SECTION 4 COMPREHENSIVE DEMONSTRATION STUDY

SALEM NJPDES PERMIT RENEWAL APPLICATION
NJPDES PERMIT NO. NJ0005622
FEBRUARY 2006

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF ATTACHMENTS

I. EXECUTIVE SUMMARY

In accordance with §316(b) of the Federal Water Pollution Control Act (also known as the Clean Water Act "CWA") and the United States Environmental Protection Agency's ("USEPA" or the "Agency") National Pollutant Discharge Elimination System-Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities, 40 CFR §125.90 *et seg.* ("Final Rule" or "§316(b) Regulations"), PSEG Nuclear LLC ("PSEG") is submitting this Comprehensive Demonstration Study ("CDS") as part of the renewal application ("Application") for its New Jersey Pollutant Discharge Elimination System ("NJPDES") permit ("Permit") for Salem Generating Station ("Salem" or the "Station"). PSEG is using existing technological, operational, and restoration measures to achieve compliance with requirements in the Final Rule.

With this CDS, PSEG demonstrates that the Station is in compliance with the national numeric performance standards for reducing impingement mortality ("IM") and entrainment ("E") (individually and collectively referred to as the "§316(b) Standard(s)"). The applicable §316(b) Standard for E requires reductions to meet a range from 60% to 90%, and the standard for IM requires reductions to meet a range from 80% to 95%, both from the calculation baseline intake configuration. The CDS also provides the required information and analyses to support the New Jersey Department of Environmental Protection's ("NJDEP" or the "Department") establishing site-specific best technology available ("BTA") performance standards based on either the cost-cost test or the cost-benefit test under the Final Rule.

A. USEPA's Final Rule

USEPA's Final Rule establishes alternative approaches for achieving compliance. Among the available alternatives are meeting the §316(b) Standards for reductions in IM and E or demonstrating that site-specific performance standards are warranted based upon a cost-cost test or a cost-benefit test. Applicants are required to submit a CDS that includes all of the information required to allow NJDEP to determine whether a facility is in compliance with the Final Rule.

B. Introduction

Salem has operated in conformance with its NJPDES Permit, including requirements relating to §316(b). Salem's most recent NJPDES Permits have included Special Conditions or Custom Requirements to address §316(b) issues. PSEG (1993a) submitted a supplemental Application to NJDEP in March1993 that proposed a combination of technological, operational, and restoration measures to address NJDEP's concerns about the potential for long-term adverse impact on populations of aquatic organisms. PSEG believed this combination of measures addressed NJDEP's concerns and was more-cost effective and environmentally desirable than retrofitting the Station with closed-cycle cooling. NJDEP, with some modifications and additions, adopted PSEG's proposal in its 1994 and 2001 NJPDES Permits.

The technological and operational measures PSEG implemented under its 1994 Permit include: improved modified-Ristroph screens with smooth mesh and improved fish buckets at the intake; a monthly average limitation on the cooling water flow (3,024 million gallons per day [11.4 million m^3/day]); and a feasibility study to assess the efficacy of sound deterrents. The technological and operational measures were determined to be available for application at Salem at a cost that was not wholly disproportionate to the environmental benefits to be realized. In addition to the technological and operational measures, PSEG also employed restoration measures and restored and preserved degraded wetlands and preserved associated buffers; installed fish ladders; and developed a Biological Monitoring Program ("BMP") to assess the effectiveness of the technological and restoration measures. In addition, two advisory committees, with representatives from federal, state, and interstate agencies and scientists with requisite expertise from academia, were established to review and provide advice on the development and implementation of the Management Plans for the restoration sites and the BMP.

In 1999, PSEG submitted an application to NJDEP for renewal of Salem's NJPDES Permit. The Permit renewal application included a comprehensive assessment of the success of the measures required under the 1994 NJPDES Permit relating to §316(b). The renewed Permit was issued in 2001. In addition to the requirements set forth in the 1994 Permit, under the 2001 Permit PSEG developed and conducted a training program for personnel responsible for the operation of the cooling water intake structures ("CWIS"). Some other requirements of the 2001 Permit included the consolidation of the two advisory committees into one committee that would focus on monitoring of the restoration program and continuation of the Management Plans for the wetland restoration/preservation sites, fish ladders, and funding of reefs.

Because there were no applicable §316(b) regulations, the 1994 and 2001 Permits were based on USEPA's 1977 draft §316(b) guidance, input from various federal and state regulatory agencies and stakeholders, and NJDEP's best professional judgment ("BPJ") determinations of BTA for the Station's CWIS as supported by extensive engineering, biological, and economic information on the available technological and operational measures. NJDEP also required PSEG to implement restoration measures to address entrainment and impingement losses at Salem.

C. PSEG Complied with All Proposal for Information Collection Requirements

PSEG submitted a Proposal for Information Collection ("PIC") to the NJDEP on November 1, 2004. The PIC addressed all requirements of 40 CFR §125.95(b)(1). A copy of the PIC is included as Attachment 4-1 to the CDS.

D. PSEG Is Submitting All Information Required by 40 CFR §125.95(a)(2) Relating to 40 CFR §122.21(r)

Section 4-III of the CDS describes the source water body for Salem's CWIS and the relationship of this water body to the operations of the CWIS. In addition, this section discusses the operation of the cooling water system ("CWS") and its relationship to the CWIS.

1. The Estuary in the Vicinity of Salem

Salem withdraws water for cooling from the estuarine portion of the Delaware River ("Delaware" or "Estuary"). The Estuary comprises all tidally inundated areas of the River from the falls at Trenton, NJ to the mouth of Delaware Bay (about 133 mi [214 km]).

The Delaware River watershed encompasses portions of Pennsylvania, New Jersey, New York, and Delaware, draining a basin approximately 13,533 mi^2 (approximately 35,050 km^2) in area. Salem is located within the Estuary Transition Zone (as delineated by USEPA's Delaware Estuary Program Scientific and Technical Advisory Committee). The Transition Zone includes the area from Marcus Hook to Artificial Island. This area is characterized by variable salinity, high turbidity, and low biological productivity. The salinity of the Estuary in the area of the Station varies from 0 to 18 parts per thousand.

Based on historical measurement over 35 years (1968 to 2004), the temperature of the Estuary varies from about 30°F (about -1°C) to about 90°F (about 32°C). Studies have shown that although the Station's cooling water discharge may have some effect on the water temperature in the vicinity of the discharge, this influence is localized and insignificant.

The Estuary's most obvious physical feature is its funnel shape with varying widths from 27 miles (43 km) in the widest part of the Bay down to 0.2 mi (0.3 km) near Trenton, NJ. With more than 1,000 mi^2 (2,590 km^2) in surface area, the Estuary contains a volume of about 450 billion ft^3 (12.7 billion m^3) and has a mean depth of 19 ft (6 m). The Estuary is approximately 2.5 mi (4 km) wide in the vicinity of the Station and less than 18 ft (5 m) deep, except for the shipping channel. A 40-ft (12-m) deep intake basin spans the front of the CWIS and tapers into ambient river depths of about 20 to 30 ft (6 to 9 m) within 200 ft (61 m) offshore.

2. Salem Operations

Salem is a two-unit baseload nuclear-powered generating station that has been in operation since 1977. As originally designed and operated in the 1970s, Salem's CWIS had the characteristics contemplated in USEPA's definition of a "Calculation Baseline" facility in the Final Rule: *i.e.*, a once through cooling water system ("OTCW"), an intake parallel with shoreline, • in. stainless steel mesh screens with intermittent rotation, and no fish return system. As currently configured, Salem, which is designed to operate 24 hrs per day for 365 days per year, continues to use the OTCW system, but has a shoreline CWIS equipped with improved modified-Ristroph traveling screens and a bi-directional fish return system.

The Station has two CWISs, a CWS CWIS, and a service water system ("SWS") CWIS. The CWS CWIS provides cooling water to condense the steam used to produce electricity. The SWS is a nuclear-safety-related CWS that supplies a dependable, continuous flow of cooling water to the heat exchangers for the nuclear and turbine equipment. The CWS CWIS is located at the shoreline on the southwestern side of Artificial Island; the SWS CWIS is located approximately 400 ft (122 m) to the north of the CWS CWIS.

The CWS CWIS includes 12 separate intake bays with a removable wave wall, ice barriers, trash racks, traveling screens, and a fish return system. Each of the 12 intake bays is serviced by a circulating, or cooling, water pump ("CWP"), with a total of six pumps (and bays) servicing each of the two units at Salem. Each CWP has a design rating of 185,000 gallons per minute ("gpm") (700 m^3/min). The average flow per pump has been below the design value; however, PSEG is requesting with this Application that the renewed NJPDES Permit authorize operation of the CWPs up to the design capacity of 185,000 gpm (700 m^3/min).

The SWS for each unit consists of six vertical turbine type pumps, six mechanical screens, one mechanical trash rake, six automatic strainers, two intake sump pumps, and associated piping, valves, and instrumentation. Each SWS pump is rated at 10,875 gpm (41 m^3/min). The actual system flow per pump depends upon system resistance characteristics for the various operating modes, but during normal operation, four of the six pumps typically provide approximately 42,000 gpm (159 m^3/min) of flow.

E. PSEG Developed an Impingement Mortality and Entrainment Characterization Study In Compliance with the Regulations

Section 4-IV is the Impingement Mortality and Entrainment Characterization Study ("IMECS"). Its purpose, according to the Final Rule, is:

> …to provide information to support the development of a calculation baseline for evaluating impingement mortality and entrainment and to characterize current impingement mortality and entrainment (40 CFR §125.95(b)(3)).

The IMECS provides all information necessary to support this purpose.

In accordance with the Final Rule, the IMECS presents the key biological data used to demonstrate compliance with these regulations, which includes a characterization of the biological community potentially affected by Salem and estimates of the IM and E.

Since Salem became operational, PSEG has conducted numerous studies that focused on a subset of fish and shellfish species present in the Estuary with the potential to be impacted by the CWIS operation. PSEG, with the approval of NJDEP, has been using representative important species or Target Species to assess IM and E at Salem. These species include Atlantic menhaden, Atlantic silverside, bay anchovy, alewife, blueback herring, American shad, Atlantic croaker, spot, white perch, weakfish, striped bass, bluefish, and blue crab. These 13 species are the Representative Species ("RS") used in the CDS.

Consistent with PSEG's assessment of the impacts of the Station on federally designated threatened and endangered species, the National Marine Fisheries Service ("NMFS") issued a "no jeopardy" determination most recently in 1999 that Salem is not likely to endanger any federally listed species. The listed species potentially affected by Salem include the shortnose sturgeon, the loggerhead turtle, the Kemp's Ridley turtle, and the green sea turtle.

As required by the Final Rule, PSEG has assessed the abundance and temporal and spatial characteristics of fish and shellfish in the vicinity of the CWIS. PSEG's extensive impingement and entrainment sampling programs during 2002 to 2004 included 24-hr sampling throughout the year that address sources of natural variability in organism abundance. As part of this assessment, PSEG analyzed annual, seasonal, and diel variations in IM and E.

The Final Rule requires that facilities describe the current configuration and operations of the facility ("Current Conditions") as well as the "Calculation Baseline" configuration and operations ("Calculation Baseline Conditions") (40 CFR

§125.95(b)(3)). Because PSEG is basing its demonstration of compliance with the §316(b) Standards on PSEG's plans for the future operation of Salem, PSEG also is providing a description of Salem's proposed configuration and operations ("Proposed Conditions").

The estimates for IM and E by species and lifestage for the Current, Calculation Baseline, and Proposed Conditions are summarized in IV-G and IV-H below.

F. The Design and Construction Technology Plan Satisfies All Regulatory Requirements and Demonstrates That Reductions in Impingement Mortality and Entrainment Meet Applicable Performance Standards

The Design and Construction Technology Plan ("DCTP") developed by PSEG (See V below) demonstrates that the technological and operational measures implemented at the Station result in reductions in IM sufficient to comply with the §316(b) Standards. The technological measures include Salem's state-of-the-art intake screens and fish return system, while the operational measures include continuous operation of the multi-speed traveling screens.

The first of the technological measures, improved intake screens, reduces the velocity of water flowing through the screen mesh (due to an increase in the open area) and therefore allows smaller and more fragile fish to avoid entrainment and survive impingement. The smoother mesh also increases the survival of fish that are impinged by limiting the abrasion of the fish and providing for easier removal of fish and debris. The composite-material screen buckets with improved hydrodynamics reduce the turbulence within the fish buckets, decrease fish/shellfish mortality, and allow the fish/shellfish to freely exit the bucket. Moreover, the reduced mesh size allows smaller fish to be impinged and returned to the Estuary instead of being entrained.

Another technological measure, the improved bi-directional fish return system, has also increased fish survival. The improved system was designed with custom-formed fiberglass troughs to maximize fish protection. PSEG studied the new system and found that no significant mortalities occur as a result of the fish return system.

The operational measure in-place at Salem includes continuous rotation of the multi-speed traveling screens. The continuous operation of the screens reduces the length of time before impinged fish are returned to the Estuary. The multi-speed rotation reduces the amount of debris that accumulates on the screen thereby maintaining the low through-screen velocity.

The installed design and construction technologies and the operational measures implemented at Salem reduce impingement mortality by 88%, which meets the §316(b) Standard for reductions in IM (80% to 95%) (40 CFR §125.94(b)(1)). Therefore, the combination of these measures has allowed PSEG to achieve compliance with the §316(b) Standard for IM.

In addition, Salem complies with the §316(b) Standard for E when the reduction in entrainment due to the change in screen mesh configuration is considered with the production from the wetlands restoration discussed in Section 4-VII below.

G. The Technology Installation and Operation Plan Will Ensure that Salem Remains in Compliance with §316(b)

PSEG is submitting its Technology Installation and Operation Plan (“TIOP”) (See VI below). The TIOP describes the inspection and preventive maintenance programs PSEG established to ensure ongoing compliance with §316(b). PSEG has established an inspection program for the technological and operational measures that are currently in-place at Salem. Monitoring, generally performed at least once per week, is conducted within the CWS CWIS and the equipment and facilities adjacent to this structure (*i.e.*, fish counting facilities and fish return system).

PSEG’s inspection procedures allow Station operators to identify and correct conditions that might prohibit the technological and operational measures from functioning as designed. In addition to the weekly inspections, specific preventative maintenance activities on the fish protection equipment are performed. The frequent inspections, together with preventative maintenance, allow PSEG to avoid disruptions to the system and maintain continuous operations. PSEG has a system for ensuring that items requiring attention identified during inspections and periodic preventative maintenance activities are tracked and addressed as part of PSEG’s work order system.

H. PSEG's Restoration of Three Former Salt Hay Farms Coupled with Reductions in Entrainment Due to the Changes in Screen Mesh Size Meet the §316(b) Standard for Entrainment

The Restoration Plan (“RP”) (See VII below) describes PSEG’s program for restoring three former diked salt hay farms comprising 4,400 acres. The purpose of the restoration program was to increase production of fish and shellfish by re-establishing conditions suitable for the growth of *Spartina alterniflora* and other desirable, naturally occurring low marsh vegetation and providing tidal exchange with the Estuary. The restoration of the former salt hay farms has enhanced the production of desirable marsh vegetation such as *Spartina alterniflora*. This increase in primary production fuels the detrital-based food web in the Delaware, resulting in increased production of primary and secondary consumers (*i.e.*, fish and shellfish), including the RS described in the IMECS. PSEG's restoration of the salt hay farms has also improved the function of the marsh habitat as nursery and refuge areas, which also serves to increase the productivity of fish and shellfish in the Estuary. These increases in the production of fish and shellfish, attributable to PSEG's wetlands restoration program, will continue long after Salem ceases operations.

As required under Salem's 1994 and 2001 NJPDES Permits, PSEG developed Management Plans to guide the restoration effort. These plans were developed by PSEG with advice from scientific experts. These plans were also reviewed by an NJDEP-approved advisory committee, which included independent scientists and representatives from natural resources regulatory agencies with oversight responsibility for fish, shellfish, and wetlands and approved by NJDEP.

As required by NJDEP, PSEG developed and implemented rigorous monitoring and adaptive management programs to track the progress of the restoration process and make any modifications necessary to achieve the Success Criteria. The monitoring plan and the data collected were reviewed by the NJDEP and the NJDEP• approved advisory committees.

Two of the three restoration sites have been fully restored years in advance of the NJDEP• approved schedule contained in the Management Plans while the third site (Commercial Township Restoration Site) has met its interim Success Criteria and is on track to being fully restored on or ahead of schedule.

PSEG estimated the production of fish and shellfish due to the restoration of the salt hay farm sites. The increased production of the restored former salt hay farm wetlands sites was estimated to be at least 18.6 million lbs (8.4 million kg) per year of secondary level consumers. When the increased production from the restored wetlands is considered together with the reductions in entrainment due to the design and construction technologies (0.3 million lbs [0.14 million kg] per year), PSEG has met the §316(b) Standard for E reductions. The combined benefits of the design and construction technologies and operational measures and the restoration measures are 18.9 million lbs (8.6 million kg) compared with 9.7 million lbs (4.4 million kg) of E under the Calculation Baseline Conditions. Therefore, PSEG has clearly demonstrated that it has met the requirements for restoration measures in 40 CFR §125.94(c)(2) and §125.95(b)(5)(iv); the restored salt hay farms are producing ecological benefits substantially similar to, or in Salem's case, substantially greater than, the level of benefits that would have been achieved by meeting the §316(b) Standard for E.

Finally, the RP, which will replace the existing Management Plans, provides PSEG's proposal for Adaptive Management ("AM") and Monitoring Plans for the term of Salem's next NJPDES Permit. These plans describe the vegetation and hydrologic monitoring and the adaptive management process for the Commercial Township Restoration Site, the site which has not yet met the final Success Criteria.

I. PSEG Has Demonstrated that Salem is Entitled to a Site-Specific Determination of BTA Because its Costs Are Significantly Greater Than USEPA's Costs

USEPA's Final Rule authorizes applicants to seek a site-specific BTA determination if its costs of complying with the §316(b) Standards are significantly greater than the costs the Agency considered for a like facility in the rulemaking (*i.e.,* the cost-cost test). In Section 4-VIII below, PSEG has demonstrated that Salem is entitled to a site-specific determination of BTA because its costs of achieving compliance with §316(b) Standards are significantly greater than the costs USEPA considered in the rulemaking.

The cost-cost test considers the actual compliance costs of installing specific technological and/or operational measures and compares them to estimates for a technology modeled by USEPA (See VIII below). The four categories of costs are (1) capital costs; (2) operating and maintenance ("O&M") costs; (3) pilot study costs; and (4) lost revenue during construction outages. These costs are annualized according to USEPA's guidelines in the Final Rule and are summed to give the total annualized cost of each alternative technological or operational measure considered.

PSEG compared USEPA's annualized costs for the addition of fine mesh screen to an existing traveling screen system with the annualized costs for each of 11 alternative technological or operational measures at Salem. Cost estimates for all technological or operational alternatives are significantly greater than USEPA's cost estimate. The cost comparisons show that the additional annual costs of the relevant alternatives range from about $12 million per year to over $100 million per year. The technological and operational alternatives that meet the §316(b) Standards have total annualized costs that are significantly greater than USEPA's annualized cost estimate of about $0.85 million per year. Therefore, Salem is entitled to a site-specific determination of BTA, in accordance with 40 CFR §125.95(b)(6) of the Final Rule.

J. PSEG Has Demonstrated that Salem is Entitled to a Site-Specific Determination of BTA Because the Costs of Implementing Additional Technological, Operational or Restoration Measures Are Significantly Greater than the Value of the Benefits

USEPA's Final Rule also authorizes applicants to seek a site-specific BTA determination if the costs for meeting the §316(b) Standards are significantly greater than the value of the benefits. Section 4-IX below presents the costs and benefits estimates for 11 alternative technological and operational measures at Salem, and includes a systematic enumeration of costs and benefits that would accrue to members of society if a particular alternative were implemented. PSEG has demonstrated that Salem is entitled to a site-specific determination of BTA because the cost of implementing additional technological, operational or restoration measures are significantly greater than the value of the associated benefits.

The §316(b) Regulations identify the categories of costs (*i.e.*, capital costs, O&M costs; pilot study costs, and lost revenue during construction outages) and benefits (*i.e.*, commercial, recreational, ecological, and, if applicable, non-use) to be assessed. The cost-benefit test results show that the costs exceed the value of the benefits by a substantial amount for all the relevant alternative technological or operational measures.

Because the alternative technological and operational measures have significantly greater costs than the value of the potential benefits, Salem is entitled to a site-specific determination of BTA, in accordance with 40 CFR §125.95(b)(6) of the Final Rule.

K. PSEG Has Developed a Site-Specific Technology Plan

The cost-cost assessment in VIII and the cost-benefit assessment in IX demonstrate that Salem is entitled to a site-specific determination of BTA. Salem's costs are significantly greater than USEPA's assumed costs for a facility similar to Salem and the costs of implementing additional measures at Salem are significantly greater than the value of the benefits that would be realized. A Site-Specific Technology Plan was developed based on the results of the cost-cost evaluation and the cost-benefit evaluation (See X below).

USEPA's regulations provide that facilities can achieve compliance with either the §316(b) Standards or site-specific performance standards through the implementation of technological, operational, or restoration measures. The technological measures utilized at Salem to meet the site-specific standard for reductions in IM include multi-speed continuously operating improved modified-Ristroph intake screens and the bi-directional fish return system. The modified-

Ristroph traveling screen improvements include Smooth-Tex ® screen mesh panels, composite material fish buckets, neoprene flap seals, and a spray wash system. These improvements have reduced IM and E at Salem. The bi-directional fish return system also reduces IM. Furthermore, PSEG has restored 4,400 acres of formerly diked salt hay farms to fully functioning salt marshes to achieve, together with the reductions associated with the new screen panels, compliance with the §316(b) Standard for reductions in E. These measures achieve an efficacy as close as practicable to the applicable performance standards without resulting in costs that are significantly greater than the value of the benefits.

The efficacy of technologies and restoration measures was determined based on actual post-implementation data for both technologies and restoration measures since the issuance of Salem's 1994 NJPDES Permit. Studies showed that the improved modified-Ristroph intake screens and bi-directional fish return system produce substantial reductions in IM at Salem. PSEG has an inspection and preventative maintenance program in place that ensures the continued operations of the screens to achieve reductions in IM and E. PSEG's restoration program was developed and implemented with guidance from NJDEP and numerous federal and state fish and wildlife agencies and was peer-reviewed by independent scientists approved by NJDEP. To ensure efficacy of restoration measures, monitoring data will be collected on changes in vegetation cover, hydrogeomorphology, and faunal response to the restoration measures until the NJDEP-approved final Success Criteria have been met for two years at each site. The monitoring and AM Program will also continue until each salt hay farm site has met the final Success Criteria for two years. The results of the extensive monitoring at the restored sites confirm that fish and shellfish in the Estuary have benefited from the restored sites and that a wide variety of fish and shellfish use the restored marshes as habitat for feeding, nursery, and refuge (See VII-D below). PSEG has also used vegetation cover data together with an aggregated food chain model to develop estimates of the increased production of fish and shellfish (See VII-E below). The wetlands restoration sites are producing ecological benefits (*i.e.*, increased production of fish and shellfish) for the Estuary that is substantially greater than the fish and shellfish lost due to E at Salem.

L. PSEG Has Submitted a Verification Monitoring Plan Appropriate for Salem that Addresses All Regulatory Requirements

A Verification Monitoring Plan ("VMP") has been submitted as part of this CDS (See XI below). Under the Final Rule, the VMP specifically addresses monitoring related to verifying the efficiency of the design and control technology and the operational measures at Salem and an approach for addressing moribund organisms. The VMP is further complemented by the monitoring component of the RP.

M. Conclusions

With this CDS, PSEG has satisfied all requirements of 40 CFR §125.95. The innovative measures that PSEG has implemented, including the technological, operational, and restoration measures described above, have ensured that Salem operates in full compliance with the §316(b) Regulations and will continue to operate in full compliance.

Based on the studies performed at Salem, PSEG has achieved compliance with the §316(b) Standard for reductions in IM by installing and operating continuously operating, multi-speed improved modified-Ristroph intake screens and a bi-directional fish return system. The DCTP demonstrates that the technological measures installed at Salem achieve an 88% reduction in IM.

In addition to these measures, the §316(b) Standard for reductions in E has been met by the tremendously successful restoration program that PSEG has implemented at three former salt hay farm wetlands restoration sites and the change in mesh configuration on the improved screen panels. The RP demonstrates that the restored wetlands produce at least 18.6 million lbs (8.4 million kg) of fish and shellfish compared with 9.7 million lbs of fish and shellfish E under Calculation Baseline Conditions. The increases in production of fish and shellfish are ecological benefits that are substantially similar to or greater than the benefits that would have been achieved through meeting the applicable §316(b) Standard for E as required by 40 CFR §125.94(c)(2).

No further measures could be installed at Salem without incurring extensive costs that would be significantly greater than the costs USEPA assumed for Salem or the value of the benefits that would be achieved.

Finally, in this CDS, PSEG is requesting that Salem's compliance with the Final Rule during the term of its next NJPDES Permit be based upon 40 CFR §125.94(d)(1) and (2). PSEG will implement the TIOP and RP for Salem or, if a site specific BTA standard is established, the Site Specific Technology Plan. As long as the Station remains in compliance with those plans, as they may be amended by their respective Adaptive Management Plans, Salem will be in compliance with applicable §316(b) Standards in 40 CFR §125.94.

II. INTRODUCTION

As part of the renewal application ("Application") for its 2006 New Jersey Pollutant Discharge Elimination System ("NJPDES") permit ("Permit"), PSEG Nuclear, LLC ("PSEG") is submitting a Comprehensive Demonstration Study ("CDS") in support of a determination that Salem Generating Station ("Salem" or the "Station") is in full compliance with §316(b) of the Federal Water Pollution Control Act ("CWA") and the United States Environmental Protection Agency's ("USEPA" or the "Agency") regulations implementing §316(b) National Pollutant Discharge Elimination System-Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities 40 CFR §125.90 *et seg.* ("Final Rule" or "§316(b) Regulations"). The CDS provides the data and information to support a determination by the New Jersey Department of Environmental Protection ("NJDEP" or the "Department") that Salem meets USEPA's §316(b) national numeric performance standards for reducing impingement mortality ("IM") and entrainment ("E") ("§316(b) Standards") at its cooling water intake structures ("CWIS"). In the alternative, the CDS also provides the required information and analyses to demonstrate that Salem is entitled to a site-specific best technology available ("BTA") determination based on either the cost-cost test or the cost-benefit test. In addition to addressing all of the CDS requirements, this document also includes background information on the source waterbody, *i.e.*, the Delaware Estuary ("Estuary"), Salem's CWIS, and its cooling water system ("CWS"), required pursuant to 40 CFR §125.95(a) and §122.21(r).

This component of PSEG's Application begins with an Executive Summary (See I above) that presents the conclusions from each section along with a succinct summary of the information that supported the conclusions. Section 4-II is this introduction that provides a brief discussion of prior best professional judgment ("BPJ") §316 determinations for Salem and a summary of the applicable regulatory requirements. In Section 4-III, the required background information on the Delaware, the Station's CWISs, and CWS is presented. Section 4-IV presents the Impingement Mortality and Entrainment Characterization Study ("IMECS") including the IM and E losses under calculation baseline and current and proposed conditions; Section 4-V presents the Design and Construction Technology Plan ("DCTP"), including the capacity utilization rate and a demonstration of compliance with the §316(b) Standards. Section 4-VI includes the Technology Installation and Operation Plan ("TIOP") and PSEG's request that future compliance be assessed based on compliance with the TIOP. PSEG presents its Restoration Plan ("RP") in Section 4-VII, which describes the restoration of the former salt hay farms to fully functioning *Spartina alterniflora* dominated marshes and demonstrates compliance with the §316(b) Standards. Section 4-VIII presents PSEG's demonstration for a site-specific determination based on the cost-cost test and Section 4-IX presents the demonstration in support of a site-specific determination based on the cost-benefit test. Section 4-X is the Site-Specific Technology Plan for Salem. Section 4-XI describes PSEG's Verification Monitoring Plan ("VMP"). Section 4-XII concludes the CDS with the determination that Salem is in full compliance with §316(b) and its implementing regulations.

A. NJPDES Permitting for Salem

Salem has operated in conformance with its NJPDES Permit, including requirements relating to §316(b). However, it was not until 1994 that NJDEP made a final BPJ determination of BTA for the Station's CWIS (NJDEP 1994a). In reaching this determination, the Department considered all of the engineering, biological, and economic information on a wide array of technological measures in the administrative record for the permit, including information provided by PSEG (1991, 1993a, 1993b, 1994) and NJDEP's consultant, Versar, Inc ("Versar"). Versar (1989) had reviewed the 1984 §316(b) Demonstration for Salem (PSEG 1984) and concluded that there was a potential for long-term population level effects on a subset of the representative important species ("RIS") or Target Species based on entrainment and impingement losses. NJDEP (1990) accepted Versar's conclusion and identified bay anchovy, spot, white perch, weakfish, and opossum shrimp as species of concern in the Fact Sheet/Statement of Basis for a 1990 Draft NJPDES Permit for Salem. NJDEP also considered PSEG's (1993a) proposal for restoration measures and information in the administrative record, including advice provided by the Department's Division of Fish and Wildlife ("DFW"). The permit issued in 1994 required certain technological upgrades, operational measures, monitoring and studies, and a restoration and conservation program to address §316(b) issues. A subsequent NJPDES Permit and BTA determination by NJDEP in 2001 also required a similar suite of measures.

1. 1994 NJPDES Permit Decision

In March 1993, PSEG (1993a) submitted a supplemental renewal application that proposed a combination of technological, operational, and restoration measures to address NJDEP's concerns about entrainment and impingement losses for a subset of the RIS in a more environmentally desirable and more cost-effective manner than retrofitting Salem to operate with closed cycle cooling, as had been proposed in an earlier NJDEP (1990) draft NJPDES Permit.

In the Fact Sheet and Statement of Basis issued by NJDEP (1993b) with its June 1993 draft NJPDES Permit for Salem, the Department reached tentative conclusions concerning the availability of technological and operational measures as BTA for

Salem. NJDEP also reached tentative conclusions concerning the use of restoration measures. The NJDEP's key determinations are summarized below.

(a) Wedgewire Screens

NJDEP (1993b) concluded, based on its consultant's report (Versar 1989) and updated information from PSEG (1991, 1993b), that wedgewire screens were not an available technology for application at Salem. NJDEP (1993b) cited the large volume of water that Salem required for condenser cooling, noting that wedgewire screens had not been successfully demonstrated under these operational conditions. The Department also noted the likely potential for biofouling, given the high sediment and detrital loadings present in the Estuary in the vicinity of Salem.

(b) Fine Mesh Screens

Likewise, NJDEP (1993b) also concluded, based upon the 1989 Versar Report and supplemental information from PSEG (1991, 1993b), that replacing the existing • in. square mesh screen panels on Salem's traveling screens with fine mesh screen panels was not an available technology for application at Salem. In reaching this conclusion, NJDEP (1993b) noted the physical and biological conditions (*i.e.*, sediment load and detrital load) at the Station and the potential for the retrofit with fine mesh screens to cause an overall increase in impingement mortality.

(c) Closed Cycle Cooling Retrofit

Relying on prior USEPA §316(b) decisions and USEPA's comments (USEPA 1991), NJDEP (1993b) found that the cost of retrofitting Salem to operate with closed cycle cooling was wholly disproportionate to the environmental benefit to be realized.

