.89%	18.17%	15.89%	17.24%	9.79%	0.50%	0.43%	0.05%	0.48%	0.41%	0.05%	0.12%
1984	8.62%	8.20%	12.58%	10.84%	6.43%	5.26%	0.17%	0.16%	0.02%	0.17%	0.16%	0.02%	0.04%
1985	4.27%	3.57%	20.51%	17.77%	4.98%	1.46%	0.07%	0.06%	0.01%	0.06%	0.06%	0.01%	0.02%
1986	3.65%	3.10%	6.58%	5.92%	3.16%	0.74%	0.09%	0.08%	0.01%	0.08%	0.08%	0.01%	0.02%
1987	10.45%	8.89%	31.75%	26.61%	9.13%	2.18%	0.25%	0.23%	0.02%	0.23%	0.22%	0.02%	0.06%
1988	29.46%	25.95%	42.78%	36.45%	23.82%	12.29%	0.68%	0.60%	0.07%	0.65%	0.57%	0.06%	0.16%
1989	24.15%	21.39%	41.70%	35.44%	18.63%	10.45%	0.55%	0.48%	0.05%	0.52%	0.46%	0.05%	0.13%
1990	23.80%	20.79%	49.40%	42.36%	19.70%	8.87%	0.55%	0.49%	0.05%	0.52%	0.47%	0.05%	0.13%
1991	32.87%	28.69%	36.23%	30.64%	26.20%	12.85%	0.77%	0.68%	0.08%	0.74%	0.65%	0.07%	0.18%
1992	46.22%	40.61%	58.82%	50.85%	39.40%	16.53%	1.19%	1.07%	0.12%	1.14%	1.02%	0.11%	0.28%
1993	28.20%	24.62%	7.95%	6.46%	23.18%	10.63%	0.66%	0.58%	0.07%	0.63%	0.56%	0.06%	0.15%
1994	33.08%	29.10%	22.24%	18.32%	26.28%	12.61%	0.81%	0.72%	0.08%	0.78%	0.69%	0.08%	0.19%
1995	10.87%	9.42%	12.09%	9.75%	8.69%	3.44%	0.25%	0.23%	0.03%	0.24%	0.22%	0.02%	0.06%
avg	22.69%	19.93%	26.45%	22.45%	18.45%	9.01%	0.53%	0.47%	0.05%	0.50%	0.45%	0.05%	0.12%

Notes:
ETM – Empirical Transport Model; CEMR – Conditional Entrainment Mortality Rate; Alternative cooling systems and intake options assume 100% mortality unless otherwise noted

Table A.2-12 Annual CMR Values for American shad – Base Flow

Year	Albany Steam Generating Station				Proposed Bethlehem Energy Center								
	ETM		CEMR		ETM								
	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Wet Cooling Tower	Wet Cooling w/ Alt. Pump Schedule	Wet Cooling w/ Intake Barrier System	Wet/Dry Cooling Tower	Wet/Dry Cooling w/ Alt. Pump Schedule	Wet/Dry Cooling w/ Intake Barrier System	Dry Cooling Tower
1975	-	-	36.57%	30.91%	-	-	-	-	-	-	-	-	-
1976	-	-	37.08%	31.36%	-	-	-	-	-	-	-	-	-
1977	-	-	3.38%	2.98%	-	-	-	-	-	-	-	-	-
1978	13.27%	11.60%	18.09%	14.90%	10.78%	5.15%	0.16%	0.14%	0.02%	0.15%	0.13%	0.01%	< 0.01%
1979	-	-	31.72%	26.61%	-	-	-	-	-	-	-	-	-
1980	41.76%	37.01%	42.26%	35.99%	33.99%	17.88%	0.56%	0.49%	0.06%	0.52%	0.46%	0.05%	0.01%
1981	27.17%	24.48%	15.64%	13.29%	21.62%	13.22%	0.33%	0.29%	0.03%	0.30%	0.27%	0.03%	0.01%
1982	25.20%	21.44%	1< 0.01%	8.17%	19.69%	9.33%	0.30%	0.25%	0.03%	0.28%	0.23%	0.03%	0.01%
1983	22.72%	19.89%	18.17%	15.89%	17.07%	9.68%	0.28%	0.24%	0.03%	0.25%	0.22%	0.03%	< 0.01%
1984	8.62%	8.20%	12.58%	10.84%	6.36%	5.20%	0.10%	0.09%	0.01%	0.09%	0.08%	0.01%	< 0.01%
1985	4.27%	3.57%	20.51%	17.77%	4.94%	1.45%	0.04%	0.04%	< 0.01%	0.03%	0.03%	< 0.01%	< 0.01%
1986	3.65%	3.10%	6.58%	5.92%	3.13%	0.73%	0.05%	0.05%	< 0.01%	0.04%	0.04%	< 0.01%	< 0.01%
1987	10.45%	8.89%	31.75%	26.61%	9.05%	2.16%	0.14%	0.13%	0.01%	0.13%	0.12%	0.01%	< 0.01%
1988	29.46%	25.95%	42.78%	36.45%	23.60%	12.15%	0.38%	0.33%	0.04%	0.35%	0.31%	0.03%	0.01%
1989	24.15%	21.39%	41.70%	35.44%	18.45%	10.33%	0.30%	0.27%	0.03%	0.28%	0.25%	0.03%	0.01%
1990	23.80%	20.79%	49.40%	42.36%	19.51%	8.78%	0.30%	0.27%	0.03%	0.28%	0.25%	0.03%	0.01%
1991	32.87%	28.69%	36.23%	30.64%	25.96%	12.71%	0.43%	0.37%	0.04%	0.40%	0.35%	0.04%	0.01%
1992	46.22%	40.61%	58.82%	50.85%	39.08%	16.36%	0.66%	0.59%	0.07%	0.61%	0.55%	0.06%	0.01%
1993	28.20%	24.62%	7.95%	6.46%	22.96%	10.52%	0.37%	0.32%	0.04%	0.34%	0.30%	0.03%	0.01%
1994	33.08%	29.10%	22.24%	18.32%	26.05%	12.47%	0.45%	0.40%	0.05%	0.42%	0.37%	0.04%	0.01%
1995	10.87%	9.42%	12.09%	9.75%	8.60%	3.40%	0.14%	0.13%	0.01%	0.13%	0.12%	0.01%	< 0.01%
avg	22.69%	19.93%	26.45%	22.45%	18.28%	8.91%	0.29%	0.26%	0.03%	0.27%	0.24%	0.03%	0.01%

Notes:
ETM – Empirical Transport Model; CEMR – Conditional Entrainment Mortality Rate; Alternative cooling systems and intake options assume 100% mortality unless otherwise noted

Table A.2-13 Annual CMR Values for Striped Bass – Peak Flow

	Albany Steam Generating Station				Proposed Bethlehem Energy Center								
	ETM		CEMR		ETM								
Year	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Wet Cooling Tower	Wet Cooling w/ Alt. Pump Schedule	Wet Cooling w/ Intake Barrier System	Wet/Dry Cooling Tower	Wet/Dry Cooling w/ Alt. Pump Schedule	Wet/Dry Cooling w/ Intake Barrier System	Dry Cooling Tower
1975	0.30%	0.09%	0.65%	0.20%	0.40%	0.03%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1976	0.24%	0.23%	0.76%	0.34%	0.17%	0.17%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1977	0.22%	0.07%	0.52%	0.15%	0.29%	0.02%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1978	0.01%	0.01%	0.03%	0.01%	0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1979	0.04%	0.02%	0.10%	0.04%	0.03%	0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1980	0.14%	0.05%	0.27%	0.09%	0.10%	0.02%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1981	0.21%	0.10%	0.32%	0.22%	0.22%	0.04%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1982	0.02%	0.01%	0.14%	0.04%	0.01%	0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1983	0.02%	0.02%	0.24%	0.08%	0.01%	0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1984	< 0.01%	< 0.01%	0.12%	0.03%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1985	0.55%	0.16%	2.53%	0.88%	0.73%	0.05%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1986	0.53%	0.49%	0.15%	0.08%	0.39%	0.34%	0.01%	0.01%	< 0.01%	0.01%	0.01%	< 0.01%	< 0.01%
1987	0.25%	0.08%	0.76%	0.21%	0.33%	0.03%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1988	0.04%	0.03%	0.22%	0.14%	0.03%	0.02%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1989	0.01%	< 0.01%	0.14%	0.04%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1990	0.11%	0.04%	0.26%	0.11%	0.13%	0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1991	1.15%	0.33%	4.39%	1.15%	1.53%	0.10%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1992	0.04%	0.03%	0.50%	0.42%	0.03%	0.02%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1993	0.11%	0.04%	0.31%	0.14%	0.12%	0.02%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1994	0.04%	0.01%	0.12%	0.03%	0.06%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1995	0.70%	0.20%	0.38%	0.01%	0.93%	0.06%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
avg	0.22%	0.10%	0.61%	0.21%	0.26%	0.05%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%

Notes:
ETM – Empirical Transport Model; CEMR – Conditional Entrainment Mortality Rate; Alternative cooling systems and intake options assume 100% mortality unless otherwise noted

Table A.2-14 Annual CMR Values for Striped Bass – Base Flow

	Albany Steam Generating Station				Proposed Bethlehem Energy Center								
	ETM		CEMR		ETM								
Year	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Wet Cooling Tower	Wet Cooling w/ Alt. Pump Schedule	Wet Cooling w/ Intake Barrier System	Wet/Dry Cooling Tower	Wet/Dry Cooling w/ Alt. Pump Schedule	Wet/Dry Cooling w/ Intake Barrier System	Dry Cooling Tower
1975	0.30%	0.09%	0.65%	0.20%	0.39%	0.03%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1976	0.24%	0.23%	0.76%	0.34%	0.17%	0.17%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1977	0.22%	0.07%	0.52%	0.15%	0.28%	0.02%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1978	0.01%	0.01%	0.03%	0.01%	0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1979	0.04%	0.02%	0.10%	0.04%	0.03%	0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1980	0.14%	0.05%	0.27%	0.09%	0.10%	0.02%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1981	0.21%	0.10%	0.32%	0.22%	0.22%	0.04%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1982	0.02%	0.01%	0.14%	0.04%	0.01%	0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1983	0.02%	0.02%	0.24%	0.08%	0.01%	0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1984	< 0.01%	< 0.01%	0.12%	0.03%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1985	0.55%	0.16%	2.53%	0.88%	0.72%	0.05%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1986	0.53%	0.49%	0.15%	0.08%	0.38%	0.33%	0.01%	0.01%	< 0.01%	0.01%	0.01%	< 0.01%	< 0.01%
1987	0.25%	0.08%	0.76%	0.21%	0.33%	0.03%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1988	0.04%	0.03%	0.22%	0.14%	0.03%	0.02%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1989	0.01%	< 0.01%	0.14%	0.04%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1990	0.11%	0.04%	0.26%	0.11%	0.13%	0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1991	1.15%	0.33%	4.39%	1.15%	1.51%	0.10%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1992	0.04%	0.03%	0.50%	0.42%	0.03%	0.02%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1993	0.11%	0.04%	0.31%	0.14%	0.12%	0.02%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1994	0.04%	0.01%	0.12%	0.03%	0.06%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
1995	0.70%	0.20%	0.38%	0.01%	0.92%	0.06%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%
avg	0.22%	0.10%	0.61%	0.21%	0.26%	0.05%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%	< 0.01%

Notes:
ETM – Empirical Transport Model; CEMR – Conditional Entrainment Mortality Rate; Alternative cooling systems and intake options assume 100% mortality unless otherwise noted

Table A.2-15 Annual CMR Values for White Perch – Peak Flow

Year	Albany Steam Generating Station				Proposed Bethlehem Energy Center								
	ETM		CEMR		ETM								
	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Wet Cooling Tower	Wet Cooling w/ Alt. Pump Schedule	Wet Cooling w/ Intake Barrier System	Wet/Dry Cooling Tower	Wet/Dry Cooling w/ Alt. Pump Schedule	Wet/Dry Cooling w/ Intake Barrier System	Dry Cooling Tower
1975	0.87%	0.78%	2.32%	1.81%	0.65%	0.29%	0.02%	0.02%	< 0.01%	0.02%	0.02%	< 0.01%	< 0.01%
1976	-	-	2.66%	1.99%	-	-	-	-	-	-	-	-	-
1977	2.61%	2.41%	2.10%	1.35%	1.93%	1.08%	0.05%	0.05%	0.01%	0.05%	0.05%	0.01%	0.01%
1978	9.33%	6.37%	2.81%	1.74%	8.82%	1.76%	0.06%	0.06%	0.01%	0.06%	0.06%	0.01%	0.02%
1979	5.53%	4.13%	1.72%	1.17%	4.88%	1.36%	0.07%	0.07%	0.01%	0.07%	0.07%	0.01%	0.02%
1980	5.13%	4.12%	2.85%	2.03%	4.29%	1.55%	0.08%	0.08%	0.01%	0.08%	0.07%	0.01%	0.02%
1981	4.34%	2.89%	1.51%	0.92%	3.96%	0.52%	0.07%	0.07%	0.01%	0.07%	0.06%	0.01%	0.02%
1982	4.46%	4.38%	2.57%	2.30%	3.24%	2.88%	0.08%	0.08%	0.01%	0.08%	0.08%	0.01%	0.02%
1983	4.57%	3.82%	2.04%	1.57%	3.56%	1.44%	0.11%	0.11%	0.01%	0.11%	0.11%	0.01%	0.03%
1984	1.48%	1.16%	2.87%	1.78%	1.27%	0.38%	0.02%	0.02%	< 0.01%	0.02%	0.02%	< 0.01%	< 0.01%
1985	2.16%	1.58%	1.19%	0.78%	1.76%	0.23%	0.06%	0.06%	0.01%	0.06%	0.06%	0.01%	0.01%
1986	1.58%	1.06%	0.47%	0.80%	1.50%	0.28%	0.01%	0.01%	< 0.01%	0.01%	0.01%	< 0.01%	< 0.01%
1987	3.38%	2.15%	1.10%	0.88%	3.25%	0.41%	0.03%	0.03%	< 0.01%	0.03%	0.03%	< 0.01%	0.01%
1988	1.31%	1.18%	1.95%	1.40%	0.99%	0.53%	0.03%	0.03%	< 0.01%	0.03%	0.03%	< 0.01%	0.01%
1989	4.02%	3.41%	2.89%	2.62%	3.32%	1.86%	0.05%	0.05%	0.01%	0.05%	0.05%	0.01%	0.01%
1990	3.12%	2.36%	3.54%	2.49%	2.76%	0.91%	0.04%	0.04%	< 0.01%	0.03%	0.03%	< 0.01%	0.01%
1991	1.14%	0.98%	1.41%	0.99%	0.88%	0.34%	0.03%	0.03%	< 0.01%	0.03%	0.03%	< 0.01%	0.01%
1992	5.63%	4.77%	2.27%	1.94%	4.37%	1.93%	0.14%	0.14%	0.01%	0.13%	0.13%	0.01%	0.03%
1993	1.01%	0.91%	0.53%	0.38%	0.76%	0.45%	0.02%	0.02%	< 0.01%	0.02%	0.02%	< 0.01%	0.01%
1994	3.21%	2.71%	0.85%	0.84%	2.48%	1.05%	0.08%	0.08%	0.01%	0.07%	0.07%	0.01%	0.02%
1995	1.37%	1.18%	0.53%	0.34%	1.04%	0.44%	0.03%	0.03%	< 0.01%	0.03%	0.03%	< 0.01%	0.01%
avg	3.31%	2.62%	1.91%	1.43%	2.79%	0.98%	0.05%	0.05%	0.01%	0.05%	0.05%	0.01%	0.01%

Notes:
ETM – Empirical Transport Model; CEMR – Conditional Entrainment Mortality Rate; Alternative cooling systems and intake options assume 100% mortality unless otherwise noted