(d) BTA for Salem

In determining BTA for Salem, NJDEP (1993b) concluded that a combination of technological improvements, together with operational measures, were BTA for Salem, based upon a BPJ determination. This determination considered the reductions in entrainment and impingement losses and the cost-effectiveness of the measures. Sufficient new data and information demonstrated that the improved modified-Ristroph screens with smooth mesh and improved fish buckets was an available technology for application at Salem at a cost that was not wholly disproportionate to the environmental benefits to be realized (NJDEP 1993b, 1994b). NJDEP (1993b, 1994b) determined that a monthly average limitation on cooling water flow (3,024 million gallons per day ("MGD") [11.4 million m^3/day]) was an available measure at a cost that was not wholly disproportionate. Finally, NJDEP (1993b, 1994b) determined that a pilot study to determine whether sound would be an effective behavioral deterrent at Salem could be implemented at a cost that was not wholly disproportionate to the potential benefits.

(e) Restoration Measures

In addition to the technological and operational measures required under the 1994 NJPDES Permit, NJDEP (1994a) also required PSEG to implement a wetlands restoration and conservation program and to install fish ladders to minimize further the potential for adverse environmental impact due to the operation of Salem's CWIS. These measures were aimed at increasing production of the RIS in the Estuary in order to minimize the potential effects of entrainment and impingement losses.

The wetlands program required the restoration, enhancement and/or preservation of degraded wetlands and upland buffers in the Estuary. The Department (1993b) noted that the RIS were dependent upon wetlands for food and habitat; therefore, the restoration of the wetlands would increase the production of these species, thereby minimizing the effects of CWIS-related losses. NJDEP (1993b) applied an aggregated food chain model ("AFCM") to estimate the number of acres of wetlands required to be restored.

NJDEP (1994a) required PSEG to develop Management Plans that would include descriptions of the design and implementation of, and the schedule for, the wetlands restoration program. In addition, NJDEP required PSEG to establish an advisory committee, the Management Plan Advisory Committee ("MPAC"), comprised of independent scientists with requisite expertise, regulatory scientists, and local members of the public to review and oversee the implementation of the Management Plans.

NJDEP (1994a) required PSEG to install five fish ladders to eliminate blockages to spawning areas traditionally used by anadromous species such as alewife and blueback herring, both RIS for Salem. NJDEP (1993b, 1994b) noted that these species were important recreational and commercial species and that the juveniles were an important forage source for weakfish and striped bass.

To provide information on the efficacy of the technological and operational measures and the status of the restoration program, the 1994 NJPDES Permit also required a variety of monitoring programs, including developing and implementing a Biological Monitoring Plan ("BMP"). The NJPDES Permit required PSEG to verify compliance with the flow limit using pump tests and to conduct impingement survival studies to assess the increased impingement survival due to the improved CWIS technology. The BMP addressed monitoring of: entrainment and impingement; detrital production, vegetation coverage, and hydrogeomorphological monitoring on the restoration sites; and the response of fish and shellfish to the restoration effort. NJDEP also required PSEG to establish a Monitoring Advisory Committee ("MAC") to provide advice on the design of the monitoring program and the interpretation of the data collected.

2. 1994 Permit Implementation

Consistent with the requirements of the Permit, PSEG (1999a) implemented the technological, operational and restoration measures required under the 1994 NJPDES Permit. PSEG also implemented the monitoring and adaptive management requirements imposed to ensure that the measures were achieving the predicted results. Although all §316(b)• related measures required under the 1994 NJPDES Permit were implemented, this section describes PSEG's efforts related to the continuously operating, multi-speed improved modified-Ristroph CWIS screens (including the improved smooth mesh panels, fish buckets, flap seals, and spray wash system), the bi-directional fish return system, and the restoration of the former salt hay farm sites. These are the measures that PSEG is relying upon for compliance with the §316(b) Standards in the Final Rule.

(a) Improved Modified-Ristroph Screens

In order to ensure that the improved modified-Ristroph screens with modified fish buckets were achieving the reductions in impingement mortality that PSEG (1993a, 1993b, 1994) predicted, the NJDEP (1994a) required PSEG to phase-in the installation of the CWIS modifications on Salem Units 1 and 2. This served two purposes: (1) allowed a side-by-side comparison of IM between the then-existing modified-Ristroph screens and buckets and the improved modified-Ristroph screens and buckets to be installed; and (2) allowed PSEG to conduct a screen operability study to determine if any improvements to the design were possible before the screens and buckets were installed on the second Salem unit.

PSEG installed the screens on Unit 2 in 1995 and then conducted the studies required under the 1994 Permit. PSEG presented its findings to NJDEP both in reports required under the 1994 NJPDES Permit and in its 1999 Application for the renewal of Salem's NJPDES Permit (PSEG 1999a). The side-by-side impingement survival study confirmed the predicted reductions in IM (PSEG 1999a, Attachment G-1). The screen operability study indicated that the screen drive motors should be replaced. More reliable motors were installed on Unit 1 as part of the initial installation and Unit 2 motors were replaced before February 27, 1997, as required under Salem's 1994 NJPDES Permit. PSEG subsequently conducted additional Latent Impingement Mortality ("LIM") studies to assess the survival of species and life stages of species not present during the side-by-side comparison. These additional studies also confirmed that the improved modified-Ristroph screens and fish buckets reduced IM substantially. Finally, PSEG monitored entrainment and impingement during the term of the Permit as required under the BMP (PSEG 1999a, Appendix G).

(b) Wetlands Restoration Program

Under the 1994 NJPDES Permit, PSEG was required to acquire control of and restore a minimum of 4,000 acres of diked salt hay farms (NJDEP 1994a). PSEG was also required to place a Deed of Conservation Restriction in favor of the Department in perpetuity on the acquired lands to ensure that they would remain as functioning wetlands and that the public would be able to use these lands for recreation, environmental education, and waterfront access.

NJDEP (1994a) further required PSEG to develop restoration plans referred to as Management Plans in the 1994 Permit. These plans were required to describe: (1) the restoration process to be implemented; (2) the management of the lands; (3) the interim and final criteria by which the progress and ultimate success of the restoration would be judged ("Success Criteria"); and (4) an adaptive management process in the event the Success Criteria were not being met or the restoration was not proceeding as planned. The MPAC reviewed the plans and made frequent visits to the sites during and after the restoration plans were implemented. MPAC considered the need for implementing any Adaptive Management ("AM") measures to ensure the timely success of the restoration process (PSEG 1999a, Attachment G-2).

PSEG (1999a, Attachment G-2) developed the Management Plans in consultation with its team of recognized experts in wetlands processes and restoration, coastal processes, and hydrology and implemented the restoration activities, with advice from MPAC, in accordance with the schedule contained in the Management Plans. PSEG also monitored a variety of parameters at both the sites being restored and at reference marshes (natural marshes in the Estuary in the vicinity of the sites being restored). PSEG conducted permit-required monitoring programs of the wetland restoration sites and submitted annual reports to MAC and NJDEP reporting on vegetative cover, production of *Spartina alterniflora* and other desirable vegetation, and creek formation. PSEG also reported annually to MAC and NJDEP on the presence and abundance of fish in the tidal creeks in the restored marshes.

Finally, the Department (1994a) required PSEG to monitor both the success of the restoration program (*i.e.*, marsh structure) and the faunal response to the restored marshes (*i.e.*, marsh function).

3. 2001 NJPDES Permit Decision

PSEG's (1999a, Appendix G) application for the renewal of Salem's NJPDES Permit included a comprehensive assessment of the success of the measures required under the 1994 NJPDES Permit relating to §316(b). Within NJDEP, a multi-disciplinary team with representatives from the DFW, Land Use Regulatory Program ("LURP"), Division of Water Quality, the Attorney General's Office, and the Southern Bureau of Water Compliance and Enforcement (collectively, the "NJDEP Team") was formed to review PSEG's application. The Department retained a consultant, ESSA Technologies, Ltd. ("ESSA"), to assist the NJDEP Team in reviewing the information that would support its BPJ §316(b) determination, including PSEG's cost-benefit analysis.

During the course of the application review process, NJDEP also consulted with representatives of various environmental groups and other governmental agencies, including the Delaware Department of Natural Resources and Environmental Control ("DNREC"), United States Fish and Wildlife Service ("USFWS"), National Marine Fisheries Service's ("NMFS"), Delaware River Basin Commission ("DRBC"), and USEPA as well as the MAC and MPAC. NJDEP (2001b) also received comments on the draft NJPDES Permit from the public during the application review process.

On December 8, 2000, NJDEP (2000a) issued the Draft NJPDES Permit for Salem. NJDEP proposed to determine that neither wedge-wire screens nor dual flow fine mesh screens were demonstrated technologies available for application at Salem, due to site-specific operational and environmental conditions at the Station. NJDEP (2001a), accepting ESSA's recommendation, required a study of a multi-sensory fish deterrent system. NJDEP (2001a) continued the requirement for a flow limitation and also included other requirements aimed at maximizing the biological efficacy of Salem's CWIS.

On July 3, 2001, the Department (NJDEP 2001a) issued a final NJPDES Permit for Salem. Recognizing the value and success of the restoration program, the 2001 NJPDES Permit required PSEG to continue implementing both the Management Plans and the biological monitoring programs to assess ongoing progress. In addition, NJDEP (2000a, 2001a) merged the MPAC and the MAC into a single committee, the Estuary Enhancement Program Advisory Committee ("EEPAC"), since the focus of the restoration program was shifting toward monitoring activities.

4. 2001 Permit Implementation

Pursuant to the requirements in Salem's Permit, PSEG developed and implemented a training program for Salem personnel responsible for the operations of the CWIS. PSEG also conducted an evaluation of the fish return system, which concluded that the fish return system does not contribute to overall impingement mortality and that no further modifications were required to enhance impingement survival (PSEG 2004b, Attachment 6). PSEG also conducted a multi-year program to assess whether application of sound, light, or bubble deterrent systems, either alone or in combination, would cause fish to avoid Salem's CWIS. These studies concluded that ambient conditions in the Estuary at the CWIS preclude the application of light and bubble deterrent systems at Salem, and that it remains unclear whether or not sound deterrents would result in meaningful reductions in impingement mortality at Salem.

PSEG continued to implement the Management Plans at the restoration sites during the term of the 2001 NJPDES Permit, achieving final Success Criteria at two of the sites. The third site has met the interim Success Criteria and is projected to meet the final Success Criteria on schedule within several years. PSEG has continued to collect monitoring data and report to NJDEP. These activities were conducted with the ongoing advice of EEPAC. A detailed description of PSEG's compliance with Salem's 2001 NJPDES Permit is contained in Section 2 of this Application.

B. PSEG Submitted a Proposal for Information Collection in Compliance with 40 CFR §125.95(a)(1)

PSEG submitted a Proposal for Information Collection ("PIC") to the NJDEP on November 1, 2004. The PIC addressed all requirements of 40 CFR §125.95(b)(1). PSEG has not received a response or comments on the PIC from NJDEP as of the date of this Application. A copy of the PIC is included as Attachment 4-1 to this CDS.

III. INFORMATION REQUIRED UNDER 40 CFR §125.95(a)

This section presents information describing: (1) the source water body for Salem's cooling water, *i.e.*, the Delaware Estuary, (2) the CWISs at Salem for the CWS and the Service Water System ("SWS") and their orientation relative to the source waterbody, and (3) the CWS and its relationship to the CWIS. This section satisfies 40 CFR §125.95(a), which directs existing facilities regulated under the Final Rule to provide the information required under 40 CFR §122.21(r)(2), (3) and (5).

A. Source Water Physical Data (40 CFR §122.21(r)(2))

The following source water physical data are being provided to characterize the waterbody in the vicinity of Salem's CWISs. This information is used, in-part, to evaluate the various measures PSEG is relying upon to meet the §316(b) Standards. PSEG has conducted numerous field studies of the source water over the last several decades.

1. Source Water

Salem withdraws water for cooling from the estuarine portion of the Delaware River ("River"). The following sections describe the River's dimensions, key physical and chemical characteristics, and provides the figures and maps required under 40 CFR §122.21(r)(2).

(a) Description

The Delaware Estuary possesses many of the same characteristics as other United States east coast estuaries, including similar morphology, hydrology, hydrodynamics, and biology.

i. Areal Dimensions

The Delaware River watershed encompasses portions of Pennsylvania, New Jersey, New York, and Delaware, draining a basin approximately 13,533 mi^2 (35,050 km^2) in area. The River runs approximately 330 mi (531 km) through the Appalachian Plateau, Ridge and Valley, Reading Prong, Piedmont, and Coastal Plain physiographic provinces. The Estuary comprises all tidally inundated areas from the falls at Trenton, New Jersey to the mouth of Delaware Bay (PSEG 1999a,

Appendix C) (See Figure III-1). This includes both the main stem of the Estuary, which extends approximately 133 mi (214 km), as well as the tidal portions of all tributaries. The Delaware Estuary mixes with the upper Chesapeake Bay via the C&D Canal located at River Mile ("RM") 59 (River Kilometer ("RK") 95).

One of the major physical features of the Estuary is its variable width (PSEG 1999a, Appendix C) (See Figure III-1). It has a classic funnel shape, widening from the ocean entrance (about 11 mi [18 km] across) to the Bay where the width is greatest (about 27 mi [43 km]), and then funneling to much narrower widths toward the Transition and freshwater Tidal River Zones (about 0.20 mi [0.3 km] at Trenton, New Jersey). The Estuary is approximately 2.5 mi (4 km) wide in the vicinity of the Station.

The surface area of the main stem of the Estuary is about 725 mi^2 (1,878 km^2) with tidal creeks adding about another 33 mi^2 (85 km^2). Wetlands bordering the Estuary measure approximately 247 mi^2 (640 km^2) or 158,080 acres, and are located primarily in the lower part of the Estuary below the C&D Canal.

The volume of the Estuary is roughly 450 billion ft^3 of water (13 billion m^3), and the tidal prism alone is about 140 billion ft^3 (4 billion m^3). The majority of the Estuary's volume is contained between RM 19 (RK 31) and the ocean entrance (RM 0 [RK 0]), which is the widest portion of the Bay and contains some of the deepest waters. Tidal flushing times for the portion of the Estuary below Philadelphia vary between about 46 days under high-flow conditions and 228 days under low-flow conditions (PSEG 1999a, Appendix C).

ii. Depths

The Estuary has a mean depth of 19 ft (6 m), with a maximum depth of nearly 148 ft (45 m) in the Delaware Bay. A 30 to 40-ft (9 to 12-m) deep dredged navigation channel extends from Trenton to Philadelphia; a 40-ft (12-m) deep channel extends from Philadelphia to the mouth of the Bay. More than half the Estuary width near Artificial Island is relatively shallow water (*i.e.*, <18 ft [5 m]) (Weston 1982).

iii. Salinity

Salinity in the Estuary varies markedly in response to external factors, including: (1) the salinity distribution of adjacent coastal waters; (2) freshwater inflow variations; (3) tides and tidal exchange processes; (4) estuarine morphology; and (5) local and non-local wind-induced circulation. Under typical high river flow conditions, the limit of salt intrusion (defined as the 1 part per thousand ("ppt") isohaline) is at

RM 54 (RK 87). Under low river flow conditions in the 1960s, this same isohaline has reached as far as RM 102 (Santoro 2004). During average flow conditions, the salinity intrusion is intermediate to these two extremes. Thus, strong spatial and temporal variations of salinity are the rule, not the exception. Superimposed on the riverine effects are the tidal impacts; the tides oscillate back and forth, over a distance of approximately 8 mi (13 km) during a tidal cycle (the tidal excursion length).

The longitudinal (axial) mean distribution of salinity decreases nearly linearly with increasing upstream distance (approximately 0.5 ppt/mi [0.3 ppt/km]) (PSEG 1999a, Appendix C). Tidal advection, as opposed to river flow, dominates this process.

Spatial gradients in salinity exist in the Bay as well (Wong and Moses-Hall 1998; Wong 1998). Wong (1994) and Wong and Munchow (1995) observed lateral salinity variations of up to 6 ppt across the wide lower Bay. Salinity was higher in the main navigation channel, with less saline waters hugging the shorelines of the Bay.

Salinity has been measured at the Salem CWIS, and the weekly average, minimum, and maximum values from 2002 through 2004 are presented in Figures III-2 through III-4, respectively. The annual average salinities in 2002, 2003, and 2004 were 8.7 ppt, 5.0 ppt, and 5.1 ppt, respectively. The weekly minimum salinities for each of these years were 0 ppt. The weekly maximum salinities in 2002, 2003, and 2004 were 20 ppt, 15 ppt, and 16 ppt, respectively. These measurements reflect the extreme variability that can occur with salinity from day to day, season to season, and year to year at Salem.

iv. Temperatures

This section describes the factors affecting the temperature of the Estuary, and the historical variability in water temperature. Appendix C (PSEG 1999a) contains more extensive data and discussion of river and estuarine water temperatures and the factors that influence them.

a) Factors Affecting Temperature

The temperature of the River depends on a number of meteorological and physical oceanographic processes, as well as on human influences. Temperature varies strongly in time, as depicted in normal seasonal temperature swings, or even in fluctuations from night to day. Temperature also varies spatially, as water temperature is commonly colder near the bottom than near the surface. Some of the major contributors to water temperature are described below.

i. Surface Heat Exchange, Air Temperature, Humidity, Wind Speed, and Cloud Cover

Solar radiation, turbulent heat exchange, and various other processes modulate the temperature of the surface waters of the Estuary. Daily heating and cooling have a major effect on this heat exchange, and diurnal (daily) cycles in surface water temperature are common. Surface heat exchange is significantly moderated by cloud cover, which varies daily, monthly, seasonally, and annually. Cloud cover has competing effects. It not only blocks short-wave radiation from reaching the earth from the upper atmosphere but also traps outgoing reradiated long-wave energy and therefore maintains higher near-surface temperatures.

ii. Tidal Effects

Tides move up and down the Estuary, transporting water of various temperatures. A record of water temperature taken at a fixed point in the Estuary would typically show variability on a tidal (semi-diurnal or twice daily) time scale. Tides may transport cooler water past a point during one phase of the tide, and warmer water during another phase of the tide.

iii. Freshwater Discharge

River and groundwater discharges to the Estuary can modulate the temperature signal as well. Freshwater may be warmer or colder than the Estuary waters, depending on the season. During the spring thaw, for instance, fresh surface-water flows may be cooler than the ocean waters, and contribute to cooling of the Estuary. In addition, freshwater flows interact with more saline oceanic water to drive the circulation in the Estuary, bringing more temperate oceanic water into the Estuary.

iv. Marsh Processes

Marshes can influence the temperature of the Estuary's waters, as they fill and empty twice daily with the tides. Marshes contribute heat to the Estuary in the summer, when marsh shallows heat rapidly and, upon draining, serve as major heat sources to the Estuary. Because water volumes in the River and over the marshes in the vicinity of the Station are almost equal, marshes can contribute significant amounts of heat (PSEG 1999a, Exhibit E-1-5). At night, marshes can have the opposite effect. The large surface area of the marshes provides for additional cooling of the estuarine water, and so can serve as a heat sink for the Estuary system. As a result of these factors, flows into and from marshes contribute to the temporal and spatial variability of ambient temperatures in open waters of the Estuary. Ambient temperature is the water temperature that would exist without the localized addition of heat from the Station. This temporal and spatial variability in ambient temperatures typically ranges from 2°F to 4°F (17°C to 16°C) daily and may amount to 7°F (14°C) or more during bright sunny days.

v. Atlantic Ocean

The Atlantic Ocean serves as both a heat source and a heat sink to the Delaware, depending on the tide and on the season. In winter, the Atlantic Ocean is generally warmer than the Estuary, thereby serving as a tidal source of heat to the Estuary. During the summer, the ocean is cooler (heats more slowly) than the Estuary, and serves as a heat sink. This moderating role of the ocean helps maintain the Estuary within a narrower range of temperatures than if it did not exchange water with the ocean.

vi. Human Influences

Human activities contribute to the heating and cooling of the Estuary. Power plants, including the Station, can serve as a source of heat to the River. Major anthropogenic heat sources to the Delaware are listed in Appendix C to PSEG's 1999 Permit Application (PSEG 1999a).

b) Historical Record

The historical record of continuous water temperature measurement in the Estuary is at least 35 years long (PSEG 1999a, Appendix C). The continuous measurement point closest to the Station is the United States Geological Survey ("USGS") gage at Reedy Island (RM 54 [RK 87]), approximately 4 mi (6.4 km) up Estuary from the Station. A nearly continuous record of water temperature at the Reedy Island site is available from 1968 through 2004, with occasional gaps due to equipment problems and maintenance.

Instantaneous water temperatures at Reedy Island vary from approximately 30°F (-1°C) up to approximately 90°F (32°C). Weekly mean temperatures at Reedy Island vary from approximately 31°F (0°C) in the winter to approximately 85°F (29°C) in the summer.

The range of temperature variability is smaller in the Atlantic Ocean than at Trenton, NJ, and the Station. Atlantic Ocean waters have an average minimum temperature of 43°F (6°C) in February and March, and an average maximum of approximately 75°F (24°C) in August. At Trenton, NJ, Delaware River temperatures vary from approximately 32°F (0°C) in mid-winter to over 86°F (30°C) in summer (Reed *et al*. 1998). These temperature differences between Trenton and the Atlantic Ocean at times set up a strong temperature gradient along the Estuary. In winter, the temperatures tend to be highest at the ocean entrance and lowest at Trenton, and vice versa in summer. The difference in temperature between Trenton and the mouth of the Bay may be as much as 7°F to 10°F (14°C to 12°C).

c) Recent Record

Both PSEG's 1999 Permit Application (PSEG 1999a) and the Salem Re-Rate Report (PSEG 1999b) rely on observed river temperatures as one element of the respective submittals. Both 1999 submittals to NJDEP use a 2-year period (1995 to 1997) and a 10-year period (1988 to 1998) in aspects of the analysis as representative of recent conditions in the vicinity of the Station at the time of the 1999 Permit Application and the subsequent increase (up to 1.5%) in approved power rating ("Rerating") of the Station. While the Station's cooling water discharge may have some effect on water temperatures at Reedy Island, the prior submittals show that the influence is small (PSEG 1999a, Appendix E, 1999b). A comparison of recent Reedy Island water temperature observations with those used previously provides a reasonable basis for verifying that observed temperatures in the vicinity of the Station during recent years are similar to those used in the prior submittals.

As shown in Figure III-5, the water temperature observations at the USGS Reedy Island site during the most recent 4-year period available do not differ from those of the preceding 10-year period. The data points labeled "DIFF" in Figure III-5 represent the difference between the daily mean temperature observed on the corresponding date and the long-term mean for that day of the year during the preceding 10-year period. Negative values on the primary vertical axis indicate water that is cooler than the long-term mean, while positive values indicate warmer than the mean. In Figure III-5, the lines labeled "+2SD" and "-2SD" represent two standard deviations ("2• ") above and below the mean for each day of the year in the 10-year period. (Note, the 2• values shown in Figure III-5 repeat annually.) The majority of observations fall within the 2• range, with more days cooler than the mean value (798) than warmer (662). There are three periods during which the observations are cooler than the lower 2• range and four periods when the observations are warmer than the upper 2• range. In each case, the excursions are concurrent with extreme meteorological conditions. For example, the period of the high excursion during the winter 2001 to 2002 corresponds with the 2001 to 2002 drought in the headwaters of the Delaware River, as indicated by the curve designated "FLOW" in Figure III-5, which represents daily observed freshwater flow at the USGS stream gage at Trenton, NJ. As discussed above, freshwater flow can have an effect on estuarine water temperatures. The same is true for the upward temperature excursion during the summer of 2002. The excursions in spring 2004 correspond with a period that the 2• curves clearly show is an annual period of large variability. In addition, there were rapidly declining river flows at Trenton during that period. Spring is normally a period when freshwater temperatures at Trenton are below the oceanic temperatures, and reduced freshwater flow can result in higher than normal temperatures.

(b) Scaled Drawing of Source Water

A scaled drawing of the Delaware Estuary is included as Figure III-6.

(c) Other Documentation that Supports Determination of Waterbody Type

The USEPA's Delaware Estuary Program Scientific and Technical Advisory Committee delineated three zones of the Estuary based on patterns of salinity, turbidity, and biological productivity (PSEG 1999a, Appendix C): the freshwater Tidal River Zone (or Upper Zone), the Transition Zone, and the Delaware Bay Zone (or Lower Zone).

The Delaware Bay Zone extends from RM 50 to RM 0 (RK 80 to RK 0). The Delaware Bay Zone is characterized by high salinity, low turbidity, and high biological productivity. This essentially marine habitat extends downbay from Artificial Island (RM 50 [RK 80]) to the mouth of Delaware Bay (RM 0 [RK 0]). Average salinity ranges from about 4 ppt to 18 ppt at the head of the Bay to about 32 ppt at the mouth.

The Transition Zone extends from Marcus Hook, PA (RM 80 [RK 129]) to the lower end of Artificial Island (RM 50 [RK 80]). The Station is located on Artificial Island (RM 50 [RK 80]), at the narrowed entrance to the Transition Zone. The Transition Zone is characterized by variable salinity (0 to 18 ppt), high turbidity, and low biological productivity.

The freshwater Tidal River Zone extends 53 river mi (85 river kilometers) from the head-of-tide at Trenton, NJ (RM 133 [RK 214]), the head of the Estuary, down to Marcus Hook, PA (RM 80 [RK 129]). Turbidity varies from low at the upstream end of this zone to moderate at the downstream end. The freshwater Tidal River Zone is the area most impacted by human use; its water quality has been improving during the past couple of decades due to improvements in process control, reduced point and non-point discharges to the extensive system, and continued regulatory attention to this water body.

The New Jersey Surface Water Quality Standards (N.J.A.C. 7:9B-1.15(d)) divide the Delaware River into 6 zones. Salem is located in Zone 5 of the Delaware River, which extends from Liston Point, Delaware (RM 48.2 [RK 78]) to Marcus Hook at the Pennsylvania• Delaware state line (RM 78.8 [RK 127]). Zone 5 is classified as "SE waters", which is the general surface water classification applied to saline waters of estuaries (N.J.A.C. 7:14A-1.1).

2. Source Water Characterization (40 CFR §122.21(r)(2)(ii))

This section describes the hydrology and geomorphology of the Estuary in accordance with 40 CFR §122.21 (r)(2)(i).

(a) Hydrological Features

The funnel shape of the Estuary (See Figure III-1) strongly influences the hydrodynamics, and consequently the hydrology of the Bay as a whole. Tidal heights increase from the Bay entrance (4.8 ft [1.5 m]) to Trenton (8.1 ft [2.5 m]); tidal height reaches 5.5 ft (1.7 m) at Reedy Point, 4 mi (6 km) upstream of the Station. The tidal amplification enhances mixing and exchange of waters with the other sections of the Estuary.

i. Freshwater Flow

The annual average freshwater flow to the Estuary is approximately 20,243 cubic feet per second ("cfs") (573 m^3) from all sources combined. Most of this flow comes from the non-tidal River (58%) and the Schuylkill River (14%). Annual mean flows from these two sources are 11,700 cfs (331 m^3/sec) and 2,746 cfs (78 m^3/sec), respectively. Only a small portion (10.3%) of the annual mean inflow is discharged below RM 59 (RK 95) (the C&D Canal). Of this small portion, 6.8% is discharged along the New Jersey shore, and 3.5% is discharged along the Delaware shore (PSEG 1999a, Appendix C). Groundwater also provides fresh water to the Estuary. However, the actual magnitude of this input has not been quantified.

Maximum and minimum flows for the River at Trenton are >19,268 cfs (546 m^3/sec) (calendar year 2003) and 5,027 cfs (142 m^3/sec) (calendar year 1965), respectively. Highest monthly average flows occur during March and April; lowest monthly average flows occur in August and September. The 1999 to 2003 period demonstrated that hydrology is a study of extremes (Santoro 2004). The period produced one of the most prolonged and intense drought periods since the 1960's and ended with 2003 producing the highest average annual flow on record for the Delaware River at Trenton, NJ.

The tidal flow of the Estuary past the Station is approximately 400,000 cfs (11,327 kilometers/sec) or about 258,526 MGD (979 million m^3/day), and the average velocity over the entire tidal cycle adjacent to Salem is 1.2 feet (0.4 m) per second ("fps") with typical ebb and flood maximums of 3.2 and 2.5 fps (1.0 and 0.8 m/sec), respectively (PSEG 1999a, Appendix C).

The Delaware Basin is a major source of water supply for approximately 15 million people living in New York, New Jersey, Pennsylvania, and Delaware. In 1986, estimated basin-wide consumption of water for domestic, industrial, commercial, and agricultural uses and power generation amounted to 11,900 cfs (337 m^3/sec), roughly equal to the mean annual river flow at Trenton (Phelan and Ayers 1994). Most of this water returns to the basin, with the exception of about 1,100 cfs (31 m^3/sec) exported to New York and northern New Jersey.

ii. Estuarine Processes

Many physical processes contribute to estuarine dynamics. Freshwater inflow (see above) is one major contributor. However, tidal fluctuations appear to be an equally dominant factor. PSEG (1999a, Appendix C) presents an overview of these dynamics. Astronomical tides are predominantly semi-diurnal (two high tides and two low tides in one day), although tidal fluctuations exist on nearly 100 other time scales as well. Tidal propagation in the Estuary is affected by the geography of the system, including its funnel shape. Vertical tides move the tidal zone up and down on the shoreline, whereas horizontal tides (currents) translate the water back and forth. The tidal excursion (distance traveled by a passive particle traveling with the water during one-half a tide) is approximately 8 mi (13 km) for much of the Estuary. This tidal variation mixes waters more rapidly than pure freshwater advection. The interaction between the tides and the river flow imposes a complex tidal signature which is manifested by differing durations of flood and ebb tides, discordance between slack water and high and low tides, and strong spatial gradients in currents and water-level elevations.

Meteorological tides also impact estuarine dynamics. Strong winds can generate significant surface stresses which can alter the water level. Winds blowing over the Atlantic Ocean can cause water levels to pile up along the coast (set-up, or storm surge); lower atmospheric pressure can have the same effect. Winds blowing over the Estuary can have a similar, though much smaller, effect. Thus, winds and lowered atmospheric pressure can cause a change in water-level elevation that will propagate through the estuarine system in a fashion similar to the tides, altering mixing rates and water velocities.

Wind waves can affect estuarine processes in a variety of ways. Wind waves result in vertical mixing of the water column. Wind waves can alter the bottom friction and hence the propagation of the tide. They stir up and transport sediment, which increases the concentration of suspended sediments and consequently affects water clarity. Wind waves also enhance coastal erosion, providing another mechanism for increasing turbidity in the water column.

Other estuarine circulation features exist. Two-layer (or stratified) flow can occur in the Estuary under suitable combinations of tidal and river flow. However, in general the Estuary is only weakly stratified, and is well-mixed vertically. Longitudinal stratification, on the other hand, is much stronger because the salt gradient along the river is strong. Estuarine fronts, areas where water masses of different origin meet, occur. Along these frontal zones, convergent mixing can take place, but dynamically the fronts are much less important than tidal, river flow, and meteorological processes.

Pape and Garvine (1982) mapped the subtidal circulation of the Delaware Bay Zone using seabed and surface drifters. They found surface drifters launched within the zone moved seaward and toward the Delaware shore. In contrast, bottom drifters launched off the bay mouth (as far as 25 mi [40 km]) offshore) moved shoreward and often into the bay, though at slower average speeds. For the period studied, their drifter measurements revealed a net surface outflow at about 2 in./sec (5 cm/sec) and a mean bottom inflow of about 0.5 in./sec (1.3 cm/sec). These early studies suggested the presence of a relatively weak estuarine gravitational circulation in the Delaware Estuary.

Wong (1994) has proposed a modification of the traditional two-layer gravitational circulation model to explain the subtidal circulation of Delaware Bay. Traditional conceptual models of estuarine circulation assume uniform across-estuary depths. However, Delaware Estuary bathymetry is characterized by a deep, center channel flanked by shoaling areas along the shores. Under the influence of riverine inflows and associated longitudinal density gradients, this characteristic across-estuary bathymetry produces a net outflow along both shores, and a return flow concentrated in the deeper part of the channel. Thus, Wong observed two branches of low salinity along the shores separated by high salinity water in the deep channel and extending to the surface.