Table A.2-16 Annual CMR Values for White Perch – Base Flow

	Albany Steam Generating Station				Proposed Bethlehem Energy Center								
	ETM		CEMR		ETM								
Year	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Once – through Cooling 100% Mortality	Once – through Cooling Estimated Mortality	Wet Cooling Tower	Wet Cooling w/ Alt. Pump Schedule	Wet Cooling w/ Intake Barrier System	Wet/Dry Cooling Tower	Wet/Dry Cooling w/ Alt. Pump Schedule	Wet/Dry Cooling w/ Intake Barrier System	Dry Cooling Tower
1975	0.87%	0.78%	2.32%	1.81%	0.64%	0.28%	0.01%	0.01%	< 0.01%	0.01%	0.01%	< 0.01%	< 0.01%
1976	-	-	2.66%	1.99%	-	-	-	-	-	-	-	-	-
1977	2.61%	2.41%	2.10%	1.35%	1.91%	1.06%	0.03%	0.03%	< 0.01%	0.03%	0.03%	< 0.01%	< 0.01%
1978	9.33%	6.37%	2.81%	1.74%	8.75%	1.74%	0.04%	0.04%	< 0.01%	0.03%	0.03%	< 0.01%	< 0.01%
1979	5.53%	4.13%	1.72%	1.17%	4.84%	1.34%	0.04%	0.04%	< 0.01%	0.04%	0.04%	< 0.01%	< 0.01%
1980	5.13%	4.12%	2.85%	2.03%	4.25%	1.53%	0.04%	0.04%	< 0.01%	0.04%	0.04%	< 0.01%	< 0.01%
1981	4.34%	2.89%	1.51%	0.92%	3.93%	0.52%	0.04%	0.04%	< 0.01%	0.04%	0.03%	< 0.01%	< 0.01%
1982	4.46%	4.38%	2.57%	2.30%	3.20%	2.85%	0.05%	0.05%	< 0.01%	0.04%	0.04%	< 0.01%	< 0.01%
1983	4.57%	3.82%	2.04%	1.57%	3.53%	1.42%	0.06%	0.06%	0.01%	0.06%	0.06%	0.01%	< 0.01%
1984	1.48%	1.16%	2.87%	1.78%	1.26%	0.38%	0.01%	0.01%	< 0.01%	0.01%	0.01%	< 0.01%	< 0.01%
1985	2.16%	1.58%	1.19%	0.78%	1.74%	0.23%	0.03%	0.03%	< 0.01%	0.03%	0.03%	< 0.01%	< 0.01%
1986	1.58%	1.06%	0.47%	0.80%	1.49%	0.28%	0.01%	0.01%	< 0.01%	0.01%	0.01%	< 0.01%	< 0.01%
1987	3.38%	2.15%	1.10%	0.88%	3.22%	0.41%	0.02%	0.02%	< 0.01%	0.01%	0.01%	< 0.01%	< 0.01%
1988	1.31%	1.16%	1.95%	1.40%	0.98%	0.53%	0.02%	0.02%	< 0.01%	0.01%	0.01%	< 0.01%	< 0.01%
1989	4.02%	3.41%	2.89%	2.62%	3.29%	1.84%	0.03%	0.03%	< 0.01%	0.03%	0.03%	< 0.01%	< 0.01%
1990	3.12%	2.36%	3.54%	2.49%	2.74%	0.90%	0.02%	0.02%	< 0.01%	0.02%	0.02%	< 0.01%	< 0.01%
1991	1.14%	0.98%	1.41%	0.99%	0.87%	0.33%	0.01%	0.01%	< 0.01%	0.01%	0.01%	< 0.01%	< 0.01%
1992	5.63%	4.77%	2.27%	1.94%	4.32%	1.90%	0.08%	0.08%	0.01%	0.07%	0.07%	0.01%	< 0.01%
1993	1.01%	0.91%	0.53%	0.38%	0.75%	0.44%	0.01%	0.01%	< 0.01%	0.01%	0.01%	< 0.01%	< 0.01%
1994	3.21%	2.71%	0.85%	0.84%	2.46%	1.04%	0.04%	0.04%	< 0.01%	0.04%	0.04%	< 0.01%	< 0.01%
1995	1.37%	1.18%	0.53%	0.34%	1.03%	0.43%	0.02%	0.02%	< 0.01%	0.02%	0.02%	< 0.01%	< 0.01%
avg	3.31%	2.62%	1.91%	1.43%	2.76%	0.97%	0.03%	0.03%	< 0.01%	0.03%	0.03%	< 0.01%	< 0.01%

Notes:
ETM – Empirical Transport Model; CEMR – Conditional Entrainment Mortality Rate; Alternative cooling systems and intake options assume 100% mortality unless otherwise noted

Table A.2-17 Spatial Distributions (D_{skl}) of Target Species Used in the ETM

Year	River Herring				American Shad				Striped Bass				White Perch			
	Eggs	YSL	PYS	JUV	Eggs	YSL	PYS	JUV	Eggs	YSL	PYS	JUV	Eggs	YSL	PYS	JUV
1975									0.0008	0.0001	0.0000	0.0116	0.0116	0.0432	0.0022	0.0000
1976									0.0362	0.0001	0.0000	0.0000				
1977									0.0009	0.0002	0.0001	0.0080	0.0929	0.1169	0.0035	
1978					0.2141	0.2103	0.0699	0.0523	0.0004	0.0001	0.0001	0.0000	0.0746	0.1700	0.0035	0.1218
1979									0.0019	0.0007	0.0002	0.0000	0.1170	0.1002	0.0135	0.0465
1980	0.4393	0.4463	0.1727	0.1505	0.8061	0.8359	0.1927	0.1455	0.0000	0.0065	0.0001	0.0000	0.1380	0.1337	0.0112	0.0290
1981	0.0000	0.0000	0.0000	0.1277	0.7850	0.4756	0.0605	0.0851	0.0070	0.0001	0.0011	0.0037	0.0301	0.0159	0.0291	0.0377
1982	0.0617	0.2426	0.0163	0.0983	0.2373	0.6850	0.0368	0.0581	0.0012	0.0003	0.0001	0.0000	0.5092	0.0510	0.0014	0.0000
1983	0.6198	0.3546	0.0148	0.0057	0.4566	0.5493	0.0228	0.0022	0.0024	0.0002	0.0000	0.0000	0.1986	0.0527	0.0355	0.0000
1984	0.1774	0.0532	0.0236	0.0131	0.4376	0.0708	0.0076	0.0026	0.0000	0.0000	0.0000	0.0000	0.0238	0.0396	0.0028	0.0105
1985	0.1925	0.3052	0.0091	0.0565			0.0482	0.1108	0.0001	0.0000	0.0002	0.0212	0.0103	0.0121	0.0279	0.0000
1986	0.2161	0.2202	0.0160	0.0071			0.0613	0.0188	0.0721	0.0006	0.0008	0.0000	0.0123	0.0246	0.0010	0.0207
1987	0.0901	0.5447	0.0937	0.1866			0.1743	0.0627	0.0012	0.0000	0.0001	0.0095	0.0094	0.0266	0.0099	0.0440
1988	0.2184	0.1952	0.0335	0.0000	0.5425	0.5591	0.1307	0.0848	0.0037	0.0000	0.0002	0.0000	0.0665	0.0333	0.0051	0.0000
1989	0.4319	0.4095	0.0217	0.0484	0.5318	0.4815	0.0749	0.0115	0.0002	0.0001	0.0000	0.0000	0.3036	0.0377	0.0014	0.0241
1990	0.6490	0.4009	0.0595	0.0598	0.3250	0.3660	0.1651	0.0950	0.0013	0.0001	0.0003	0.0031	0.1121	0.0376	0.0053	0.0279
1991	0.3046	0.4629	0.0414	0.0367	0.4772	0.7051	0.1475	0.0608	0.0002	0.0001	0.0004	0.0445	0.0289	0.0314	0.0070	0.0000
1992	0.9302	0.5943	0.1578	0.0429	0.4714	0.6867	0.4529	0.2383	0.0039	0.0000	0.0002	0.0000	0.2753	0.0675	0.0403	0.0000
1993	0.2248	0.1268	0.0722	0.0000	0.3770	0.4920	0.1784	0.1006	0.0028	0.0002	0.0002	0.0027	0.0648	0.0197	0.0038	0.0000
1994	0.1318	0.3444	0.1345	0.1351	0.5182	0.5854	0.2200	0.0360	0.0000	0.0000	0.0001	0.0016	0.1390	0.0487	0.0223	0.0000
1995	0.2590	0.1774	0.0535	0.0638	0.1122	0.1314	0.0995	0.0195	0.0000	0.0000	0.0003	0.0271	0.0384	0.0410	0.0072	0.0000

Note: River herring were not processed in LRS collections prior to 1980; American shad were not reported during 1979 in LRS collections, and no eggs or larvae were collected from 1985 to 1987; White perch were not reported in LRS collections during 1976, and no juvenile estimates were made for the LRS during 1977.

YSL – Yolk Sac Larvae
PYS – Post Yolk Sac Larvae
JUV – Juveniles

Table A.2-18 Coefficients Used to Estimate Boundary Temperatures (X_1 and X_2) for the Double Hinged Line Model for Striped Bass and White Perch Thermal Mortality

Coefficient	Eggs	YSL	PYS	JUV
a1	21.762	53.875	29.672	24.120
a2	39.246	24.537	41.254	36.266
b1	0.943	-1.354	0.147	0.516
b2	0.136	1.090	-0.031	0.142
c1	-1.110	-0.407	-0.312	-0.806
c2	-1.741	-2.672	-1.471	-1.122

YSL – Yolk Sac Larvae
PYS – Post Yolk Sac Larvae
JUV - Juveniles

Table A.2-19 Mechanical Mortality Rate (M_M) Estimates Used in ETM

Species	Albany Steam Station Existing Operations				BEC Once-Through Operation			
	Eggs	YSL	PYS	JUV	Egg	YSL	PYS	JUV
River herring	1.0	0.794	0.794	0.794	1.0	0.833	0.833	0.833
American shad	1.0	0.794	0.794	0.794	1.0	0.833	0.833	0.833
Striped bass	1.0	0.266	0.287	0.254	1.0	0.484	0.484	0.484
White perch	1.0	0.566	0.566	0.464	1.0	0.829	0.829	0.829

YSL – Yolk Sac Larvae
PYS – Post Yolk Sac Larvae
JUV - Juveniles

Table A.2-20 Annual Instantaneous Entrainment Mortality Values (E_{skl}) Used in the ETM for Albany Steam Station Existing Operations

Year	River Herring and American Shad				Striped Bass				White Perch			
	Eggs	YSL	PYS	JUV	Eggs	YSL	PYS	JUV	Eggs	YSL	PYS	JUV
1975	1.000	0.794	0.794	0.794	1.000	0.303	0.287	0.254	1.000	0.930	0.566	0.464
1976	1.000	0.794	0.794	0.794	1.000	0.297	0.287	0.254	1.000	0.916	0.566	0.464
1977	1.000	0.794	0.794	0.794	1.000	0.304	0.287	0.254	1.000	0.918	0.566	0.464
1978	1.000	0.794	0.794	0.794	1.000	0.305	0.287	0.254	1.000	0.917	0.566	0.464
1979	1.000	0.794	0.794	0.794	1.000	0.303	0.287	0.254	1.000	0.927	0.566	0.464
1980	1.000	0.794	0.796	0.796	1.000	0.313	0.287	0.254	1.000	0.920	0.566	0.464
1981	1.000	0.794	0.794	0.794	1.000	0.313	0.287	0.254	1.000	0.925	0.566	0.464
1982	1.000	0.794	0.794	0.794	1.000	0.300	0.287	0.254	1.000	0.922	0.566	0.464
1983	1.000	0.794	0.794	0.794	1.000	0.317	0.287	0.254	1.000	0.933	0.566	0.464
1984	1.000	0.794	0.794	0.794	1.000	0.310	0.287	0.254	1.000	0.942	0.566	0.464
1985	1.000	0.794	0.794	0.794	1.000	0.305	0.287	0.254	1.000	0.933	0.566	0.464
1986	1.000	0.794	0.794	0.794	1.000	0.301	0.287	0.254	1.000	0.924	0.566	0.464
1987	1.000	0.794	0.794	0.794	1.000	0.312	0.287	0.254	1.000	0.930	0.566	0.464
1988	1.000	0.794	0.797	0.797	1.000	0.309	0.287	0.254	1.000	0.926	0.566	0.464
1989	1.000	0.794	0.794	0.794	1.000	0.306	0.287	0.254	1.000	0.915	0.566	0.464
1990	1.000	0.794	0.794	0.794	1.000	0.307	0.287	0.254	1.000	0.940	0.566	0.464
1991	1.000	0.794	0.794	0.794	1.000	0.322	0.287	0.254	1.000	0.939	0.566	0.464
1992	1.000	0.794	0.794	0.794	1.000	0.295	0.287	0.254	1.000	0.926	0.566	0.464
1993	1.000	0.794	0.794	0.794	1.000	0.312	0.287	0.254	1.000	0.919	0.566	0.464
1994	1.000	0.794	0.794	0.794	1.000	0.308	0.287	0.254	1.000	0.919	0.566	0.464
1995	1.000	0.794	0.794	0.794	1.000	0.324	0.287	0.254	1.000	0.929	0.566	0.464

YSL – Yolk Sac Larvae
PYS – Post Yolk Sac Larvae
JUV - Juveniles

Table A.2-21 Annual Instantaneous Entrainment Mortality Values (E_{ski}) Used in the ETM for the BEC Once-Through Alternative

Year	River Herring and American Shad				Striped Bass				White Perch			
	Eggs	YSL	PYS	JUV	Eggs	YSL	PYS	JUV	Eggs	YSL	PYS	JUV
1975	1.000	0.883	0.883	0.883	1.000	0.510	0.484	0.484	1.000	0.972	0.829	0.829
1976	1.000	0.883	0.883	0.883	1.000	0.506	0.484	0.484	1.000	0.967	0.829	0.829
1977	1.000	0.883	0.883	0.883	1.000	0.511	0.484	0.484	1.000	0.968	0.829	0.829
1978	1.000	0.883	0.883	0.883	1.000	0.511	0.484	0.484	1.000	0.967	0.829	0.829
1979	1.000	0.883	0.883	0.883	1.000	0.510	0.484	0.484	1.000	0.971	0.829	0.829
1980	1.000	0.883	0.884	0.884	1.000	0.517	0.484	0.484	1.000	0.969	0.829	0.829
1981	1.000	0.883	0.883	0.883	1.000	0.517	0.484	0.484	1.000	0.971	0.829	0.829
1982	1.000	0.883	0.883	0.883	1.000	0.508	0.484	0.484	1.000	0.969	0.829	0.829
1983	1.000	0.883	0.883	0.883	1.000	0.520	0.484	0.484	1.000	0.974	0.829	0.829
1984	1.000	0.883	0.883	0.883	1.000	0.515	0.484	0.484	1.000	0.977	0.829	0.829
1985	1.000	0.883	0.883	0.883	1.000	0.511	0.484	0.484	1.000	0.974	0.829	0.829
1986	1.000	0.883	0.883	0.883	1.000	0.509	0.484	0.484	1.000	0.970	0.829	0.829
1987	1.000	0.883	0.883	0.883	1.000	0.516	0.484	0.484	1.000	0.973	0.829	0.829
1988	1.000	0.883	0.885	0.885	1.000	0.514	0.484	0.484	1.000	0.971	0.829	0.829
1989	1.000	0.883	0.883	0.883	1.000	0.512	0.484	0.484	1.000	0.967	0.829	0.829
1990	1.000	0.883	0.883	0.883	1.000	0.513	0.484	0.484	1.000	0.976	0.829	0.829
1991	1.000	0.883	0.883	0.883	1.000	0.524	0.484	0.484	1.000	0.976	0.829	0.829
1992	1.000	0.883	0.883	0.883	1.000	0.504	0.484	0.484	1.000	0.971	0.829	0.829
1993	1.000	0.883	0.883	0.883	1.000	0.516	0.484	0.484	1.000	0.968	0.829	0.829
1994	1.000	0.883	0.883	0.883	1.000	0.513	0.484	0.484	1.000	0.968	0.829	0.829
1995	1.000	0.883	0.883	0.883	1.000	0.525	0.484	0.484	1.000	0.972	0.829	0.829

YSL – Yolk Sac Larvae
PYS – Post Yolk Sac Larvae
JUV - Juveniles

Table A.2-22 Target Species Life History Input Parameters for Equivalent Adult Analysis

Species	Lifestage	Duration (days)	Weight (g)	Mortality (M)	Fishing (F)	Survival (S)
River herring	Egg	6	--	0.0752	0.00000	0.6367
	Yolksac larvae	13	--	0.1423	0.00000	0.1571
	Post Yolksac larvae	40	--	0.0438	0.00000	0.1728
	Juvenile	306	--	0.0206	0.00000	0.0017
	Age 1	365	--	0.0008	0.00000	0.7407
	Age 2	365	--	0.0008	0.00000	0.7407
	Age 3	365	--	0.0008	0.00000	0.7407
	Age 4	365	169.0	0.0020	0.00012	0.4610
American shad	Egg	5	--	0.4203	0.00000	0.1239
	Yolksac larvae	5	--	0.3300	0.00000	0.2169
	Post Yolksac larvae	26	--	0.1160	0.00000	0.0489
	Juvenile	329	--	0.0103	0.00000	0.0330
	Age 1	365	--	0.0008	0.00000	0.7408
	Age 2	365	--	0.0008	0.00000	0.7408
	Age 3	365	--	0.0008	0.00000	0.7408
	Age 4	365	1732.8	0.0016	0.00090	0.7408
Striped bass	Egg	2	--	0.6900	0.00000	0.2515
	Yolksac larvae	6	--	0.3680	0.00000	0.1099
	Post Yolksac larvae	46	--	0.1104	0.00000	0.0062
	Juvenile	311	--	0.0102	0.00000	0.0414
	Age 1	365	--	0.0029	0.00000	0.3350
	Age 2	365	--	0.0004	0.00000	0.8491
	Age 3	365	--	0.0004	0.000048	0.8151
	Age 4	365	2610.4	0.0004	0.000160	0.7189
White perch	Egg	4	--	0.6967	0.00000	0.0636
	Yolksac larvae	4	--	0.5245	0.00000	0.1227
	Post Yolksac larvae	26	--	0.1258	0.00000	0.0378
	Juvenile	331	--	0.0041	0.00000	0.2526
	Age 1	365	--	0.0018	0.00000	0.5000
	Age 2	365	25.7	0.0018	0.00000	0.5000

Note(s): S = Finite survival rate (S = exp(-Zd * t)), where Z (instantaneous mortality rate) = Natural mortality rate (M) + Fishing Mortality Rate (F).

Appendix 2

APPENDIX B

Description Of Methodlogies And Data Related To The Cost Benefit Analysis Of Cooling System Alternatives At Bethlehem Energy Center

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B.1. Costs Associated with Construction and Operation and Maintenance

The costs of constructing and operating a cooling system will vary from one system to another. For example, a once-through cooling system for the proposed plant will require the installation of large circulating water pumps, pipe, traveling screens and a fish return system due to the large cooling water flowrate required. Any of the closed-loop cooling options, however, will require the construction of cooling towers and a cooling-tower pump structure, but with a smaller makeup water line and discharge (blowdown) to the river, thus necessitating smaller pumps, pipe, screens and fish return systems. A wet/dry cooling tower would require large capital expenditures to mitigate visible plumes from the tower. The associated infrastructure costs would be similar to the normal cooling tower arrangement. An air cooled condenser option will require a large capital expenditure for the condenser in order to maintain a constant electrical output in the warm summer months when electricity is in demand, and this type of cooling is highly inefficient. However, with this option, river water withdrawal and the associated costs for pumps, pipe, screens and fish return systems would be minimized. Additionally, all of the closed-loop systems require the consumption of more electrical energy than a once-through system due to the need to operate cooling-tower fans in addition to operating smaller condenser circulating-water pumps.

A more in-depth discussion of these issues and a presentation of cost estimates for each of the options is presented below.

B.1.1. Capital Costs

Table B-1 summarizes estimated capital costs for each of the cooling options. Estimates for the once-through system and the infrastructure for the cooling tower options with condensers for the wet options are based on Sargent & Lundy in-house data and vendor catalogs and data for equipment and structures typically found at a utility-grade installation. Estimates for the cooling towers were based on budgetary estimates received from a cooling tower manufacturer (Hamon 2000). The estimated cost for the plume mitigated (hybrid) tower as shown in Table B-1 is based on the 19°F, 60% RH design point.

The costs for two optional arrangements are included for the wet cooling tower options. The first is the conversion of an existing oil storage tanks to an overnight water storage tank. Makeup water would be pumped into this tank at night when fish activity is at a minimum, and during the day when fish activity is high, makeup water for the cooling towers would be drawn from the tank instead of the Hudson River. The second option is the use of a gunderboom on the makeup water intake structure, which would further mitigate the potential for fish entrainment.

B.1.2. Operation and Maintenance Costs

The costs associated with operating maintaining different cooling systems are summarized in Table B-2. These data are based on a survey performed for the development of the SOAPP WorkStation computer code sponsored by the Electric Power Research Institute (EPRI). All estimates are adjusted to 1999 dollars and account for the cost of chemicals added to treat circulating water and cooling tower water. Note that operation and maintenance costs for the three wet/dry cooling tower design points are the same.

Besides the complexities involved with the wet cooling tower due to dry sections for plume mitigation and the dry air cooled exchanger cooling tower, additional maintenance may be required to clean airborne debris that may collect between the fins of the heat-exchanger tubes. For example, during the spring, pollen and seeds from surrounding trees are carried by the air and can potentially clog the fins. Special, semi-automatic spray cleaners are available, but they add to the overall cost and annual maintenance of the towers.

B.2. Costs Associated with Power Impacts

Implementation of cooling system alternatives would result in impacts to electric power generation at Bethlehem. Chapter 8 includes the incremental cost associated with these power impacts as one component of the costs of cooling system alternatives. This section provides background and methodologies for estimating the costs associated with power impacts.

B.2.1. General Approach

Implementation of cooling system alternatives typically results in impacts to electric power generation. These impacts may affect the quantity of power supplied to power markets (including energy and capacity), the magnitude of operating costs, or both. Both of these impacts result in real-resource costs since either more costly power generation resources are utilized to replace lost power, or additional labor and materials are utilized to respond to power impacts at the generating station.

Implementation of cooling system alternatives at Bethlehem is not anticipated to significantly reduce the quantity of power supplied to the power markets because net generation capacity at Bethlehem will generally exceed the quantity of power that can be transmitted. Bethlehem's net generation capacity exceeds 750 megawatts under most weather conditions and cooling system alternatives. The quantity of power Bethlehem can transmit to power markets, however, is limited by a 750 megawatt transmission constraint. Consequently, Bethlehem generally has excess generation capacity to make up any losses due to power impacts.

Power impacts will, however, increase the cost of power generation at Bethlehem. Additional fuel and variable operations and maintenance costs will be necessary to maintain the same level of energy production for the market under different cooling system alternatives. These additional costs serve as the basis for power costs estimates in this study.

Under some circumstances, Bethlehem's net generation capacity may fall below 750 megawatts. For dry cooling towers, for example, net generation capacity would fall below 750 megawatts when the dry bulb temperature rises above 94 degrees. Under these conditions, the power impact associated with dry cooling towers would result in a reduction in the quantity of power that Bethlehem can supply to electricity markets. These losses would include losses of both energy and capacity. The energy costs in this study understate the power costs under these conditions for two reasons. First, power cost estimates in this study do not include capacity costs. Second, energy cost estimates based on fuel and O&M costs would less than or equal to energy costs estimates based on marginal energy costs in the New York Independent Operator System (NYISO).[1]

[1] Since Bethlehem would be operating at full capacity if there were a constraint on net generation (i.e., the quantity of power provided to power markets), this suggests either that Bethlehem or some higher cost unit is the marginal generation unit in the system. Any generation replacing the lost generation from Bethlehem would be over equal or greater marginal cost. Further, Bethlehem would be highly

(continued...)

This study considers power impacts resulting from changes in station power output after the installation of a cooling system alternative. The following two impacts are considered:

- *Increased Auxiliary Power.* Increases in power demands needed to operate auxiliary equipment will increase the quantity of energy (in megawatt-hours) generated by Bethlehem. Generation of this energy results in increases in fuel and variable operations and maintenance costs.

- *Performance (heat rate) Penalties.* Implementation of cooling system alternatives will lead to reduced station efficiency, resulting in an increased in heat rate. These impacts occur due to turbine backpressure from cooling towers. Heat rate penalties result in increases in the fuel utilization and costs.

Estimates of the power costs of the Bethlehem cooling system alternatives reflect the real resource costs resulting from power impacts. Power impacts results in social costs since real resources (i.e., fuel and resources associated with operations and maintenance) would be utilized in response to the power impacts.

The following section describes the methodology used for estimating the social cost associated with power impacts.

B.2.2. How Cost Impacts are Modeled

The cost of power impacts is estimated by multiplying the quantity of additional natural gas used as a result of power impacts (auxiliary power and heat rate penalties) by the price of natural gas. Auxiliary power impacts also lead to increases in variable operations and maintenance costs. Chapter 3 provides further discussion of the effect of intake systems on plant performance.

For auxiliary power impacts, monthly changes in natural gas consumption are estimated by multiplying the quantity of auxiliary power (in kwh) by the gross heat rate (in Btu per kwh). Table B-3 provides estimates of the change in auxiliary power relative to the Once Through alternative.

For heat rate impacts, monthly changes in natural gas consumption are estimated by multiplying the monthly change in gross heat rate (in Btu per kwh) by the total kilowatt-hours of generation in each month. The change in heat rate due to each alternative relative to the Once Through alternative is presented in Table B-4. Total monthly generation is estimated assuming a 65 percent utilization rate.

Natural gas prices are based on the forward prices for natural gas in the New York Merchantile Exchange (NYMEX), as reported in the Wall Street Journal (Wall Street Journal 2000). NYMEX prices are available through the year 2003. After this period, gas prices are based on forecasts from the Energy Information Administration in their report, Annual Energy Outlook for 2001 (Energy Information Administration 2000). Table B-5 reports the monthly natural gas prices used in this report.

(...continued)

likely to be operating at full capacity on any day on which the cooling system alternatives constrain net generation (e.g., when the dry bulb temperature rises above 94 degrees.)

The prices in Table B-5 include costs associated with gas transmission. The cost of gas transmission costs is based on gas transmission tariff rates for transport from Henry Hub, Louisiana to the New York region (Federal Energy Regulatory Commission 2000).

Auxiliary power impacts also lead to increases in variable operations and maintenance costs. These costs are estimated by multiplying the quantity of auxiliary power by the variable O&M cost (in dollars per megawatt-hour). The variable O&M costs is $5.2 per megawatt-hour, based on data from the Energy Information Administration (U.S. Department of Energy, 2000).

The annual cost of power impacts for each year is estimated by summing costs across months. The total cost is calculated by summing annual energy costs across years, with appropriate discounting. The magnitudes of the power impacts for each alternative depend on these auxiliary power requirements and reductions in plant efficiency, which are reported in Appendix C. Note that these costs are estimated relative to the costs of the Once Through alternative.

B.3. Cost Associated with Change in Air Emissions

Implementation of cooling system alternatives at Bethlehem would lead to increases in fuel consumption at Bethlehem. This change would lead to changes in air emissions, including NO_X and CO_2, or changes in the cost of controlling these emissions. The net effect of this change in emissions at Bethlehem constitutes part of the costs of the cooling system alternatives. This section outlines the methodology used to estimate the value of these air emissions.

B.3.1. Conceptual Background

Increased air emissions can impose two types of costs on society:

1. Environmental impacts; and

2. Added pollution control costs.

Which of these two types of costs are imposed depends upon the nature of the regulatory requirements imposed on emitters. There are two cases.

- *Case A: No regulation, emission standards or technology-based standards.* If no regulations are imposed, or if the regulations are based upon emission standards (e.g., maximum emissions per unit of input or output) or technology-based standards (i.e., requirements to adopt a particular emission control technology), increased emissions from one facility can increase costs associated with environmental impacts.

- *Case B: Emissions cap with tradable allowances.* In contrast, if the regulations establish an emissions cap and allow emitters to trade allowances (i.e., right to emit) among themselves, increased emissions from one facility lead to added pollution control costs rather than environmental impacts.

The following subsections explain these two cases in more detail.

B.3.1.1. No Regulation, Emission Standards or Technology Standards

Under emission standards, technology standards, or no regulation, increased emissions from one facility may not be offset by reductions elsewhere, which would result in an increase in total emissions. When total emissions increase, the potential social costs also increase. The potential social costs include the marginal effects of increased emissions on the health of individuals, possible increased health care costs, lost productivity due to illness, property impacts, and impacts to natural resources. Marginal costs, which measure the impact of the next increment of emissions given current levels, are more relevant than average costs because marginal costs measure the increase in costs given existing emission levels from all sources. In other words, increases in emissions from fossil-fueled generators could potentially increase social environmental impact under these regulatory approaches.

B.3.1.2. Emissions Cap with Tradable Permits

If pollutants are regulated by an emissions trading program in which total emissions are capped (known as a "cap-and-trade" program), increased emissions from one facility would not increase the total emissions from all facilities included in the program. Increased emissions from one facility would be offset by reductions at other facilities, leaving total emissions from facilities within the program constant. As a result, the implementation of fish loss reduction alternatives would not create additional environmental impact costs due to an increase in total emissions.[2]

Although total emissions within the program would not change, the cost of keeping total emissions below the emissions cap would increase. The change in cost could be estimated by calculating the difference between the total cost of achieving the cap with and without the power affected by each alternative. To offset the additional emissions from other power, additional emissions reductions would need to come from existing sources. The cost of achieving additional abatement of air emissions would be equal to the marginal cost of emissions reductions from existing facilities. The total costs of abating emissions from other sources can therefore be calculated by multiplying the marginal cost of abatement by the quantity of additional emissions from the other power sources.

Determining the marginal cost of abatement is typically a complex and detailed process. If the trading program operates efficiently, however, the market price of allowances would equal the marginal cost of abatement.[3] Thus, emission allowance prices can be used to estimate marginal

[2] This analysis ignores several complications that could result in additional environmental costs under a cap-and-trade program. For one thing, if power increased at facilities outside the cap-and-trade program in response to the reduction at Bethlehem, the increased emissions might not be compensated for by reductions at other facilities. The cap-and-trade programs for SO_2 and NO_X apply to broad geographic areas, however, and the possibility of increased emissions outside the cap-and-trade program can be ignored. Secondly, the redistribution of emissions that occurs might lead to different local environmental impacts around the facilities whose emissions decrease and increase. Without a detailed model that predicts environmental impacts around the facilities, it is not possible to quantify these localized effects.

[3] Under a cap-and-trade program, the marginal cost of additional reductions is equal to the market price for permits. If emission permits were more expensive than the cost of reductions, firms would undertake emission reduction investments and sell the permits on the emissions trading market. These investments would drive the price of permits down until firms were indifferent between purchasing permits and undertaking emission reduction investments.

abatement costs. The additional air emission costs of due to power impacts can be estimated as the allowance prices times the quantity of additional emissions.

The remainder of this section describes the specific methodologies used to estimate the costs for NO_X and CO_2, the two air pollutants for which costs are calculated. (These calculations ignore other pollutants that increase (e.g., particulate matter) when fossil fuel generation increases.) These descriptions include a summary of current regulations, the approach used to model cost impacts, and the data sources.

B.3.2. Oxides of Nitrogen (NO_X)

B.3.2.1. Regulation

In 1994, a group of northeastern states participating in the Ozone Transport Commission (OTC) committed themselves to achieving region-wide NO_X emission reduction targets by 1999 and 2003 through an emissions trading program. (See NESCAUM / MARAMA (1996) for details on the NO_X Budget Program.) The NO_X Budget Program is a "cap and trade" program that allows large generators of NO_X emissions to trade allowances to meet emission targets in a cost-effective manner. Emission targets are limited to a five-month control period from May to September.

The participating states have committed to achieving a 75 percent reduction from 1990 levels in NO_X emissions (55 percent in Northern areas) by the year 2003. The target will be achieved in two stages, one in 1999 and the second more stringent stage coming into effect in 2003. Allowances are distributed based upon the allocation formulas established in each state's implementing rule. Firms are allowed to trade emissions allowances, as long as they hold enough allowances to cover actual emissions. Allowances may be banked, though their value may be diminished if the quantity of banked allowances in the region is high.

The EPA has also promulgated regulations that will require 22 states and the District of Columbia to revise their State Implementation Plans (SIPs) to reduce NO_X emissions. The so-called NO_X SIP Call includes two major components:

- *Individual State NO_X Caps* – State NO_X caps ("budgets") are based upon emissions targets for individual sources using standard emission factors and projected 2007 activity levels (U.S. Environmental Protection Agency 1998a). The emission targets for electric power sources are based on an emission factor of 0.15 lb./mmBtu, (roughly comparable to an 85 percent reduction in emissions for most units). Thus, utilities in states with large amounts of coal-fired power have to make large reductions or trade for NO_X allowances from utilities in other states.

- *Cap-and-Trade Program for NO_X* – The SIP Call allows for a cap-and-trade program for NO_X emissions across all 22 states. Trading would be allowed among electric power and large industrial boilers, which together account for about 90 percent of the required emissions (U.S. Environmental Protection Agency 1998a).

The NO_X SIP Call is anticipated to go into effect in the year 2003.

B.3.2.2. How The Values For NO_x Are Modeled

Costs associated with NO_X emissions are calculated by multiplying forecast allowance prices per ton of emissions times the quantity of additional tons of emissions. The quantity of additional NO_X

emissions is estimated by multiplying the increase in natural gas utilization (in MMBtu) by the NO_X emission rate (tons per MMBtu). The methodology for estimating increases in natural gas utilization are described in Section B. Increases in emissions are estimated relative to emissions associated with the Once Through alternative.The NO_X emission rate is based on data provided in Chapter 4 (EPA 1998).