Wong’s modified gravitational circulation model for the Delaware Bay is supported by observations by Keiner and Yan (1997). Using a suite of satellite temperature images and statistical techniques, Keiner and Yan reported net outflows along the sides of the Estuary, and the presence of in-flowing waters over the center channel. Wong and Munchow (1995) observed “fronts” in the Delaware Bay Zone- regions in which observed salinity and temperature gradients are steep and typically involve small-scale circulation. In particular, relatively dense waters were observed in the middle of the Bay Zone, mingling with less dense waters near the shores. On an even smaller scale, Wong (1994) observed lateral temperature variations of 3.7°F over a 500-ft distance (2°C over a 152-m distance) within the zone.

The along-estuary (axial) flows described by Wong's conceptual model are likely coupled with transverse (across-estuary) circulation patterns (Wong 1994; Wong 1998; Wong and Moses-Hall 1998). The characteristic across-estuary bathymetry provides greater frictional resistance in the tidal shoals relative to the deep channel. As a result, a transverse shear develops in the tidal flow, with enhanced flows in the channel. The lateral salinity profile is advected further in the channel than the adjacent shoals (Huzzey 1988). On a flooding tide, this pattern of "differential advection" produces relatively higher salinity over the channel and lower salinity along the shores, as simulated by DiLorenzo *et al.* (1992). The associated transverse density gradient may produce two transverse circulation cells characterized by converging surface flows (and sinking) at the center of the channel and diverging bottom flows, as observed in other estuaries (*e.g.*, Valle-Levinson and Lwiza 1995). This transverse circulation may aggregate suspended particles, oil slicks and biota along the main axis of the Delaware Estuary.

The modified gravitational circulation model includes two branches of buoyant outflow along the shores separated by a dense inflow centered along the deep channel (PSEG 1999a, Appendix C). However, Wong (1994) also reports that local wind may drive two branches of flows along the shores in the direction of local wind stress, and a return flow against the wind that is concentrated in the deep channel. These processes may either reinforce or counteract each other, depending on wind magnitude and direction. A strong wind blowing up the Estuary would tend to counteract the modified gravitational circulation and reduce transverse shear. Conversely, a wind blowing down the Estuary may reinforce the two effects and enhance transverse variability.

An additional feature of the Estuary subtidal variability is the recent discovery of a buoyancy-driven coastal current—a seaward flow that is driven by density differences between the brackish Estuary waters and salty oceanic waters (Garvine 1991). This current bends southward at the mouth of Delaware Bay to form a broad (12 mi [19 km] wide), slow-moving (1• 2 in./sec [2.5• 5 cm/sec]) plume along the inner continental shelf off Delaware (Garvine 1991; Munchow and Garvine 1993). The coastal current is identifiable by a salinity/temperature signature that is coherent over the length of the Delmarva Peninsula.

(b) Geomorphological Features

The morphology of the Estuary has been influenced by several factors, including: (1) the rise and fall of coastal sea levels over the last 100,000 years; (2) the Estuary's generally unconsolidated sediments; (3) the strength of currents, waves and freshwater discharge; and (4) historical dredging activities. Delaware Estuary sediments include sands, clays and gravels of Cretaceous-to-Recent age. Near the Delaware's headwaters at Trenton, the substrate consists of rocks of the Piedmont Province.

Gross morphologic features of the Delaware include a relatively deep entrance, a relict river channel, adjacent tidal shallows, a wide lower bay, and a narrow upstream channel. The pelagic zone width varies from about 11 mi (18 km) at the mouth of the Bay Zone to about 27 mi (43 km) at its widest point (approximately RM 12 [RK 19]). Further upstream, the Estuary narrows gradually to a width of about 0.12 mi (0.19 km) at Trenton, NJ (RM 133 [RK 214]). Corresponding cross-sectional areas also decrease upstream from the widest point. This funnel-shaped geometry, which is typical of many drowned river valleys, concentrates upstream flows and contributes to amplification of upper-estuary tides.

Coastal plain marshes border the lower Estuary along the New Jersey and Delaware shorelines. These marshes are incised by numerous tidal creeks. During the past century, many Delaware Estuary marshes were modified by diking and dredging activities (Sebold 1992).

In the Delaware Bay Zone, the bathymetry is dominated by deep navigation channels flanked by expansive tidal shallows. Depths exceeding about 100 ft (30 m) are found on the western side of the bay mouth. From this area, deep and elongated channels radiate landward. These channels are interspersed with narrow, finger-like shoals. Broad, shallow areas (approximately 9 to 17 ft [3 to 5 m] deep) border the eastern and western shorelines of Delaware Bay. These morphologic features influence the Delaware Bay Zone's temperature and circulation patterns.

The Delaware Bay Zone is generally oriented towards the northwest. In the Transition Zone at RM 50 (RK 80), the estuarine channel turns abruptly (See Figure III-1) through a triple bend. By RM 60 (RK 96.6), the channel is oriented northeastward along the fall zone. Beyond this point, the channel meanders slightly through the remainder of the Transition Zone and the Tidal Fresh Zone to the head-of-tide at Trenton, NJ.

In the major navigation channels, the natural tidal system has been modified extensively by dredging activities. Before dredging occurred, typical channel depths ranged from about 17 to 24 ft (5.2 to 7.3 m), corresponding to the relic Delaware River channel (Snyder and Guss 1974). In 1885, the federal government enacted legislation authorizing the U.S. Army Corps of Engineers ("USACOE") to improve and maintain these channels on a permanent basis (Bryant and Pennock 1988). Subsequently, the USACOE implemented 16 shallow-draft projects and 6 deep-draft projects.

Of these USACOE projects, the “Philadelphia-to-the-Sea Project” (adopted in 1910 and modified in 1930, 1935, 1938, 1945, 1954, and 1958) resulted in minimum channel depths of 40 ft (12.2 m) that extend over a reach of the estuary from Philadelphia to the mouth of the Estuary, and channel widths that increase from 400 ft (121.9 m) at Philadelphia to 1,000 ft (304.8 m) in the seaward portion of the Estuary. The “Philadelphia-to-Trenton Project” (adopted in 1930 and modified in 1935, 1937, 1946, 1954, and 1976) constructed a 40 ft deep, 400 ft wide (12.2 m deep, 121.9 m wide) channel extending 23.5 mi (37.8 km) from Philadelphia to the upstream end of Newbold Island (DiLorenzo *et al.* 1992). By 1964, the channel between Philadelphia and the Trenton Marine Terminal was dredged to 35 to 40 ft (10.7 to 12.2 m).

While these USACOE projects incrementally deepened and widened the Estuary’s main navigation channel, the most rapid depth changes occurred below Philadelphia at the onset of World War II (Snyder and Guss 1974). Presently, a 40 ft (12.2 m) deep shipping channel is maintained from Philadelphia to the sea, while an approximately 30 to 40 ft (9.1 to 12.2 m) deep channel extends between Philadelphia and Trenton. In 1992, Congress authorized ongoing studies to support further dredging of the main navigation channel to depths of 45 ft (13.7 m).

In the vicinity of the Station, the cross-stream bathymetry has a central channel flanked by much shallower water, which has two principal effects on tidal flow (Weston 1982). First, the highest tidal velocities and the bulk of the tidal volume transport should be found in the relatively narrow band of deep water centered on the navigation channel. Second, tidal currents in the shallower water should show a phase lead over those in the deeper water.

A relatively deep (~40 ft [12 m]) intake basin spans the front of the CWIS and tapers into ambient river depths (~20 to 30 ft [6 to 9 m]) within 200 ft (61 m) offshore (WHG 2002). The sides of the intake basin typically have an angle of 30 degrees or less. As the intake basin fills with sediments, it is dredged to keep the CWIS intake bays and openings clear. The Salem intake basin was last dredged in 1996 and bathymetric surveys are typically performed in the spring and fall of each year to determine the need for dredging.

3. Cooling Water System CWIS Zone of Influence (40 CFR §122.21(r)(2)(ii))

This section describes the CWS CWIS zone of influence and the studies conducted to determine the zone of influence, as required by 40 CFR §122.21(r).

(a) Physical Studies Implemented

Hydro-Research-Science ("HRS") conducted physical modeling studies to assist with designing Salem's CWS CWIS (Rudavsky 1969). HRS describes the test results of the hydraulic model studies performed to address sedimentation, detritus, and icing problems at Salem (Rudavsky and Yuan 1979). Weston (1982) completed a study of currents in the near field (*i.e.*, area within 500 ft [152 m] of the shoreline bounded up-Estuary by the (SWS) CWIS and down-Estuary by the southern end of the CWS CWIS) and far field (*i.e.*, about one mile up and down-Estuary from the CWS CWIS) to determine the effect of the intake on the surrounding current regime. The Woods Hole Group, formerly Aubrey Consulting, Inc. (WHG 1995a), completed a field measurement program to provide data for a numerical model of the complex three-dimensional local circulation patterns around the CWS CWIS. Following the data collection program, a three-dimensional numerical hydrodynamic model of the entire Estuary was calibrated and verified. The focus of the model was on characterizing the detailed current patterns as they are affected by both the Station's CWIS and once through cooling water ("OTCW") discharge (WHG 1995b).

(b) Methods Used in Studies

HRS (Rudavsky 1969) developed a physical model to evaluate the overall layout of the CWS CWIS and its effect on flow, velocity, and eddy patterns near the CWIS. The model of the CWIS was constructed to an undistorted linear scale ratio, model to prototype, of 1:48. The model covered an area in the Estuary of approximately 4,220 ft (1,286 m) by 2,400 ft (732 m). The major measuring devices used in the model include manually operated point gages, current velocity meters, dye meters, and orifice meters. Tests on the model consisted of reproducing the full tidal cycle and determining current velocities and directions in the immediate vicinity of the screen well, through the screen well, and in the pump cells. Floating objects were used to observe and record surface currents, flow distribution, and eddy formation. Subsurface current patterns were determined by means of introduced dye.

Weston (1982) conducted a near field velocity survey by a fixed point method utilizing remote reading current meters to characterize the horizontal and vertical variations in current speed and direction near the intake structure. Weston (1982) also performed a current velocity and circulation survey using a particle trajectory method and drifters and drogues to examine the influence of the CWS and SWS intakes on ambient tidal currents. Both of the Weston (1982) surveys were performed during major tidal stages (*i.e.*, ebb, low slack, flood, and high slack) to measure flow characteristics under varying tidal conditions.

The WHG (1995a) field monitoring program in the spring of 1995 focused on the acquisition of wind, tidal elevation, tidal current, temperature, salinity, and bathymetry data to prescribe the boundary conditions for the numerical modeling. The sensors employed included: current meters, tide gauges, acoustic doppler current profilers (“ADCP”), conductivity-temperature-depth (“CTD”) profilers, and real time atmospheric monitoring using an anemometer to measure wind speed and direction. The sensors were used in three modes:

- ship-based observations made at four intervals during the course of the program;
- *in-situ* sensors deployed for approximately the entire three-month observation period; and
- real time acquisition and telemetering of meteorological and estuary data.

Shipboard field data collection efforts included: bathymetry using a fathometer, ADCP measurements, CTD measurements, and location using a real time Global Positioning System. The vessel-mounted ADCP recorded the spatial variation of current speed and direction as the vessel tracked lines in the vicinity of the CWS CWIS. The in-situ meters and gauges were deployed on both sides of the Estuary at both the north (north tip of Artificial Island to the south tip of Reedy Island) and south (mouth of Hope Creek, NJ to Liston Point, DE) boundaries of the three-dimensional portion of the model, a distance of approximately 5 mi (8 km). Additionally, a real-time system measured directional currents at two depths within the dredged area (approximately 100 ft [30 m] offshore from the CWS CWIS).

Following the data collection program (WHG 1995a), a three-dimensional numerical model of the Estuary was calibrated and verified with a focus on characterizing the detailed current patterns as they are affected by both the Station’s CWS intake and discharge (WHG 1995b). The model was developed to assess flow patterns around the CWS CWIS and nearby features (*e.g.*, Sunken Ship Cove and Hope Creek Jetty).

(c) Description of CWS CWIS Zone of Influence

The influence of the CWS CWIS is small compared to the strong tidal currents in the Estuary and is confined to a region within approximately 150 ft (46 m) of the CWIS (WHG 2002). The zone of influence is approximately 50 to 100 ft (15 to 30 m) offshore from the CWIS under ebb and flood tidal conditions and expands to about 150 ft (46 m) under the short-lived slack tidal conditions.

4. Service Water System CWIS Zone of Influence (40 CFR §122.21(r)(2)(ii))

Section 4-III-A of the CDS describes the zone of influence of the SWS CWIS and the studies conducted to determine it, as required by 40 CFR §122.21(r).

(a) Physical Studies Implemented

The Weston (1982) physical studies described in III-A-3-(a) above specifically addressed the SWS and its zone of influence.

(b) Methods Used in Studies

The methods used in the Weston (1982) physical studies are described in III-A-3-(b) above.

(c) Description of SWS CWIS Zone of Influence

Weston (1982) states that velocities in front of the SWS intake were too weak to provide any significant information concerning withdrawal behavior. At typical SWS withdrawal rates of approximately 40,000 gallons per minute ("gpm") (151 m^3/sec), the SWS intake had little, if any, influence on the tidal flow. Sampling stations monitored near the SWS intake were uniform in reflecting ambient currents (Weston 1982).

5. Locational Maps of the CWS and SWS CWISs (40 CFR §122.21(r)(2)(iii))

Figure III-7 shows the location of the CWIS for both the CWS on the southwestern side of Artificial Island and the SWS, approximately 400 ft (122 m) to the north of the CWS CWIS.

B. CWIS Data (40 CFR §122.21(r)(3))

The following describes the CWS CWIS and SWS CWIS addressing the specific aspects identified in 40 CFR §122.21(r)(3).

1. Cooling Water System CWIS (40 CFR §122.21(r)(3))

(a) Narrative CWS CWIS Description (40 CFR §122.21(r)(3)(i))

The CWS CWIS, located on the southwestern side of Artificial Island, includes 12 separate intake bays with a curtain wall, ice barriers, removable trash racks, traveling screens, and a bi-directional fish return system (PSEG 1999a, Appendix B) (See Figure III-8).

Each of the 12 intake bays is serviced by a cooling or circulating water pump ("CWP"), with a total of six pumps (and bays) servicing each of the two units. Each intake bay is approximately 11 ft (3 m) wide and 50 ft (15 m) deep. Each CWP has a design rating of 185,000 gpm (700 m^3/min) at 27 ft (8 m) total dynamic head ("TDH"). A more detailed description can be found in the DCTP below.

There have been three distinct traveling screen designs at Salem; the most recent upgrades began in 1995. Currently, each traveling screen unit is a vertical, chain-link, four post type machine on which the screen rotates continuously to collect debris and fish as the water passes through the screen. At the bottom of each screen panel there is a composite material fish bucket. The use of the composite material allowed for the design of a hydrodynamically improved bucket that minimizes turbulent flow in the bucket. There is also a low-pressure spray wash system designed to remove fish from the screens and into the fish return trough. There is a high pressure spray wash system that removes debris from the screens into the debris return trough. The fish and debris troughs are joined after leaving the building. The troughs are bi-directional; they are emptied in the direction of the tide, so that fish and debris will flow away from the CWIS and avoid being re-impinged on the screens.

i. Configuration

The Station's CWIS is located in Lower Alloways Creek Township, Salem County, NJ at RM 50 (RK 80) on the Estuary, approximately 18 mi (29 km) south of the Delaware Memorial Bridge. The Station is located on a projection of land known as Artificial Island on the eastern shore of the Estuary. The CWIS is located at the shoreline.

ii. Location in Water Column

Water enters the CWS CWIS through the entire water depth that is approximately 42 ft (13 m) below the mean high tide ("MHT") elevation.

(b) Latitude and Longitude (40 CFR §122.21(r)(3)(ii))

The CWS CWIS is located at the latitude of 39• 27' 39" and a longitude of 75• 32' 09".

(c) Operation of CWS CWIS (40 CFR §122.21(r)(3)(iii))

Salem Units 1 and 2 are designed to operate continuously as base-load electrical generating units. The CWIS operates continuously, although the number of pumps in service may vary.

i. Design Intake Flows

Salem's CWIS is equipped with 12 CWPs each with a design capacity of 185,000 gpm (700 m^3/min).

ii. Daily Hours of Operation

Salem is designed to run as a base load unit. Each unit has six CWPs. Station operation data were reviewed for 2002 through 2004 to determine the number of hours that the CWIS was in operation. With the exception of two days, there was at least one pump that was operating for 24 hrs a day. For the two days which did not meet this criterion, multiple pumps ran in excess of 20 hrs for the day. For all intents and purposes, the Salem CWIS operates 24 hrs a day.

iii. Number of Days of Year in Operation

Salem is designed to run as a base load unit. A review of Station operation data indicated that, from 2002 through 2004, cooling water flows exceeded zero every day of the year.

iv. Seasonal Changes

There are routine, scheduled outages that occur for reactor refueling. These outages, typically occurring in the fall and the spring, result in one of Salem's two units being shut down. However, even during refueling outages, the CWIS has at least one CWP in service.

2. Service Water System CWIS (40 CFR §122.21(r)(3))

(a) Narrative SWS CWIS Description (40 CFR §122.21(r)(3)(i))

The SWS for each unit consists of six vertical turbine type pumps, six mechanical screens, one mechanical trash rake, six automatic strainers, two intake sump pumps, and associated piping, valves, and instrumentation (See Figure III-9). Each SWS pump is rated at 10,875 gpm (41 m^3/min). The actual system flow per pump depends upon system resistance characteristics for the various operating modes. The SWS CWIS is located approximately 400 ft (122 m) north of the CWS CWIS. The SWS is located at the shoreline (See Figure III-7).

(b) Location in Water Column

Water enters the SWS CWIS through the entire water depth, which is a depth of approximately 22 ft (7 m) below MHT.

(c) Latitude and Longitude (40 CFR §122.21(r)(3)(ii))

The latitude for the SWS CWIS is 39• 27’ 42” and the longitude is 75• 32’ 13”

(d) Operation of SWS CWIS (40 CFR §122.21(r)(3)(iii))

The SWS CWIS provides cooling water for nuclear-safety related equipment and systems. This section describes its configuration.

i. Design Intake Flows

During Station startup and normal operation, four of the six SWS pumps per unit are operated to provide the nominally required 42,000 gpm (159 m^3/min) flow. When the Station is not generating electricity for sale on the grid, the SWS flow requirement drops to approximately 28,500 gpm (108 m^3/min).

ii. Daily Hours of Operation

The SWS operates 24 hrs per day.

iii. Number of Days of Year in Operation

The SWS is a nuclear-safety-related CWS that supplies a dependable, continuous flow of cooling water to nuclear safety-related systems. Its CWIS operates 365 days per year.

iv. Seasonal Changes

There are seasonal variations in the SWS CWIS operations. When ambient water temperatures are lower during the colder months, the SWS operates with fewer pumps in service.

3. Flow Distribution and Water Balance Diagram (40 CFR §122.21(r)(3)(iv))

Figure III-10 is a flow distribution and water balance diagram ("Diagram"), for Salem, as required by 40 CFR §122.21(r)(3). The Diagram identifies all sources of water used at Salem, including cooling water for the CWS and SWS. It also shows all discharges of water from Salem.

4. Engineering Drawings of CWIS (40 CFR §122.21(r)(3)(v))

(a) Cooling Water System

Figure III-11 is the engineering drawing of the CWS CWIS. It provides a plan view (downward looking view) of the Salem's CWIS at two elevations, elevation 80 ft (24 m) and elevation 100 ft (30 m) (PSEG Datum) as well as a cross section view of the intake structure shown on the lower part of the drawing in Section B-B. The plan view shows each of the 12 intake bays, and the relative locations of the trash rack, the traveling water screens, and the CWPs. The cross section view shows a "side" view of the trash rack and trash rake, of a traveling water screen and of a CWP. PSEG submitted a complete set of engineering drawings for Salem's CWIS as part of its 1999 Permit Application (PSEG 1999a, G-1-1 Addenda 8 and 9).

(b) Service Water System

Figure III-12 is the engineering drawing of the SWS CWIS. It provides a plan view of the SWS CWIS at two elevations, elevation 112 ft (34 m) and elevation 126 ft (38 m) (PSEG Datum). The plan view at elevation 112 ft (34 m) shows each of the 12 intake bays, and the relative locations of the trash rack, the traveling water screens, and the service water intake pumps. The plan view at elevation 126 ft (38 m) shows equipment removal hatches for maintenance.

C. Cooling Water System Data (40 CFR §122.21(r)(5))

Section 4-III-C provides a description of Salem's CWS, its relationship to its CWIS, and its operations.

1. Narrative Description of the CWS and its Relationship to the CWIS (40 CFR §122.21(r)(5)(i))

(a) Proportion of Design Intake Flow Used in the System

The vast majority of water withdrawn via the CWIS CWS is used in the CWS; it is designed so that approximately 99% of the design intake flow is used in the CWS. The remainder of the cooling water is used as screen wash water.

(b) Number of Days Per Year CWS Operates

The CWS for the Station (Units 1 and 2 combined) essentially operates 365 days per year. Forced outages may occur that would result in reduced operation of the CWS.

(c) Seasonal Changes in Operation of CWS

As described above, the units operate on an 18 month refueling outage schedule, with one or the other unit being taken out of service in the spring or the fall. There are no other seasonal changes in the operation of the CWS.

2. Design and Engineering Calculations Prepared by a Qualified Professional (40 CFR §122.21(r)(5)(ii))

Engineering calculations are provided for the Heat Balance calculation for the CWS (Calculation S-C-CW-MDC-1496). An engineering calculation for the SWS provides SWS design basis temperature calculation (Calculation S-C-SW-MDC-1068r3). These are included as Attachment 4-2 to the CDS.

IV. IMPINGEMENT MORTALITY AND ENTRAINMENT CHARACTERIZATION STUDY (IMECS) (40 CFR §125.95(b)(3))

The purpose of the IMECS, according to USEPA's regulations, is

> …to provide information to support the development of a calculation baseline for evaluating impingement mortality and entrainment and to characterize current impingement mortality and entrainment.

A. Introduction and Overview

The IMECS presents the key biological data that are used to demonstrate compliance with the §316(b) Standards. As described in PSEG's Proposal for Information Collection (Attachment 4-1) and discussed in more detail below, PSEG is relying primarily on biological data collected during 2002-2004 in accordance with the NJDEP-approved IBMWP. As its name implies, the IBMWP is a more comprehensive biological monitoring program than was utilized in prior applications. In particular, impingement and entrainment sampling at the Station during this period was statistically optimized based upon a statistical analysis to minimize uncertainty in Station loss estimates. Furthermore, the period of sampling for the baywide monitoring programs during 2002-2004 was increased from April to November, instead of April to October, as it had been in the previous program. Baywide sampling during 2002-2004 was also increased spatially, with samples being obtained along the entire tidal portion of the Estuary, i.e. from the mouth of the Delaware Bay to near the fall line in Trenton. The IBMWP was reviewed with EEPAC on several occasions, and was the subject of NJDEP scrutiny. NJDEP approved the IBMWP on July 28, 2003. Annual monitoring results developed under the IBMWP have also been submitted to the EEPAC and the NJDEP.

In addition, in accordance with Section G.9 of the 2001 Permit, PSEG was required to analyze sampling biases and process errors concerning both its impingement and entrainment sampling. These analyses resulted in the development of refinements to the calculations of both impingement and entrainment losses using more robust and realistic factors for calculating errors due to sampler avoidance, latent impingement mortality, and similar parameters applied to raw impingement and entrainment counts. The improved monitoring program and analytical enhancements implemented beginning in 2002 provide a more complete, precise and scientifically sound set of data than previous years; and, consequently, are the most appropriate data for demonstration of compliance with the §316(b) Standards.

Section 4-IV-B provides general information on species present throughout the entire Estuary based on the scientific literature and PSEG's monitoring data. It also presents more detailed information on the species in the vicinity of Salem. The IMECS also addresses the threatened or endangered ("T&E") species potentially affected by Salem, and reviews the NMFS's "no jeopardy" determinations regarding the T&E species affected by Salem's operations (See IV-C below). The IMECS also discusses PSEG's use of RIS in prior studies and identifies the NJDEP• approved RIS used in evaluations of IM and E at Salem (See IV-D below). The IMECS then presents data on annual, seasonal, and diel variations of RIS and target species (collectively, the Representative Species ("RS")) in the vicinity of Salem (See IV-E below). Next, the IMECS describes the current configuration and operations of the Station, the "Calculation Baseline" configuration and operations, and Salem's proposed configuration and operations (See IV-F below). Finally, the IMECS describes the monitoring program and the data collected for IM and E, the methodology for calculating IM and E, and the estimates of IM and E for each configuration/operations scenario (See IV-G and IV-H below, respectively).

B. Taxonomic Identification of All Life Stages of All Species Present in the Vicinity of the CWIS (40 CFR §125.95(b)(3)(i))

In addition to the information available in peer-reviewed scientific literature, PSEG has conducted biological monitoring in the Delaware and at Salem for more than 30 years. The following discussion provides information on the species present in the Estuary in the vicinity of Salem. As noted in III above and Appendix C of the 1999 Application (PSEG 1999a), Salem is located in the Transition Zone of the Estuary where salinities and turbidity are extremely variable due to a number of factors (*e.g.*, freshwater inflow, tides). These physical conditions result in a transient and highly diverse biological community. This information is based both on peer reviewed literature and data PSEG collected through the NJDEP-approved Improved Biological Monitoring Work Plan ("IBMWP") in the years 2002 to 2004 (PSEG 2003a, 2004a, 2005a). This section summarizes the most recent data available (2002 to 2004) on the abundance and distribution of species and their life stages present in the vicinity of Salem's CWIS, *i.e.*, monitoring zone 7, the zone in which Salem is located (See Figure IV-1).

1. Fish Species

Over the years, more than 200 fish species have been collected from the Delaware Estuary and its freshwater drainages (Able 1992; Able and Fahay 1998; Allen *et al.* 1978; Cooper 1983; de Sylva *et al.* 1962; Horwitz 1986; Lee *et al.* 1980; Raasch and Altemus 1991; Rohde *et al.* 1994; Wang and Kernehan 1979) (See

Tables IV-1 and IV-2). Not all of these species, regardless of life stage, are or have been present in the Estuary in the vicinity of Salem's CWIS.

Table IV-3 provides a summary of data from the bottom trawl component of the IBMWP. Bottom trawl sampling in zone 7, the zone in which Salem is located, was dominated by Atlantic croaker (*Micropognias undulatus*), hogchoker (*Trinectes maculatus*), and white perch (*Morone americana*). In 2004, Atlantic croaker comprised 47.3% of the catch; hogchoker comprised 24.5% of the catch, and weakfish was 14.7% of the catch (PSEG 2005a). In 2003, hogchoker was 35.9% of the catch; Atlantic croaker was 30.9% of the catch; and white perch was 17.2% of the catch (PSEG 2004a). In 2002, Atlantic croaker comprised 70.9% of the catch, hogchoker comprised 13.3% of the catch and bay anchovy comprised 5.8% of the catch (PSEG 2003a).

In Table IV-4, the data from PSEG's pelagic trawl program is summarized. Pelagic trawl sampling in zone 7, the zone in which Salem is located, was dominated by bay anchovy (*Anchoa mitchilli*) and Atlantic croaker. Bay anchovy comprised 58.8% of the catch in 2004 (PSEG 2005a), 69.2% of the catch in 2003 (PSEG 2004a) and 53.6% of the catch in 2002 (PSEG 2003a). Atlantic croaker comprised 35.7% of the catch in 2004, 23.9% of the catch in 2003 and 41.1% of the catch in 2002.

Table IV-5 presents a summary of the data collected in the ichthyoplankton sampling program for the years 2002 to 2004 (PSEG 2003a, 2004a, 2005a). Ichthyoplankton sampling in zone 7, the zone in which Salem is located, was dominated by striped bass (*Morone saxatilis*) (43.0% in 2004, 63.1% in 2003, and 50.8% in 2002), bay anchovy (26.6% in 2004, 21.0% in 2003 and 28.6% in 2002) and *Morone* spp. (17.5% in 2004, 10.5% in 2003, and 10.1% in 2002).

Beach seine sampling in zone 7, the zone in which Salem is located, is presented in Table IV-6. In 2004, the dominant species collected in zone 7 were Atlantic silverside (*Menidia menidia*) (64.2%) and bay anchovy (17.9%) (PSEG 2005a). Collections in 2003 were also dominated by Atlantic silverside (50.8%) and bay anchovy (23.7%) (PSEG 2004a). In 2002, zone 7 collections were dominated by Atlantic silverside (35.8%), bay anchovy (23.6%) and Atlantic menhaden (*Brevoortia tyrannus*, 21.9%) (PSEG 2003a).

Table IV-7 presents a summary of the 2002 through 2004 impingement data. These finfish were predominantly juveniles; however, adult fish were also present. The dominant finfish collected in 2004 included white perch (48.8%), weakfish (*Cynoscion regalis*, 16.7%), and Atlantic croaker (14.5%) (PSEG 2005a). The dominant finfish collected in 2003 included white perch (59.3%) and weakfish (17.8%) (PSEG 2004a). In 2002, the dominant finfish collected were Atlantic croaker (66.5%) and spotted hake (*Urophycis regia*, 11.9%) (PSEG 2003a).

A summary of entrainment data is presented by species and life stage in Table IV-8. Entrainment sampling at Salem in 2004 resulted in the collection of a range of finfish life stages, including 61,593 eggs, 42,419 larvae, 6,507 juveniles, and 162 adults representing at least 27 species (PSEG 2005a). In 2004, the fish egg collections were dominated by bay anchovy (99.8%), while the fish larvae collections were dominated by bay anchovy (47.3%), naked goby (*Gobiosoma bosc*, 43.1%), and striped bass (3.4%). The juvenile fish collections were dominated by Atlantic croaker (60.7%), bay anchovy (27.8%), and weakfish (5.5%). The adult collections were dominated by naked goby (50.6%) and bay anchovy (38.9%).

In 2003 entrainment sampling, fish egg collections were dominated by bay anchovy (96.2%), while the fish larvae collections were dominated by naked goby (64.1%), bay anchovy (21.4%) and striped bass (9.2%) (PSEG 2004a). Juvenile fish collections in 2003 were dominated by Atlantic croaker (44.4%), bay anchovy (21.1%), and striped bass (14.1%). Adult fish collections in 2003 were dominated by bay anchovy (56.8%) and naked goby (40.7%).

In 2002 entrainment sampling, fish egg collections were dominated by bay anchovy (98.2%); larvae collections were dominated by naked goby (60.7%), bay anchovy (21.7%) and striped bass (10.6%); juvenile fish collections were dominated by Atlantic croaker (74.6%) and Atlantic menhaden (12.9%); and adult collections were dominated by bay anchovy (49.5%), naked goby (21.6%), and Atlantic silverside 19.8%) (PSEG 2003a).

In summary, based on the results of the sampling techniques employing different collection gear, the most abundant and widespread finfish of the Delaware in the vicinity of Salem currently appears to be bay anchovy. Ecologically, this species is one of the most important finfish species of the Mid-Atlantic region, serving as primary forage for many economically important piscivores (*e.g.*, striped bass) and as an essential trophic link in estuarine food webs (Morton 1989).