Allowance price forecasts are based on the current allowance price index from Cantor Fitzgerald (2000). This index is based on the price of actual trades and current buyer and seller offers. The price in 2002 is $538 per ton of NO_X based on an average of prices over a three month period (July to September 2000). Vintage permit prices are not available for NO_X permits beyond 2002. Consequently, prices for years beyond 2002 are based on the vintage price adjustments for SO_2 allowances. The final values for allowances prices used in each year are included in Table B-6.

Note that since NO_X emissions would only lead to cost increases during the summer NO_X season when emission caps are imposed, using permit prices for all annual costs is likely to overstate the actual emission savings.

B.3.3. Carbon Dioxide (CO_2)

B.3.3.1. Regulation

No regulations currently constrain emissions of carbon dioxide (CO_2). However, the Kyoto Protocol agreed upon in December 1997 calls for significant reductions of greenhouse gas (GHG) emissions from Annex 1 countries (mainly developed countries) by the period 2008-2012. The U.S. Kyoto target is to reduce CO_2 emissions by 7 percent below 1990 emission rates. Although the treaty has not been ratified, this analysis assumes that the Kyoto Protocol will be implemented.

B.3.3.2. How Cost Impacts Are Modeled

Before the proposed Kyoto implementation dates, the analysis assumes no regulation of CO_2 emissions. Changes in CO_2 emissions (due to increases at other facilities or decreases at Bethlehem) are valued based upon the marginal impacts they generate.

The analysis assumes that starting in 2008, emission levels are capped based upon the commitments made at Kyoto. This analysis assumes that the U.S. will adopt a national allowance program to meet its Kyoto target. Added power, therefore, would not lead to additional emissions since there is a cap on total emissions. However, the costs of remaining under the emissions cap will change due to several different effects.

The cost of CO_2 emissions is based on costs associated with increases in emissions at Bethlehem. The cost of changes in emissions at Bethlehem are estimated as follows:

- *Period 2003 to 2007.* The costs of CO_2 emissions are calculated by multiplying the annual CO2 emissions from increased natural gas utilization by an estimate of the dollar value of the marginal CO2 impact based on the relevant literature.

- *Period 2008 to 2028.* The costs of CO_2 emissions are calculated by multiplying the annual CO2 emissions from increased natural gas utilization by the forecast emission permit cost per ton.

Changes in emissions are estimated relative to the costs associated with the Once Through alternative. The CO_2 emission rate is based on data provided in Chapter 4. The following sections provide further details on the values (i.e., costs per ton) used in the calculation of CO_2 costs.

B.3.3.3. CO_2 Values

B.2.3.3.1. CO_2 Impacts: 2003 to 2007

The marginal impact value used in this study is based on the average of values from earlier studies that estimated the social impact resulting from climate change, summarized in the IPCC's Climate Change 1995 monograph (Bruce, Lee, and Haites 1996).[4] The report summarizes the marginal impact estimates at different future dates, assuming a "business as usual" policy where no additional regulations are instituted. Marginal impact estimates for years in between those presented are estimated by a linear interpolation of the marginal impact value for the two closest years. Table B-6 presents estimates of the marginal value of additional CO_2 emissions used in this study.

B.2.3.3.2. CO_2 Costs: 2008 to 2028

Estimates of the cost of additional CO_2 emissions from 2008 to 2028 are based on estimates of the marginal cost of reducing CO_2. This estimate is based on an analysis of the Kyoto Protocol by the Energy Information Administration (EIA) (U.S. Department of Energy 1998). EIA's analysis assumes that the U.S. achieves some emission reductions through international emissions trading so that the resulting annual domestic emissions are 9 percent above 1990 levels. The analysis also assumes that domestic reductions are achieved through an emissions trading program.[5] Since this policy is the least-cost approach to achieving domestic reductions, estimates of the costs of additional CO_2 emissions under these assumptions are conservative.

As discussed above, for emissions controls under a cap-and-trade program, the social cost of reducing emissions is equal to permit prices. We therefore assume that the social cost of reducing CO_2 emissions is equal to the CO_2 permit prices. Prices for CO_2 allowances after 2008 are based on the EIA study of the Kyoto Protocol. Allowance prices used in this study are based on the same scenario discussed above (i.e., emissions at 9 percent above 1990 levels). The permit costs in this

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[4] The values for studies by Cline were not included in the averages since some of these studies assume zero discount rates. For each study, the mid-point of the range of values is used.

[5] The analysis assumes domestic implementation using a CO_2 tax. As EIA points out, however, the analysis and results are equivalent to that for an emissions trading program.

case are $44 per ton of CO_2 in 2010 and $38 per ton of CO_2 in 2020.[6] To calculate values between 2008 and 2021, a linear extrapolation of the 2010 and 2020 values is made. The permit prices used in the analyses are presented in Table B-6.

[6] These are converted from values of $129 per ton of carbon in 2010 and $123 per ton of carbon in 2020 using a conversion factor of 3.67 to convert carbon to CO_2.

B.4. Valuation of Commercial Catch

Chapter 8 evaluates the incremental benefits of changes in fisheries catch that would occur due to the implementation of cooling system alternatives. This section describes the procedures and data used to estimate the value of fish caught commercially. These commercial values are used to estimate additional commercial harvest benefits that would result from the implementation of fish loss reduction alternatives. The term fish is used in this attachment to refer to both fin fish and macroinvertebrates.

B.4.1. Conceptual Approach

In theory, both producers and consumers could gain from increases in commercial catch. To estimate the gains to producers, the analysis assumes that the additional fish are caught by fishermen and marketed by wholesalers without any additional effort and that there is no decrease in prices due to the increase in harvest. Thus, producer's revenues are assumed to increase by the product of the current wholesale price and the additional harvest, while their costs remain the same.

This approach makes the conservative assumption that there are no additional costs associated with increased effort to catch and market additional fish. In fact, cost increases are likely to occur. Since the fisheries on the East Coast are currently open-access, it is possible that most of the economic gains from additional catch might be eroded by increases in either each boat's effort or the number of boats harvesting. Economic theory predicts such entry or increased effort, and most empirical experience with open-access fisheries confirms the erosion of economic profits (see Anderson 1986 and OECD 1997). If such entry or additional effort occurred, the producer benefits due to increased catch would be smaller than estimated here, and perhaps zero.

The potential gains to consumers in the form of lower prices are not estimated here. While there may be some effect on price from increased catch, the gains are likely to be relatively small since price changes as a result of the additional fish associated with cooling system alternatives are not likely to be large.

The revenues to fishermen and wholesalers (as described above) are used to value the entire benefits resulting from additional commercial catch. These estimates are reasonable, since, as noted above, benefits to producers are overstated and consumer benefits are likely to be small.

B.4.2. Data

Wholesale prices are presented below in Table B-7 for each of the species considered. Prices are derived from monthly averages of daily prices at Fulton Fish Market in New York for different species by grade and state of origin. Fulton Fish Market is the largest fish market on the east coast, and is considered representative of market prices for the entire coast (see, e.g. Norton, Smith and Strand 1983). Annual prices are estimated by averaging across size grades and months for fish originating from the state of New York, or the closest state if no New York data are available. For striped bass, which had relatively few price observations, data from all states are used. Final values are estimated by averaging across annual estimates.

B.5. Valuation of Recreational Catch

This attachment describes the method and data used to develop estimates of the value that recreational anglers place on additional pounds of fish caught. This recreational value is used to put a dollar value on the changes in fish caught by recreational anglers if the cooling system alternatives evaluated in Chapter 8 were implemented. The attachment includes background on the methodological approach used to develop the recreational values used in this study. As noted in Chapter 8, the additional fish consist of a variety of species of finfish, all of which are caught by recreational fishermen.

B.5.1. Methodological Approach

This section provides methodological background on the approach used to develop values for changes in recreational fisheries catch.

B.5.1.1. Choice Of Valuation Methodology

There are two general approaches to developing information to value recreational fishing benefits. The first approach is to perform an original study that would involve collecting primary data and statistical analyses to determine willingness to pay. The second approach, known as the "benefits transfer" approach, is to use results from existing studies. As the EPA guidelines note:

> The advantages to benefit transfer are clear. Original studies are time consuming and expensive; benefit transfer can reduce both the time and financial resources needed to develop benefit estimates... Additionally, while the quality of primary research is unknown in advance, the analyst performing benefit transfer is able to gauge the quality of existing studies prior to conducting the transfer exercise. (U.S. Environmental Protection Agency 2000, p. 86)

The benefits transfer approach was determined to be the superior approach to estimate recreational fishing benefits in this application. An original study would have required measuring the values of additional recreational catch for many species across a wide geographic range, including the entire Hudson River and the surrounding near-shore marine areas, an impractical alternative in this context. Moreover, as noted in the EPA guidelines, the benefits transfer approach allowed us to gauge the quality of the existing studies before conducting the transfer exercise.

B.5.1.2. Choice of Benefits Transfer Methodology

The EPA guidelines provide the following discussion of alternative benefit transfer methods:

> There are four types of benefit transfer studies; point estimate, benefit function, meta-analysis, and Baysian techniques. The point estimation approach involves taking the mean value (or range of values) from the study case and applying it directly to the policy case. As it is rare that a policy case and study case will be identical, this approach is not generally recommended. . . . The benefits function transfer approach is more refined but also more complex. . . . The most rigorous benefit transfer exercise uses meta-analysis. Meta-analysis is a statistical method

> of combining a number of valuation estimates that allows the analyst to systematically explore variation in existing value estimates across studies. . . . An alternative to the meta-analysis approach is the Baysian approach. These techniques provide a systematic way of incorporating study case information with policy case information. (U.S. Environmental Protection Agency 1999, p. 7-33 to 7-34)

Meta-analysis was selected as the method for performing a benefits transfer to develop recreational fishing values for Bethlehem cooling system alternatives. Meta-analysis was chosen for two reasons:

1. *Analytical soundness.* The meta-analysis is analytically sound. As noted above, the EPA guidelines state that meta-analysis is "(t)he most rigorous benefit transfer exercise."

2. *Sufficient number of relevant studies.* Sufficient relevant studies were available to implement the meta-analysis method. Meta-analysis provides an approach to integrate *all* of these studies, rather than relying on a single one.

B.5.1.3. Methodological Issues Related to the Meta-Analysis

Studies that include catch rate can be used to develop estimates of the increased value that fishermen place on trips with a higher expected catch. Figure B-1 illustrates the relationship between the benefit per angler trip and the catch rate (i.e., pounds per trip) indicated by the empirical evidence. As the catch rate increases, the value of the trip increases. However, the *added* value from each additional pound of catch decreases as the catch rate increases. The value of the additional catch can be measured by the *marginal* value, i.e. the value that recreational fishermen place on an additional pound of fish caught per angler trip.[7] The slope of the curve in Figure B-1 illustrates the marginal value. The decreasing slope of the benefit curve as catch increases shows the decreasing marginal benefit of additional pounds of catch. This result is consistent with the basic economic concept of diminishing marginal returns, and is confirmed by the existing recreational valuation literature (for example, see Smith, Palmquist, and Jakus (1991)).

This relationship between the marginal value and the catch rate (i.e., pounds per trip) is also illustrated in Figure B-2. The curve shows that the value placed on a given change in the expected catch rate is relatively high when the catch rate is low. As the catch rate increases, the value that recreational fishermen place on additional fish caught per trip decreases. If this figure were based upon empirical data, the results could be used to calculate, for any given baseline catch rate, the per pound value to recreational fishermen of a small change in the catch rate.

B.5.2. Empirical Estimates

Changes in fisheries catch due to the implementation of cooling system alternatives at Bethlehem would be dispersed over the Hudson River Estuary and the near-shore marine areas. These additional fish would represent relatively small increases in the total catch, resulting in a small increase in the catch for each angler above the present level of catch they expect on each trip. To

[7] The marginal value measures the change in value from a small change in the catch rate. Formally, the marginal benefit is the derivative of the function relating the total value per trip to the catch rate.

measure the value that fishermen place on these small changes, we estimate the marginal value curve, the relationship illustrated in Figure B-2.

This subsection describes the empirical strategy used to estimate the marginal value curve. The next section outlines the overall methodology. We then provide the empirical results.

B.5.2.1. Overview Of Methodology

Figure B-3 summarizes the steps involved in using the results of the existing literature to develop an estimate of the value that recreational fishermen place on additional fish.

Step 1: Obtain recreational fishing value studies. The first step is to obtain studies that estimate the additional value that recreational fishermen place on additional catch. These studies include both journal articles and published reports.

Step 2: Determine relevant studies. The next step is to select studies that are relevant to fishing affected by the Station. Studies were selected based upon fishery location and mode of fishing.

Step 3: Conduct a statistical meta-analysis of the marginal value of increased catch. This step uses the relevant studies and statistical estimation procedures to determine the relationship illustrated in Figure B-2. (This study is referred to as a *meta-analysis* because it uses results from many studies.)

Step 4: Determine the marginal value per pound of fish. The final step is to use the results of the meta-analysis to calculate the appropriate marginal value for fish relevant to this study.

B.5.2.2. Recreational Fish Valuation Studies Used In The Analyses

A large number of studies have been performed to value the benefits from recreational fishing. Not all of these studies, however, are suitable for the valuation of cooling system alternatives at Bethlehem. The EPA guidelines provide recommendations for choosing studies for use in a benefits transfer, including steps for identifying existing, relevant studies and for reviewing the studies for quality and applicability.

> *Identify existing, relevant studies.* Existing, relevant studies are identified by conducting a literature search. This literature search should, ideally, include searches of published literature, reviews of survey articles, examination of databases, and consultation with researchers to identify government publications, unpublished research, works in progress, and other "gray literature."
>
> *Review available studies for quality and applicability.* . . . [T]he analyst should review and assess the studies identified in the literature review for their quality and applicability to the policy case. . . . Assessing studies for applicability involves determining whether available studies are comparable to the policy case. (U.S. Environmental Protection Agency 2000, p. 86)

To identify all studies suitable for the valuation of fish gains that would occur if cooling system alternatives were implemented at Bethlehem, we reviewed scores of studies that have been conducted to estimate the dollar value of recreational fishing. These studies related to different geographic locations (East coast, West coast, different states), different fishing environments (marine, lake, river, ocean, etc.), different types of fishing (shore, private boat, charter boat, etc.), different target species, and different estimation methodologies (travel cost, contingent valuation, random utility). Many of these studies are not relevant to characteristics of fishing in the Hudson River and Estuary and other areas that might be affected by changes in fish cropping at Bethlehem.

The criteria to select the specific studies for the meta-analysis included the following:

1. *Studies must be relevant to the resource being valued.* The studies had to meet the following criteria:

   - East Coast,[8]

   - marine and tidal river environments, and

   - bank and private boat fishing (excluding charter boat).

   These criteria identify studies that provide values relevant to the types of benefits that would be generated by cooling system alternatives at Bethlehem, i.e., increases in recreational fishing catch along the East Coast.

2. *Studies must contain adequate information on the value of a marginal or incremental change in catch rate.* This criterion was used so that the study results were in a form consistent with the model specification being used in the statistical analysis. In addition, studies must report the baseline catch rate (in pounds per trip) or be based on a survey sample that allows catch rates to be estimated from an external source.

3. *Studies must be scientifically sound.* Studies must employ scientifically sound methodological approaches and be implemented in a scientifically sound manner. The three critical components in such an assessment are sampling protocols, response rates, and estimation techniques.

The studies meeting all three criteria were included in the meta-analysis. No additional criteria were applied when selecting studies. Table B-8 and B-9 summarize the studies that are used in our meta-analysis. The table has multiple entries for studies that estimate incremental benefits using different geographic areas or methodologies.