2. Shellfish/Macroinvertebrate Species

Shellfish/macroinvertebrate species with a potential for impact by Salem have been previously evaluated (PSEG 1999a). Specifically, blue crab (*Callinectes sapidus*), opossum shrimp (*Neomysis americana*), and scud (*Gammarus* spp.) had been evaluated because of their potential involvement with the Station, present or future value for human use, or importance for transfer of energy within the system (PSEG 1999a). Opossum shrimp and scud were two of the eleven species selected in the late 1970s by regulatory personnel for further evaluation (See IV-D-1 below). Blue crab has been evaluated because it is representative of the shellfish biotic category, frequently collected in impingement samples; and has economic significance as a commercial and recreational species.

Impingement sampling data collected at Salem in 2004 (See Table IV-7) suggest that blue crab is an abundant component of the Delaware estuarine ecosystem; 2,452 blue crab were collected in 1,560 impingement samples; 99% of the blue crab collected were alive (PSEG 2005a). In 2003 sampling, 1,343 blue crab were collected in 1,560 impingement samples; 99% of the blue crab were collected alive (PSEG 2004a). In 2002 sampling 8,845 blue crab were collected in 1,580 samples; 99% of the blue crab were collected alive (See Table IV-7) (PSEG 2003a).

Bottom trawl sampling in zone 7, the zone in which Salem is located, resulted in the collection of 17 blue crab in 2004, 13 blue crab in 2003 and 74 blue crab in 2002 (See Table IV-3). Pelagic trawl sampling in zone 7 resulted in the collection of 10 blue crab in 2004, 8 blue crab in 2003 and 14 blue crab in 2002 (See Table IV-4). Beach seine sampling in zone 7 resulted in the collection of 108 blue crab in 2004, 79 blue crab in 2003, and 191 blue crab in 2002 (See Table IV-6) (PSEG 2005a, 2004a, 2003a).

Ichthyoplankton sampling conducted in zone 7, the zone in which Salem is located, resulted in the collection of 660,928 scud in 2004, 718,923 scud in 2003 and 38,483 scud in 2002. In addition, 219,896 opossum shrimp were collected in 2004; 356,871 were collected in 2003; and 134,028 were collected in 2002 (See Table IV-5) (PSEG 2003a, 2004a, 2005a).

C. Species Protected under Federal, State or Tribal Law (Threatened or Endangered Species) (40 CFR §125.95(b)(3)(i) and (ii))

Federally designated T&E species potentially affected by Salem include the shortnose sturgeon (*Acipenser brevirostrum*), the loggerhead turtle (*Caretta caretta*), the Kemp's Ridley turtle (*Lepidochelys kempii*), and the green sea turtle (*Chelonia mydas*) (collectively, "Sea Turtles"). In addition to these species, the Atlantic sturgeon (*Acipenser oxyrinchus*) was proposed for listing, but in September 1998, USFWS and NMFS decided not to place it on the endangered species list but to retain it as a candidate species, stating that the current catch moratorium was sufficient protection for the species. Data from Salem indicate that Station operations are not having adverse effects on these species.

1. NMFS Consultations

NMFS has made numerous government-issued "no jeopardy" determinations for Sea Turtles and shortnose sturgeon under Section 7.0 of the Endangered Species Act ("ESA"). Biological opinions and incidental take statements issued by NMFS (1991, 1992, 1993, 1999) (See Attachment 4-3) found that the continued operation of Salem had not jeopardized and is not likely to jeopardize the continued existence of any populations of threatened or endangered Sea Turtles. Similarly, biological assessments conducted pursuant to the ESA since 1979 found that the continued operation of Salem had not jeopardized and is not likely to jeopardize the continued existence of shortnose sturgeon or result in destruction or adverse modification of their habitat (NMFS 1991, 1992, 1993, 1999). Attachment 4-3 includes the Biological opinions and incidental take statements issued by NMFS.

2. Summary of Data on Threatened or Endangered Species Impingement

Seven shortnose sturgeon and four Sea Turtles have been collected from the vicinity of the Salem CWIS since the last NMFS consultation in early 1999 and during the period 1999 through 2004. Shortnose sturgeon were collected on March 30, 1999, April 18, 2000, April 9, 2003, April 18, 2004, September 13, 2004, and October 1, 2004; four were alive, two dead, and one had a severed tail and died shortly after collection. A total of 20 shortnose sturgeons have been collected in the vicinity of Salem during the period 1978 through 2004 and the highest number of collections in a year was three in the fall of 1991 and spring of 1998. Sea Turtles were collected on July 12, 2000, August 31, 2000, August 31, 2001, and July 17, 2004. A total of 101 Sea Turtles (74 Loggerhead, 24 Kemps' Ridley, and 3 Green Sea) have been collected in the vicinity of Salem during the period 1978 through 2004 and the highest number of collections in a year was 25 in the summer and early fall of 1991. The causes of mortalities (*e.g.*, ship propellers) were predominately non-Salem related (See Attachment 4-3).

D. PSEG's Use of a Representative Species Approach for the CDS Is Fully Consistent with the §316(b) Rule; the List of Representative Species Has Been Approved by NJDEP

PSEG has conducted numerous studies to assess the effects of Salem's CWIS on the fish and shellfish of the Estuary. Since Salem became operational, these studies have focused on a subset of the species present in the Estuary with the potential to be impacted by the CWIS's operation. This approach was consistent with USEPA's early guidance for conducting CWIS impact assessments and remains consistent with USEPA's Final Rule. In PSEG's prior §316(b) assessments, these species have been referred to as RIS or target species; in this CDS, PSEG uses the RS terminology USEPA adopted in the Final Rule (69 Fed. Reg. 41618).

1. PSEG's Use of Representative Species in Prior Studies

The RS that PSEG selected for use in the past filings were determined after considering multiple sources of information and Agency guidance. Details on how the list evolved from 1978 through 1999 are provided below.

(a) Historic Guidance

USEPA's 1977 draft §316(b) guidance ("Draft Guidance") used the term RIS to designate a small number of species that are both representative of other species in a waterbody and important in that they have special human use or ecological value. Pursuant to USEPA's (1977) Draft Guidance, certain species would be selected as representative of various categories of species, such as those that are:

- representative, in terms of their biological requirements, of a balanced, indigenous community of fish, shellfish, and wildlife;
- commercially or recreationally valuable;
- threatened or endangered;
- critical to the structure and function of the ecological system (*e.g.*, habitat formers);
- potentially capable of becoming nuisance species;
- necessary in the food-chain for the well-being of the species designated in the categories 1) through 4) above; and
- one of the species designated in 1) through 6) above and have a high potential for entrapment/impingement and/or entrainment.

According to the Draft Guidance, species are not considered RIS simply because of high susceptibility to entrainment or impingement; one of the other six criteria must be satisfied as well. The Draft Guidance suggests that consideration of 5 to 15 species should be adequate and that T&E species must always be considered.

(b) RIS Selection for Prior §316(b) Demonstration

Relying on USEPA's Draft Guidance in 1978, PSEG proposed 11 species (bay anchovy, alewife (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), American shad (*Alosa sapidissima*), Atlantic croaker, spot (*Leiostomus xanthurus*), white perch, weakfish, striped bass, opossum shrimp, and scud) for its original §316(b) plan of study. USEPA, the permitting authority for New Jersey facilities at that time, established an inter-agency Technical Advisory Group ("TAG"), chaired by USEPA, and consisting of representatives of the United States Nuclear Regulatory Commission, NJDEP, NMFS, USFWS, DRBC, and DNREC to review PSEG's plan of study and to provide ongoing advice during its implementation. TAG selected the same 11 species for the 1984 Salem §316(b) Demonstration (USEPA 1981).

PSEG continued to use these 11 RIS in its updates to the §316(b) Demonstration for Salem in 1991, 1993, and 1994. For PSEG's 1999 Application, a reassessment of the RIS list was conducted by scientists developing the §316 studies. The following criteria were used to select RIS for the Salem 1999 §316(b) Demonstration (PSEG 1999a):

- spatial and temporal distribution of the species in the Estuary in relation to the Station;
- ecological role and importance;
- economic importance;
- susceptibility to impingent and/or entrainment at Salem;
- threatened/endangered species; and
- other species of interest.

Based on the re-evaluation, blue crab was added to the RIS list for detailed evaluation. Blue crab is representative of the shellfish category, historically the third most impinged species at the Station, and has economic significance as a commercial and recreational species. Blue crab supports the most economically valuable fisheries resource of the Estuary, producing an annual dockside value of approximately $2.5 million between 1988 and 1995 (Kahn 2003).

2. NJDEP has Approved Representative Species for Evaluating Impingement Mortality and Entrainment at Salem

Under Salem's 1994 NJPDES Permit, PSEG identified RIS for the biological monitoring at Salem in its BMWP. The data collected were submitted to the MAC for review prior to submittal to NJDEP. Over the term of the 1994 Permit, MAC members questioned whether the RIS list should be modified (NJDEP 2000b). Consequently, NJDEP (2000a) proposed requiring that PSEG review the RIS list in developing the IBMWP. In particular, the Fact Sheet for Salem's 2000 Draft Permit stated that consideration should be given to the appropriateness of the existing RIS as well as possible inclusion of Atlantic silverside and Atlantic menhaden, as several MAC members had suggested specifically that these species should be added as RIS.

In issuing the 2001 NJPDES Permit for Salem, NJDEP (2001a) required in Custom Requirement G.6.a that PSEG develop an IBMWP and reconsider its RIS list. Custom Requirement G.3.d. of the 2001 Permit also required the establishment of EEPAC to provide technical advice concerning the design, implementation, modifications, and interpretation of the IBMWP. The members of the EEPAC were approved by the Department and include representatives from the agencies with jurisdiction over aquatic resources (*e.g.*, NJDEP, USFWS, NMFS, USEPA, DNREC, and DRBC) as well as independent scientists from academia with expertise in estuarine fish and other aquatic resources.

As required by Salem's 2001 NJPDES Permit, PSEG assessed its historic RIS list and the additional species identified by NJDEP. PSEG included a revised RIS list as part of the draft IBMWP. The revised RIS list included the nine finfish and blue crab that had been RIS for the 1999 §316(b) Demonstration. PSEG also proposed including Atlantic silverside, Atlantic menhaden, and bluefish (*Pomatomis saltatrix*) as "Target Species".

In preparing the list of proposed RIS for NJDEP's review and approval, PSEG also reviewed the information available on opossum shrimp and scud. Scud and opossum shrimp are highly abundant throughout the Estuary. Scud are most abundant in freshwater and low salinity waters of the Delaware. Opossum shrimp thrive in varying salinities throughout the Estuary. Populations of opossum shrimp and scud have relatively rapid turnover rates; several cohorts are produced within a single year. These species have both high reproductive rates and high natural mortality rates. Assessments prior to PSEG's 1999 Application concluded that Salem had not and would not have an adverse environmental impact on these macroinvertebrates (PSEG 1999a, Appendix F).

As part of its 1999 Application, PSEG had used a Local Depletion Model ("LDM") to relate entrainment rates of these organisms at the Station to tidally-driven exchanges of water and organisms between the region of the Estuary from which the Station withdraws water and the neighboring regions. The LDM showed that the potential for local depletion of both species by Salem is negligible (PSEG 1999a, Appendix F). PSEG's assessments over the years have concluded that given the size of the Estuary and the reproductive rates of these organisms relative to the Station's cooling water flow rates, it is not plausible that Salem could have an adverse impact on scud or opossum shrimp populations in the Estuary (PSEG 1999a, Appendix F). Opossum shrimp and scud were therefore not proposed as RIS for the IBMWP.

PSEG submitted the IBMWP to NJDEP for its approval after it had been reviewed with EEPAC (PSEG 2002a). The NJDEP approved the IBMWP on July 28, 2003. The IBMWP requires river abundance monitoring for nine historical finfish RIS, blue crab and the three Target Species: Atlantic silverside, Atlantic menhaden, and bluefish.

3. Representative Species Under the Final Rule

USEPA's Final Rule states that for purposes of determining compliance with the §316(b) Standards, applicants may choose whether to base their assessment on all species subject to IM and E or on RS. USEPA notes:

> …that a single approach may not be optimal in all cases. The Agency has therefore not prescribed the methods (including a metric) for assessing success in meeting performance standards…Rather, the Director must determine whether a clearly defined all-species approach or representative species approach is appropriate on a case-by-case basis, based upon the information and proposed methods presented by the facility (69 Fed. Reg. 41618).

In reviewing and approving PSEG's list of RIS for compliance with the IBMWP and the other Custom Requirements in Salem's 2001 NJPDES Permit, NJDEP assessed the same factors to be considered in determining RS for the IMECS. The IMECS, like the IBMWP, seeks to identify the species present in the vicinity of the CWIS and to characterize impingement mortality and entrainment. The RIS identified in the IBMWP have been reviewed by EEPAC and approved by NJDEP for the IBMWP. Therefore, the RS approach is appropriate for Salem and bay anchovy, alewife, blueback herring, American shad, Atlantic croaker, spot, white perch, weakfish, striped bass, Atlantic silverside, Atlantic menhaden, bluefish, and blue crab are the appropriate species for consideration as RS for the IMECS and for determining compliance with the §316(b) Standards in the CDS.

E. Annual, Seasonal and Diel Variations in Representative Species and Target Species in the Vicinity of the CWIS (40 CFR §125.95(b)(3)(ii))

In the IMECS, applicants are required to characterize spatial distributions and abundance of fish and shellfish present in the vicinity of the CWIS. This data must be sufficient to characterize the annual, seasonal, and diel variations in IM and E. The characterization must be based upon data that are representative of current biological and Station operating conditions (40 CFR §125.95(b)(3)(ii)).

1. Spatial Distribution and Abundance

Salem's 1999 Application included in-depth assessments of the biological community of the Estuary (PSEG 1999a, Appendix C). It also included detailed life history reports on the RS and target species that presented information concerning the overall range and abundance of these species (PSEG 1999a, Appendix C, Attachments B). This information has been updated and is included in Section 5 of this 2006 Application. Section 5 of this Application includes descriptions of the major habitat zones, organism movements, and community energy structures in the Delaware Estuary. It provides the biological context for understanding an organism's exposure to the Station's CWIS. In addition, it includes summaries of life history for each of the species selected as RS. Salem is located in the salinity transition zone of the Estuary; most of the finfish RIS are only present in the vicinity of Salem for portions of their life histories. The summaries are based on current scientific information. The information in Section 5 addresses the first requirement of the IMECS.

2. Annual, Seasonal and Diel Variations

To address the requirement of the Final Rule relating to annual, seasonal, and diel variances in the IM and E, PSEG analyzed the Station's impingement loss and entrainment data for the RS from 2002, 2003, and 2004. These data sets best represent IM and E of fish and shellfish present in the vicinity of the CWIS under current Station operations and biological conditions. These data were collected pursuant to the requirements of Salem's 2001 NJPDES Permit and the IBMWP, which had been reviewed by EEPAC and approved by NJDEP. As PSEG's NJDEP• approved entrainment and impingement monitoring programs were conducted over a three year period, during all months of the year over representative 24-hr periods, the monitoring program was designed to capture annual, seasonal and diel variability in the IM and E of fish and shellfish in the vicinity of the CWIS.

(a) Adequacy of Data Collection

PSEG analyzed the variability in density of the fish and shellfish potentially susceptible to IM and E over the years in connection with the development of BMPs for the Station (PSEG 2002a). PSEG's 2002 analysis was conducted to address a requirement in Salem's current NJPDES Permit (NJDEP 2001a) that PSEG determine the sampling frequency necessary to evaluate impingement and entrainment losses adequately.

The first step in this analysis was to identify an appropriate metric for judging the adequacy of the sampling program. There are no established regulatory guidelines for determining the adequacy of a sampling program for IM and E. However, in general, relatively broad 95% confidence intervals indicate high uncertainty while relatively narrow 95% confidence intervals indicate low uncertainty. PSEG used 95% confidence intervals that are ±25% of the mean, based upon Robson and Regier (1964).

Applying this standard to the analysis of the IM sampling program, PSEG's IM sampling program of 1,560 samples allocated evenly throughout the year results in 95% confidence intervals that are lower than the ±25% level of precision for all RIS. Applying the same standard to the E sampling program, PSEG's program results in 95% confidence intervals that are lower than the ±25% level of precision for all life stages of all RIS except juvenile blueback herring.

The program allocates 1,687 samples annually between the peak entrainment period (14 samples/day, 4 days/week, from April through July, inclusive) and the non-peak period (7 samples/day, 3 days/week, from August through March) (PSEG 2002a, 2004b, Attachment 2). Based on the life history of blueback herring, no reasonable entrainment sampling program would be expected to yield precise results. Blueback herring spawn in fresh and brackish water tributaries well upriver from the Station in early spring. They typically remain in their natal impoundments until they migrate to the sea in the fall of their first year. Juvenile blueback herring only occur in entrainment samples under rare and unusual circumstances, such as storm-related flooding during the early juvenile period. During such events, entrainable-sized fish are washed down-Estuary into the vicinity of Salem. It is, therefore, impractical to develop a sampling program based on juvenile blueback herring entrainment; it would require almost 13,000 samples to achieve a ±25% level of precision.

(b) Methodology for Characterizing Annual, Seasonal, and Diel Variations

Impingement loss and entrainment data were examined for annual, seasonal, and diel variations for each species and each life stage/age.

As discussed in IV-F below, PSEG is basing its demonstration of compliance with the §316(b) Standards on the Company's proposed future operations of the Station. These Proposed Conditions (See IV-F below) assume that Salem is operating at design flow unless a unit has been taken out of service for a regularly scheduled refueling outage. Because the objective of the analysis presented in IV-E of the CDS is to characterize annual, seasonal, and diel variability, PSEG is using the IM and E estimates for the Proposed Conditions. Use of these estimates eliminates the compounding effects of variations in Station operations present in current operations.

As a convention, impingement data are presented by age (*e.g.*, 0-year old [*i.e.*, juvenile], 1-year old, 2-years old) and entrainment data are presented by life stage (*e.g.*, eggs, yolk-sac larvae, post yolk-sac larvae, juvenile, 1-year old adult, 2-year old adult). The results of each analysis are presented as a series of graphs (See Figures IV-2 through IV-70). Each graph represents the impingement loss or entrainment of a single species, broken out by life stage/age. Descriptions of each of the three analyses are below.

i. Annual Variation

The impingement losses and numbers entrained were totaled for each species by life stage/age in each of the three years. Figures IV-2 through IV-24 present the fraction of the total annual impingement losses and numbers entrained (2002, 2003, and 2004) by life stage/age that occurred in each year for each species. The analysis of impingement losses contains one graph for each of the RS. The analysis of the entrainment data includes one graph for each finfish species except American shad and bluefish, which were not entrained. The analysis of annual IM and E data using the Proposed Conditions confirms prior assessments. There is inter-annual variability in the number of organisms (by species, age, and lifestage) present in the vicinity of Salem's CWIS, as is expected in an area of the Estuary with high inter-annual variability in salinity levels.

ii. Seasonal Variation

The IM and E data were analyzed for seasonal variations. To accomplish this, the data were examined on a monthly basis. This illustrates the temporal occurrence of each species and life stage/age that was lost due to impingement or entrainment throughout the course of an average year.

The impingement losses and numbers entrained were first totaled for each species by life stage/age and month in each of the three years. The fraction of the total yearly impingement and entrainment that occurred in each month was then calculated. These fractions were then averaged across the three year study period to determine the average fraction of annual impingement and entrainment that occurred in each month.

Figures IV-25 through IV-47 provide detail on the seasonal patterns of impingement and entrainment of each species. Each graph displays the fraction of annual impingement losses or numbers entrained that occur in each month, displayed in decimal form. The analysis of impingement losses contains one graph for each of the RIS and target species. Three species, Atlantic menhaden, blueback herring, and white perch required two pages to present the seasonal patterns due to the number of ages for which data existed. The first page includes ages zero through three; the second page includes ages four through eight. The analysis of the entrainment data includes one graph for each species except American shad and bluefish, which were not entrained. The analysis of seasonal variability in the vicinity of the CWIS indicates strong seasonal patterns of abundance that are species specific and consistent with the known spawning seasons, spawning locations, and migration patterns of the species.

iii. Diel Variation

The diel variation analysis required slightly different methods when dealing with the IM and E data. Both the IM and E values were calculated on a daily basis. To conduct these analyses, the daily values were allocated to four different time periods: 12:00 midnight through 5:59 am; 6:00 am through 11:59 am; 12:00 noon through 5:59 pm; and 6:00 pm through 11:59 pm. The IM analysis is described first; the analysis of E data follows.

The impingement collection rate (numbers impinged per minute of sample) was used to allocate the total impingement losses into the four different time periods described above. The impingement sampling rate for each sample was first allocated to the appropriate time period. The average weekly rate was calculated for each time period. Then, the fraction of the weekly rate that occurred in each period was determined. These fractions were applied to the impingement losses for each week to estimate the number of fish lost to impingement for each time period. The weekly estimates of losses were then used to determine the fraction of the annual number of fish lost to impingement that occurred in each time period. These fractions were then averaged across the three year study period to determine the average fraction of annual impingement losses that occurred in each time period.

The diel characterization of impingement losses includes one figure for each species, with the fraction of impingement occurring in each diel time period displayed in decimal form (See Figures IV-48 through IV-60). The analysis of impingement losses contains one graph for each of the RS.

The entrainment collection density (numbers entrained per cubic meter of sample) was used to allocate the total numbers entrained into the same four time periods used in the impingement analysis described above. The entrainment sampling density for each sample was first allocated to the appropriate time period. The average weekly density was calculated for each time period. Then, the fraction of the total weekly density that occurred in each time period was determined. These fractions were applied to the numbers entrained in each week to estimate the number of fish entrained in each time period. These weekly estimates of numbers entrained each time period were used to determine the fraction of the total annual number of fish lost that were lost in each time period. The fractions were averaged across the three year study period to determine the average fraction of annual entrainment that occurred in each time period.

The diel characterization of entrainment losses includes one chart for each species, with the fraction of entrainment occurring in each diel time period displayed in decimal form (See Figures IV-61 through IV-70). The analysis of the entrainment data includes one graph for each RS except American shad and bluefish, which were not entrained.

The diel analysis for IM and E indicated the presence of diel patterns of abundance in the vicinity of the CWIS for many species and ages. PSEG's IM and E sampling program was designed to account for diel variability by collecting multiple samples over each 24-hr sampling period.

F. Station Operating Scenarios Used in the CDS (40 CFR §125.95(b)(3))

The Final Rule requires that facilities describe the current configuration and operations of the facility ("Current Conditions") as well as the "Calculation Baseline" configuration and operations ("Calculation Baseline Conditions") (40 CFR §125.95(b)(3)). Because PSEG is basing its demonstrations of compliance with the §316(b) Standards on PSEG's plans for the future operation of Salem, PSEG also is providing a description of Salem's proposed configuration and operations ("Proposed Conditions").

1. Current Station Configuration and Operations (40 CFR §125.95(b)(3))

Salem uses once through cooling, has a shoreline CWIS equipped with improved modified-Ristroph screens and a bi-directional fish return system. The Station has operated under a cooling water intake flow limitation since 1994. See III-B-1 and III-C-1 above, for a more detailed description of Salem's CWIS and its operations.

(a) Once Through Cooling Water System

Salem's once through OTCW system, or CWS, supplies cooling water to the main condensers of each unit to condense turbine exhaust steam and transfer heat to the Estuary. The CWPs withdraw the cooling water from the Estuary and circulate the water through the main condenser, and back to the Estuary.

(b) Intake Parallel with Shoreline

The intake for the CWS is located at the southwestern side of the Salem Site which is located in Lower Alloways Creek Township, Salem County, New Jersey, at RM 50 (RK 80) on the Estuary, 18 mi (29 km) south of the Delaware Memorial

Bridge. The CWIS is located parallel to the Estuary shoreline and consists of 12 separate intake bays (six for each unit), each approximately 11 ft (3 m) wide and 50 ft (15 m) high.

The CWIS consists of the following components: trash racks with rakes and traveling screens, and a fish return system. The trash racks are constructed of half inch wide steel bars on 3.5 in. (9 cm) centers; the size of the slot opening is 3 in. (8 cm). Two trash rakes clean the debris from trash racks into basket lined pits at the ends of the CWIS, and the removed debris is de-watered and disposed of off-site. In the winter, removable ice barriers are installed on the face of each of the 12 intake bays to prevent damage during icing conditions. The barriers are removed in early spring and re-installed in late fall.

(c) Improved Modified-Ristroph Screens

Each improved modified-Ristroph screen unit is a vertical, chain-link, four-post type machine on which the screen rotates continuously to collect debris and fish as the water passes through the screen. Each traveling screen panel is 10 ft (3 m) wide by 21 in. (0.5 m) high with a composite material (non-metallic) frame, and each screen contains 62 panels. The wire mesh on each panel screen is 14-gauge (0.100 in. [2.5 mm]) Smooth Tex ® screening material with openings ¼ in. wide by ½ in. (6 mm by 12 mm) high. At the bottom of each screen panel there is a composite material fish bucket. The use of the composite material allowed for the design of a hydrodynamically improved bucket with an integral, curved lip or leading edge that eliminates turbulent flow in the bucket. As the fish bucket travels over the head sprocket of the traveling screen, organisms slide onto the screen face and are washed by the low-pressure system into the fish return system. The neoprene flap seals between the traveling screen frames and the fish and debris troughs were redesigned to maintain a closer fit. This minimizes the possibility of fish not being washed into the fish return trough. One low-pressure (nominally 10 lbs per square inch gauge (“psig”) [0.7 kg/cm^2 gauge]) spray header is located outside the screen unit and two low-pressure (nominally 15 psig [1 kg/cm^2 gauge]) spray headers are located inside the screen unit. The spray is washed into an upper fiberglass (18-in. by 30-in. [46-cm by 76-cm]) trough. As the panels rotate to the fish removal position, the spray wash helps to slide fish on the screen surface over a flap seal into a bi-directional fish trough. As the panels continue to rotate, the remaining debris is removed into a bi-directional debris trough using two inside high-pressure (90 to 100 psig [6 to 7 kg/cm^2 gauge]) spray headers.

(d) Fish Return System

In 1990, PSEG replaced the original rectangular concrete and steel trough assemblies for fish and debris return with custom-formed troughs. The fish return trough is approximately 30 in. (76 cm) wide and 18 in. (46 cm) deep with 6-in. (15-cm) radius rounded corners at the bottom. Smooth fiberglass material forms the trough which minimizes any damage to the aquatic organisms traveling along the trough. Water depth in this bi-directional fish return system is maintained at approximately 3 in. (8 cm) or greater. The fish and debris troughs are joined after the troughs leave the building. The intersection of the fish and debris troughs were redesigned to enhance fish survival. The troughs are bi-directional in that they are emptied in the direction of the tide, so that fish and debris will flow away from the CWIS, in effort to minimize re-impingement. The troughs are also designed to allow diversion to the respective fish counting pools for impingement sampling.

(e) Operating Practices and Procedures

As noted above in Section 4-III, Salem is a baseload nuclear-powered generating station. As such, it operates continuously at or near full power, unless it is taken out of service for planned or unplanned outages. This section describes current operational characteristics of the Station.

i. Flow Limitation

The Station's present NJPDES Permit limits the amount of water that can be withdrawn from the Estuary to a 3,024 MGD (11.4 million m^3/day) (as a monthly average) or 2,100,000 gpm (7,949 m^3/min).

ii. Continuously Operating Screens

The rotational speeds of the continuously rotating traveling screens increase as trapped materials constrict and restrict flow through the screens. The screen assemblies automatically change speed in response to the differential pressure across the screens. Due to design improvements and the lighter composite material, the screens are capable of operating at 6-35 feet per minute ("fpm") (2-11 m/min).

iii. Outages

The annual refueling outage durations for 1999 through 2004 for Salem Unit 1 ranged from 0 days in 2003 to 65 days in 2004. The annual outage durations for

Unit 2 ranged from 0 days in 2001 and 2004 to 55 days in 1999. The Salem units are currently operating on an 18-month refueling cycle. In order to have the units in operation during the peak demand periods in winter and summer, the units' outages are scheduled for separate periods, either in fall or spring. Unplanned or forced outages do occur for various reasons, such as component maintenance, and these may affect the scheduling and duration of planned outages.

2. Calculation Baseline Station Configuration and Operations (40 CFR §125.95(b)(3))

In developing the §316(b) Standards, USEPA developed a Calculation Baseline configuration. As originally designed and operated, Salem had the characteristics USEPA used to describe its Calculation Baseline facility. USEPA's Calculation Baseline Conditions are described below.

(a) Once Through Cooling Water System

USEPA defines the Calculation Baseline Configuration facility as a facility with an OTCW system. Salem has always operated with an OTCW system.

(b) Intake Parallel with Shoreline

USEPA's definition of the Calculation Baseline CWIS is a shoreline CWIS. As described in IV-F-1-(b) above, Salem's CWIS is and has always been parallel with the shoreline.

(c) Standard • In. Mesh Screens

The original mesh of the traveling screens at Salem was stainless steel woven mesh with • -in. square opening and remained that way until the screen mesh size was modified in 1995 (See IV-F-1-(c) above). This is the screen mesh USEPA used in its definition of a Calculation Baseline facility.

(d) No Fish Return System

USEPA's Calculation Baseline facility is equipped with conventional traveling screens; there are no fish buckets or fish return system. The original design for Salem included conventional traveling screens designed and operated to prevent debris (which would have included fish) from entering the CWS. The CWIS did not include fish buckets or a fish return system.

(e) Baseline Practices and Procedures

This section describes the "Calculation Baseline" practices and procedures that PSEG is assuming for the CDS. Except for refueling outages, as discussed below, these represent the practices and procedures in place at Salem Unit 1 when it began commercial operations.

i. Screens Rotated Based on Differential Pressure

The traveling screens, as originally designed, did not operate continuously. The original Linkbelt screen assembly was designed for intermittent operation and debris handling with no fish handling capacities. The screens could be operated manually or on differential pressure when the debris loading on the screens was excessive.

ii. Design Flow

The design flow of the once through CWS is 2,220,000 gpm (8,404 m^3/min); the average daily design flow for the Station is 3,196.8 MGD (12.1 million m^3/day).

iii. Outage Schedules

For the Calculation Baseline Conditions, PSEG is applying the outage schedule being used for the Proposed Conditions, which assumes a spring and fall refueling outage of approximately 25 days.

3. Proposed Conditions

In its 1991 and 1993 §316(b) Demonstrations (PSEG 1991, 1993b), PSEG based its estimates of entrainment and impingement losses on cooling water intake flows of 175,000 gpm (662 m^3/min) per CWP. In its Supplemental Application to NJDEP, PSEG (1993a) also based the number of acres of wetlands to be restored on entrainment and impingement losses associated with this cooling water flow. As a result, NJDEP imposed a flow limitation of 3,024 MGD (11.4 million m^3/day) as a monthly average.

PSEG has made substantial improvements to Salem over the past years and intends to continue upgrading various systems at the Station, including the CWPs. Also, like most other operators of nuclear-powered generating stations, PSEG is continuing to reduce the number of days required for refueling outages. Consequently, PSEG, in demonstrating compliance with the §316(b) Standards in this CDS, is basing its IM and E estimates on 185,000 gpm (700 m^3/min) per CWP, *i.e.*, the maximum design flow, and the projected durations for future outages, *i.e.*, 25 days. PSEG is, therefore, providing a description of its Proposed Conditions of Salem for the five year period of the Station's next NJPDES Permit.

(a) Once Through Cooling Water System

The proposed once through CWS is the same as described for the Calculation Baseline and Current Condition in IV-F-2-(a) and IV-F-1-(a), respectively, above.

(b) Intake Parallel with Shoreline

The CWIS for the Proposed Conditions is parallel with the shoreline and the same as described for the Current Conditions in IV-F-1-(b) above.

(c) Improved Modified-Ristroph Screens

The improved modified-Ristroph screens for the Proposed Conditions are the same as described for the Current Conditions in IV-F-1-(c) above.

(d) Fish Return System

The fish return system for the Proposed Conditions will be the same as described for Current Conditions in IV-F-1-(d) above.

(e) Operating Practices and Procedures

The operating practices and procedures for the Proposed Conditions for Salem are described below.

i. Design Flow

For purposes of the Proposed Conditions for the CDS, PSEG is using the maximum design flow of 185,000 gpm (700 m^3/min) for a total design flow of 2,220,000 gpm (8,404 m^3/min per unit. The average daily flow for the Proposed Conditions is 3,196.8 MGD (12.1 million m^3/day).

ii. Continuously Operating Screens

The continuously operating screens for the Proposed Conditions are the same as described in IV-F-1-(e)-ii above.

iii. Outages

For the Proposed Operating Conditions, PSEG is assuming that refueling outages will be, on average, 25 days and that the Station will continue to operate on an 18 month refueling schedule. Outages will be planned for spring and fall months. Forced outages may also occur due to equipment.

G. Estimation of Impingement Mortality (40 CFR §125.95(b)(3)(iii))

The following text describes the process that PSEG used to estimate IM. This includes information on both data sources and methodology.

1. Data

(a) IBMWP Impingement Monitoring Program

Impingement monitoring is conducted in accordance with the IBMWP developed to address requirements of Salem's 2001 NJPDES Permit (PSEG 2002a). The objectives of this monitoring program are: to estimate the numbers of species impinged at Salem; to estimate their densities; and to estimate their initial survival rates.

i. Methodology

Impingement samples are collected at the fish counting pools located adjacent to the Salem CWS CWIS. Sampling is conducted in either the north or south pool, depending on the direction of tidal flow in the river. The north counting pool measures 27.2 x 11.2 ft (8.3 x 3.4 m). The south counting pool measures 30.5 x 14.8 ft (9.3 x 4.5 m). Samples are diverted from the fish/debris return trough into the counting pools by opening a swing gate across the discharge trough. Water exits the sampling pool through screen panels across the end of the pool. Screen mesh on these sampling pool screen panels matches the mesh of the CWS traveling screens. Both pools have a maximum water depth of 3 ft (0.9 m), maintained by water overflow pipes. The floor level of each pool is 4.9 ft (1.5 m) below the level of the discharge troughs at the point where screen water is admitted to the pools.

Samples are diverted to the pools through fiberglass slides designed to reduce water velocity (PSEG 1999a, Appendix F).

To collect impingement samples, a timed sub-sample of total flow from the combined fish and debris troughs is diverted into the appropriate north or south fish counting pool as dictated by tide and trough discharge direction. Sample duration ranges from one to three minutes and is dependent largely on specimen and detrital abundance. At the end of the timed interval, trough flow is returned to the normal discharge mode, and the sample is allowed a five-minute acclimation period before the pool is drained.

As the pool is drained, debris (vegetative matter) is examined for finfish and blue crab, and all specimens are collected. Each specimen is examined and classified as live, dead, or damaged. Specimens in each category are sorted by species, and the total number and aggregate weight of each species is determined. All specimens, or a representative subsample (at least 100 specimens) of each species, are measured to the nearest millimeter. Weights are determined to the nearest 0.1 g with an electronic scale. The following parameters are recorded with all samples: the number of pumps and screens in operation; tidal stage and elevation; air temperature; sky condition; wind direction; wave height; water temperature; and salinity. Air and water temperatures are measured with a field thermometer, and salinity is measured using a refractometer. Detritus taken with the sample is weighed to the nearest 0.1 kg with a scale.

ii. Frequency

Since 1998, sampling has been scheduled throughout the year (January through December), 3 days per week, with up to 10 samples collected per 24-hr period (1,560 samples annually). Samples are taken at approximately 2½-hr intervals during each 24-hr period. The 24-hr sampling event provides for monitoring over a complete diel period and two full tidal cycles. The three sampling days are chosen randomly within the seven-day weekly sampling time frame. As discussed above, a sampling optimization study conducted in 2002 (PSEG 2004b, Attachment 2) indicated that the existing sampling program is sufficient to yield 95% confidence intervals of ±25% or less for annual impingement estimates of nearly all RIS species.

iii. Collection Efficiency

Collection efficiency studies have been conducted to estimate the proportion of fish specimens impinged but not collected during impingement sampling. Fish may not be collected for a variety of reasons, including leaks in traveling screens and organisms being overlooked in the sample (ECSI 1998).

To address these issues, PSEG conducted the following collection efficiency studies: the 1979 to 1982 study; the 1998 study; the 1999 to 2000 study; and the 2002 study. The results of the first two studies were used to develop impingement estimates for Salem's 1999 Application (PSEG 1999a, Appendix F). In developing estimates for this Application, PSEG reviewed all studies, which are summarized below.

The initial collection efficiency studies at Salem began in 1979 and continued through February 1982. These studies were fully described in PSEG (1999a, Appendix F) as well as PSEG (1984) and associated documents.

The 1998 collection efficiency testing program was conducted between April and September. For these studies, test specimens were collected and separated into two species groups. Group 1 consisted of bay anchovy, blueback herring, alewife, and American shad. Group 2 consisted of white perch, striped bass, weakfish, spot, and Atlantic croaker. Specimens ranging from 20 to 75 mm in length were collected and separated into 11 length groups. The studies were conducted with 200 fish per species group and length group, totaling 4,400 fish.

For the 1998 program, dead fish were stained and measured for use in these studies. Early trials were conducted with specimens released at mid-depth in front of a traveling screen. The releases were later modified by placing specimens directly into the fish buckets on traveling screen panels.

The screenwash containing the stained fish was sampled and the fish were counted to determine the proportion collected in the fish counting pools. Collection efficiency was expressed by the number of stained fish collected divided by the number of fish stained and released.

Similar studies were conducted in 1999 and 2000. These studies were conducted to measure “screen wash” efficiency and “counting pool” efficiency. “Trough” efficiency was also assessed. In 1998, there were mostly assessments of trough efficiency. In 1999, there were mostly assessments of screen wash efficiency.

The most recent impingement collection efficiency program was conducted in 2002 (PSEG 2004b, Attachment 4). As part of an assessment of fish collection pool mortality, PSEG conducted a study which involved the introduction of live fish into both the Salem fish collection pools and an off-site, full scale replica of the pools. The purpose of the study was to estimate mortality of fish solely attributable to the pool and collection process. Because known numbers of fish were introduced and subsequently collected, the study also provides an estimation of true impingement collection efficiency. The following methods were used for both the on-site testing at

Salem and in the laboratory model, and will be described together unless otherwise noted.

Collection pool mortality testing involved the release of a known number of test specimens (approximately 50 per test) into the combined trough discharge just upstream of the opened counting pool swing gate, while simultaneously releasing known number of fin-clipped control fish (approximately 50 per test) directly into the fish collection pool. The collection pool was then sampled using the standard impingement monitoring procedures.

The tests were conducted as follows:

- step 1 - an impingement sample was started by opening the pool swing gate;
- step 2 - a group of test specimens was released directly into the combined trough, while a group of marked control specimens was released gently into the pool from a transport bucket;
- step 3 - the sample was run for five minutes;
- step 4 - the impingement sample was terminated by closing the pool swing gate;
- step 5 - the water in the pool was allowed to rest for five minutes and was then drained normally; and
- step 6 - all specimens were collected, identified as test or control fish based on presence or absence of fin clips, counted, and held in a holding facility for 48 hrs for the follow-up mortality evaluation.

Test specimens were obtained from a regional supplier of live baitfish. Testing was conducted with live alewife because alewives are relatively fragile fish and would therefore be susceptible to pool mortality effects, if present. The lengths of alewife that were evaluated ranged from about 45 to 130 mm (1.8 to 5.1 in.) fork length (“FL”). A total of 36 tests, each consisting of approximately 50 test and 50 control fish, were conducted in the fish counting pool. An additional 12 tests were conducted in the laboratory model.

All of the studies discussed above were re-evaluated to estimate the impingement collection efficiency value for each species. The results of these additional studies, confirmed the collection efficiency values used by PSEG (1999a, Appendix F) in the 1999 Application and accordingly the collection efficiency rates, have been used again in this CDS.

(b) Impingement Survival

There are two separate components to impingement survival: initial mortality and latent mortality. Both are described in detail below.

i. Initial

The initial condition of all specimens collected during regular impingement sampling is evaluated immediately upon collection. The condition category assignment is made according to the following criteria:

- live - swimming vigorously, no apparent wounds or damage, no orientation problems, behavior normal;
- dead - no vital signs, no body or opercular movement, no response to gentle probing; and
- damaged - struggling or swimming on side or other evidence of orientation problems, evidence or indication of abrasion or laceration.

Initial mortality values are computed on a sample-by-sample basis. Monthly average values are shown in Table IV-9.

ii. Latent

Finfish impinged on Salem's traveling screens may not exhibit the effects of this contact until some later time. For this reason, "Live" and "Damaged" category finfish are held for periods up to 48 hrs to determine any delayed mortality. This delayed mortality is often referred to as LIM. The following section describes procedures used to conduct these studies.

Sampling of impinged fish to be held for latent mortality observations was generally conducted during March through November in the North and South fish counting pools at Salem's CWS CWIS. During each week of sampling, three 8-hr collection events were scheduled. Typically a collection event began 1 hr after high-slack water and continued until 1 hr after low-slack water.

Test specimens were collected by diverting a timed sample of screen-wash water into the appropriate fish counting pool as determined by tidal current direction. The sample duration was governed by the number of specimens needed to complete the daily sampling quota, the remaining holding capacity, the number of live and damaged specimens taken in previous samples, and the prevailing detrital loads. Sample durations were typically one or two minutes. Individual specimens typically were sighted, identified, and conditions determined as they swam in the pool; then the specimens were dip-netted and immediately placed into a holding tank.

For the most recent studies (2002 to 2003) (PSEG 2004b, Attachment 9), the holding facility was a closed system consisting of a 450-gal (1.7 m^3) reservoir tank, a 15-gal (57-liters) sump tank, and 16 round 20-gal (76-liters) fiberglass tanks. Holding water was circulated through PVC pipe and multiple filters to these tanks using a submersible pump. Earlier LIM studies (1997 to 2001) used rectangular holding tanks. The temperature of holding water was controlled using a thermostat-controlled chiller/heater combination. Aeration was provided via an air pump and air hoses, which ran to all the tanks. Water temperature, salinity, and dissolved oxygen concentrations were monitored on a daily basis during the latent study periods. Adjustments were made, as necessary, to maintain the holding facilities at ambient levels. Ambient conditions were monitored in the fish counting pools as part of the testing program. Specimen loading in the holding facility was 25 to 250 fish per tank depending on size and species of fish.

Live and/or damaged specimens collected and held for latent mortality observations were evaluated at 24-hr intervals during the 2-day (48-hr) holding period. Individual specimens were held to form a composite sample from the day's collection effort without regard to the specific one to three minute sample in which they were taken. Consequently, the holding period for some specimens may have been as short as 40 hrs or as long as 56 hrs, instead of the specified 48 hrs.

Approximately 24-hrs from the mid-point of the initial collection window, all tanks were inspected for dead specimens. The dead specimens were removed and their lengths recorded. At the 48-hr observation and termination, all specimens were categorized as live, dead or damaged, and then measured. Specimens were measured to the nearest millimeter; FL was measured for all species with emarginated or forked caudal fins; for all other species, total length ("TL") was measured. Table IV-10 presents the monthly average LIM values based on these studies.

(c) CWIS Flow During Impingement Monitoring Is Representative of Salem's Operations

Impingement sampling at Salem is based on a target of 1,560 samples per year collected under the following schedule: 10 samples per day, 3 days per week during January through December.

The sampling frequency and total number of samples targeted for collection during the program was determined through an optimal allocation analysis described in PSEG (2004b, Attachment 2). Within each week, sample days are selected randomly, without regard to Station operation. Consequently, impingement samples represent an unbiased selection of Station flows.

2. Methodology for Calculating Impingement Mortality

Based on records of Station operations, the number of samples collected at various CWIS flowrates (both as pumps in service and as flow in cubic meters per minute) at the time of the 2002 to 2004 impingement samples is shown in Table IV-11.

(a) Current Conditions

The estimates of IM for the Current Conditions were based on actual flow data for Station Units 1 and 2 over 2002 to 2004.

i. Description of Model

The calculation methodology for computing IM (losses) is based on the extrapolation of timed intake samples to the desired period. As described below, a 1 to 3 minute sample of the combined fish- and debris-trough wash water is collected in a fish counting pool. The average number of fish taken per minute is then scaled to daily, weekly, monthly, or annual estimates. Adjustments are made for: the number of CWPs in service; efficiency of the fish collection process; age class composition of the organisms collected; and the survival (initial and latent) rates under the prevailing conditions. A detailed description of the calculation process is presented in Attachment 4-4.

ii. Total Impingement Loss

The total impingement loss by year, month, species, and age is the sum of the fish initially classified as dead due to impingement plus the estimated loss due to latent mortality. As discussed above, the estimates of IM for the Station include losses due to the operation of both the CWS CWIS and the SWS CWIS. The impingement losses for the SWS CWIS by year, month, species, and age were estimated from the CWS losses and the relative flows (See Attachment 4-4). No survival is assumed for organisms impinged at the SWS CWIS.

Impingement losses for the CWS and the SWS in each year and month and for each species and age were adjusted from actual to “normalized” flow conditions (See Attachment 4-4).

(b) Calculation Baseline Conditions

The Final Rule establishes a §316(b) Standard for reductions in IM. Compliance with the standard is judged against the impingement mortality that would occur if the facility's CWIS had Calculation Baseline configuration consisting of an intake parallel with the shoreline equipped with conventional traveling screens with mesh configured with • in. square openings and no fish return system. To estimate IM for the Calculation Baseline using the IM data developed from PSEG's 2002 to 2004 IBMWP, adjustments were made to account for the differences in the fish and shellfish impinged with the current ¼ in. by ½ in. mesh versus the original • in. square mesh.

The adjustments are species and length dependent. PSEG was able to develop reliable adjustments by comparing impingement data collected while Salem operated with a Calculations Baseline Conditions CWIS and impingement data collected while Salem operated with the Current Conditions CWIS (See Attachment 4-4).

(c) Proposed Conditions

Modeling of the Proposed Conditions (*i.e.*, PSEG's proposal for future Salem operations) was based on the following assumptions: (1) 185,000 gpm (700 m^3/min) per pump operation; (2) all 12 CWIS CWPs are in operation except during planned outages; and (3) a 25-day planned refueling outage in spring and fall using an 18 month cycle for each unit.

3. Estimates of Impingement Mortality

(a) Current Conditions

Estimates of IM for Current Conditions were calculated by species, life stage, and year. The results are provided in Table IV-12. These estimates of IM for the Current Conditions include estimates for the CWS CWIS and SWS CWIS. The estimates for the SWS assume 100% IM (See Attachment 4-4).

(b) Calculation Baseline Conditions

Estimates of IM for Calculation Baseline Conditions were calculated by species, life stage, and year. The results are provided in Table IV-13. The IM estimates for the Calculation Baseline Conditions assume 100% mortality for all impinged fish or shellfish. The estimates of the fish impinged have also been adjusted to address the difference in the screen mesh configuration between the Current and Calculation Baseline Conditions (See Attachment 4-4).

(c) Proposed Conditions

Estimates of IM for Proposed Conditions were calculated by species, life stage, and year. The results are provided in Table IV-14. As with the Current Conditions, IM estimates assume 100% mortality for the organisms impinged at the SWS. Estimates of IM also have been adjusted to account for the Proposed Conditions assumption of design flow and the planned refueling outage schedule (See Attachment 4-4).

H. Estimation of Entrainment (40 CFR §125.95(b)(3)(iii))

Entrainment loss estimates were developed for the Station based on the three different flow scenarios described below: Current; Calculation Baseline; and Proposed. The sections below describe the data and methods used to develop the estimates and present the estimates.

1. Data

Data used to estimate entrainment at the Station came from a variety of sources, including the IBMWP entrainment monitoring programs and CWIS flow data.

(a) IBMWP Entrainment Monitoring Program

Entrainment monitoring is conducted annually in accordance with the IBMWP developed to address requirements in Salem's 2001 NJPDES Permit. The objective of this program is to produce accurate density estimates of fish entrained through the CWIS at Salem (PSEG 2002a) (See Attachment 4-4).

i. Design

Abundance samples were collected at the CWIS intake bays 12B or 22A. Samples collected at the intake locations were taken at a point inboard of the vertical traveling screens and upstream of the CWPs. This sampling location was chosen to ensure the collection of specimens that had been entrained and to eliminate possible sample contamination by larger, potentially impingeable specimens.

The entrainment abundance collection apparatus consists of one or more fish pumps and a net-in-tank "abundance chamber." Sampling pumps are of 6-in. (15.2-cm), single-port, centrifugal design with variable rotations per minute electric drives. Typically a Neilsen Model 5-1506 has been used. Sample volume is measured with a Sparling Envirotech Flowmeter (Model PDS-115); a valved "tee" assembly is used to divert water to the abundance chamber. The abundance chamber consists of a 3.3-ft (1-m) plankton net positioned atop a 260-gal (1.0-m^3) cylindrical tank with 0.02-in. (0.5-mm) mesh (See Figure IV-71). The net is fitted with a screened (0.02-in. [0.5-mm] mesh) plastic catch bucket at the cod end, and the net mouth is positioned approximately 11.8 in. (30 cm) above the tank top to allow overflow through the plankton net mesh.

Abundance samples were collected by pumping water through the abundance net and chamber at a rate of 264 to 396 gpm (1.0 to 1.5 m^3/min). The sample volume typically ranged from 13,209 to 19,813 gal (50 to 75 m^3), depending on the concentration of detritus and/or jellyfish and ctenophores. Following sampling, the net was washed and the contents rinsed into a jar and preserved in a 10% formalin-Rose Bengal solution. Field data recorded at the time of collection included time, location, gear, flowmeter readings, tidal stage and height, air and water temperature, salinity, and dissolved oxygen level. Field sheets were returned to the laboratory and proofed twice before data were entered into an electronically readable form.

Once collected and fixed in formalin, samples were then returned to the laboratory and washed. Ichthyoplankton were removed and stored in 40% isopropanol. Larval, juvenile, and adult fishes were identified to the lowest practicable taxonomic level, and then counted. Up to 25 specimens per life stage per sample were measured to the nearest 0.02 TL (0.5 mm). Fish eggs were identified to the lowest practicable level, counted, and an assessment of viability was made. This was done on the basis of clarity of the perivitelline space and integrity of embryo and yolk material.

A Folsom plankton splitter or a 10-ml Hensen-Stempel pipette was used to subsample entrainment abundance collections that met a minimum specimen-number criterion. Criteria were based on the best-fit relationship between the coefficient of variance and mean number of specimens per subsample as determined by repetitively subsampling collections containing a known number of specimens and the chosen level of precision. Taxa and life stages were considered separately within each sample. Exceptionally large specimens were removed prior to subsampling. Subsampling techniques were applied typically to fish eggs; larval fish were subsampled on only a few occasions. Samples were suspended in 42.7, 85.4, 140.4, 341.7 in^3 (700, 1,400, 2,300 or 5,600 ml) of water and subsampled several times with a 0.6 in^3 (10 ml) Hensen-Stempel pipette. The mean number per subsample was used to indicate if the sample could be split, if additional pipette samples were needed, or if the whole sample must be processed.

ii. Frequency

From January through March and August through December 2002, sampling was conducted three days a week, with eight samples collected per day (one every three hours). From April through July 2002, sampling was conducted five days a week, with twelve samples collected per day (one every two hrs). An adjustment to the sampling frequency was made for 2003 and 2004. For those years, sampling was conducted three days a week, with seven samples collected per day (one every 3 hrs 25 min) from January through March and from August through December. From April through July, sampling was conducted four days a week, with fourteen samples collected per day (approximately every 1 hr 42 min).

iii. Gear Efficiency

Entrainment losses theoretically could be underestimated due to two major factors: (1) small organisms may be extruded through the mesh of the collection net, and (2) larger organisms may avoid the collection device through active avoidance or through habitat selection. These two potential biases are described below.

a) Net Extrusion

Gear efficiency-related to net extrusion was quantified by determining a Relative Probability of Capture (“RPC”), through a comparison of gear efficiency in the Estuary with gear efficiency in the Station (PSEG 2004b, Attachment 3). Attachment 4-4 provides the detailed methodology and equations.

Under the assumption that the densities of larvae in the Station and in the Estuary are equal, namely, that DS = DE, the RPC reduces to the quotient of gear efficiencies.

b) Net Avoidance and Vertical Stratification

In the 1999 Permit Application, an analysis of intake and discharge data collected in 1980 indicated that entrainment data should be corrected for avoidance of the intake sampler. However, there was considerable uncertainty associated with these results due to difficulties pairing the intake and the discharge samples and the low number of samples available. As a result, another approach for addressing the entrainment sampler avoidance question was developed that relied on independent data from more extensive sampling programs.

On balance, the results of these analyses do not support the conclusion that juvenile fish avoid the entrainment sampler; and therefore, do not support the inclusion of an adjustment factor to account for the possibility of avoidance of the entrainment sampler in the estimates of numbers entrained. If anything, the results suggest that estimates of numbers of juveniles entrained (based on entrainment sampling) may be biased high (See Exhibit 4-4-1 for the detailed analysis).

(b) Entrainment Survival For Cost-Benefit Analysis

Entrainment survival studies were conducted at Salem in the early 1980s. Data from those early studies are summarized in PSEG (1984) and PSEG (1999a, Appendix F). Information on entrainment survival has been updated from studies conducted at various power plants nationally and is summarized in PSEG (2004b, Attachment 8). Although PSEG believes these data are representative of conditions at Salem and has used them previously in estimating entrainment, the Final Rule only allows entrainment survival to be considered in the cost-benefit analyses with agency approval. Therefore, PSEG is not using entrainment survival in its estimates of Current, Calculation Baseline, or Proposed Conditions for the IMECS, DCTP, or RP. Consistent with prior use and Department approval, PSEG is applying entrainment survival values in the cost-benefit analysis (See IX below; See Section 6 of this Application).

(c) CWIS Flow During Entrainment Monitoring Is Representative of Salem's Operations

Entrainment sampling at Salem is based on a target of 1,687 samples per year collected under the following schedule:

7 samples per day, 3 days per week during August through March

14 samples per day, 4 days per week April through July.

The program is stratified such that the greatest number of samples is taken during the period of greatest historic ichthyoplankton abundance, April through July. The actual number of samples taken during each period was determined through an optimal allocation analysis described in PSEG (2004b, Attachment 2).

Within each week, sample days are selected randomly, without regard to Station operations. Consequently, entrainment samples represent an unbiased selection of the Station's CWIS flows.

Based on the records of Station operations provided by PSEG staff, CWIS flow (as pumps in service and flow in cubic meters per minute) at the time of the 2002 to 2004 entrainment samples is shown in Table IV-15.

2. Methodology for Calculating Entrainment

(a) Current Conditions

Entrainment losses at Salem were estimated using on-site entrainment sampling data from 2002 to 2004 and Station operating information (*e.g.*, cooling and service water withdrawal, power production). As in previous submittals, entrainment loss estimates were scaled up from in-plant sampling data, as modified by gear efficiency, recirculation (re-entrainment), and entrainment mortality rates (assumed to be 100%).

Data reduction and analytical methods were generally similar to those followed in previous submittals. However, some changes were made when interpolating entrainment density calculations for those periods when no sampling occurred. A detailed description of the methods and rationale used to estimate entrainment is provided in Attachment 4-4.

(b) Calculation Baseline Conditions

The Final Rule establishes a §316(b) Standard for reductions in E. The standard is judged against Calculation Baseline entrainment associated with a traveling screen with • in. square mesh.

As described above, PSEG installed Smooth-Tex ® Mesh screens with ¼ in. by ½ in. openings. As a result of this change in mesh configuration, a fraction of the organisms entrained under Calculation Baseline Conditions no longer pass through the screens. PSEG developed species-specific, length-dependent correction factors to estimate E for the Calculation Baseline. The correction factors are the ratio between the impingement by the Current Conditions traveling screen and the impingement by the Calculations Baseline traveling screens.

The correction factors are estimated for Salem by comparing two time periods. Salem Units I and II began commercial operation in 1977 and 1981, respectively. At that time, Salem operated with Calculation Baseline Conditions. Salem operated with Current Conditions during the 2002 to 2004 data collection period. See Attachment 4-4 for information on the application of the correction factors to estimate E for the Calculation Baseline. The correction factors for relevant species and lengths are given in Table IV-16.

(c) Proposed Conditions

Modeling of the E estimates for the Proposed Conditions was based on the assumption of: (1) 185,000 gpm (700 m^3/min) per pump operation, (2) operation of all 12 CWPs except during planned outages, and (3) 25-day planned refueling outages in the spring and fall with each unit being on an 18 month refueling schedule.

3. Estimates of Entrainment

(a) Current Conditions

Estimates of E for the Current Conditions were calculated by species, life stage, and year. The results are provided in Table IV-17.

(b) Calculation Baseline Conditions

Estimates of E for the Calculation Baseline Conditions were calculated by species, life stage, and year. The results are provided in Table IV-18.

(c) Proposed Conditions

Estimates of E for the Proposed Conditions were calculated by species, life stage, and year. The results are provided in Table IV-19.

V. DESIGN AND CONSTRUCTION TECHNOLOGY PLAN (DTCP) (40 CFR §125.95(b)(4))

The DCTP demonstrates that: (1) the reduction in IM resulting from the existing technological and operational measures at Salem satisfy the §316(b) Standard for reductions in IM; and (2) the reduction in E resulting from the existing technological measures at Salem together with the production from the restoration measures satisfy the §316(b) Standard for reductions in E through the restoration standard established at 40 CFR §125.94(c)(2) and §125.95(b)(5)(iv). In addition to demonstrating compliance with the §316(b) Standards, the DCTP provides all of the information required under 40 CFR §125.95(b)(4).

A. Overview of DCTP

First, the DCTP addresses the Final Rule's requirements for information on the Station's capacity utilization rate. Section 4-V-B, below, provides the total net generating capacity for Units 1 and 2 and the Station as a whole, based on five years of Station performance data. It then presents the annual net generating capability for each unit and the combined Station, based on five years of Station data. Finally, it provides the capacity utilization rate for Salem's proposed operations, which is the capacity utilization rate used to demonstrate compliance with the Final Rule. Following the discussion of the capacity utilization rate, the DCTP describes the technological measures (*i.e.*, Salem's state-of-the-art intake screens and fish return system) and the operational measures (*i.e.*, continuously operating, multi-speed traveling screens) for reducing impingement mortality (See V-C below). Then, the DCTP describes the technological measures (the ¼ in. by ½ in. mesh screen panels) that account for a portion of the reduction in entrainment (See V-D below). Next, the DCTP presents PSEG's methodologies used to calculate reductions in IM and E and the results of the calculations (See V-E and V-F, below respectively). Finally, the DCTP presents engineering drawings for the technological measures (See V-G below).

As described in the following sections, Salem is a baseload nuclear generating facility with an average capacity utilization rate of 87% from 2000 to 2004. PSEG has already installed state-of-the-art design and construction technologies at Salem to reduce IM and E. PSEG also has implemented operational measures that further minimize the effect of the CWIS on fish and shellfish that are entrained or impinged. As described below, these reductions in IM and E losses resulting from the technologies and measures, together with the increased production associated with the restoration measures described in Section 4-VII, are more than sufficient to achieve compliance with the §316(b) Standards for IM and E. PSEG does not need to propose any additional measures to achieve compliance with USEPA's Final Rule.

B. Capacity Utilization Rate (40 CFR §125.95(b)(4)(i))

As defined in USEPA's Final Rule, "capacity utilization rate" is the ratio between the average annual net generation of power by the facility (in MWh) and the total net capability of the facility to generate power (in MW) multiplied by the number of hours during a year (40 CFR §125.93). This section provides the data and information necessary to calculate the capacity utilization rate for Salem, as required by the Final Rule. Because, however, Salem presently operates as, and will continue to operate as, a baseload generating station, PSEG is not relying on the capacity utilization rate as a basis for a determination that the §316(b) Standard for E does not apply to the Station.

1. Total Net Generating Capability (MWh)

In accordance with 18 CFR §4.51, PSEG uses net Maximum Dependable Capacity ("MDC") as the generating capability measure to calculate capacity utilization rates. These values are recorded annually and sent to the Federal Energy Regulatory Commission ("FERC"). MDC is defined as the gross electrical output as measured at the output terminals of the turbine-generator during the most restrictive seasonal conditions, less the normal Station service loads. The most restrictive seasonal conditions are dependant upon the type of heat sink the unit uses. In the case of the Salem units, which use the Estuary as the cooling medium, the most restrictive seasonal condition would be when the river water temperatures in the vicinity of the Station reach their annual maximum, *i.e.,* the summer.

The values presented for each unit are averages over a five year period from 2000 through 2004.

(a) Salem Unit 1

The average annual MDC for Salem Unit 1 is 9,700,712 MWh. Average monthly values are presented in Table V-1.

(b) Salem Unit 2

The average annual MDC for Salem Unit 2 is 9,657,086 MWh. Average monthly values are presented in Table V-1.

(c) Salem Units 1 and 2

The average annual MDC for Salem Units 1 and 2 combined is 19,357,798 MWh. Average monthly values are presented in Table V-1.

2. Five Year Average Annual Net Generation (MWh)

Net Generation is the amount of electrical generation in Megawatts produced by the generator (Gross Generation) less the Station Power and Light ("SPL") load. SPL load is the electrical load necessary to operate the power plant. The net generation value is calculated by taking the measured generation at the generator terminals and subtracting the SPL load. The meter information is tabulated and sent to FERC ("FERC Reports") (PSEG 2000, 2001, 2002b, 2003b, 2004c).

(a) Annual MWh 2000 to 2004 Salem Unit 1

The annual net generating capacity for Salem Unit 1 is 8,347,107 MWh. This estimate, based on the FERC Reports for 2000 through 2004, represents an average year.

Table V-1 includes average monthly net generation and the average annual net generation for Unit 1.

(b) Annual MWh 2000 to 2004 Salem Unit 2

The annual net generating capacity for Salem Unit 2 is 8,616,810 MWh. This capacity, based on the FERC Reports for 2000 through 2004, represents an average year.

Table V-1 includes average monthly net generation and the average annual net generation for Unit 2.

(c) Annual MWh 2000 to 2004 Salem Units 1 & 2

The annual net generating capacity for both Salem Units 1 and 2 combined is 16,963,917 MWh per year. This capacity estimate, based on the FERC Reports for 2000 through 2004, represents an average year.

Table V-1 includes average monthly net generation and the average annual net generation for Salem Units 1 and 2.

3. Capacity Utilization Rate for Compliance with Performance Standards

The Capacity Utilization Rate is calculated by dividing the total net generation for a given period by total net capability of the facility to generate power (in the case of Salem, the MDC), and is expressed as a percentage. High water temperatures in the Estuary during the summer months result in lower turbine efficiency and lower generating capability. Therefore the MDC yields a generation level which is typically lower than the generation level experienced most of the year. As such, the monthly MDC capacity factor can be above 100%, especially in the winter months when the generation is higher due to lower water temperatures in the Estuary. Typically, due to outages and power reductions, the MDC capacity factor is below 100%.

The five year average capacity utilization rate for Salem Units 1 and 2 combined is 87.6%. This value is the ratio of the five year average annual net generation value for 2000 through 2004 (See V-B-2-(c) above) to the average maximum dependable capacity for Salem for 2000 through 2004 (See V-B-1-(c) above).

C. Design and Construction Technologies and Operational Measures to Reduce Impingement Mortality (40 CFR §(b)(4)(i)(A))

As discussed in this section, PSEG has already installed improved modified-Ristroph traveling screens and made improvements to Salem's bi-directional fish return system to reduce IM. NJDEP determined that these design and construction technologies represented BTA in prior §316(b) BPJ decisions for the Station (NJDEP 1993a, 1993b, 1994a, 1994b, 2000a, 2000b, 2001a, 2001b). PSEG is continuing to rely on these design and control technologies to reduce impingement mortality and achieve compliance with the §316(b) Standard.