B.5.2.3. Statistical Analyses

The value that an angler derives from a fishing trip can be expressed as a function of the pounds of fish caught per trip:

(1) $$V = \gamma + (\alpha + \varepsilon) catch + \beta * \sqrt{catch} + \mu .$$

[8] We excluded studies based upon Florida fisheries because none of the species ranges extended to Florida. See Table E-6.

where *V* is the dollar value per angler trip, *catch* is the pounds of fish caught per trip, γ, α and β are unknown parameters, and ε and μ are error terms. This functional form is chosen because the marginal value is decreasing as the catch rate increases, consistent with the economic theory of declining marginal returns. If the number of fish caught per trip changes, the change in value is:

(2) $$\Delta V = (\alpha + \varepsilon)\Delta catch + \beta * \Delta\sqrt{catch}.$$

where Δ represents the change in a variable.[9] Dividing by the change in catch ($\Delta catch$) leads to the following equation:

(3) $$\frac{\Delta V}{\Delta catch} = \alpha + \beta\frac{\Delta\sqrt{catch}}{\Delta catch} + \varepsilon$$

This equation is estimated in the meta-analysis. Table B-9 shows the specific data used in the estimation. These data include the change in value per angler trip as reported in each study (in nominal and real dollars), the size of the increase in catch, and the estimate of the catch rate (i.e., average pounds of fish per trip) for the relevant location.[10] Equation (3) is estimated using standard statistical techniques yielding the following results.[11]

(4) $$\frac{\Delta V}{\Delta catch} = -12.63 + 94.48\frac{\Delta\sqrt{catch}}{\Delta catch}$$

From this relationship, the marginal value can be estimated by taking the derivative of (1) and substituting the estimated values of α and β:[12]

(5) $$MV = -7.84 + 47.24/\sqrt{catch}$$

Figure B-4 shows equation (5) graphically. The results show decreasing marginal value, which, as noted, is consistent with the existing literature.

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[9] Therefore, $\Delta\sqrt{catch} = \sqrt{catch + increment} - \sqrt{catch}$, where *increment* is the increase in catch for which the change in willingness to pay is measured.

[10] When studies report marginal benefits, rather than the benefit of an incremental change in catch, the independent variable, $\frac{\Delta\sqrt{catch}}{\Delta catch}$, is measured by the taking the limit as $\Delta catch \to 0$. As a result, the independent variable is $\frac{1}{2\sqrt{catch}}$ for these observations.

[11] The regression is estimated in Stata using ordinary least squares regression techniques. The t-statistic on the coefficient is 4.27, which is significant at the 99 percent confidence level, while the t-statistic on the constant is 2.88, which is also significant at the 99 percent confidence level. The regression has an adjusted-R^2 of 0.40.

[12] The marginal value is $MV = \alpha + \frac{\beta}{2\sqrt{catch}}$, since $E[\varepsilon]=0$.

B.5.2.4. Results: Value Per Pound Of Recreational Catch

The statistical relationship in equation (5) can be used to estimate the dollar value for additional pounds of fish at the baseline catch rate relevant to this study, which we assume is the average catch rate for recreational fishermen from New York State.[13] The average fish per trip for recreational fishermen in this area is 3.62 fish per angler trip.[14] An average weight of 2.26 pounds per fish translates into a baseline catch rate of 8.18 pounds per angler trip.[15]

Using the statistical relationship in equation (5) and Figure B-4 and this baseline catch rate, we calculated the dollar value of an additional fish to be $3.88 (2000 dollars) per pound. This value is used to determine the recreational catch benefits of reduced cropping of fish at the Station.

[13] This geographic area reflects the region where the fish gains at Bethlehem are most likely to result in increases in recreational or commercial catch.

[14] This figure is the weighted average over the period from 1990 to 1998, as reported by the National Marine Fisheries Service in their Marine Recreational Fisheries Statistical Survey database (National Marine Fisheries Service 2000). The area includes the inland and ocean waters of New York.

[15] Pounds per fish is calculated by taking the total weight of harvested fish and dividing by the total number of fish harvested over the same geographic range and years described in the previous footnote.

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TABLES

TABLE B-1 Summary of Cooling System Construction Costs (x $1000)

DESCRIPTION	COOLING SYSTEMS ONCE THROUGH COST	MECHANICAL DRAFT COST	WET/DRY HYBRID COST	AIR COOLED CONDENSER COST
Total Equipment/Materials Includes: Civil, structural, cooling system equipment & piping, pumps, valves, electrical, etc.	$ 12,002	$ 11,697	$ 15,387	$ 26,957
Total Site Labor Includes: Contractor labor - craft rates and fringe benefits, taxes, etc.	$ 10,287	$ 8,342	$ 10,059	$ 11,773
Total Other Includes: Contract equipment, gen'l conditions, consumables, freight, small tools and consumables, etc.	$ 1,672	$ 1,503	$ 1,908	$ 2,905
Total Scope Adjustments Includes: Engineering & design, support, procurement, startup & comm., licensing, indirects, escalation, fees, etc.	$ 4,550	$ 4,521	$ 5,648	$ 10,515
Total Site Adjustments Includes: Contingency	$ 4,089	$ 3,937	$ 4,898	$ 7,850
Schedule acceleration (3months)	$ -	$ -	$ -	$ 8,000
TOTAL PROJECT COST	$ 32,600	$ 30,000	$ 37,900	$ 68,000

TABLE B-2 Annual Cooling System Operating and Maintenance Costs

Item	Once Through	Wet Cooling Tower	Wet/ Dry Tower With Plume Mitigation	Dry Cooling Tower
Fixed Maintenance Labor	$50,000	$62,500	$63,600	$71,000
Materials	$704,400	$881,100	$897,000	$1,000,200
Overhead	$15,000	$18,800	$19,100	$21,300
Consumables	$56,500	$633,800	$595,100	$56,000
Total Cost	$825,900	$1,596,200	$1,574,800	$1,148,500

TABLE B-3 Change in Auxiliary Power Relative for Closed-Cycle Cooling Alternatives (Relative to Once Through Cooling) (kwh)

Alternative	January	February	March	April	May	June	July	August	September	October	November	December
Wet Tower	964	971	1,002	1,161	1,300	1,300	1,293	1,297	1,310	1,212	1,071	979
Wet/Dry Tower	1,403	1,415	1,467	1,631	1,771	1,775	1,771	1,773	1,781	1,682	1,542	1,428
Dry Tower	(431)	(355)	(52)	1,649	3,139	3,337	3,377	3,353	3,289	2,190	701	(279)

TABLE B-4 Change in Heat Rate for Closed-Cycle Cooling Alternatives (Relative to Once Through Cooling) (Btu/kwh)

Alternative	January	February	March	April	May	June	July	August	September	October	November	December
Wet Tower	45	44	42	43	45	52	57	54	47	44	43	44
Wet/Dry Tower	44	43	41	42	45	52	57	54	46	44	42	43
Dry Tower	82	81	78	80	82	98	109	102	86	80	80	81

TABLE B-5 Natural Gas Prices, 2003-2028

	NATURAL GAS PRICES ($2000/MMBtu)												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
2003	$5.06	$4.89	$4.68	$4.43	$4.36	$4.37	$4.39	$4.38	$4.39	$4.41	$4.55	$4.67	$4.55
2004	$5.34	$5.17	$4.95	$4.68	$4.61	$4.62	$4.64	$4.63	$4.64	$4.66	$4.81	$4.94	$4.81
2005	$4.01	$3.88	$3.71	$3.51	$3.46	$3.47	$3.48	$3.48	$3.49	$3.50	$3.61	$3.71	$3.61
2006	$4.06	$3.93	$3.76	$3.55	$3.50	$3.51	$3.52	$3.52	$3.53	$3.54	$3.65	$3.75	$3.65
2007	$4.10	$3.97	$3.80	$3.59	$3.54	$3.55	$3.56	$3.56	$3.57	$3.58	$3.69	$3.79	$3.69
2008	$4.15	$4.01	$3.84	$3.63	$3.58	$3.59	$3.60	$3.59	$3.60	$3.62	$3.73	$3.83	$3.73
2009	$4.19	$4.06	$3.88	$3.67	$3.62	$3.63	$3.64	$3.63	$3.64	$3.66	$3.77	$3.87	$3.77
2010	$4.24	$4.10	$3.93	$3.71	$3.66	$3.67	$3.68	$3.67	$3.68	$3.70	$3.81	$3.92	$3.81
2011	$4.29	$4.15	$3.97	$3.75	$3.70	$3.71	$3.72	$3.71	$3.72	$3.74	$3.85	$3.96	$3.86
2012	$4.33	$4.19	$4.01	$3.79	$3.74	$3.75	$3.76	$3.76	$3.77	$3.78	$3.90	$4.00	$3.90
2013	$4.38	$4.24	$4.06	$3.84	$3.78	$3.79	$3.80	$3.80	$3.81	$3.82	$3.94	$4.05	$3.94
2014	$4.43	$4.29	$4.10	$3.88	$3.82	$3.83	$3.84	$3.84	$3.85	$3.86	$3.98	$4.09	$3.98
2015	$4.48	$4.33	$4.15	$3.92	$3.86	$3.87	$3.88	$3.88	$3.89	$3.91	$4.03	$4.14	$4.03
2016	$4.52	$4.38	$4.19	$3.96	$3.90	$3.91	$3.93	$3.92	$3.93	$3.95	$4.07	$4.18	$4.07
2017	$4.57	$4.42	$4.23	$4.00	$3.95	$3.95	$3.97	$3.96	$3.97	$3.99	$4.11	$4.22	$4.11
2018	$4.62	$4.47	$4.28	$4.04	$3.99	$3.99	$4.01	$4.00	$4.01	$4.03	$4.15	$4.27	$4.16
2019	$4.67	$4.52	$4.32	$4.09	$4.03	$4.04	$4.05	$4.04	$4.06	$4.07	$4.20	$4.31	$4.20
2020	$4.71	$4.56	$4.37	$4.13	$4.07	$4.08	$4.09	$4.09	$4.10	$4.11	$4.24	$4.36	$4.24
2021	$4.76	$4.61	$4.41	$4.17	$4.11	$4.12	$4.13	$4.13	$4.14	$4.15	$4.28	$4.40	$4.28
2022	$4.81	$4.65	$4.45	$4.21	$4.15	$4.16	$4.17	$4.17	$4.18	$4.20	$4.32	$4.44	$4.33
2023	$4.86	$4.70	$4.50	$4.25	$4.19	$4.20	$4.21	$4.21	$4.22	$4.24	$4.37	$4.49	$4.37
2024	$4.90	$4.74	$4.54	$4.29	$4.23	$4.24	$4.26	$4.25	$4.26	$4.28	$4.41	$4.53	$4.41
2025	$4.95	$4.79	$4.59	$4.34	$4.27	$4.28	$4.30	$4.29	$4.30	$4.32	$4.45	$4.58	$4.46
2026	$5.00	$4.84	$4.63	$4.38	$4.31	$4.32	$4.34	$4.33	$4.34	$4.36	$4.50	$4.62	$4.50
2027	$5.05	$4.88	$4.67	$4.42	$4.36	$4.36	$4.38	$4.37	$4.39	$4.40	$4.54	$4.66	$4.54
2028	$5.10	$4.93	$4.72	$4.46	$4.40	$4.40	$4.42	$4.42	$4.43	$4.45	$4.58	$4.71	$4.58

Source: Wall Street Journal 2001; U.S. Department of Energy 2000; NERA calculations as described in text.

TABLE B-6 Air Emissions Costs from Power Impacts ($2000/Ton Emissions)

Year	SO2	NOX	CO2
2002	154	538	5
2003	152	533	5
2004	151	527	6
2005	149	522	6
2006	148	517	6
2007	146	512	6
2008	145	507	55
2009	143	502	50
2010	142	497	46
2011	141	493	41
2012	139	488	37
2013	138	483	32
2014	137	478	28
2015	135	474	23

TABLE B-7 Commercial (Wholesale) Fishing Prices per Pound by Year ($2000)

Fin Fish	1990	1991	1992	1993	1994	1995	1996	1997	1998	1990-1998 Average
American Shad	$0.71	$0.96	$0.56	$0.74	**	**	$0.55	$0.60	**	$0.69
River Herring[a]	**	**	**	**	**	**	**	**	**	$0.16[b]
Striped Bass	$3.91		$2.85	$3.57	$3.40	$2.32	$2.87	$2.41	$2.54	$2.98
White Perch	$1.02	$0.69	$0.96	$1.37	$1.62	$1.44	$1.44	$0.70	$0.98	$1.13

** Denotes data not available

[a] The river herring category combines alewife and blueback herring.

[b] River herring prices are calculated by multiplying ex-vessel prices by the average ratio of wholesale to ex-vessel prices for other species.

Source: NMFS (1990-1998)

TABLE B-8 Studies used in Meta Analysis

Author	Publication Year	Methodology	Model	Geographic Area	Species	Type of Fishing
Agnello & Han	1993	Travel Cost		Long Island	General	Boat & Shore
Agnello	1988	Travel Cost		New York to Florida	Bluefish	Boat & Shore
	1988	Travel Cost		New York to Florida	Summer Flounder	Boat & Shore
	1988	Travel Cost		New York to Florida	Weakfish	Boat & Shore
Bockstael, Graefe et. al. [a]	1986	Travel Cost		South Carolina (inlet)	General	Boat
	1986	Travel Cost		South Carolina	General	Boat
Gautam & Steinback	1998	Random Utility		Maine to Virginia	Striped Bass	Boat & Shore
	1998	Travel Cost		Maine to Virginia	Striped Bass	Boat & Shore
Hicks, Steinback, Gautam & Thunberg	1999	Random Utility		Maine to Virginia	Big Game	Boat & Shore
	1999	Random Utility		Maine to Virginia	Small Game	Boat & Shore
	1999	Random Utility		Maine to Virginia	Bottom Fish	Boat & Shore
	1999	Random Utility		Maine to Virginia	Flat Fish	Boat & Shore
Norton, Strand & Smith	1980	Travel Cost		New England	Striped Bass	Boat & Shore
	1980	Travel Cost		Mid-Atlantic	Striped Bass	Boat & Shore
	1980	Travel Cost		Chesapeake	Striped Bass	Boat & Shore
	1980	Travel Cost		South Atlantic	Striped Bass	Boat & Shore
McConnell & Strand [b]	1994	Random Utility	Expected Catch Model	New York to Georgia	General	Boat & Shore
	1994	Random Utility	Increase in Expected Catch	New York to Georgia	General	Boat & Shore
	1994	Random Utility	Historical Catch Model	New York to Georgia	General	Boat & Shore
	1994	Travel Cost		New York to Georgia	General	Boat & Shore
	1994	Travel Cost		New York to Georgia	General	Boat & Shore
	1994	Travel Cost		New York to Georgia	General	Boat & Shore
Schuhmann [c]	1998	Random Utility	Historic Catch	North Carolina	General	Boat
	1998	Random Utility	Expected Catch	North Carolina	General	Boat
	1998	Random Utility	Historic Catch	North Carolina	General	Shore
	1998	Random Utility	Expected Catch	North Carolina	General	Shore
Whitehead, Haab & Huang	1999	Random Utility		Albemarle, Pamlico Sounds, NC	General	Boat & Shore

[a] Study evaluates an on-site intercept survey from Murrel's Inlet, South Carolina and a general mail survey of South Carolina fishermen.

[b] Marginal recreational values are estimated by the authors using three different approaches for both the random utility and travel cost methods. The results from all three are included as separate data points since the authors do not state a preferred model and results vary dramatically.

[c] Marginal recreational values are estimated by the author using both an expected catch and historical catch models. Results for both models are presented since the author does not state a preferred modeling approach.

TABLE B-9 Data Used in Meta Analysis

Author	Study Year [a]	Baseline Catch (Pounds per trip) [b]	Size of Marginal Increment (Pounds) [c]	Value of Increment ($2000) [d]	Value per Pound ($2000/Pound) [e]
Agnello & Han	1981	3.93	0.79	2.58	3.29
Agnello	1980	10.52	0.00		0.00
	1980	2.17	0.00		0.00
	1980	11.64	0.00		0.00
Bockstael, Graefe et. al.	1985	11.70	2.34	41.69	17.82
	1985	9.31	1.86	13.82	7.42
Gautam & Steinback	1994	6.60	12.06	45.11	3.74
	1994	6.60	12.06		1.51
Hicks, Steinback, Gautam & Thunberg	1994	6.57	19.33	5.39	0.31
	1994	6.57	2.51	2.89	1.28
	1994	6.57	1.15	1.97	1.90
	1994	6.57	1.35	4.01	3.30
Norton, Strand & Smith	1980	5.15	14.30	348.08	24.34
	1980	6.86	14.30	205.04	14.34
	1980	10.01	14.30	146.07	10.21
	1980	5.01	14.30	36.93	2.58
McConnell & Strand	1988	5.17	0.53	10.65	20.02
	1988	5.17	0.53	5.37	10.10
	1988	5.17	0.53	0.37	0.69
	1988	5.17	0.53	1.28	2.41
	1988	5.17	0.53	1.30	2.44
	1988	5.17	0.53	3.14	5.90
Schumann	1990	6.48	1.62	12.66	7.82
	1990	6.48	1.62	9.18	5.67
	1990	3.66	0.92	8.11	8.86
	1990	3.66	0.92	6.28	6.86
Whitehead, Haab & Huang	1995	3.20	1.92		32.83

[a] Study year indicates the year for which the data were collected.
[b] The pounds per trip are calculated from the following sources: Agnello & Han, and Agnello – Calculated from fish per trip reported by study and MRFSS fish weight data; Bockstael et. al., and Norton, Strand & Smith – Calculated from study data; Gautam & Steinbeck, and McConnell and Strand – Calculated from *Marine Recreational Fisheries Statistical Survey Database* for the study year or the closest year for which data are available in the study state.
[c] Increment size is the increase in catch for which the change in individual value is estimated (i.e. the incremental value). The studies measure the change in the value of a trip for an increase in either the number of fish caught or a percentage increase in the total catch. Average fish size and total catch estimates are used to convert these increments into pounds. For studies reporting marginal values of increased catch, the average pounds per fish is used to convert numbers of fish to pounds of fish. For these studies, average fish weight is reported in parentheses.
[d] The value of incremental is the increase in individual consumer surplus for the incremental increase in catch per trip, reported in nominal dollars of the study year. The increment size, which varies across the studies, is reported in the increment size column. For Agnello and the travel cost results from Gautam & Steinback, the marginal value of increased catch (measured in number of fish) is reported. The GDP Deflater (CPI) to convert dollars in the study year to year 2000 dollars (Congressional Budget Office, 1998).
[e] Change in value per pound is estimated by dividing the incremental value (in $1998) by the increment size. For Agnello, Whitehead et al., and the travel cost results from Gautam & Steinback, the marginal value for increased catch (measured by weight) is reported.