1. Salem Operates with Improved Modified-Ristroph Intake Screens as Required by the 1994 Permit and Described in the 1999 Renewal Application

As required under Salem's 1994 NJPDES Permit, PSEG made improvements to the modified-Ristroph screens at Salem's CWIS. With these modifications, the CWIS was determined to be BTA for Salem (NJDEP 1993a, 1993b, 1994a,1994b, 2000a, 2000b, 2001a, 2001b). The improvements to the screen panels, fish buckets, flap seals, and spray wash system are described below.

(a) Screen Panels

The original stainless steel screen panels with standard cross-stitch woven mesh resulted in a coarse-mesh screen. Fish were more likely to experience a partial de-scaling as they slid over the screen during the fish retrieval cycle (PSEG 1999a, Appendix B). As part of the improvements required under Salem's 1994 NJPDES Permit, the traditional 12-gauge stainless steel wire mesh was replaced with smooth slot-woven, Smooth-Tex ®, mesh (See Figure V-1). This mesh reduces the probability that fish would experience descaling when sliding over the mesh during transfer from the fish bucket to the fish return trough. The new screen mesh openings and weave were chosen because they had been found to be superior at handling fish in laboratory flume studies and onsite at Consolidated Edison's Indian Point Unit 2 and New York Power Authority's Indian Point Unit 3.

The new weave pattern allowed the use of thinner wire in the panel mesh and resulted in a different mesh opening. The mesh opening size was reduced from a • square in. opening to a ¼ in. by ½ in. rectangular opening. The new wire is 14 gauge instead of 12 gauge, resulting in less wire obstruction in each screen panel, providing an approximate 25% increase in the openings and a 20% reduction in the velocity of the water flowing through the screen mesh. This reduction in velocity decreases the force a fish experiences if impinged onto the screen. Additionally, Envirex studies showed that the debris is less likely to become entangled on the new Smooth-Tex ® screen mesh than previous screen patterns, which minimizes screen clogging, thereby maintaining the lower velocities. Not only does the smooth outer surface limit abrasion of the fish and provide for easier removal of fish and debris, but the reduced opening width increases the survivability of fish impinged on screens (PSEG 1999a, Attachment G-1).

A "Free-slide" mesh mounting is also part of the improved screens. The mesh mounting hardware is configured behind the smooth mesh surface, which reduces the debris carryover and increases the ease of debris removal by the sprays (PSEG 1999a, Attachment G-1).

(b) Fish Buckets

The modifications to the traveling screens replaced the original steel buckets with newly designed, hydrodynamically-improved fish buckets (See Figures V-1 and V-5). The modified-Ristroph through-flow screen buckets are 10-ft-long (3 m) composite-material fish buckets that are integral to the bottom-support member of the screen panel. As the fish bucket travels over the head sprocket of the traveling screen, organisms slide onto the screen face and are washed into the fish trough by the low-pressure spray system (See Figures V-2 and V-7).

Using composite materials, the fish bucket was redesigned to include an integral, curved lip or “leading edge.” This lip efficiently redirects inlet water flow through the entire lower portion of the basket’s screen surface area. Additionally, the curved lip eliminates the turbulent flow pattern that existed in previous fish bucket designs (PSEG 1999a, Attachment G-1) (See Figure V-3). An additional benefit to using composite materials is that fish do not adhere to nonmetallic composite materials; rather, fish freely exit the bucket with the water as it is spilled onto the screen surface during the fish removal cycle.

Each newly designed bucket is configured to form an interlocking seal with the basket frame below it during ascending and descending travel. The vertical water depth of the fish bucket is approximately 4 in. (10 cm). Having this depth of water prevents any freezing of the fish during the winter months by, providing an acceptable environment for the fish while they are in the bucket. The position of the flow spoiler is approximately 3 in. (8 cm) from the screen face, which leaves a sufficient opening to encourage fish to enter the sheltered region under the flow spoiler.

The composite material buckets have special upper and lower lip geometrics designed to provide an optimum cross-section profile, which cannot be readily fabricated with steel. Additional advantages of using composite-material buckets over steel are corrosion resistance and weight reduction. The use of lighter composite material baskets allowed an increase of the maximum carriage speed from 17.5 to 35 fpm (5.3 to 10.7 m/min) providing quicker return of impinged fish to the Estuary and reduced debris loading which lessens the stress on impinged fish.

(c) Flap Seals

Fish and debris can sometimes pass between the fish and debris trough seals (See Figures V-2 and V-6). The neoprene flap seals between the traveling screen frames and the fish and debris troughs were redesigned to improve sealing, enhance the entry of fish into the troughs and allow for installation and adjustment of the seals during operation. The fish and debris trough flaps were redesigned to maintain a closer fit to the traveling screen, thus reducing the possibility of the fish or debris bypassing their respective troughs. The reliability of the flap seals was increased by inserting a chock (*i.e.*, wedge) in the screen guide track that prevents the settling and misalignment of the screens with respect to the fixed flap seal.

(d) Screen Wash System

Modifications to the intake screens to increase the survival of impinged fish include upgrades to the screen wash system. These upgrades included improvements to the screen wash spray headers, debris shields, and screen wash pumps and strainers.

i. Screen Wash Spray Headers

Each original screen had been equipped with five screen wash spray headers (See Figures V-2 and V-7) located as follows: one outside fish spray header, two inside fish spray headers, and two inside debris spray headers. The three fish spray headers were all low-pressure sprays (10 to 15 lbs psig [0.7 to 1.0 kg/cm^2 gauge]). The outside fish spray header was designed to keep the screen mesh lubricated with water during the fish removal cycle. The inside spray headers were designed to provide a gentle outward lift to the fish as they slide down the screen into the fish trough. The debris sprays, located lower in the traveling screen housing, were high-pressure sprays (90 to 100 psig [6 to 7 kg/cm^2 gauge]) that wash the debris into the debris trough after fish had been removed to the fish return trough by the low pressure sprays.

The spray wash water system was modified to improve water flow to the modified traveling screens (PSEG 1999a, Exhibit G-1-1). A total of eight spray nozzles were added to the spray headers of each traveling screen. Two low-pressure spray nozzles were added to the source pipe at each end of the two inside fish spray headers (a total of four nozzles) to provide better spray coverage and improved fish handling. These low-pressure spray nozzles provide a continuous stream of water to these areas which allows the fish to be washed from the screen panels into the buckets. The fish spray nozzles operate at a nominal pressure of 15 psig (1.0 kg/cm^2 gauge), a pressure selected to minimize de-scaling and other injuries to fish that could occur at higher pressures. In addition, two high-pressure spray nozzles were added to each of the two main debris spray headers (a total of four nozzles) to provide better spray coverage and improve debris removal. These nozzles are aimed to avoid spraying fish with high-pressure water. The debris spray nozzles operate at pressures of approximately 90 to 100 psig (6 to 7 kg/cm^2 gauge) to assure removal of debris from the screen panels.

Research conducted by Envirex during the conceptual design phase identified the optimum placement of the spray nozzles to provide a spray pattern that gently transfers fish from the screen surface to the return trough. Testing and adjustments to achieve these design conditions were performed during the modification of each traveling screen. Further, the correct placement for removal of fish and debris from the traveling screens was confirmed during fish survival tests conducted on the screens between June 20, and August 24, 1995 (PSEG 1999a, Exhibit G-1-2).

Although not required under the Salem's 2001 NJPDES Permit or the Custom Requirement G.2.b.ii work plan, PSEG subsequently analyzed the traveling screen spraywash pressures to determine if the wash pressure was contributing to fish mortality (PSEG 2004b, Attachment 6). A fully functioning pilot-scale traveling screen was constructed in a laboratory flume. Alewives were introduced under varying spraywash pressures (0• 100 psig [0 to 7 kg/cm^2 gauge]) and held for 48 hrs. No significant mortalities were found to be associated with spraywash pressures up to 100 psig (7 kg/cm^2 gauge) (which is the maximum pressure in the Station's debris removal system).

ii. Debris Shields

The original screens did not include debris shields above the spray nozzles. Previously, debris would occasionally fall within the screen as the screen panels articulated over the top of the drive assembly and would cover the spray nozzles. This would cause the spray patterns to become irregular and reduce the effectiveness of the screen wash system. To eliminate this problem, debris shields were added above the inside spray nozzles to keep them free from any fallen debris, further ensuring consistent spray patterns and efficient fish and debris removal (PSEG 1999a, Exhibit G-1-1).

iii. Other Screen Wash System Modifications

The screen wash pumps, located in the CWIS, provide river water to clean the traveling screens of debris and to wash fish and other aquatic organisms gently from the screens into the fish trough. To increase reliability and performance, the screen wash pumps were replaced with new pumps designed to handle the river debris and silt with a first-stage debris cutter. The new pumps also have upgraded materials for the wear ring, shafting, and sleeves to improve reliability and performance (PSEG 1999a, Exhibit G-1-1).

The screen wash strainer is located after the wash water pump, before the screen spray headers. It strains debris from the river water to keep the spray headers from clogging. The original design of the screen wash strainer required multiple controls to operate the strainer. When an 8-psig (0.56-kg/cm^2 gauge) pressure differential across the strainer was detected, the associated blowdown valve would open for approximately five minutes to backwash the strainer. In addition, the strainer would automatically initiate a backwash sequence every 30 min if the differential pressure ("DP") did not reach 8 psig (0.56 kg/cm^2 gauge) so that debris would not be impinged on the strainer screen for durations over 30 min. The high volume of debris captured by these strainers, at times, left the duration between cycles at only 1 to 2 min (PSEG 1999a, Exhibit G-1-1).

To enhance the reliability of the strainer operation and provide for smoother operation of the screen wash pumps at consistently reduced strainer DPs, the backwash operation was modified to be continuous. The modified design now starts the strainer motor simultaneously with the start of the screen wash pump. The automatic blowdown valves have been replaced with manual valves that are normally closed but have a drilled port through the valve plug of sufficient size to pass the required backwash flow. Should the backwash valve become plugged with debris, the operator can operate the manual valve to remove the unwanted debris. The process of continuous rotation and blowdown for the strainer results in improved efficiency and reliability of the screen wash system (PSEG 1999a, Exhibit G-1-1).

These additional modifications have significantly upgraded the screen wash system. The new equipment is inherently more reliable and thus improves the availability of the spray wash water to the traveling screens. The continuous operation of the strainers results in the system header pressures being more stable and therefore provides a more consistent screen wash spray. This helps assure that the circulating water traveling screens perform as intended and provides assurance that the system will operate reliably.

2. Salem Operates with an Improved Bi-Directional Fish Return System as Described in the 1999 Renewal Application

PSEG replaced the original rectangular trough assemblies for fish and debris with custom-formed fish troughs (See Figure V-8). The fish return trough is approximately 30 in. (76 cm) wide and 18 in. (46 cm) deep with 6-in. (15-cm) radius rounded corners at the bottom. Smooth fiberglass material forms the fish trough which minimizes any damage to the fish traveling along the trough (Ronafalvy *et al*. 1999). Water depth in this bi-directional fish return system is maintained at approximately 3 in. with one unit operating and greater than three inches with both units in operation (normal configuration).

The intersection of the fish and debris troughs was redesigned to enhance fish survival. The fish trough is aligned parallel to and above the debris trough. At the end of the fish trough, the water from the fish trough drops approximately 3 in. into the debris trough and is cushioned by the water in the debris trough. The neoprene flap seals between the traveling screen frames and the troughs were also redesigned to improve sealing, enhance the entry of fish into the troughs, and allow for installation and adjustment of the seals during operation (PSEG 1999a, Attachment G-1).

Based on NJPDES Custom Requirement G.2.b.ii of Salem’s 2001 NJPDES Permit, PSEG was required to evaluate ways to reduce fish mortality associated with the fish collection pools and the fish return trough at the CWIS. PSEG conducted a series of studies to determine if Salem's fish return/collection systems increased the mortality rates of fish re-entering the Estuary. The first involved a literature review and modeling exercise; the second involved fish testing at an off-site testing facility; and the third was a study at Salem's CWIS (PSEG 2004b, Attachment 6).

PSEG conducted a comprehensive literature review of potential stressors in the fish return/collection systems identifying the types and magnitudes of stressors found to be injurious to fish. These potential stressors include shear, abrasion, turbulence, and impact. The literature values were then compared to the results from a Computational Fluid Dynamics ("CFD") model of the existing Salem fish return system which quantified these stressors by simulating the end-of-pipe discharge, the return troughs, and the fish collection pools. The stressor values calculated by the CFD model were lower than the values reported in the literature as being injurious to fish (PSEG 2004b, Attachment 6).

To verify the model results, PSEG conducted empirical testing using a physical model of the Salem fish return and sampling system. At an off-site laboratory, fish testing facilities were constructed, replicating both the end-of-pipe discharge and the fish collection pool to evaluate the latent mortality of live fish. No significant mortalities of test fish were observed. PSEG then conducted on-site testing at the existing fish collection pool. During these tests, alewives were introduced under high and low flow (3 or 13 cfs [0.08 or 0.4 m^3/sec]) with two depths of cushion water (approximately 10 and 20 in. [25 and 51 cm]). No significant mortalities were observed, verifying the laboratory results (PSEG 2004b, Attachment 6).

These results confirm that the Station's fish return system is designed to maximize fish protection. The data demonstrate that the fish collection pools, end-of-pipe discharges, and fish/debris return troughs do not contribute to the overall impingement mortality rate. Changes to the design or operation of the fish return system would not be expected to improve overall fish survival potential at Salem Station's CWIS (PSEG 2004b, Attachment 6).

3. Operational Measures to Reduce Impingement Mortality

As with design and control technologies, PSEG made improvements to operational measures at Salem. These operational measures are described below.

(a) Continuously Operating Traveling Screens

The existing screens are capable of operating at variable speeds between 6 and 35 fpm (2 and 11 m/min) since the improvements made in 1995. As DP across the screen increases, the speed automatically increases. By increasing the screen speed, the cycle time for each individual screen element and the transit time of fish in the buckets are reduced. As part of the 1995 improvements to Salem's CWIS, PSEG also replaced the screen motors and the associated electrical equipment, including cables, breakers, starters, and contactors.

All speeds are fully automated, shifting speeds as screen differential pressure increases. By doubling the maximum speed during high debris load periods, less debris accumulates on the screen. This permits the spray wash system to be more effective in assisting fish removal to the fish sluice trough and debris removal to the debris sluice trough. In addition, the debris filtration capability was increased, which results in maintaining lower differential pressure across the surface of basket screens during periods of high debris loading and, therefore, a lower through-screen velocity. As USEPA identified in the Preamble to the Final Rule, reducing through-screen velocity can help reduce entrainment and impingement mortality (67 Fed. Reg. 17151; 69 Fed. Reg. 41601).

D. Design and Construction Technologies to Reduce Entrainment (40 CFR §125.95(b)(4)(i)(B))

The modifications to the CWIS traveling water screen panel mesh reduce entrainment. The mesh on the original stainless steel screens had • in. square openings. These square openings allowed more larvae and juvenile fish to become entrained. On the improved modified-Ristroph screens, the rectangular ¼ in. by ½ in. openings do not allow all of the same larval and juvenile fish to be entrained (See Figure V-4). Many of these organisms that were previously entrained are now impinged and returned to the river alive.

In addition, the smaller, thinner wire used for the new mesh allows for a larger opening for flow. This increase reduces the through screen flow velocity. The reduced through-screen velocity also reduces the number of organisms entrained and enhances the survival of the smaller fish that are impinged.

E. Calculation of Reductions in Impingement Mortality (40 CFR §125.95(b)(4)(i)(C))

This section demonstrates that Salem meets the §316(b) Standard for reductions in IM. Salem meets this standard based on the reductions in IM achieved through already installed and/or implemented technological and operational measures.

1. Applicable Impingement Mortality Performance Standard

The §316(b) Standard for reduction in IM (40 CFR §125.94(b)(1)) is a reduction in "impingement mortality for all life stages of fish and shellfish by 80% to 95% from the calculation baseline." Because PSEG is using the compliance alternative set forth in 40 CFR §125.94(a)(2) for impingement, the §316(b) Standard for reductions in IM is applicable to Salem.

2. Impingement Survival Due to Design and Construction Technologies and Operational Measures

The design and construction technologies described in V-C above, reduce IM by returning impinged fish and shellfish alive to the Estuary. PSEG conducted studies to estimate the increased impingement survival that is achieved with the installed continuously operating, multi-speed improved modified-Ristroph traveling screens and bi-directional fish return system (PSEG 2004b, Attachment 9) (See IV-G above). Estimates of impingement survival from those studies were used to determine the reductions in IM attributable to the installed design and construction technologies.

3. Metric and Methodology for Determining Reductions in Impingement Mortality

In order to estimate the reduction in IM due to design and construction technologies, the fates of organisms that would have been impinged under the Calculation Baseline Conditions were determined for the Proposed Conditions. The reduction in IM was computed as the difference between the estimated IM under Calculation Baseline Conditions and the estimated IM under Proposed Conditions. For this calculation, the number of organisms impinged is the same for the Calculation Baseline and the Proposed Conditions. However, the number of organisms that die from impingement (*i.e.*, impingement mortality) is different for the two scenarios. Under the Calculation Baseline Conditions, all impinged organisms are assumed to die because the Calculation Baseline configuration has conventional traveling screens and no fish return system, whereas under the Proposed Conditions, organisms have a probability of survival due to the improved Ristroph-modified screens and the bi-directional fish return system (PSEG 2004b, Attachment 9) (See IV-G above for discussion of estimates of impingement survival rates).

The use of biomass as a common metric to calculate losses due to IM and E is a methodology which has both scientific merit and has been used historically as part of determining losses and potential benefits of technologies, operational measures and restoration measures, for both the 1994 and 2001 NJPDES Permits for Salem. A more detailed discussion of the biomass models and calculations is presented in Section 7.

In sum, the conversion of loss numbers to biomass provides a common metric of evaluation based upon a variety of factors so that losses of individual fish species can essentially be summed to one common loss number, i.e. pounds of biomass. Conversely, gains in fish production, including those attributable to restoration measures, can similarly be converted to an equivalent level of benefits also expressed as pounds of biomass. By creating a common metric, one unit of measure can be utilized to evaluate fish protection technologies and restoration measures and the losses to determine whether those benefits meet the §316(b) Standards, or to determine a site-specific standard for IM and E.

This methodology was utilized by NJDEP (1993b) in making its BTA determination as part of the 1994 Permit. The 1999 Application again utilized biomass to evaluate losses and benefits of technologies, operational measures and restoration measures, and was subsequently used as a basis by NJDEP (2000b) in making its BTA determination for the 2001 Permit. This Application continues the use of this common metric as improved by further refinements of the applicable models, which are detailed in Section 7 of the Application.

The estimates of reductions in IM were based on the estimates of numbers of organisms impinged and the mortality factors presented in IV-G. However, the impingement estimates for the Proposed Conditions that are presented in IV-G were modified for use in determining reductions in impingement mortality to accurately reflect the reductions in IM. Those estimates were modified because they included organisms that would have been entrained under the Calculation Baseline Conditions but will be impinged under the Proposed Conditions due to the change in the configuration of the openings in the mesh. Under the Calculation Baseline Conditions, the mesh has • in. square openings; under the Proposed Conditions, the mesh has ¼ in. by ½ in. openings. This change results in fewer entrained fish. This is the reason that the estimates of the number of organisms impinged, in IV-G, is greater for the Proposed Conditions than for the Calculation Baseline Conditions. Those fish entrained under the Calculation Baseline configuration that are now impinged under the Proposed Condition configuration are considered in the evaluation of E reductions (See IV H above and V-F below).

In order to sum IM over the RS (*i.e.,* American shad, alewife, Atlantic silverside, Atlantic croaker, bay anchovy, blueback herring, spot, striped bass, weakfish, white perch, blue crab, Atlantic menhaden, and bluefish), the estimate of annual IM for each species is converted into units of biomass on date of loss (See Attachment 7-1 of this Application). The species-specific estimates of annual IM (pounds wet weight) are then summed to produce a single estimate of annual IM (pounds wet weight). This calculation is conducted separately for the two scenarios (Calculation Baseline Conditions and Proposed Conditions) and for each year (2002 to 2004).

4. Reductions in Impingement Mortality Resulting from Design and Construction Technologies and Operational Measures

The average annual (2002 to 2004) reduction in IM (Calculation Baseline Conditions vs Proposed Conditions) was estimated to be 326,674 lbs (148,177 kg) (wet weight) per year. This is an 88% reduction from 370,242 lbs (167,939 kg) under Calculation Baseline Conditions to 43,568 lbs (19,762 kg) under Proposed Conditions (See Attachment 7-1 of this Application)[1].

5. Conclusions

The installed design and construction technologies and the operational measures implemented at Salem reduce impingement mortality by 88%, which is within the range of reductions (80% to 95%) required by the §316(b) Standard for reductions in IM (40 CFR §125.94(b)(1)). Therefore, Salem is in compliance with the §316(b) Standard for reductions in IM.

F. Calculation of Reductions in Entrainment (40 CFR §125.95(b)(4)(i)(C))

This section demonstrates that Salem is in compliance with the §316(b) Standard for reductions in E. Salem meets this performance standard based on the reductions in E achieved through already installed technological measures and the substantial increase in production of fish and shellfish attributable to a component of PSEG's restoration measures, the restoration of three formerly diked salt hay farms.

1. Applicable Entrainment Performance Standard

The §316(b) Standard for reductions in E (40 CFR §125.94(b)(2)) is a reduction in "entrainment for all life stages of fish and shellfish by 60% to 90% from the calculation baseline." The §316(b) Standard for reductions in E applies to Salem because Salem has a capacity utilization rate greater than 15% (See V-B above) and withdraws water for cooling from an estuary .

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[1] Based on the NJDEP-approved IBMWP, the 13 species PSEG identified as RS for the CDS comprise more than 99% of the age-0 production foregone impingement biomass calculated using the modeling described in Attachment 6-12 to this Application.

The increased production of fish and shellfish attributable to the restoration measures is considered together with reductions in entrainment due to design and construction technologies. According to 40 CFR §125.95(b)(4)(i)(C), "Reductions in ... entrainment as a result of any design and construction technologies and/or operational measures already implemented at your facility should be added to ... any increases in fish and shellfish within the waterbody attributable to your restoration measures."

2. Metric and Methodology for Determining Reductions in Entrainment

As discussed above in IV-F, biomass is the appropriate metric for determining reductions in E at Salem. In order to estimate the reduction in E due to design and construction technologies, the fates of organisms that would have been entrained under the Calculation Baseline Conditions are determined for the Proposed Conditions. Some of those organisms are entrained under the Proposed Conditions, (some, due to the installation of the improved modified-Ristroph traveling screens) are impinged instead. The reduction in entrainment is computed as the difference between 1) the number of organisms that would have been entrained under Calculation Baseline Conditions, and 2) the number of those organisms that are entrained or lost due to IM under Proposed Conditions. For this calculation, all organisms entrained are assumed to die, but organisms that are impinged under Proposed Conditions are assumed to have a probability of survival due to the improved modified-Ristroph screens and bi-directional fish return system (See IV-G above and Attachment 4-4 for discussion of estimates of impingement survival rates).

To allow increases in production of fish and shellfish attributable to the restoration measures to be added to the reductions in E due to design and construction technologies (as specified in 40 CFR §125.95(b)(4)(i)(C)), the estimates of annual numbers of organisms entrained (used in the calculations of reduction in E due to design and construction technologies) are translated into units of annual production lost (pounds, wet weight per year). The estimates of annual production lost due to entrainment are computed using the methods described in Attachment 7-1 of this Application, and included the weight of organisms on the date of entrainment plus the production forgone from the date of entrainment to what would have been the first birthday of the organism. Annual estimates of production lost due to entrainment are based on annual (2002 to 2004) estimates of E of the finfish RS (*i.e.*, American shad, Atlantic menhaden, Atlantic silverside, alewife, Atlantic croaker, bay anchovy, blueback herring, spot, striped bass, weakfish, white perch, and bluefish).

3. Metric and Methodology for Determining Increases in Production Due to Restoration Measures

As described in VII below, PSEG has restored three former salt hay farm sites to functioning salt marshes. The increased production of fish and shellfish from these sites is considered in the DCTP.

PSEG has demonstrated in the RP (See VII below) that the restored salt hay farms have increased production of fish and shellfish in the Estuary (at the secondary consumer level) by 18.6 million lbs (8.4 million kg) (wet weight). As such, PSEG has demonstrated compliance with the standard for out-of-kind restoration in 40 CFR §125.95(b)(5)(iv). PSEG's restored wetlands are producing ecological benefits (*i.e.*, increased production of fish and shellfish) that are substantially similar to or greater than the benefits that would be realized by in-kind restoration. As described in VII below, the metric used for quantifying increases in fish and shellfish within the waterbody attributable to the restoration measures is the annual production of secondary consumers (pounds, wet weight, per year). Secondary consumers include age-0 fish of the RS entrained and also include other taxonomic groups of fish and shellfish. Estimates of production of secondary consumers attributable to the restored salt hay farm marshes are based on empirical data (2002 to 2004) on the biomass of aboveground vegetation within the restored salt hay farm marshes (See Attachment 7-1 of this Application). The vegetation data is used to estimate aboveground primary production (*i.e.*, production of aboveground marsh vegetation) within the salt hay farm marshes. To convert the primary production to production of secondary consumers, three trophic transfers are used: 1) vegetation to the detrital complex, 2) detrital complex to primary consumers, and 3) primary consumers to secondary consumers (See Attachment 7-1 of this Application).

4. Reductions in Entrainment due to Technological and Operational Measures and Increases in Production due to Restoration Measures

The average annual (2002 to 2004) reduction in production lost due to entrainment (Calculation Baseline Conditions vs Proposed Conditions) was estimated to be 332,204 lbs (150,685 kg) (wet weight) per year. This is an approximately 3% reduction from 9,674,481 lbs (4,237,586 kg) (wet weight) under

Calculation Baseline Conditions to 9,342,277 lbs (4,388,271 kg) (wet weight) under Proposed Conditions (See VII-E below).[2]

The average annual (2002 to 2004) production of all secondary consumers (including age-0 fish of the species entrained at Salem) attributable to the salt hay farm marshes, under the scenario of all salt hay farm sites having met vegetative Success Criteria established under the Management Plans, is estimated to be 18,575,270 lbs (8,425,601 kg) (wet weight) per year (See VII-E below). As noted in Section 7-III of this Application, aboveground production is only a portion of the total primary production and, therefore, these estimates likely under-represent the total secondary production attributable to the salt hay farm marshes.

The average annual combined benefit (in accordance with 40 CFR §125.95(b)(4)(i)(C)) is the production of 18,907,474 lbs (8,576,286 kg) wet weight, per year of secondary consumers, which includes the species of fish entrained at Salem. 332,204 lbs (150,685 kg) is attributable to the installed design and construction technologies; 18,575,270 lbs (8,425,601 kg) is attributable to the restoration measures.

5. Conclusions

The average annual entrainment under Calculation Baseline Conditions, expressed in terms of lost production of secondary consumers, is estimated to be 9,674,481 lbs (4,388,271 kg) (wet weight) per year. The average annual benefit, also expressed in terms of production of secondary consumers, due to design and construction technologies and the salt hay farm restoration measures is estimated to be 18,907,474 lbs (8,576,286 kg) (wet weight) per year. The combined benefits of the design and construction technologies and the restoration measures (in accordance with 40 CFR §125.95(b)(4)(i)(C)) are greater than the benefits that would have been realized through in-kind restoration or compliance with the §316(b) Standard for E. Therefore, Salem clearly meets the standards applicable when out-of-kind restoration measures are being used (40 CFR §125.95(c)(2) and §125.95(b)(5)(iv)).

[2] Based on the NJDEP-approved IBMWP, the 13 species PSEG identified as RS for the CDS comprise more than 98% of the age-0 production foregone entrainment biomass calculated using the modeling described in Attachment 6-12 to this Application.

G. Design and Engineering Calculations, Drawings and Estimates Supporting Descriptions of Technological and Operational Measures to Reduce Impingement Mortality and Entrainment (40 CFR §125.95(b)(4)(i)(D))

The design and construction technologies PSEG is relying on to meet the §316(b) Standard for reductions in IM have been installed and fully operational at Salem for approximately 10 years. These measures include: the screen panels, fish buckets, flap seals, spray wash system, and the bi-directional fish return system. The screen panels, which are the design and construction technology that contributes to the reductions in entrainment, have also been installed and operational during the time period. Full sets of engineering drawings have been submitted to NJDEP as part of PSEG's 1999 NJPDES Application (PSEG 1999a, Addenda G-1-1-8 and G-1-1-9). NJDEP has inspected these design and construction technologies on numerous occasions and has retained independent consultants to review their operations and their biological efficacy (ESSA 2000).

1. Engineering Drawings of Improved Screens

Engineering drawings are provided as Figures V-4 through V-7, inclusive, for the components of the improved modified-Ristroph traveling screens that contribute to enhanced survival of impinged fish and shellfish. They are: the screen panels; the fish buckets; the flap seals; and the spray wash system.

(a) Screen Panels

The Smooth-Tex ® mesh screen panels with the ¼ in. by ½ in. openings reduce both IM and E. Figure V-4 is an engineering drawing that depicts the screen mesh panels. Figure V-4 provides a view of a typical improved composite material fish bucket in Detail "C". The side view shows the flow through the bucket and the direction of travel; the isometric view in Detail "C" shows the screen mesh and a portion of the frame of the bucket.

(b) Fish Buckets

The composite-material, molded fish buckets reduce IM. Figure V-5 is an engineering drawing that depicts the fish buckets. Figure V-5 provides a drawing of Salem's fish bucket assembly. Section views "A-A", "B-B", "C-C", "D-D" and "H-H" show the cross section view of the improved modified-Ristroph style fish buckets with the curved bucket that holds water for fish survival and with the fish lip at the end of the bucket.

(c) Flap Seals

The neoprene flap seals reduce impingement mortality. Figure V-6 is an engineering drawing that depicts the flap seals. Figure V-6 provides a drawing of the flap seal on Salem's CWIS screens. Detail "A" shows a cross section view of the flap that closes the gap between the traveling water screen and the fish trough. A detail in the upper right of the drawing shows a visual reference of the orientation of the flap, the traveling water screen, and the fish trough.

(d) Spray Wash System

The Spray Wash System reduces impingement mortality. Figure V-7 is an engineering drawing that depicts the spray wash system. Figure V-7 shows the spray wash piping. The detail in the lower left corner shows a front view of the spray piping. Sections "B-B" and "C-C" show side views of the spray piping. Section "F-F" shows a view of the spray piping orientation within the traveling water screen.

2. Engineering Drawing of Bi-Directional Fish Return System

The bi-directional fiberglass fish return system also reduces IM. Figure V-8 is an engineering drawing depicting the fish return system. Figure V-8 shows the bi-directional fish return trough. The detail in the top center of the drawing shows the elevation routing of the fiberglass fish trough. A typical trough section on the left side of the drawing shows the curved cross section of the trough, designed to maximize fish survival by removing any sharp corners that may injure fish and possibly impede the ability of the fish to survive the return to the river.

H. Conclusions

PSEG's implementation of the design and construction technologies and operational measures described in this DCTP has ensured that Salem meets the §316(b) Standard for reductions in IM. The technologies and measures have reduced impingement mortality by 88%. PSEG has also met the applicable standard for E (40 CFR §125.94(c)(2) and §125.95(b)(5)(iv)) through the implementation of design and construction technologies and restoration measures. PSEG has demonstrated that the there has been a 0.3 million lbs (0.14 million kg) reduction in E from the Calculation Baseline E due to the design and construction technologies, and a 18.6 million lbs (8.4 million kg) increase in production of fish and shellfish due to the salt hay farm restoration program. When compared to Calculation Baseline E of 9.7 million lbs (4.4 million kg), PSEG has clearly demonstrated that the restoration measures are producing benefits that are substantially similar to or greater than the benefits that would have been achieved by meeting the applicable §316(b) Standard for E.

VI. TECHNOLOGY INSTALLATION AND OPERATION PLAN (TIOP) (40 CFR §125.95(b)(4)(II))

Facilities, like Salem, that have elected to achieve compliance with the §316(b) Standards using the compliance alternative in 40 CFR §125.94(a)(2) are required to submit a TIOP as part of the CDS. Section 4-VI presents the TIOP for Salem.

A. Introduction

The TIOP first identifies the design and construction technologies that PSEG has installed to meet the §316(b) Standards for IM and E. The TIOP also describes PSEG's proposed monitoring program and the activities that PSEG will implement to maximize the biological efficacy of the measures. Since PSEG has already demonstrated compliance with the §316(b) Standard for IM (as discussed in the DCTP), no adaptive management plan is required or included in this TIOP. PSEG requests that its compliance during the term of Salem's next NJPDES Permit be based upon compliance with the TIOP.

1. Brief Overview of Regulatory Requirements

The Final Rule specifies that the TIOP must include a schedule for installation and maintenance of any new design and construction technologies and operational measures; a list of operational and other parameters to be monitored; a list of activities to ensure efficacy of installed technologies and operational measures; and a schedule and methodology for assessing efficacy of installed technologies and measures in meeting applicable performance standards.

2. PSEG Has Well-Established and Properly Implemented Inspection and Maintenance Procedures for the CWIS

PSEG's existing comprehensive inspection program is designed to provide for timely identification and correction of conditions that could detract from the technologies' ability to achieve reductions in IM and E.

3. Normal Operation of CWS CWIS

As described above in III, IV, and V, Salem's CWIS has 12 intake bays, each of which is equipped with an improved modified-Ristroph traveling screen and a CWP. If the traveling screen is out of service and not operational for any reason, the CWP is taken out of service. The CWP remains out of service until the traveling screen is returned to service. If the CWP is not operating, no IM or E occurs at that intake bay.

4. Design and Construction Technologies Relied Upon in DCTP to Meet Performance Standards

PSEG made a series of improvements to Salem's CWIS over the operating life of the Station. As described above in the DCTP (See V above), PSEG installed a state-of-the-art screening system and fish return system at Salem. The screening system includes smooth-mesh screen panels with ¼ in. by ½ in. openings. The improved system also includes composite material fish buckets re-designed with an extended lip that bends inward to reduce turbulence within the buckets, and flap seals that enhance the removal of fish and shellfish from the screens to the buckets. Moreover, the system includes a dual-pressure spray wash system and debris and fish return troughs. The bi-directional fish return system minimizes the re-impingement of fish and shellfish.

As described in detail in V above, the combination of the state-of-the-art intake technology and PSEG's current operating practices have allowed PSEG to meet the §316(b) Standard for IM. PSEG has also met the §316(b) Standard for E when the reductions in entrainment due to the existing design and construction technologies are considered with the increased production from restoration of the salt hay farm wetland restoration sites.

5. Operational Measures Relied Upon to Meet §316(b) Standards

PSEG, over the operating life of Salem, has made improvements to the continuously rotating travel screens. The latest of these modifications is the operation of the screens at variable speeds. The rotating screens originally operated at a constant speed unless an operator manually adjusted the rotating speed. Now, as differential pressure across the screen increases, the speed automatically increases. By increasing the screen speed, the cycle time for each individual screen element and the transit time of fish in the baskets are reduced. The variable speeds also decrease the debris accumulation on the screens during periods of high debris loading, reducing stress on impinged fish.

6. Scope of TIOP

The DCTP identified the components of Salem's CWIS that contribute to reductions in IM and E. These are:

- the Smooth-Tex ® ¼ in. by ½ in. mesh screens;
- the composite material fish buckets;
- the neoprene flap seals;
- the spray wash system;
- the bi-directional fish return system; and
- continuously operating traveling screens.

Because the purpose of the TIOP is to ensure that the measures identified as contributing to the reductions in IM and E are properly installed, operated, and maintained, the TIOP addresses the first five design components of Salem's CWIS identified above.

As stated above in VI-A-3, if a traveling screen is not in service for any reason, the CWP associated with the screen is also removed from service. Therefore, the TIOP does not address the screen assemblies, the screen drive motors, or other components of the CWIS that are required to support general operation of the traveling screens and the CWPs.

7. Because the Technological Measures Required to Meet the §316(b) Standards Are Already Installed, PSEG Is Not Required to Submit a Schedule for the Installation and Maintenance of New Technological Measures Under 40 CFR §125.95(b)(4)(ii)(A)

40 CFR §125.95(b)(4)(ii)(A) requires that applicants installing new design and construction technologies submit a schedule for installing and maintaining the new technology. PSEG has already installed the CWIS design and construction technologies and has implemented the operational measures necessary for Salem to achieve compliance with the §316(b) Standards. Since PSEG does not need to install any new design and construction technologies, PSEG does not need to submit a schedule in compliance with 40 CFR §125.95(b)(4)(ii)(A) of the Final Rule.

B. Operational and Other Parameters to be Monitored (40 CFR §125.95(b)(4)(ii)(B))

PSEG has an established program for monitoring the CWIS for the CWS at Salem. PSEG monitors the condition and operability of the five CWS CWIS components to ensure that the reductions in IM and E presented in the DCTP continue to be achieved. Table VI-I lists the parameters included in the TIOP monitoring program. This section of the TIOP identifies the parameters that have been and will continue to be monitored and where the monitoring occurs, and the frequency of inspections.

1. Parameters to Be Monitored

PSEG has developed a series of procedures that detail the inspection of the CWIS at Salem, including the improved modified-Ristroph screens, fish buckets, flap seals, screen wash system, and the bi-directional fish return system.

(a) Smooth-Tex ® Screen Panels with ¼ in. by ½ in. Mesh

PSEG has established procedures that describe the circulating water traveling screen periodic inspections. In accordance with these procedures, the screens are regularly inspected for corrosion, damaged mesh, and wear of the screen assemblies and associated components.

(b) Fish Buckets

As part of the overall on-site inspections, the condition and operability of the fish buckets are monitored. Specifically, the bucket, frame, and fasteners are assessed for corrosion and/or other damage. In addition, the bucket angle is examined to determine whether the bucket is operating at full capacity without impediments.

(c) Flap Seals

The fish and debris lip/flap seal are inspected for overall condition, alignment, rotation efficiency, and debris loading. In addition to the cleanliness of the flap seals, the procedures include a thorough inspection of the debris accumulation ensuring that there are no blockages due to the build-up of debris.

(d) Screen Wash System

Existing procedures include the disassembly and inspection of the circulating water screen wash pump auto strainer. PSEG operators also inspect the overall spray wash system checking for corrosion and/or other damage; alignment of the spray headers; and spray header pressure.

(e) Bi-Directional Fish Return System

The bi-directional fish return system is inspected for its overall condition as well as corrosion and/or other damage; orientation of discharge relative to tides; and cleanliness of the trough with regard to debris accumulation.

2. Monitoring Methods and Locations

The monitoring program relies upon visual inspection by trained operators and is conducted within the CWS CWIS. The monitoring is also conducted at the fish return system which is adjacent to the CWIS.

3. Monitoring Frequency

PSEG monitors the screen panels, fish buckets, flap seals, spray wash system, and the material conditions of the fish return system on a weekly basis (See Table VI-1).

C. Activities to Ensure, to Degree Practicable, the Efficacy of Installed Technologies and Schedule for Implementation (40 CFR §125.95(b)(4)(ii)(C))

Numerous activities are undertaken on a periodic basis to maintain this system with its various equipment and structural components. PSEG will continue to implement the following programs to ensure the efficiency of the installed technologies for reducing IM and E:

- operator training;
- preventive maintenance; and
- notification and work order process.

These programs are providing, and will continue to provide, adequate assurance that the technological measures will produce reductions in IM and E sufficient to meet the §316(b) Standards.

As an integral part of the monitoring program, PSEG has an established program for ensuring that any problems or issues identified during routine inspections of the design and construction technologies will be properly resolved.

In addition to routine maintenance, work orders for repair activities will be implemented to assure that the traveling screens and circulating water equipment function properly.

1. Operator Training Program

PSEG developed a training program for personnel responsible for the operation of the CWIS at Salem. The annual training program serves two main purposes. First, it enhances employees' awareness of the importance of the CWIS in protecting the aquatic resources of the Delaware. Second, the training sessions provide a forum for employees to raise ideas about improvements in screen operations that might improve the survival of impinged organisms. The following topics will be covered during training sessions:

- the relevant requirements of Salem's NJPDES Permit;
- the relevant requirements of the Final Rule;
- the fish affected by the CWIS;
- the components of the CWIS that most affect survival of fish and shellfish; and
- the relationship between tides, currents and the operation of the bi-directional fish return system.

PSEG will maintain records of employees who participate in the annual training sessions and the materials covered in each class.

2. Preventative Maintenance Procedures

PSEG will continue to implement maintenance activities on a routine basis to ensure that the screen mesh, fish buckets, flap seals, spray wash system, and bi-directional fish return system operate properly (See Table VI-2). Maintenance procedures on these systems are carried out on either quarterly, semi-annual, or annual intervals, or on an as-needed basis. Specifically, PSEG's preventative maintenance will include lubricating and cleaning specified components of the spray wash system. In addition, each entire screen assembly is typically removed and refurbished every three years. Also, Salem operators routinely remove debris from the fish troughs and flap seals. This routine maintenance will maximize equipment life and run Salem at optimal conditions, thus minimizing stress on fish.

3. Notification and Work Order Tracking and Completion

Station personnel will enter a notification of any problems with the screen panels, fish buckets, flap seals, spray wash system, or bi-directional fish return system into the computerized system PSEG uses to manage equipment and Station processes. A work order will then be generated to perform a one-time maintenance task. Periodic maintenance activities automatically generate work orders on the required interval basis. Work orders are assigned to an individual or organization and tracked for completion.

D. Schedule and Methodology for Assessing Efficacy of Installed Design and Construction Technologies (40 CFR §125.95(b)(4)(ii)(D))

Pursuant to PSEG's prior NJPDES Permits, PSEG was required to monitor and assess the efficacy of installed design and construction technologies through various studies (See II above). The improved technologies that PSEG has implemented over the years include improved modified-Ristroph screens, improved screen mesh, fish buckets and flap seals, and spray wash system with a bi-directional fish return system. PSEG has conducted seven years of post-installation monitoring of IM, and the data from the most-recent three years are provided in the IMECS and discussed in the DCTP.

In the DCTP, PSEG demonstrated compliance with the §316(b) Standard for reductions in IM based on these measures. PSEG also demonstrated partial compliance with the §316(b) Standard for E based on the configuration of the screen mesh (PSEG exceeded the standard for reductions in E by the implementation of the technological measures and the wetland restoration program). Since PSEG has conducted extensive post-installation monitoring spanning more than seven years and has met reductions in IM and E to meet the §316(b) Standards, no additional verification monitoring is required. PSEG also requests that its compliance during the term of Salem's next NJDPES Permit be based upon compliance with the TIOP.

1. Previous Assessments Have Demonstrated the Biological Efficacy of the Installed Design and Construction Technologies

NJDEP (1994a) required PSEG to conduct a side-by-side survival study to compare impingement survival rates between the modified-Ristroph screens and the improved screens in 1995 prior to the installation of the improved screens to Unit 1. The initial study results indicated substantial improvements in impingement survival (PSEG 1999a, Attachment G-1, Exhibit G-1-2). In addition to this initial study, PSEG conducted latent impingement mortality studies over several years (See V above) (PSEG 2004b, Attachment 9). The DCTP has used the information from these studies to show that the improved modified-Ristroph traveling screens achieve an 88% reduction in IM from the Calculation Baseline IM.

2. PSEG Completed an NJDEP-Required Study to Maximize the Efficacy of the Screen Design and Implemented the Improvements

To ensure that the improved modified-Ristroph screens with modified fish buckets were achieving the predicted reductions in impingement mortality (PSEG 1993a), NJDEP (1994a) required PSEG to phase in the installation of the CWIS modifications (*i.e.,* the improved screens were installed on Unit 2 and tested before installation occurred on Unit 1) (PSEG 1999a, Attachment G-1, Exhibit G-1-1). The phasing allowed an assessment of the optimization of the design (NJDEP 1993a, 1993b, 1994a 1994b). Once the optimization assessment was complete, PSEG made further improvements to the design of the screens based on the results of the required testing. After the newly improved screens were installed on Unit 2, PSEG retrofitted Unit 1 with the latest screen design. The PSEG assessment has demonstrated that the intake screens at Salem reflected the optimal design for reducing impingement and entrainment losses at Salem's CWIS. The DCTP confirms this assessment.

3. Conclusion

PSEG's prior assessments of design and construction technologies at Salem's CWIS, together with a continued inspection program that verifies the efficacy and efficiency of the improvements, demonstrated that PSEG has met the §316(b) Standards. As indicated throughout the CDS, PSEG has conducted extensive post-installation monitoring of IM and E. This post-installation monitoring demonstrates that PSEG is in compliance with the applicable §316(b) Standards. Therefore, no further biological verification monitoring is required to demonstrate the efficacy of these measures.

VII. RESTORATION PLAN (RP) (40 CFR §125.95(b)(5))

In this section of the CDS, PSEG presents its RP, as required by 40 CFR §125.95(b)(5). Although PSEG has undertaken a multi-faceted restoration program, the EEP, in compliance with Salem's 1994 and 2001 NJPDES Permits and commitments to DNREC, this Restoration Plan only addresses the restoration of formerly diked salt hay farms. PSEG has demonstrated that the increased production of fish and shellfish from these sites, above, is more than sufficient for achieving compliance with the Final Rule.

A. Introduction

The RP for Salem discusses PSEG's efforts in restoring 4,400 acres of formerly diked salt hay farms. PSEG is relying on the restoration of these sites in combination with the reductions in entrainment achieved by the technological measures described in the DCTP to meet the §316(b) Standard for reductions in E. (As the DCTP demonstrates, Salem achieves compliance with the IM reduction standard based on its existing technological and operational measures.)

1. Restoration Requirements of the Final Rule

USEPA's Final Rule at 40 CFR §125.94(c) authorizes the use of restoration measures to meet either the national numeric performance standards or a site-specific performance standard. Applicants using restoration measures must demonstrate that:

- the use of design and construction technologies and operational measures are less feasible, less cost effective, or less environmentally desirable than meeting the §316(b) Standards in whole or in part through the use of restoration measures; and
- the restoration measures will produce ecological benefits (*i.e.*, fish and shellfish), including maintenance or protection of community structure and function in the waterbody, at a level that is substantially similar to the level that would be achieved by meeting the numeric §316(b) Standards.

USEPA's Final Regulations (40 CFR §125.95(b)(5)(iv)) also establish performance standards for in-kind restoration measures (*i.e.*, measures that address the species identified in the IMECS) and out-of-kind restoration measures (*i.e.*, measures that address fish and shellfish species different from those identified in the IMECS) (collectively, the "Restoration Standards"). For in-kind restoration, applicants must demonstrate that the restoration measures produce a level of the fish and shellfish substantially similar to the reductions in IM and E that would be achieved under the applicable §316(b) Standard. For out-of-kind restoration, applicants must demonstrate that the restoration measures produce ecological benefits substantially similar to or greater than the benefits that would be realized through in-kind restoration. As discussed below, PSEG demonstrates compliance with the Restoration Standard for out-of-kind restoration.

40 CFR §125.95(b)(5) describes the information applicants must include in their RP if restoration measures are being used, in whole or in part, to achieve compliance with the Final Rule. The RP must include:

- a demonstration that design and construction technology measures and operation measures were evaluated and an explanation of the determination that restoration measures are more feasible, cost-effective or environmentally desirable;
- a narrative description of the design and operations of the restoration measures;
- identification of species of concern identified in consultation with fish and wildlife agencies with responsibility for potentially affected fisheries and wildlife;
- quantification of the increased production of fish and shellfish and a demonstration that all of the §316(b) Standards and/or Restoration Standards are met when reductions due to technological or operational measures and/or increase due to restoration measures are considered along with an uncertainty analysis and a timeline for the accrual of the ecological benefits;
- design calculations, drawings, and estimates that document that the restoration measures in combination with design and construction technologies and/or operational measures, or alone, meet the applicable Restoration Standard and, §316(b) Standard; *i.e.*, the restoration measures will produce ecological benefits substantially similar to or greater than the benefits that would be realized through in-kind restoration;
- an adaptive management-based plan for implementing, maintaining, and demonstrating the efficacy of the restoration measures, including: a monitoring plan; the activities to be undertaken to ensure the efficacy of the restoration measures along with the linkages between the activities and the monitoring plan; and a process for revising the RP;
- a summary of consultations with appropriate fish and wildlife management agencies on the use of restoration measures;
- a peer review of the RP, if requested by the NJDEP; and
- a description of the information to be included in bi-annual status reports.

The following RP for Salem includes all of the information required under 40 CFR §125.95(b)(5) of USEPA's Final Rule.

2. Background to PSEG's Restoration Program

PSEG first proposed the EEP in response to concerns raised by NJDEP in its 1990 Draft NJPDES Permit for Salem. Specifically, NJDEP was concerned about the long-term effects of entrainment and impingement losses of certain RIS, including bay anchovy, spot, white perch, and weakfish (Versar 1989; NJDEP 1990, 1993b).

PSEG's EEP proposal was supported by scientific and technical information demonstrating the linkages between the restorations of diked salt hay farms to fully functioning salt marshes dominated by desirable vegetation such as *Spartina alterniflora* and to aquatic production (PSEG 1993a). NJDEP considered PSEG's proposal and re-issued a draft NJPDES Permit requiring the restoration of a minimum of 4,000 acres of diked lands in the Estuary (NJDEP 1993a) in addition to other restoration and conservation measures.

To ensure that all interested regulatory agencies and the public had ample opportunity to provide input into the Department's final decisions, NJDEP provided for a public comment period of more than six months on the 1993 Draft Permit and also held three public hearings. USEPA, NMFS, USFWS, DNREC and DRBC all participated in the public comment process (NJDEP 1993b, 1994b).

In incorporating restoration measures in Salem's 1994 NJPDES Permit, NJDEP went far beyond a simple requirement to restore the degraded wetlands. NJDEP (1994a) established a comprehensive regulatory scheme that incorporated requirements for:

- a timetable for acquiring the lands and establishing conservation restrictions in favor of the Department;
- the development of Management Plans, which were to include the following: a detailed design for the restoration (including but not limited to the plan for breaching dikes and constructing upland dikes, and for measures to protect roadways, property and improvements in the vicinity of the restoration sites from flooding); an anticipated schedule for natural re-vegetation of the sites; and a dedication for public use of the restored sites;
- the establishment of an advisory committee, MPAC, which included (1) regulatory scientists from the agencies who participated in the comment process on the 1993 Draft Permit as well as NJDEP's DFW and its Office of Mosquito Control Coordination, (2) scientists from academia, and (3) representatives of local government;
- the review of the Management Plans by MPAC prior to their being submitted to NJDEP for approval; and

- implementation of a BMP to provide data and information on the status of the restoration, including detrital production and hydrological monitoring, and the response of fish and shellfish to the restoration.

PSEG complied with all of the requirements of the 1994 NJPDES Permit relating to the salt hay farm restoration as well as additional requirements established through the development of Management Plans and the work plan for the BMP (PSEG 1999a, Appendix G, Attachment G-2). These additional requirements included developing Success Criteria, an adaptive management process and additional monitoring. All of these are described in greater detail in VII-C below.

NJDEP imposed similar requirements in Salem's 2001 NJPDES Permit relating to the wetlands restoration program, monitoring plans and advisory committees. PSEG has also complied with all of these requirements.

3. Species of Concern for the Restoration Program Were Identified in Consultation with Fish and Wildlife Agencies

As indicated in IV-C and VII-A-2 above, federal, state and interstate fish and wildlife management agencies were involved in identifying the species of concern for PSEG's restoration program. As early as the development of Salem's first §316(b) Demonstration, USEPA had established and chaired a TAG to provide advice to PSEG on the design and implementation of it's §316(b) studies. In addition to USEPA scientists, TAG included representatives from NJDEP's DFW, NMFS, USFWS, DNREC and DRBC (PSEG 1999a, Appendix A). TAG reviewed the list of "Target Species" for the 1984 §316(b) Demonstration, which included bay anchovy, spot, white perch, and weakfish (*i.e.*, the species of concern for the wetlands restoration program). The Target Species were, as discussed in IV above, among the RIS selected for Salem's §316 Demonstration using USEPA's Draft Guidance (USEPA 1977). The RS for the CDS includes these species.

As described in greater detail below, the fish and wildlife agencies with jurisdiction over the fish and shellfish in the Estuary participated in the public comment process that led to NJDEP's approval of EEP. The agencies reviewed Salem's §316(b) Demonstration (PSEG 1984), the Technical Appendix supporting the wetlands restoration (PSEG 1993a) and NJDEP's (1993a) Draft NJPDES Permit incorporating EEP. These agencies also have had representatives that have served on the MAC, MPAC and EEPAC. They have been materially involved in the identification of the species of concern for this RP at all key steps in the process from 1984 through the present.

4. Ecological and Other Benefits of Wetland Restoration Measures

The primary objective of PSEG's salt hay farm wetland restoration program was to increase the production of fish and shellfish in the Estuary. As this RP demonstrates, this objective has been met. PSEG, however, also recognized that this restoration effort would result in a myriad of other benefits for the Estuary, including, but not limited to, improved habitat for aquatic, terrestrial and avian organisms, reduced habitat for salt marsh mosquitoes, stormwater runoff and flood protection, enhanced opportunities for public access, and recreational activities. The following summarizes the other benefits to the Estuary.

(a) Estuary-Wide Benefits to Fish and Shellfish

The restoration of the salt hay farms has enhanced the production of desirable marsh vegetation such as *Spartina alterniflora*. This increase in primary production which is now exported to the Estuary, in turn, increases the amount of plant material that is broken down into detritus, which subsequently increases the food supply to, and production of, primary and secondary consumers (*i.e.*, fish and shellfish). Moreover, the EEP has improved the function of the marsh habitat as nursery and refuge areas, which all serve to increase the productivity of fish and shellfish.

(b) In-Marsh Benefits to Fish and Shellfish

Healthy tidal wetlands that are linked to estuarine and coastal waters provide critical ecosystem support by serving as highly favorable habitat for aquatic organisms. In particular:

- marsh creeks are used for feeding, breeding, and shelter by a variety of fish and invertebrates, and marshes are important habitat for both estuarine resident and continental shelf species (Peters and Schaff 1991; Rountree and Able 1992a; Rozas and Hackney 1984; Shenker and Dean 1979; Talbot and Able 1984; Weinstein 1979);
- consumer fish in marshes feed on abundant bottom-dwelling invertebrates (Boesch and Turner 1984; Peters and Schaff 1991; Smith *et al.* 1984);
- the movement of fish in and out of wetland areas is an important energy transfer linkage between marshes and estuarine and coastal waters (Cadigan and Fell 1985; Conover and Ross 1982; Currin 1984; van Montfrans *et al.* 1991; Weinstein and Walters 1981); and
- large carnivorous fish (including such commercially and recreationally valuable species as weakfish, summer flounder (*Paralichthys dentatus*), striped bass, and bluefish) use the estuary on a seasonal basis and derive substantial food

resources from forage fish and shellfish associated with marshes (Pennock 1988).

These findings have been confirmed, extended, and supported by recent studies and reviews. Large, carnivorous estuarine fish species have been documented to use shallow nearshore waters to a greater degree than was previously realized (Rountree and Able 1997; PSEG 1999a, Exhibits G-3-1, G-3-3, and G-3-5). Growth and survival of many species is promoted by tidal wetland habitats (Kneib 1997), and marshes are important contributors to growth of early life history stages (Ayvazian *et al.* 1992; Baltz *et al.* 1993; Kneib 1997; PSEG 1999a, Exhibits G-3-4, G-3-6, G-3-7, and G-3-9). Studies performed in the Estuary reveal a strong signature of tidal marsh production in the biomass of ecologically and commercially important fish species including bay anchovy, white perch, and weakfish (Litvin and Weinstein 2003). Because of the substantial contributions of tidal marshes to dissolved organic material in the estuarine water column and to the nutrient dynamics of the estuary (discussed below), this finding also suggests trophic linkage to tidal wetlands. Through the trophic relay (Kneib 2000), consumer biomass produced via primary production arising on tidal marshes is distributed throughout the estuary and linked to coastal waters.

Other studies supplement findings based on stable isotopes by evaluating trophic relationships, fish distribution, and the importance of nonbiological parameters to fish growth throughout the estuarine ecosystem. Warmer water and favorable oxygen and salinity conditions contribute to the value of tidal wetlands and estuarine shallows as nursery areas for enhancing growth and survival of fishes (Necaise *et al.* 2005; Peterson *et al.* 2004). The physical structure of tidal marshes plays an important role in their overall contribution to fish production (Kneib 2003). In particular, the presence of marsh creeks and wetland edges may give fish access to both trophic resources and favorable abiotic conditions and so provide the initial impetus for the trophic relay that makes the wetlands so important in the productivity of the entire coastal system. Teal and Howes (2000) showed in a retrospective analysis that fish catch in Long Island ports in 1880 were strongly related to the total length of marsh edge in the nearby estuarine ecosystem. Marsh edge appears to be a zone of intense biological activity and a key to the trophic relay (Kneib 2000) that links estuary primary production to secondary production of fish and shellfish.

In addition to food, marshes provide fish and shellfish with other important habitat support (PSEG 1999a, Attachment G-3, Exhibits G-3-4, G-3-5, G-3-9, G-3-10). Water on the marsh surface may shelter fish from cold winter temperatures (Smith and Able 1994) and provide optimal temperatures for growth during the active season (Brett *et al.* 1969; Pietrafesa *et al.* 1986). Marshes may shelter some fish from predation (Joseph 1973; Nixon and Oviatt 1973), but also serve as a focus for feeding by trophic generalists (Moyle and Cech 1996). Tidal wetlands provide important spawning habitat, for both marsh resident species and other estuarine fishes (Moyle and Cech 1996; PSEG 1999a, Exhibits G-3-6 and G-3-7).

(c) Other Ecological Benefits

PSEG's restoration of the three salt hay farm sites has provided numerous other ecological benefits beyond those to fish and shellfish. Restoration of tidal flow to diked salt hay farms has resulted in dramatic changes in the vegetation cover and extent of open water and mudflat on these sites. These changes have resulted in a corresponding increase in habitat for wading birds, waterfowl, shorebirds and raptors. Shorebirds feed on the exposed mudflats at the sites, especially during the low tides. The species documented at the sites include greater and lesser yellowlegs (*Tringa melanoleuca* and *T. flavipes*), red knot (*Calidris cannutus*), sanderling (*C. alba*), dunlin (*C. alpina*), semipalmated plover (*C. semipalmatus*), ruddy turnstone (*Arenaria interpres*), dowitcher (*Limnodromus griseus*) and black-bellied plover (*Squatarola squatarola*). Other birds that utilize the sites include double crested cormorant (*Phalacrocorax auritus*), great egret (*Casmerodius albus*), snowy egret (*Egretta thula*), blue heron (*Ardea herodias*), clapper rail (*Rallus longirostris*), willet (*Catoptrophorus semipalmatus*), black skimmer (*Rynchops nigra*), oyster catcher (*Haematopus palliatus*), glossy ibis *(Plegadis falcinellus)*, Canada goose *(Branta canadensis)*, blue-winged teal *(Anas discors)*, mute swan *(Cygnus olor)*, and various species of gull and tern. These include laughing gull (*Larus atricilla*), herring gull (*L. argentatus*), common tern (*Sterna hirundo*) and royal tern (*S. maxima*). Some of these species are listed or being considered for listing as threatended and endangered species by state and federal resource management agencies.

PSEG also installed four osprey *(Pandion haliaetus)* nesting towers at each of the restoration sites that have contributed to a significant increase in osprey numbers within the Estuary. As an example, five nesting pairs of osprey utilized the Commercial Township Restoration Site ("CTRS") during 2005. Four of these pairs used the nesting platforms that PSEG installed at the site. These nesting pairs have fledged young birds that have added to the osprey population of the Delaware. Data collected by The Nature Conservancy indicates that 26 osprey fledged from salt hay farm restoration sites during 2005.

Mammals such as the muskrat *(Ondatra zibethicus)*, river otter *(Lontra canadensis)*, and raccoon *(Procyon lotor)* forage over the areas as well.

Prior to the implementation of the restoration program, the restoration sites were optimal breeding habitats for the salt marsh mosquito (*Ochlerotatus sollicitans*). Because normal daily tidal inundation was restored at the salt hay farm sites, the mosquito breeding habitat was virtually eliminated. County mosquito commissions have been able to substantially reduce the application of insecticides to control mosquito populations in these areas (NJDEP 2001b).

(d) Stormwater Runoff Control, Flood Protection

The restored sites were designed for appropriate drainage of the adjacent upland and water control structures were constructed to allow stormwater to drain from the upland edge. These control structures have allowed floodwaters from extreme storm events and normal runoff from upland areas to successfully drain into the restored marsh. The restored salt marshes also provide protection from pollution in storm runoff by immobilizing pollutants in their sediments and by enhancing the degradation of organic pollutants such as hydrocarbons and pesticides. The diversity of microorganisms, the supply of inorganic nutrients, and the alternate flooding and draining of a tidal marsh all promote these activities.

(e) Public Access, and Educational Programs

The design plans for each of the salt hay farm restoration sites included significant public access facilities to promote the use and educational values of the sites. These facilities include observation platforms, car-top boat launches, boardwalks, and floating observation platforms. All three sites are included on the New Jersey Cultural Heritage Trail as "A Point of Interest."

The public access improvements at the CTRS represent the most extensive program of facility development of the three sites and may be the most extensive array of public access improvements anywhere in the Delaware Estuary. The construction of three observation platforms at the CTRS provides rare access to the internal areas of the tidal wetland. Two of the platforms are handicapped accessible and have associated boardwalks. A two-mile nature trail connects the three platforms and boardwalks. This trail traverses a variety of upland field, salt marsh, and wooded edge habitats and has proved popular with bird watchers. A number of interpretive signs have been installed at this site. A car-top boat launch has also been provided at the CTRS as a means of providing access to the tidal stream network that has been established as part of the restoration of the site. The CTRS is also extensively used for hunting, fishing, and crabbing.

The Maurice River Township Restoration Site (“MRTRS”) has also been popular for a variety of users. The majority of uses have been centered on fishing and crabbing. However, bird watching from the observation platform is also popular. The availability of a car-top boat launch has provided access points to reach more distant areas of the restoration site.

The Dennis Township Restoration Site ("DTRS") has been a popular destination for many different types of users. Their activities have included both active and passive forms of outdoor recreation. Waterfowl hunters utilize the site for access to West Creek and the near shore marshes of the Delaware Bay. The car-top boat launch has proved functional for the use of duck boats and other small crafts. A floating observation platform is also present at the site.

5. Approach for Comparing Benefits from Restoration Measures to Benefits from Reducing Impingement Mortality and Entrainment

As discussed in VII-D, below, and in Section 7-II of this Application, the benefits from the restored salt hay farm sites extend to multiple trophic levels, to multiple taxonomic groups, and likely to the full geographic extent of the Estuary. The ecological benefits clearly are not limited to the RS or species of fish and shellfish identified in the IMECS, although those species do benefit from the restoration measures. For these reasons, PSEG's restoration measures are considered out-of-kind restoration measures for the purposes of meeting the Final Rule.