FIGURES

FIGURE B-1. Hypothetical Value per Fisherman Trip at Different Catch Rates

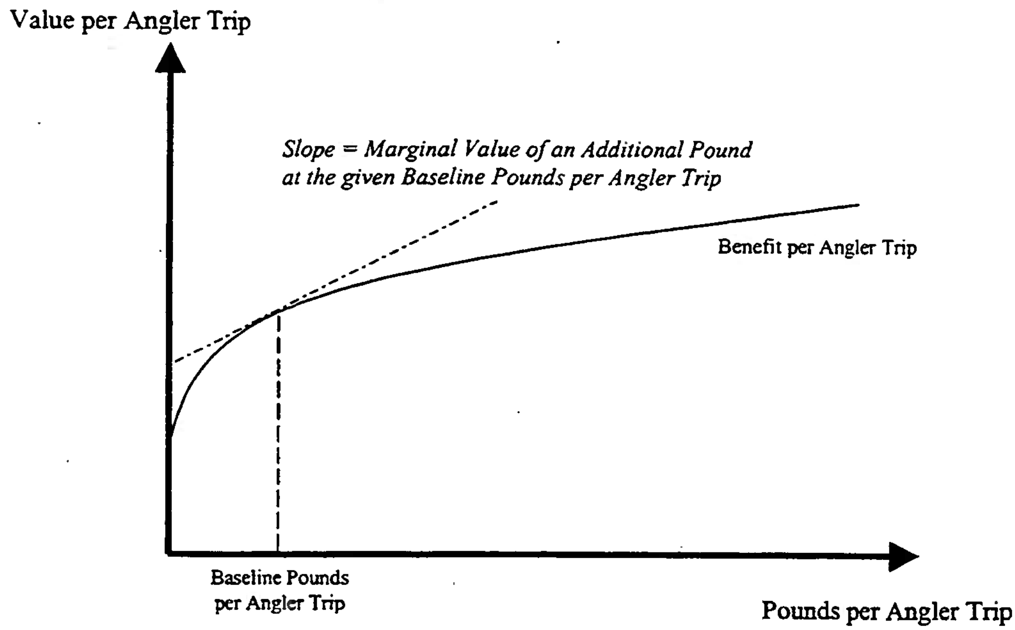


FIGURE B-2. Hypothetical Marginal Value per Fisherman Trip at Different Catch Rates

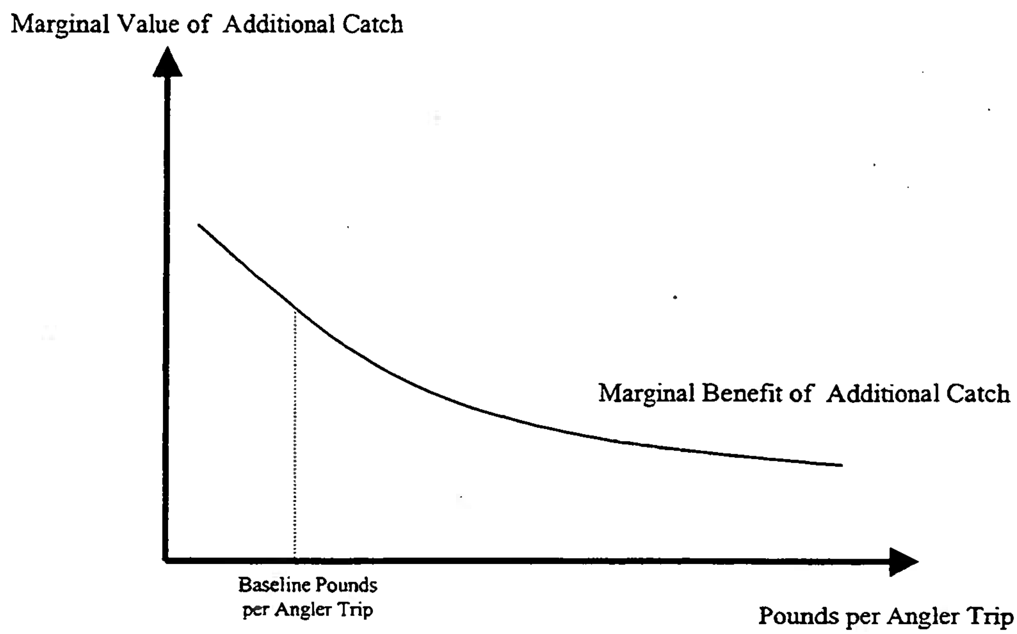


FIGURE B-3. Methodology for Estimating Recreational Fish Value

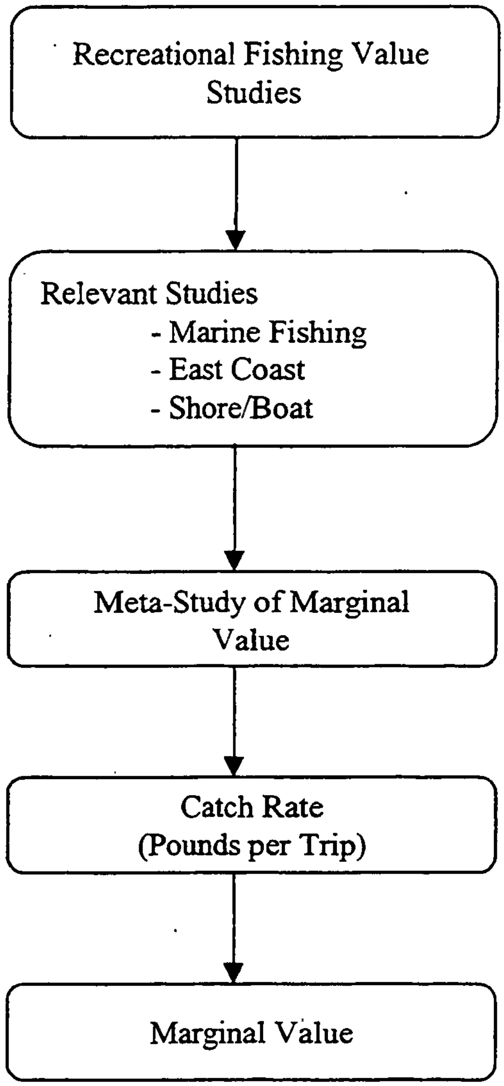
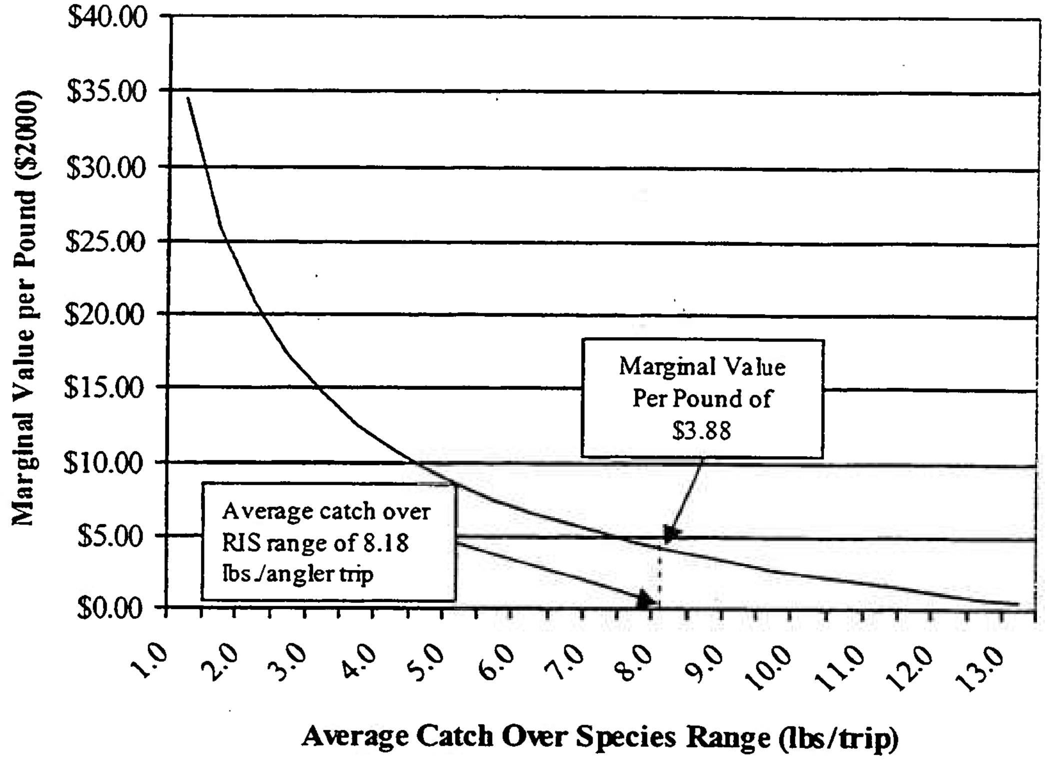


FIGURE B-4. Estimated Marginal Value of Additional Recreational Catch



Source: NERA calculation as described in text.

Appendix 3

APPENDIX C. DETAILED COST TABLES

Chapter 8 evaluates the incremental costs and benefits of cooling system alternatives for Bethlehem relative to the Wet Tower alternative. This attachment provides the details of the calculation of total costs for each cooling system alternative evaluated in Chapter 8 and the proposed cooling system, including closed-cycle cooling with wet towers and wedge-wire screens. Table C-1 provides the present value of costs by component for all alternatives. Tables C-2 to C-9 provide annual cost estimates, by component, for each alternative. Cost components include:

- Construction Costs;
- Operating and Maintenance Costs; and
- The value of lost power resulting from energy losses and air emissions; and

All costs are based on the data developed in Chapter 8 and Appendix B. Tables C-2 to C-9 also provide the total annual cost for each alternative. Construction costs reflect the total cost of construction associated with each alternative. O&M costs reflect the costs of operating the cooling system at BEC. Power costs are estimated relative to the power costs of the Once Through alternative. Total present values for each cost component are calculated as of January 1, 2002 using a real interest rate of 7 percent, consistent with recommendations by the Office for Management and Budget (Office of Management and Budget 1996).

The table for each alternative includes notes providing data and assumptions used to calculate the cost estimates. The table for each alternative also provides the duration of construction, which determines when alternatives actually become effective.

Note that NERA's calculation of present value takes into account the monthly pattern of expenditures where these data are available (e.g., construction costs). Where monthly expenditure data are not available, NERA assumes that expenditures are evenly distributed over the year. Note that the standard calculation of present value assumes that payments are made at the end of each period. Where the "payments," or expenditures, occur throughout the year, this approach leads to improper discounting. To correct for this effect, NERA's present value calculations include a six-month adjustment. This adjustment results in present value calculations which assume payments are made in the middle of the period, the correct approach for payments evenly distributed over the period.

REFERENCES

Office of Management and Budget. 1996. "Economic Analysis of Federal Regulations Under Executive Order 12866," January 11.

Table C - 1. Present Value of Costs by Component for Fish Protection Alternatives

	COST COMPONENT ($millions)				
	Construction	Power		O&M	Total
Alternative		Energy	Air		
Once Through	$30.64	$0.00	$0.00	$3.90	$34.54
Wet Tower and Wedge Wire Screen	$28.19	$3.60	$1.47	$14.91	$48.17
Wet Tower, Wedge Screen, Gunderboor	$29.34	$3.60	$1.47	$15.51	$49.92
Wet Tower, Wedge Screen,Tank	$30.26	$3.60	$1.47	$14.91	$50.23
Wet/Dry Tower	$35.62	$5.05	$2.06	$14.00	$56.72
Wet /Dry Tower and Gunderboom	$36.83	$5.05	$2.06	$14.60	$58.54
Wet /Dry Tower and Tank	$37.68	$5.05	$2.06	$14.00	$58.78
Dry Tower	$63.91	$5.12	$2.13	$4.57	$75.72

Note: Present values in millions of January 2000 dollars as of January 1, 2002.

Source: NERA calculations as described in text.

Table C - 2. Once Through Annualized Costs by Component ($000)

Year	Construction	Power		O&M	Total
		Energy	Air		
2002	$21,733	$0	$0	$0	$21,733
2003	$10,655	$0	$0	$169	$10,823
2004	$0	$0	$0	$356	$356
2005	$0	$0	$0	$356	$356
2006	$0	$0	$0	$356	$356
2007	$0	$0	$0	$356	$356
2008	$0	$0	$0	$356	$356
2009	$0	$0	$0	$356	$356
2010	$0	$0	$0	$356	$356
2011	$0	$0	$0	$356	$356
2012	$0	$0	$0	$356	$356
2013	$0	$0	$0	$356	$356
2014	$0	$0	$0	$356	$356
2015	$0	$0	$0	$356	$356
2016	$0	$0	$0	$356	$356
2017	$0	$0	$0	$356	$356
2018	$0	$0	$0	$356	$356
2019	$0	$0	$0	$356	$356
2020	$0	$0	$0	$356	$356
2021	$0	$0	$0	$356	$356
2022	$0	$0	$0	$356	$356
2023	$0	$0	$0	$356	$356
2024	$0	$0	$0	$356	$356
2025	$0	$0	$0	$356	$356
2026	$0	$0	$0	$356	$356
2027	$0	$0	$0	$356	$356
2028	$0	$0	$0	$356	$356
Present Value	$30,637	$0	$0	$3,899	$34,535

Note: Present values as of January 1, 2002. All values in thousands of January 2000 dollars. Parentheses indicate negative values.

Construction Duration 18 months
Construction Start Date January 1, 2002

Table C - 3. Wet Tower Annualized Costs by Component ($000)

Year	Construction	Power: Energy	Power: Air	O&M	Total
2002	$20,000	$0	$0	$0	$20,000
2003	$9,805	$176	$11	$645	$10,637
2004	$0	$380	$24	$1,361	$1,764
2005	$0	$298	$24	$1,361	$1,683
2006	$0	$301	$25	$1,361	$1,687
2007	$0	$304	$26	$1,361	$1,690
2008	$0	$307	$205	$1,361	$1,872
2009	$0	$309	$203	$1,361	$1,873
2010	$0	$312	$200	$1,361	$1,873
2011	$0	$315	$197	$1,361	$1,873
2012	$0	$318	$194	$1,361	$1,873
2013	$0	$321	$192	$1,361	$1,873
2014	$0	$324	$189	$1,361	$1,873
2015	$0	$327	$186	$1,361	$1,874
2016	$0	$330	$184	$1,361	$1,874
2017	$0	$333	$181	$1,361	$1,874
2018	$0	$336	$178	$1,361	$1,874
2019	$0	$338	$176	$1,361	$1,875
2020	$0	$341	$173	$1,361	$1,875
2021	$0	$344	$170	$1,361	$1,875
2022	$0	$347	$167	$1,361	$1,875
2023	$0	$350	$165	$1,361	$1,875
2024	$0	$353	$162	$1,361	$1,876
2025	$0	$356	$159	$1,361	$1,876
2026	$0	$359	$157	$1,361	$1,876
2027	$0	$362	$154	$1,361	$1,876
2028	$0	$365	$151	$1,361	$1,876
Present Value	$28,194	$3,601	$1,466	$14,907	$48,167

Note: Present values as of January 1, 2002. All values in thousands of January 2000 dollars. Parentheses indicate negative values.

Construction Duration 18 months
Construction Start Date January 1, 2002

Table C - 4. Wet Tower with Seasonal Gunderboom Annualized Costs by Component ($000)

	Construction	Power		O&M	Total
Year		Energy	Air		
2002	$20,483	$0	$0	$0	$20,483
2003	$10,042	$176	$11	$671	$10,900
2004	$0	$380	$24	$1,416	$1,819
2005	$0	$298	$24	$1,416	$1,738
2006	$0	$301	$25	$1,416	$1,742
2007	$200	$304	$26	$1,416	$1,945
2008	$0	$307	$205	$1,416	$1,927
2009	$0	$309	$203	$1,416	$1,928
2010	$0	$312	$200	$1,416	$1,928
2011	$200	$315	$197	$1,416	$2,128
2012	$0	$318	$194	$1,416	$1,928
2013	$0	$321	$192	$1,416	$1,928
2014	$0	$324	$189	$1,416	$1,928
2015	$200	$327	$186	$1,416	$2,129
2016	$0	$330	$184	$1,416	$1,929
2017	$0	$333	$181	$1,416	$1,929
2018	$0	$336	$178	$1,416	$1,929
2019	$200	$338	$176	$1,416	$2,130
2020	$0	$341	$173	$1,416	$1,930
2021	$0	$344	$170	$1,416	$1,930
2022	$0	$347	$167	$1,416	$1,930
2023	$200	$350	$165	$1,416	$2,130
2024	$0	$353	$162	$1,416	$1,931
2025	$0	$356	$159	$1,416	$1,931
2026	$0	$359	$157	$1,416	$1,931
2027	$200	$362	$154	$1,416	$2,131
2028	$0	$365	$151	$1,416	$1,931
Present Value	$29,342	$3,601	$1,466	$15,510	$49,918

Note: Present values as of January 1, 2002. All values in thousands of January 2000 dollars. Parentheses indicate negative values.

Construction Duration 18 months
Construction Start Date January 1, 2002

Table C - 5. Wet Tower with Holding Tank Annualized Costs by Component ($000)					
	Construction	Power		O&M	Total
Year		Energy	Air		
2002	$21,467	$0	$0	$0	$21,467
2003	$10,524	$176	$11	$645	$11,356
2004	$0	$380	$24	$1,361	$1,764
2005	$0	$298	$24	$1,361	$1,683
2006	$0	$301	$25	$1,361	$1,687
2007	$0	$304	$26	$1,361	$1,690
2008	$0	$307	$205	$1,361	$1,872
2009	$0	$309	$203	$1,361	$1,873
2010	$0	$312	$200	$1,361	$1,873
2011	$0	$315	$197	$1,361	$1,873
2012	$0	$318	$194	$1,361	$1,873
2013	$0	$321	$192	$1,361	$1,873
2014	$0	$324	$189	$1,361	$1,873
2015	$0	$327	$186	$1,361	$1,874
2016	$0	$330	$184	$1,361	$1,874
2017	$0	$333	$181	$1,361	$1,874
2018	$0	$336	$178	$1,361	$1,874
2019	$0	$338	$176	$1,361	$1,875
2020	$0	$341	$173	$1,361	$1,875
2021	$0	$344	$170	$1,361	$1,875
2022	$0	$347	$167	$1,361	$1,875
2023	$0	$350	$165	$1,361	$1,875
2024	$0	$353	$162	$1,361	$1,876
2025	$0	$356	$159	$1,361	$1,876
2026	$0	$359	$157	$1,361	$1,876
2027	$0	$362	$154	$1,361	$1,876
2028	$0	$365	$151	$1,361	$1,876
Present Value	$30,261	$3,601	$1,466	$14,907	**$50,235**

Note: Present values as of January 1, 2002. All values in thousands of January 2000 dollars. Parentheses indicate negative values.

Construction Duration 18 months
Construction Start Date January 1, 2002

Table C - 6. Wet/Dry Tower Annualized Costs by Component ($000)					
	Construction	Power		O&M	Total
Year		Energy	Air		
2002	$25,267	$0	$0	$0	$25,267
2003	$12,387	$245	$16	$605	$13,254
2004	$0	$533	$33	$1,277	$1,844
2005	$0	$418	$34	$1,277	$1,730
2006	$0	$422	$35	$1,277	$1,735
2007	$0	$426	$36	$1,277	$1,740
2008	$0	$430	$288	$1,277	$1,995
2009	$0	$434	$284	$1,277	$1,995
2010	$0	$438	$280	$1,277	$1,996
2011	$0	$442	$276	$1,277	$1,996
2012	$0	$446	$273	$1,277	$1,996
2013	$0	$450	$269	$1,277	$1,996
2014	$0	$454	$265	$1,277	$1,997
2015	$0	$458	$261	$1,277	$1,997
2016	$0	$463	$258	$1,277	$1,997
2017	$0	$467	$254	$1,277	$1,998
2018	$0	$471	$250	$1,277	$1,998
2019	$0	$475	$246	$1,277	$1,998
2020	$0	$479	$242	$1,277	$1,999
2021	$0	$483	$239	$1,277	$1,999
2022	$0	$487	$235	$1,277	$1,999
2023	$0	$491	$231	$1,277	$1,999
2024	$0	$495	$227	$1,277	$2,000
2025	$0	$499	$224	$1,277	$2,000
2026	$0	$503	$220	$1,277	$2,000
2027	$0	$507	$216	$1,277	$2,001
2028	$0	$512	$212	$1,277	$2,001
Present Value	$35,618	$5,050	$2,055	$13,996	$56,718

Note: Present values as of January 1, 2002. All values in thousands of January 2000 dollars. Parentheses indicate negative values.

Construction Duration 18 months
Construction Start Date January 1, 2002

Table C - 7. Wet /Dry Tower with Seasonal Gunderboom Annualized Costs by Component ($0(

Year	Construction	Power Energy	Power Air	O&M	Total
2002	$25,750	$0	$0	$0	$25,750
2003	$12,624	$245	$16	$631	$13,517
2004	$0	$533	$33	$1,332	$1,899
2005	$0	$418	$34	$1,332	$1,785
2006	$0	$422	$35	$1,332	$1,790
2007	$300	$426	$36	$1,332	$2,095
2008	$0	$430	$288	$1,332	$2,050
2009	$0	$434	$284	$1,332	$2,050
2010	$0	$438	$280	$1,332	$2,051
2011	$200	$442	$276	$1,332	$2,251
2012	$0	$446	$273	$1,332	$2,051
2013	$0	$450	$269	$1,332	$2,051
2014	$0	$454	$265	$1,332	$2,052
2015	$200	$458	$261	$1,332	$2,252
2016	$0	$463	$258	$1,332	$2,052
2017	$0	$467	$254	$1,332	$2,053
2018	$0	$471	$250	$1,332	$2,053
2019	$200	$475	$246	$1,332	$2,253
2020	$0	$479	$242	$1,332	$2,054
2021	$0	$483	$239	$1,332	$2,054
2022	$0	$487	$235	$1,332	$2,054
2023	$200	$491	$231	$1,332	$2,254
2024	$0	$495	$227	$1,332	$2,055
2025	$0	$499	$224	$1,332	$2,055
2026	$0	$503	$220	$1,332	$2,055
2027	$200	$507	$216	$1,332	$2,256
2028	$0	$512	$212	$1,332	$2,056
Present Value	$36,835	$5,050	$2,055	$14,598	$58,538

Note: Present values as of January 1, 2002. All values in thousands of January 2000 dollars. Parentheses indicate negative values.

Construction Duration 18 months
Construction Start Date January 1, 2002

Table C - 8. Wet /Dry Tower with Holding Tank Annualized Costs by Component ($0(

Year	Construction	Power		O&M	Total
		Energy	Air		
2002	$26,729	$0	$0	$0	$26,729
2003	$13,104	$245	$16	$605	$13,970
2004	$0	$533	$33	$1,277	$1,844
2005	$0	$418	$34	$1,277	$1,730
2006	$0	$422	$35	$1,277	$1,735
2007	$0	$426	$36	$1,277	$1,740
2008	$0	$430	$288	$1,277	$1,995
2009	$0	$434	$284	$1,277	$1,995
2010	$0	$438	$280	$1,277	$1,996
2011	$0	$442	$276	$1,277	$1,996
2012	$0	$446	$273	$1,277	$1,996
2013	$0	$450	$269	$1,277	$1,996
2014	$0	$454	$265	$1,277	$1,997
2015	$0	$458	$261	$1,277	$1,997
2016	$0	$463	$258	$1,277	$1,997
2017	$0	$467	$254	$1,277	$1,998
2018	$0	$471	$250	$1,277	$1,998
2019	$0	$475	$246	$1,277	$1,998
2020	$0	$479	$242	$1,277	$1,999
2021	$0	$483	$239	$1,277	$1,999
2022	$0	$487	$235	$1,277	$1,999
2023	$0	$491	$231	$1,277	$1,999
2024	$0	$495	$227	$1,277	$2,000
2025	$0	$499	$224	$1,277	$2,000
2026	$0	$503	$220	$1,277	$2,000
2027	$0	$507	$216	$1,277	$2,001
2028	$0	$512	$212	$1,277	$2,001
Present Value	$37,679	$5,050	$2,055	$13,996	$58,780

Note: Present values as of January 1, 2002. All values in thousands of January 2000 dollars. Parentheses indicate negative values.

Construction Duration 18 months
Construction Start Date January 1, 2002

Table C - 9. Dry Tower Annualized Costs by Component ($000)

Year	Construction	Power		O&M	Total
		Energy	Air		
2002	$45,333	$0	$0	$0	$45,333
2003	$22,225	$310	$20	$198	$22,753
2004	$0	$534	$35	$417	$986
2005	$0	$420	$35	$417	$872
2006	$0	$424	$36	$417	$877
2007	$0	$428	$37	$417	$882
2008	$0	$431	$297	$417	$1,146
2009	$0	$435	$293	$417	$1,146
2010	$0	$439	$290	$417	$1,146
2011	$0	$443	$286	$417	$1,146
2012	$0	$447	$282	$417	$1,146
2013	$0	$452	$278	$417	$1,146
2014	$0	$456	$274	$417	$1,147
2015	$0	$460	$270	$417	$1,147
2016	$0	$464	$266	$417	$1,147
2017	$0	$468	$262	$417	$1,147
2018	$0	$472	$258	$417	$1,147
2019	$0	$476	$254	$417	$1,147
2020	$0	$480	$250	$417	$1,148
2021	$0	$484	$247	$417	$1,148
2022	$0	$488	$243	$417	$1,148
2023	$0	$492	$239	$417	$1,148
2024	$0	$496	$235	$417	$1,148
2025	$0	$500	$231	$417	$1,148
2026	$0	$504	$227	$417	$1,148
2027	$0	$509	$223	$417	$1,149
2028	$0	$513	$219	$417	$1,149
Present Value	$63,905	$5,121	$2,127	$4,569	**$75,723**

Note: Present values as of January 1, 2002. All values in thousands of January 2000 dollars. Parentheses indicate negative values.

Construction Duration 18 months
Construction Start Date January 1, 2002

Appendix 4

Table D - 1. Present Value of Benefits by Component for Fish Protention Alternatives

	Benefit Component ($2000 millions)		
Alternative	**Recreational**	**Commercial**	**Total**
Once Through	$0.704	$0.096	$0.80
Wet Tower and Wedge Wire Screen	$3.977	$0.561	$4.54
Wet Tower, Wedge Screen, Gunderboom	$4.059	$0.572	$4.63
Wet Tower, Wedge Screen,Tank	$3.987	$0.562	$4.55
Wet/Dry Tower	$3.981	$0.561	$4.54
Wet /Dry Tower and Gunderboom	$4.059	$0.572	$4.63
Wet /Dry Tower and Tank	$3.991	$0.563	$4.55
Dry Tower	$4.047	$0.570	$4.62

Note: Present values in millions of January 2000 dollars as of January 1, 2002. Parentheses indicate negative values.

Table D - 2. Annual Biomass Benefits (lbs.): Once Through

Species	Total	Recreational	Commercial
American Shad	41,893	23,460	18,433
River Herring	1,797	1,133	664
Striped Bass	(1,020)	(847)	(172)
White Perch	316	31	285

Notes: All weights expressed in pounds of adult equivalents. Parentheses indicate negative values. "0" entries indicate a positive value of less than 0.5.

Source: Appendix A

Table D - 3. Annual Biomass Benefits (lbs.): Wet Tower

Species	Total	Recreational	Commercial
American Shad	224,307	125,611.68	98,695
River Herring	10,927	5,903.04	5,024
Striped Bass	3,681	2,740.69	940
White Perch	2,128	141.83	1,986

Notes: All weights expressed in pounds of adult equivalents. Parentheses indicate negative values.
"0" entries indicate a positive value of less than 0.5.

Source: Appendix A

Table D - 4. Annual Biomass Benefits (lbs.): Wet Tower with Seasonal Gunderboom

Species	Total	Recreational	Commercial
American Shad	229,075	128,282	100,793
River Herring	11,095	6,009	5,085
Striped Bass	3,690	2,745	945
White Perch	2,158	144	2,014

Notes: All weights expressed in pounds of adult equivalents. Parentheses indicate negative values.
"0" entries indicate a positive value of less than 0.5.

Source: Appendix A

Table D - 5. Annual Biomass Benefits (lbs.): Wet Tower with Holding Tank

Species	Total	Recreational	Commercial
American Shad	224,903	125,946	98,957
River Herring	10,959	5,921	5,037
Striped Bass	3,680	2,740	940
White Perch	2,128	142	1,986

Notes: All weights expressed in pounds of adult equivalents. Parentheses indicate negative values.
"0" entries indicate a positive value of less than 0.5.

Source: Appendix A

Table D - 6. Annual Biomass Benefits (lbs.): Wet/Dry Tower

Species	Total	Recreational	Commercial
American Shad	224,540	125,742	98,797
River Herring	10,936	5,908	5,027
Striped Bass	3,682	2,741	941
White Perch	2,129	142	1,987

Notes: All weights expressed in pounds of adult equivalents. Parentheses indicate negative values. "0" entries indicate a positive value of less than 0.5.

Source: Appendix A

Table D - 7. Annual Biomass Benefits (lbs.): Wet /Dry Tower with Seasonal Gunderboom

Species	Total	Recreational	Commercial
American Shad	229,099	128,295	100,803
River Herring	11,096	6,010	5,086
Striped Bass	3,690	2,745	945
White Perch	2,158	144	2,014

Notes: All weights expressed in pounds of adult equivalents. Parentheses indicate negative values.
"0" entries indicate a positive value of less than 0.5.

Source: Appendix A

Table D - 8. Annual Biomass Benefits (lbs.): Wet /Dry Tower with Holding Tank

Species	Total	Recreational	Commercial
American Shad	225,110	126,061	99,048
River Herring	10,966	5,926	5,040
Striped Bass	3,681	2,740	940
White Perch	2,130	142	1,988

Notes: All weights expressed in pounds of adult equivalents. Parentheses indicate negative values.
"0" entries indicate a positive value of less than 0.5.

Source:

Table D - 9. Annual Biomass Benefits (lbs.): Dry Tower

Species	Total	Recreational	Commercial
American Shad	228,361	127,882	100,479
River Herring	11,070	5,993	5,076
Striped Bass	3,689	2,744	945
White Perch	2,154	144	2,010

Notes: All weights expressed in pounds of adult equivalents. Parentheses indicate negative values. "0" entries indicate a positive value of less than 0.5.

Source: Appendix A

Table D - 10. Annual Benefits ($1000): Once Through

Species	Recreational	Commercial
American Shad	$91.12	$12.65
River Herring	$4.40	$0.11
Striped Bass	($3.29)	($0.51)
White Perch	$0.12	$0.32
Total RIS Benefits	$92.34	$12.57

Notes: RIS forage fish included in game fish gains.
All values in thousands of January 2000 dollars.
Parentheses indicate negative values.
Source: NERA calculations as described in text.

Table D - 11. Annual Benefits ($1000): Wet Tower

Species	Recreational	Commercial
American Shad	$487.86	$67.73
River Herring	$22.93	$0.82
Striped Bass	$10.64	$2.81
White Perch	$0.55	$2.25
Total RIS Benefits	$521.98	$73.60

Notes: RIS forage fish included in game fish gains.
All values in thousands of January 2000 dollars.
Parentheses indicate negative values.
Source: NERA calculations as described in text.

Table D - 12. Annual Benefits ($1000): Wet Tower with Seasonal Gunderboom

Species	Recreational	Commercial
American Shad	$498.23	$69.17
River Herring	$23.34	$0.83
Striped Bass	$10.66	$2.82
White Perch	$0.56	$2.28
Total RIS Benefits	$532.79	$75.10

Notes: RIS forage fish included in game fish gains.
All values in thousands of January 2000 dollars.
Parentheses indicate negative values.
Source: NERA calculations as described in text.

Table D - 13. Annual Benefits ($1000): Wet Tower with Holding Tank		
Species	**Recreational**	**Commercial**
American Shad	$489.15	$67.91
River Herring	$23.00	$0.82
Striped Bass	$10.64	$2.81
White Perch	$0.55	$2.25
Total RIS Benefits	$523.35	$73.79

Notes: RIS forage fish included in game fish gains.
All values in thousands of January 2000 dollars.
Parentheses indicate negative values.
Source: NERA calculations as described in text.

Table D - 14. Annual Benefits ($1000): Wet/Dry Tower

Species	Recreational	Commercial
American Shad	$488.36	$67.80
River Herring	$22.95	$0.82
Striped Bass	$10.65	$2.81
White Perch	$0.55	$2.25
Total RIS Benefits	$522.51	$73.68

Notes: RIS forage fish included in game fish gains.
All values in thousands of January 2000 dollars.
Parentheses indicate negative values.
Source: NERA calculations as described in text.

Table D - 15. Annual Benefits ($1000): Wet /Dry Tower with Seasonal Gunderboom

Species	Recreational	Commercial
American Shad	$498.28	$69.18
River Herring	$23.34	$0.83
Striped Bass	$10.66	$2.82
White Perch	$0.56	$2.28
Total RIS Benefits	$532.84	$75.11

Notes: RIS forage fish included in game fish gains.
All values in thousands of January 2000 dollars.
Parentheses indicate negative values.
Source: NERA calculations as described in text.

Table D - 16. Annual Benefits ($1000): Wet /Dry Tower with Holding Tank		
Species	**Recreational**	**Commercial**
American Shad	$489.60	$67.9709
River Herring	$23.01	$0.8180
Striped Bass	$10.64	$2.8068
White Perch	$0.55	$2.2548
Total RIS Benefits	$523.81	$73.85

Notes: RIS forage fish included in game fish gains.
All values in thousands of January 2000 dollars.
Parentheses indicate negative values.
Source: NERA calculations as described in text.

Table D - 17. Annual Benefits ($1000): Dry Tower

Species	Recreational	Commercial
American Shad	$496.68	$68.95
River Herring	$23.28	$0.82
Striped Bass	$10.66	$2.82
White Perch	$0.56	$2.28
Total RIS Benefits	$531.17	$74.88

Notes: RIS forage fish included in game fish gains.
All values in thousands of January 2000 dollars.
Parentheses indicate negative values.
Source: NERA calculations as described in text.

Table D - 18. Total Benefits: Once Through

Year	Recreational RIS	Commercial RIS	Total
2002	$0.0	$0.0	$0.0
2003	$45.2	$6.2	$51.3
2004	$92.3	$12.6	$104.9
2005	$92.3	$12.6	$104.9
2006	$92.3	$12.6	$104.9
2007	$92.3	$12.6	$104.9
2008	$92.3	$12.6	$104.9
2009	$92.3	$12.6	$104.9
2010	$92.3	$12.6	$104.9
2011	$92.3	$12.6	$104.9
2012	$92.3	$12.6	$104.9
2013	$92.3	$12.6	$104.9
2014	$92.3	$12.6	$104.9
2015	$92.3	$12.6	$104.9
2016	$92.3	$12.6	$104.9
2017	$92.3	$12.6	$104.9
2018	$92.3	$12.6	$104.9
2019	$92.3	$12.6	$104.9
2020	$92.3	$12.6	$104.9
2021	$92.3	$12.6	$104.9
2022	$92.3	$12.6	$104.9
2023	$92.3	$12.6	$104.9
2024	$92.3	$12.6	$104.9
2025	$92.3	$12.6	$104.9
2026	$92.3	$12.6	$104.9
2027	$92.3	$12.6	$104.9
2028	$92.3	$12.6	$104.9
Present Value	$703.5	$95.7	**$799.2**

Notes: Present values as of January 1, 2002.
All values in thousands of January 2000 dollars.
Parentheses indicate negative values.
Source: NERA calculations as explained in text.

Table D - 19. Total Benefits: Wet Tower

Year	Recreational RIS	Commercial RIS	Total
2002	$0.0	$0.0	$0.0
2003	$255.5	$36.0	$291.5
2004	$522.0	$73.6	$595.6
2005	$522.0	$73.6	$595.6
2006	$522.0	$73.6	$595.6
2007	$522.0	$73.6	$595.6
2008	$522.0	$73.6	$595.6
2009	$522.0	$73.6	$595.6
2010	$522.0	$73.6	$595.6
2011	$522.0	$73.6	$595.6
2012	$522.0	$73.6	$595.6
2013	$522.0	$73.6	$595.6
2014	$522.0	$73.6	$595.6
2015	$522.0	$73.6	$595.6
2016	$522.0	$73.6	$595.6
2017	$522.0	$73.6	$595.6
2018	$522.0	$73.6	$595.6
2019	$522.0	$73.6	$595.6
2020	$522.0	$73.6	$595.6
2021	$522.0	$73.6	$595.6
2022	$522.0	$73.6	$595.6
2023	$522.0	$73.6	$595.6
2024	$522.0	$73.6	$595.6
2025	$522.0	$73.6	$595.6
2026	$522.0	$73.6	$595.6
2027	$522.0	$73.6	$595.6
2028	$522.0	$73.6	$595.6
Present Value	$3,976.6	$560.7	**$4,537.3**

Notes: Present values as of January 1, 2002.
All values in thousands of January 2000 dollars.
Parentheses indicate negative values.
Source: NERA calculations as explained in text.

Table D - 20. Total Benefits: Wet Tower with Seasonal Gunderboom

Year	Recreational RIS	Commercial RIS	Total
2002	$0.0	$0.0	$0.0
2003	$260.8	$36.8	$297.5
2004	$532.8	$75.1	$607.9
2005	$532.8	$75.1	$607.9
2006	$532.8	$75.1	$607.9
2007	$532.8	$75.1	$607.9
2008	$532.8	$75.1	$607.9
2009	$532.8	$75.1	$607.9
2010	$532.8	$75.1	$607.9
2011	$532.8	$75.1	$607.9
2012	$532.8	$75.1	$607.9
2013	$532.8	$75.1	$607.9
2014	$532.8	$75.1	$607.9
2015	$532.8	$75.1	$607.9
2016	$532.8	$75.1	$607.9
2017	$532.8	$75.1	$607.9
2018	$532.8	$75.1	$607.9
2019	$532.8	$75.1	$607.9
2020	$532.8	$75.1	$607.9
2021	$532.8	$75.1	$607.9
2022	$532.8	$75.1	$607.9
2023	$532.8	$75.1	$607.9
2024	$532.8	$75.1	$607.9
2025	$532.8	$75.1	$607.9
2026	$532.8	$75.1	$607.9
2027	$532.8	$75.1	$607.9
2028	$532.8	$75.1	$607.9
Present Value	$4,059.0	$572.1	**$4,631.1**

Notes: Present values as of January 1, 2002.
All values in thousands of January 2000 dollars.
Parentheses indicate negative values.

Source: NERA calculations as explained in text.

Table D - 21. Total Benefits: Wet Tower with Holding Tank

Year	Recreational RIS	Commercial RIS	Total
2002	$0.0	$0.0	$0.0
2003	$256.1	$36.1	$292.3
2004	$523.3	$73.8	$597.1
2005	$523.3	$73.8	$597.1
2006	$523.3	$73.8	$597.1
2007	$523.3	$73.8	$597.1
2008	$523.3	$73.8	$597.1
2009	$523.3	$73.8	$597.1
2010	$523.3	$73.8	$597.1
2011	$523.3	$73.8	$597.1
2012	$523.3	$73.8	$597.1
2013	$523.3	$73.8	$597.1
2014	$523.3	$73.8	$597.1
2015	$523.3	$73.8	$597.1
2016	$523.3	$73.8	$597.1
2017	$523.3	$73.8	$597.1
2018	$523.3	$73.8	$597.1
2019	$523.3	$73.8	$597.1
2020	$523.3	$73.8	$597.1
2021	$523.3	$73.8	$597.1
2022	$523.3	$73.8	$597.1
2023	$523.3	$73.8	$597.1
2024	$523.3	$73.8	$597.1
2025	$523.3	$73.8	$597.1
2026	$523.3	$73.8	$597.1
2027	$523.3	$73.8	$597.1
2028	$523.3	$73.8	$597.1
Present Value	$3,987.0	$562.1	**$4,549.1**

Notes: Present values as of January 1, 2002.
All values in thousands of January 2000 dollars.
Parentheses indicate negative values.

Source: NERA calculations as explained in text.

Table D - 22. Total Benefits: Wet/Dry Tower

Year	Recreational RIS	Commercial RIS	Total
2002	$0.0	$0.0	$0.0
2003	$255.7	$36.1	$291.8
2004	$522.5	$73.7	$596.2
2005	$522.5	$73.7	$596.2
2006	$522.5	$73.7	$596.2
2007	$522.5	$73.7	$596.2
2008	$522.5	$73.7	$596.2
2009	$522.5	$73.7	$596.2
2010	$522.5	$73.7	$596.2
2011	$522.5	$73.7	$596.2
2012	$522.5	$73.7	$596.2
2013	$522.5	$73.7	$596.2
2014	$522.5	$73.7	$596.2
2015	$522.5	$73.7	$596.2
2016	$522.5	$73.7	$596.2
2017	$522.5	$73.7	$596.2
2018	$522.5	$73.7	$596.2
2019	$522.5	$73.7	$596.2
2020	$522.5	$73.7	$596.2
2021	$522.5	$73.7	$596.2
2022	$522.5	$73.7	$596.2
2023	$522.5	$73.7	$596.2
2024	$522.5	$73.7	$596.2
2025	$522.5	$73.7	$596.2
2026	$522.5	$73.7	$596.2
2027	$522.5	$73.7	$596.2
2028	$522.5	$73.7	$596.2
Present Value	$3,980.6	$561.3	**$4,541.9**

Notes: Present values as of January 1, 2002.
All values in thousands of January 2000 dollars.
Parentheses indicate negative values.
Source: NERA calculations as explained in text.

Table D - 23. Total Benefits: Wet /Dry Tower with Seasonal Gunderboom

Year	Recreational RIS	Commercial RIS	Total
2002	$0.0	$0.0	$0.0
2003	$260.8	$36.8	$297.5
2004	$532.8	$75.1	$608.0
2005	$532.8	$75.1	$608.0
2006	$532.8	$75.1	$608.0
2007	$532.8	$75.1	$608.0
2008	$532.8	$75.1	$608.0
2009	$532.8	$75.1	$608.0
2010	$532.8	$75.1	$608.0
2011	$532.8	$75.1	$608.0
2012	$532.8	$75.1	$608.0
2013	$532.8	$75.1	$608.0
2014	$532.8	$75.1	$608.0
2015	$532.8	$75.1	$608.0
2016	$532.8	$75.1	$608.0
2017	$532.8	$75.1	$608.0
2018	$532.8	$75.1	$608.0
2019	$532.8	$75.1	$608.0
2020	$532.8	$75.1	$608.0
2021	$532.8	$75.1	$608.0
2022	$532.8	$75.1	$608.0
2023	$532.8	$75.1	$608.0
2024	$532.8	$75.1	$608.0
2025	$532.8	$75.1	$608.0
2026	$532.8	$75.1	$608.0
2027	$532.8	$75.1	$608.0
2028	$532.8	$75.1	$608.0
Present Value	$4,059.4	$572.2	**$4,631.6**

Notes: Present values as of January 1, 2002.
All values in thousands of January 2000 dollars.
Parentheses indicate negative values.
Source: NERA calculations as explained in text.

Table D - 24. Total Benefits: Wet /Dry Tower with Holding Tank

Year	Recreational RIS	Commercial RIS	Total
2002	$0.0	$0.0	$0.0
2003	$256.4	$36.1	$292.5
2004	$523.8	$73.9	$597.7
2005	$523.8	$73.9	$597.7
2006	$523.8	$73.9	$597.7
2007	$523.8	$73.9	$597.7
2008	$523.8	$73.9	$597.7
2009	$523.8	$73.9	$597.7
2010	$523.8	$73.9	$597.7
2011	$523.8	$73.9	$597.7
2012	$523.8	$73.9	$597.7
2013	$523.8	$73.9	$597.7
2014	$523.8	$73.9	$597.7
2015	$523.8	$73.9	$597.7
2016	$523.8	$73.9	$597.7
2017	$523.8	$73.9	$597.7
2018	$523.8	$73.9	$597.7
2019	$523.8	$73.9	$597.7
2020	$523.8	$73.9	$597.7
2021	$523.8	$73.9	$597.7
2022	$523.8	$73.9	$597.7
2023	$523.8	$73.9	$597.7
2024	$523.8	$73.9	$597.7
2025	$523.8	$73.9	$597.7
2026	$523.8	$73.9	$597.7
2027	$523.8	$73.9	$597.7
2028	$523.8	$73.9	$597.7
Present Value	$3,990.6	$562.6	**$4,553.2**

Notes: Present values as of January 1, 2002.
All values in thousands of January 2000 dollars.
Parentheses indicate negative values.
Source: NERA calculations as explained in text.

Table D - 25. Total Benefits: Dry Tower

Year	Recreational RIS	Commercial RIS	Total
2002	$0.0	$0.0	$0.0
2003	$260.0	$36.6	$296.6
2004	$531.2	$74.9	$606.0
2005	$531.2	$74.9	$606.0
2006	$531.2	$74.9	$606.0
2007	$531.2	$74.9	$606.0
2008	$531.2	$74.9	$606.0
2009	$531.2	$74.9	$606.0
2010	$531.2	$74.9	$606.0
2011	$531.2	$74.9	$606.0
2012	$531.2	$74.9	$606.0
2013	$531.2	$74.9	$606.0
2014	$531.2	$74.9	$606.0
2015	$531.2	$74.9	$606.0
2016	$531.2	$74.9	$606.0
2017	$531.2	$74.9	$606.0
2018	$531.2	$74.9	$606.0
2019	$531.2	$74.9	$606.0
2020	$531.2	$74.9	$606.0
2021	$531.2	$74.9	$606.0
2022	$531.2	$74.9	$606.0
2023	$531.2	$74.9	$606.0
2024	$531.2	$74.9	$606.0
2025	$531.2	$74.9	$606.0
2026	$531.2	$74.9	$606.0
2027	$531.2	$74.9	$606.0
2028	$531.2	$74.9	$606.0
Present Value	$4,046.6	$570.4	**$4,617.1**

Notes: Present values as of January 1, 2002.
All values in thousands of January 2000 dollars.
Parentheses indicate negative values.

Source: NERA calculations as explained in text.

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APPENDIX D. DETAILED BENEFIT TABLES

This attachment provides the detailed information on the calculation of total benefits for each cooling system alternative evaluated in Chapter 8 and the proposed cooling systems, which include closed-cycle cooling with wet towers and wedge-wire screens. For all alternatives, fish gains (i.e., pounds) and benefits are estimated relative to current operations at the ASGS. These tables are organized as follows:

1. *Table D-1* provides the present value of benefits for all alternatives species.

2. *Tables D-2 through D-9* provide the base year increases in species, in pounds of adult equivalents, due to each alternative. The commercial and recreational quantities reflect the percentages of each species caught by recreational and commercial fishermen over the relevant species range. Appendix B provides details on the estimation of the pounds of equivalent adults of commercial/recreational species.

3. *Tables D-10 through D-17* provides the benefits estimates, in dollars, for each species in the base year. The benefits from each species are provided in the top portion of the table and are calculated by multiplying the biomass increases resulting from the alternative for that species by the appropriate value per pound. The commercial and recreational values per pound for each species are provided in Appendix B.

4. *Tables D-18 through D-25* provide the annual benefits due to each alternative. These benefit estimates reflect the total value of the increases in populations of all species due to each alternative. Total present values for each cost component are calculated as of January 1, 2002 using a real interest rate of 7 percent, consistent with recommendations by the Office of Management and Budget (Office of Management and Budget 1996). Note that the calculation of present values take into account the months in which an alternative would operate during the first year of operation. In later years, we assume that benefits are evenly distributed over the year. Note that the standard calculation of present value assumes that payments are made at the end of each period. Where the "payments," or benefits, occur throughout the year, this approach leads to improper discounting. To correct for this effect, present value calculations include a six-month adjustment. This adjustment results in present value calculations that assume payments are made in the middle of the period, the correct approach for payments evenly distributed over the period.

REFERENCES

Office of Management and Budget, 1996. "Economic Analysis of Federal Regulations Under Executive Order 12866", January 11.