As noted in VII-A-1 above, for out-of-kind restoration measures, 40 CFR §125.95(b)(5)(iv) requires a demonstration that, "the restoration measures produce ecological benefits substantially similar to or greater than those that would be realized through in-kind restoration." According to the Final Rule, the required benefits that would be realized through in-kind restoration (*i.e.*, "restoration measures that address the same fish and shellfish species identified in the IMECS") would be the production of "a level of these fish and shellfish substantially similar to that which would result from meeting applicable performance standards in 40 CFR §125.94(b)..." The Final Rule did not, however, establish a metric that could be applied to the ecological benefits of the restoration measures, to the ecological benefits of producing fish and shellfish affected by IM and E, and to the benefits of reducing losses of fish and shellfish due to IM and E.

Based on over 10 years of experience in analyzing the benefits of EEP, PSEG selected the annual production of secondary consumers (pounds, wet weight, per year) attributable to the restored marshes as the metric for quantifying ecological benefits from restoration. Secondary consumers include age-0 fish of the species of fish and shellfish affected by IM and E and also include other taxonomic groups. Production by lower trophic levels (*i.e.*, primary consumers) was included in the assessment by assuming all production by primary consumers was consumed by secondary consumers. In order to directly compare this metric of the benefits of the restoration measures to the benefits that would be achieved by complying with the applicable performance standards (*i.e.*, the benefits that would be achieved by complying with the requirements of in-kind restoration), losses due to entrainment were translated into units of loss of annual production (pounds, wet weight, per year) of secondary consumers.

Compliance with the Restoration Standard in 40 CFR §125.95(b)(5)(iv) was determined by comparing the estimate of the production that would be gained by complying with the applicable performance standard to the production attributable to the restoration measures in combination with installed design and construction technologies. The production that would be gained by complying with the applicable performance standards is a level of production equivalent to the production lost under the Calculation Baseline conditions times the percentage reduction (in IM or E) required by the performance standard.

6. Overview of Section

For ease of review, the information is organized according to the subsections of 40 CFR §125.95(b)(5). After this introduction, VII-B presents PSEG's demonstration that it has evaluated technological and operation measures and that the use of restoration measures is more feasible, cost-effective, or environmentally desirable. In VII-C, PSEG describes the design and operation of the restored salt hay farm sites. VII-D summarizes the results of recent data on the response of fish and shellfish to the restoration and presents information supporting PSEG's conclusion that the wetlands restoration program is producing fish and shellfish. VII-E summarizes the quantification of the ecological benefits of the restoration program and describes PSEG's compliance with the §316(b) Standard for E and Restoration Standards. In VII-F, PSEG presents the information that supports its quantification of increased production due to the restoration of the salt hay farms. VII-G summarizes PSEG's AM Program and Monitoring Plan for the term of Salem's next NJPDES Permit at CTRS. It also describes the activities that PSEG will undertake to ensure the efficacy of the restoration measures. Finally, this section describes in greater detail, PSEG's consultations with fish and wildlife agencies, the peer review process NJDEP required for Salem's restoration program, and the information to be included in the reports to NJDEP.

7. Summary and Conclusions

PSEG has implemented a wetlands restoration program, as required by NJDEP beginning in 1995. The program has been a tremendous success. Two of the three formerly diked salt hay farm sites, DTRS and MRTRS, are fully restored years in advance of the NJDEP-approved schedule contained in the Management Plans; the third site, CTRS, has met its interim Success Criteria and is on track to be fully restored on schedule. As required by NJDEP, PSEG developed and implemented a rigorous monitoring program to assess the response of fish and shellfish to the wetlands restoration. The data collected through this monitoring program and through other studies commissioned by PSEG have been used to demonstrate increased production of fish and shellfish in the Estuary. When the increased production from the restored wetlands is considered together with the reductions in E due to the design and construction technologies, PSEG has met USEPA's §316(b) Standards for reductions in E.

B. Demonstration that Restoration Measures are More Feasible, Cost-Effective or Environmentally Desirable than Use of Design and Construction Technologies and Operational Measures (40 CFR §125.95(b)(5)(i))

In connection with the prior renewals of its NJPDES Permit, PSEG thoroughly evaluated technologies, operational measures, and restoration measures. With the exception of the technological, operational, or restoration measures required under Salem's NJPDES Permits, no other technologies are feasible or cost-effective for application at Salem (NJDEP 1993b, 1994b, 2000b, 2001b). PSEG proposed restoring wetlands because the amount of *Spartina* marshes available as a food source and habitat would benefit the ecosystem of the Delaware in addition to offsetting the losses at the Station (PSEG 1993a; 1993b; 1994; 1999a, Appendix G, Attachments G-2 and G-3). The restoration of the formerly diked salt hay farms is more environmentally desirable than achieving compliance through additional technological or operational measures. NJDEP (2001b) recognized that the restoration of the salt hay farms would increase fish production in the Estuary and provide numerous other benefits.

This discussion focuses on past assessments by PSEG which have been reviewed by NJDEP and NJDEP's prior determinations on these criteria. This Application includes PSEG's current assessments. Section 6 provides detailed engineering evaluations of alternate technological and operational measures; the results confirm prior assessments. There are no technologies or operational measures that are feasible for installation at Salem at a cost that is reasonable, *i.e.*, not significantly greater than the value of benefits. PSEG has also demonstrated clearly in this RP and in Section 7 of this Application that the restoration of the former salt hay farms is more environmentally desirable than installing technologies.

1. Prior PSEG Assessments and NJDEP Determinations that Other Technologies are Not Feasible

PSEG conducted thorough evaluations of control technologies and operational measures in each of its §316(b) Demonstrations (PSEG 1984; 1991, Appendices J, K, L; 1993b, Appendices J, K, L; 1999a, Appendix F) (See also Section 6 of this

Application). The conclusions PSEG reached in these demonstrations have, to date, been confirmed by NJDEP (1993b, 1994b, 2000b, 2001b).

PSEG used a systematic approach for these evaluations. First, the full range of technological and operational measures was identified. Based on an initial screening, technologies and operational measures potentially available for installation were evaluated in detail to determine if they could feasibly be installed and operated.

Prior to issuing the 1994 and 2001 NJPDES Permits for Salem, NJDEP evaluated a variety of intake technologies for Salem in light of the site-specific factors and conditions at Salem. NJDEP determined that with the exception of the measures required under those Permits (*i.e.*, the improved modified-Ristroph screens and the studies to assess the feasibility of various behavioral deterrent systems), no other technologies were feasible for installation and operation at Salem (NJDEP 1993b, 1994b, 2001b).

In the Fact Sheet accompanying the 1993 Draft Permit, the Department specifically rejected closed cycle cooling, wedgewire screens, and fine mesh screens as not being feasible, given the site-specific circumstances at Salem (NJDEP 1993b).

PSEG has also conducted a comprehensive evaluation of technologies as part of this Application; this evaluation uses the same approach PSEG applied in its prior §316(b) Demonstrations. The following subsections summarize the information on the potentially available technologies that would have been biologically effective in reducing IM and E. The most current evaluation is presented in Section 6 of this Application.

(a) Wedge-Wire Screens

Although wedge-wire screens have been shown to be effective in reducing fish impingement and entrainment at several other power plants, PSEG's (1991, 1999a) assessment concluded that wedge-wire screens cannot be demonstrated to be an available technology for application at Salem for the following reasons:

- Salem's cooling water flow rate is more than five times the flow rate of any facility at which this technology has been applied;
- suspended solids and detrital loadings are substantial, increasing the potential for screen clogging; and
- substantial maintenance and biofouling control difficulties would occur; the kinds of organisms present in the brackish waters in the vicinity of Salem create the

potential for a significant biofouling problem and the submerged off-shore location of the screen elements would make maintenance difficult and costly.

NJDEP's consultants concurred with PSEG's assessment (ESSA 2000; Versar 1989); NJDEP concluded that wedge-wire screens are not an available technology given the volume of once-through cooling water used by the Station and potential for biofouling due to the Station's location (NJDEP 1993b). Due to the high degree of uncertainty regarding potential biological effectiveness and the ability to maintain wedge-wire screens in a condition that would not seriously impact Station operations, the wedge-wire screen alternative is still not considered to be an available technology for Salem (See Attachment 6-2 of this Application).

(b) Fine Mesh Screens

Although several different configurations of fine mesh screens have been installed and are in operation at other power plants, PSEG (1991, 1993b, 1999a) submitted detailed information explaining why this technology was not feasible for Salem. The decreased open surface area of the screens would present substantial operation and maintenance difficulties. Simple replacement of the existing screen panels with the fine mesh panels would not be an available technology due to the presence of severe biofouling and detrital loading conditions at Salem.

Based on an engineering evaluation, and considering the opinions of those suppliers actively engaged in the business of manufacturing fine mesh screens, using fine mesh screens applied over, or instead of, the existing larger mesh screen system is neither feasible nor cost effective at Salem. Therefore, NJDEP concluded that fine mesh screens are not an available technology for application at the Station since fine mesh screens may cause an overall increase in IM rates for early life stages of many species (NJDEP 1993b, 1994b).

2. Prior PSEG Assessments and NJDEP Determinations that Other Technologies and Operational Measures are Not Cost-Effective

As with the evaluations of feasibility, PSEG conducted thorough evaluations of the cost-effectiveness of control technologies and operational measures in its §316(b) Demonstrations (PSEG 1991; 1993b; 1994; 1999a, Appendix F). NJDEP retained independent contractors to review the 1999 cost-benefit evaluation. The conclusions PSEG reached in these demonstrations have, to date, been accepted by NJDEP. In addition, PSEG is presenting an updated cost-benefit analysis in the CDS (See IX below) and in Section 6 of this Application that confirms these prior conclusions.

(a) Costs of Installing Closed Cycle Cooling

PSEG (1984; 1993b; 1994; 1999a, Appendix F) and NJDEP (1993b, 1994b, 2000b, 2001b) have repeatedly concluded that the installation of closed cycle cooling towers is not cost-effective for Salem and the costs are wholly disproportionate to the environmental benefit to be realized. For example, in its 1991 Comments, PSEG estimated that capital expenditures for the retrofit ranged from $475 million for natural draft cooling towers to $625 million for mechanical draft towers. PSEG further estimated that annual operating and maintenance costs would increase by approximately $4 million. PSEG further indicated that the capital costs associated with installing a new 100 MW combustion turbine unit to replace the lost capacity alone are estimated at $41 million (PSEG 1991). NJDEP and its consultant, ESSA, concluded that installing closed cycle cooling is not cost-effective (NJDEP 1993b, 2000b, 2001b; ESSA 2000). For the 1999 NJPDES Permit application, PSEG (1999a, Appendix F) projected these costs to 1998 dollars to further assess the cost of retrofitting Salem with closed-cycle cooling towers. The retrofit, including construction and operation and maintenance costs, was estimated to be $712 million for natural draft towers to $849 million for mechanical draft towers. With the submission of this Application, the cost of installation of these towers was again assessed. Based on 2005 dollars, the natural draft towers would cost about $995 million and $1,019 million for mechanical draft towers. See Section 6 for further detail regarding the 2005 cost estimates.

PSEG (1991; 1993b; 1999a) (See Section 6 of this Application) has conducted detailed engineering studies to determine the cost of retrofitting Salem to operate with closed cycle cooling. The cost-benefit studies based on these engineering cost estimates concluded that the costs were either wholly disproportionate (PSEG 1991, 1993b, 1994, 1999a) or significantly greater (See IX below and Section 6 of this Application) than the benefits that would be realized. After reviewing PSEG's analyses, NJDEP (1993b, 1994b, 2000b, 2001b) concluded that the installation of closed cycle cooling towers is not cost-effective for Salem and is wholly disproportionate to the environmental benefit to be realized.

(b) Costs of Implementing Flow Reduction Plans

As part of its 1999 Application, PSEG again evaluated "seasonal flow reductions" as an intake protection technology. Specifically, PSEG considered a 10%, 25%, and 45% flow reduction coincident with periods of high biological productivity. NJDEP carefully considered flow reductions and could not justify requiring additional operational controls in Salem's 2001 Permit (NJDEP 2001b).

3. The Use of Restoration Measures is More Environmentally Desirable than Meeting the §316(b) Standard Solely Through the Use of Technological or Operational Measures

The restored salt hay farms are producing substantial benefits to the Estuary, as demonstrated in VII-E below. The restoration sites will continue to provide this increased production to the Estuary long after Salem ceases operations (PSEG 1993b; 1994; 1999a, Attachments G-2, G-3) (See also Section 7 of this Application for PSEG's current assessment). Two of the three restored wetlands are now self-sustaining salt marshes that can naturally function to accommodate the constantly changing and complex environment in which they reside.

The restoration, through the use of ecological engineering, has returned natural marsh function to more than 4,000 acres of formerly diked lands, allowing the sites to respond to variations in weather and tide levels (Teal and Weistan 2005). The restoration sites will continue to provide numerous benefits to the Estuary including: improved ecological diversity; increased habitat, refuge, and forage areas for aquatic and terrestrial wildlife; protection and enhancement of water quality; decreased stormwater flooding, reduced shoreline erosion and mosquito breeding habitat; and preservation of upland buffers and wetlands in perpetuity. When the substantial increase in the production of fish and shellfish associated with the marsh restoration is considered with the host of other benefits, PSEG has clearly demonstrated that restoring wetlands is more environmentally desirable than installing additional technological measures or implementing additional operations restrictions.

In addition to recognizing the increased production of fish and shellfish, the Department also acknowledged that the restoration would help to ensure the long-term protection of the ecology of the Delaware and provide critical habitat for numerous species of fish and shellfish (NJDEP 2001b). NJDEP (2001b) also recognized that the restoration effort also provides other important benefits including research, public access, ecotourism, education, and mosquito control.

C. Narrative Description of the Design and Operation of the Existing Restoration Measures that Produce Fish and Shellfish (40 CFR §125.95(b)(5)(ii))

This section of the CDS describes PSEG's restoration of former salt hay farms, which is the restoration measure PSEG is using in combination with existing design and construction technologies to demonstrate that it meets the §316 Standard for reductions in E and the Restoration Standards. It first provides a summary of PSEG's overall approach for the former salt hay farm restoration. It then describes, in greater detail, the specific design for each of the three former salt hay farm sites located in Dennis, Maurice River, and Commercial Townships.

1. Overview of PSEG's Wetlands Restoration and Preservation Program

PSEG, in conjunction with its team of nationally-recognized experts in wetlands ecology, coastal processes, and hydrology, developed its restoration approach based upon sound science and ecological engineering principles. The approach also incorporates appropriate metrics for monitoring the progress of the restoration and utilizes adaptive management as the means for making mid-course modifications to the restoration plan, as necessary. PSEG also developed a broad outreach program to involve scientists and engineers from governmental agencies and academia, local governmental officials in the three host communities and members of the general public in the process.

PSEG developed a systematic process to identify and secure wetland restoration sites in the Estuary. The evaluation process was conducted within a decision framework that balanced multiple, diverse factors and prioritized the sites for land acquisition. An inventory of the Delaware Estuary was initially developed through review of aerial photographs to quantify the extent of degraded wetlands potentially available for restoration. Additional priority restoration sites, including diked salt hay farms, were identified by the NJDEP. Following the initial evaluation, available resource documents were reviewed and field reconnaissance of potential sites was conducted to identify properties suitable for restoration.

Among the most suitable sites identified in the Estuary for restoration were diked salt hay farms. Diked salt hay farms were considered desirable for restoration since they had been intertidal salt marshes dominated by *Spartina alterniflora* until dikes were constructed to restrict tidal flow. Restricting tidal flow favored the production of marsh species such as *Spartina patens*, *Distichlis spicata*, and *Juncus gerardii* as an agricultural "salt hay" crop. Because these salt hay farms were isolated from the Delaware Bay by dikes, and the grasses were harvested by the farmer, the diked sites contributed little detritus to the food web of the Delaware Estuary. Isolation from tidal flow also resulted in a loss of habitat for transient marine fish species and created a public nuisance because of the extremely high mosquito production within these areas. Only five diked salt hay farms were present within the Delaware Estuary.

Following initial identification of the potential diked salt hay farm sites and preliminary landowner inquiries to determine availability for purchase, additional evaluations (including topographic surveys, flood potential studies, and field visits) were conducted on the three potential available sites for acquisition to determine tidal elevation ranges for each site and the suitability for restoration efforts. Based upon availability, salt hay farm sites in Dennis, Maurice River and Commercial Townships were acquired for restoration.

(a) Ecological Engineering

In the absence of human intervention, coastal marshes are naturally self-engineered ecosystems. They maintain themselves in the context of coastal geophysical processes, responding at effective temporal and spatial scales to changes in sea level, alterations of sediment input, and shifts in weather and climate. Because the number of parameters affecting coastal ecosystem structure is enormous, and because interactions among these parameters are very complex, natural, self-engineered systems are best able to accommodate the constantly changing environment. Therefore, PSEG relied upon ecological engineering in developing its plans for the restoration of the diked salt hay farms.

Ecological engineering is an integrated approach to environmental management pioneered by William J. Mitsch, Ph.D. and Sven E. Jorgensen in the late 1980s (Mitsch and Jorgensen 1989). Mitsch and Jorgensen developed the concept of ecological engineering as a strategic tool to help assure sustainable interactions between humans and the environment. For complex environmental management actions, such as PSEG's wetland restoration program, ecological engineering is the most effective and appropriate approach because it recognizes the importance of using human engineering to initiate and encourage natural processes which are then allowed to complete the restoration. Thus, ecological engineering assures that the ecosystem follows the most natural path, the path most likely to be stable into the future (PSEG 1999a, Attachment G-2).

Ecological engineering is defined (Mitsch and Jorgensen, 1989) as "…the design of human society with its natural environment for the benefit of both." The principles on which an effective ecological engineering program for wetland restoration is based are: 1) understanding wetland function; 2) giving the system sufficient restoration time; and 3) allowing for the self-designing capacity of the natural system (Mitsch and Wilson, 1996). PSEG's restoration program was founded on and maintains these principles (PSEG 1999a, Attachment G-2).

Ecological engineering (Mitsch 1995) has been an integral component of PSEG's restoration program from the initial planning phase. Wetland characteristics in the Delaware Estuary were investigated thoroughly before any restoration activities were undertaken. In selecting degraded wetlands for restoration, PSEG considered the relationship between tide levels and vegetation, including local effects of diking and *Phragmites* invasion (PSEG 1999a, Attachment G-2). The design approach set forth in the Management Plans using ecological engineering emphasized appropriate levels of engineering design and subsequent minimal site disturbance while maximizing the potential for a successful, self-sustaining wetland.

PSEG prepared site-specific designs following detailed investigation of geomorphological, hydrological, and biological conditions at each restoration site, as well as in adjacent natural marshes (*i.e.*, reference marshes). Taken together, the understanding of wetland function developed on both estuary-wide and site-specific bases allowed PSEG to optimize engineering parameters and maximize the opportunity for restoration success. Management Plans were scoped to incorporate the appropriate level of engineering necessary to allow natural engineering to take over the restoration process. For example, engineered creeks were designed for the low order tributaries (*i.e.*, larger marsh creeks) leaving the marsh to develop smaller creeks and microtopographic relief as appropriate to its own internal drainage pattern. In addition, seeds coming in with the tides formed the basis for revegetation of the sites. During the implementation of the designs, wetland scientists guided the construction to be sure that the restoration properly addressed environmental conditions and encouraged the natural processes (PSEG 1999a, Attachment G-2).

Individual site restoration Management Plans incorporated sufficient time for success, as determined by analysis of data on earlier restorations. Lag periods and vegetation recovery times were considered, and final restoration Success Criteria were developed after accounting for temporal processes (such as modes of plant reproduction and fauna colonization) that would affect the restoration period. It was anticipated that recovery would occur over a period of years following the completion of engineering activities on each site. PSEG’s AM Program was developed to monitor, guide, and respond to the temporal process of restoration by providing a means for implementing interim actions to help assure that final restoration goals are met (PSEG 1999a, Attachment G-2).

(b) Use of Reference Marshes

As part of the restoration program, PSEG selected two sets of reference marshes to serve different functions in the restoration program. The first set was used to understand how a natural, or naturally-restored, marsh functions on a multi-year basis to determine the time course for the success of the restoration efforts and to establish the bounds of expectation for the restoration sites (time course marshes). The second set has provided data for annual comparisons of the occurrence of flora and fauna at the restoration sites and, thus, provides a reference point for determining annual variations in marsh vegetation (annual monitoring reference marshes). The selection of both types of reference marshes required coordination with the regulatory and scientific communities, including the MPAC.

The time course marshes were selected from review of aerial photographs, historical records, and evaluation of tidal creek geomorphology, marsh history, and current marsh characteristics. A combination of pristine and “natural” restoration marsh areas that resulted from failure of historic tidal control structures was selected to determine the time necessary for complete restoration and to establish the bounds of expectation for the restoration sites. The marshes selected were Mad

Horse Creek, Fishing Creek, Oranoaken Creek, Moores Beach-West, and Wheeler Farm (See Figure VII-1). Based on conditions observed in these marshes, interim and final Success Criteria for hydrologic conditions and vegetative coverage were developed.

Selection of reference marshes for annual comparisons is essential to evaluate the success of the restoration efforts (Brinson 1993; Kentula *et al.* 1992; Kusler and Kentula 1990; Weinstein *et al.* 1997). A *Spartina alterniflora* dominated reference marsh (the Moores Beach-West reference marsh) was selected to serve as the basis for evaluating the restoration success of the salt hay farm wetland restoration sites.

A detailed discussion of the selection and use of reference marshes is contained in PSEG's 1999 Application (PSEG 1999a, Appendix G, Exhibit G-2-2).

(c) Management Plans

For each of the restoration sites acquired, a conceptual design was developed for incorporation into a Management Plan, as required by the 1994 NJPDES Permit (NJDEP 1994a). Management Plans were prepared for each site to provide an integrated framework for restoring the structure and function to the degraded wetlands and applying preservation measures to the associated upland buffers. The restoration designs used ecological engineering (Mitsch 1995), optimizing the level of engineering design and subsequent site disturbance while maximizing the potential for successful, self-sustaining wetlands. The Management Plans provided an overview of site conditions prior to restoration activities, identified design provisions for implementation, assessed potential environmental and off-site impacts, provided a schedule for implementation, identified Success Criteria, and established an AM Program designed to ensure the long-term success of the restoration process. The Management Plans were developed with in-depth advice and review of the MPAC and NJDEP and were approved by NJDEP.

Before implementing the Management Plans, all required federal, state, and local permits were obtained (See Table VII-2). Thereafter, construction, as dictated by the site-specific Management Plans and regulatory permits, was implemented. The Management Plans provided details on dike construction and maintenance procedures, tidal flow restoration techniques, property and roadway protection measures, and an anticipated schedule for natural re-vegetation.

The Management Plans provided both interim and final Success Criteria to measure the progress of the restoration activities. The Success Criteria provided definitive vegetation and hydrology milestones for each of the restoration sites. In addition, criteria have been established to evaluate negative impacts associated with the restoration process, including potential impacts to off-site resources. These Success Criteria were subsequently incorporated into USACOE and NJDEP Permits.

(d) Stakeholder Involvement in the Restoration Process

An essential aspect of the restoration process for each of the sites was the extensive stakeholder involvement in the design, implementation, monitoring, and restoration management processes. As part of the PSEG team, scientific experts and professional consulting firms assisted company representatives in collecting site-specific information and developing the Management Plans for each site. These activities formed the basis for the development plans subsequently reviewed by the stakeholders. Stakeholder participation through MPAC, MAC, local community involvement committees ("CIC"), and regulatory review was a key component in the development of the wetland restoration program.

Following the completion of the wetland restoration activities at the sites, continuing advisory committee involvement has been provided through EEPAC, with representation from both the previous MPAC and MAC. In total, there have been 37 MPAC, MAC, and EEPAC meetings held since 1994 at which independent scientists, scientists from regulatory agencies, and representatives of the public have had opportunities to provide input to the planning, design, monitoring, and evaluation of success of the wetland restoration program that has been implemented for Salem (See Table VII-1). This process also enabled NJDEP to listen to the technical and scientific dialogue of the scientists and ensure that any public concerns were properly addressed.

In addition to the MPAC and MAC described above, CICs were established in the New Jersey communities where restoration projects have been implemented. The CICs provided comments on the development and implementation of the Management Plans, with an emphasis on both the salt marsh restoration and public use aspects of the plans. In addition to the CICs, PSEG conducted at least one "open house" for each of the salt hay farm wetland restoration sites. The open house forum provided an opportunity for all residents of the community to review restoration plans and offer input.

The NJDEP regulatory review process associated with LURP permits also provided local, county, state, and federal agencies an additional opportunity for public comment and review of the wetland restoration plans. In many cases, the approval process required public hearings, providing an opportunity for the public at large to offer comments regarding site development plans. Table VII-2 provides a listing of all permit applications submitted and approvals received with respect to the wetland restorations at the salt hay farm sites. As listed in this table, more than 50 regulatory approvals from 9 regulatory bodies, including federal, state, county and local agencies, were necessary to implement the restorations at these sites.

In summary, stakeholder input in the development and implementation of the wetland restoration plans for the sites has been significant. Through the MPAC, MAC, EEPAC, CICs, regulatory bodies, and public hearings, the plans for wetland restoration activities have been subjected to review by a multitude of interests and are reflective of many of the concerns raised by stakeholders.

(e) Success Criteria and Adaptive Management

PSEG's wetland RP was developed to provide permanent ecological benefits to the Estuary. Salem's NJPDES Permit required PSEG to restore normal daily tidal inundation to the salt hay farm wetland restoration sites. Interim and final Success Criteria were established to define restoration success based on conditions observed at the "time course reference marshes" over a period of time. Both the interim and final Success Criteria address vegetation coverage and hydrologic criteria that define the ability of the site to contribute to the productivity of the Estuary.

As described previously, PSEG used the "time course reference marshes" to provide data on the pace and end point of wetland restoration at the salt hay farm sites. Review of available historical aerial photography for the time course reference marshes, which include undisturbed salt marshes and previously "self-restored" (by storms or human intervention) diked areas, established reasonable end-points for successful restoration. Based on these data, it was anticipated that the salt hay farm restoration sites should reach their targeted vegetative coverage end-points no later than the twelfth year following the completion of restoration activities. The vegetative criteria that were established as indicators of successful restoration were defined as follows:

- no less than 76% of the total restoration area at the sites in Dennis Township and Commercial Township will be colonized by desirable vegetation;
- no less than 66% of the total restoration area at the site in Maurice River Township will be colonized by desirable vegetation;
- open water and associated intertidal mud flat areas of the restored sites in Dennis and Commercial Townships will represent less than 20% of the total restoration area;
- open water and associated intertidal mud flat areas of the restored site in Maurice River Township will represent less than 30% of the total marsh area to allow for the potential continuation of valuable shorebird habitat at that site; and
- *Phragmites australis* coverage at all sites will be reduced to less than 4% of the total restoration area (5% of the total vegetated marsh plain).

PSEG's AM Program is based on expected restoration timelines (Weinstein *et al.* 1997) that provide an objective and systematic foundation for evaluating the program. Central to the adaptive management process is establishing criteria and thresholds to guide decisions and activities (Haney and Power 1996; Weinstein *et al.* 1997). This is particularly important in wetland restoration programs, where definitions of success and appropriate measurement techniques must be established to define whether objectives are met (Pacific Estuarine Research Laboratory 1990).

AM is an approach for monitoring, assessing and addressing the progress of restoration based on regular and documented observations of an adaptive management team ("AM Team") comprised of experts in tidal wetlands restoration and ecology. The AM Team's goal is to ensure marsh restoration success through the identification and reporting of threshold triggers and to develop corrective actions. PSEG's AM Team and/or site managers inspect the restoration sites periodically to evaluate site conditions that might ultimately interfere with restoration success. Specific inspections include: evaluating developing and existing vegetation and channels, and looking for indications of sediment erosion, poor drainage, sedimentation, or premature erosion of internal berms. Upon determination that corrective measures are necessary, PSEG, in consultation with members of the EEPAC and the appropriate resource management agencies, evaluates feasible alternatives for the resolution of an identified problem, and, after review and approval of the proposed corrective measure(s) by NJDEP, PSEG implements the appropriate corrective measures. Components of PSEG's AM approach have been published in the scientific literature (Teal and Weinstein 1999; Weinstein *et al.* 1997). The AM process is shown in Figure VII-2. Descriptions of threshold triggers established for vegetation coverage and hydraulic issues associated with the salt hay farm restorations are provided below.

A relatively rapid recolonization of the marsh plain by *Spartina* spp. and other desirable marsh vegetation with a concurrent reduction in *Phragmites australis* coverage was a primary focus of the marsh restoration effort at each of the salt hay farm sites. Anticipated recolonization rates were developed from scientific literature and from historic data to provide a frame of reference for the restoration progress. In order to prevent severe and/or persistent downward departures from the anticipated rates from leading to the failure to meet the established Success Criteria for each site, an annual vegetative threshold was established to trigger corrective action. For the salt hay farms sites, the threshold is met if the areal coverage of *Spartina* spp. with other desirable marsh vegetation does not increase at a rate of approximately 9% per year in two consecutive years (after an initial two year lag).

Because achieving the appropriate hydrology is essential for restoration success, several hydrologic thresholds were also established to ensure a natural tidal cycle was achieved in the restored marshes. The hydrologic thresholds that triggered further action include:

- Excessive Ponding - Because excessive ponding on the marsh surface at low tide will prevent recolonization of *Spartina* and other desirable species, standing water persistently remaining on more than 25% of the marsh plain during normal low tides after an initial two-year lag would trigger the AM process.
- Tidal Occlusion - For the restoration to meet its final objectives, persistent closure of either existing or engineered creeks would trigger further evaluation and possible implementation of the AM process.
- Internal Berms - The restoration design for the Commercial Township wetland restoration site incorporates low wave-damping berms inside the restoration area. Severe erosion of these berms, before vegetation is re-established (to a point where the marsh plain is stabilized) would trigger the AM process.
- Upland Flooding - Unanticipated flooding of upland areas outside the restoration areas is unlikely, but could occur as a result of storm water retention by upland berms or tidal flooding following restoration. In either case, the AM process would be triggered if extensive standing water is present on a persistent basis. Single-event flooding, *e.g.*, flooding associated with an exceptional storm, would not trigger corrective action. Repeat flooding associated with routine storm events would trigger the AM process.

Surpassing the thresholds would trigger further evaluation through the AM process, and the implementation of NJDEP-approved corrective measures, if appropriate. Also, additional data collection and/or corrective measures may be implemented as approved by the NJDEP at areas that are not progressing as anticipated or which are approaching a threshold limit. Because of the progress of the restoration effort at these sites, the thresholds based upon internal berms and upland flooding are no longer applicable. Potential corrective actions for the hydrologic and vegetative AM threshold triggers at the wetland restoration sites are discussed in this RP.

Interim vegetative and hydrologic criteria were also developed to document that progress was being made toward the final Success Criteria during the initial years following the completion of restoration activities at the sites. The interim vegetation coverage criterion for the salt hay farm wetland restoration sites was met when at least 45% coverage by *Spartina* spp. and other desirable marsh vegetation was attained after seven growing seasons. This time frame includes a two-year lag following the completion of restoration implementation activities to allow for the commencement of the revegetation process. Following the two year lag, an average of 9% increase in vegetation coverage annually was necessary to meet the 45% interim vegetation coverage criterion.

The interim hydrologic criterion was satisfied for each site when it was demonstrated that normal tidal flow had been established within three years following completion of restoration implementation activities. Documentation of tidal flow was based on measurement of water elevations (measured with tide gauges) and marsh plain elevation (measured by survey) to allow computation of hydroperiod. Other tidal flow documentation included measurement of several geomorphologic parameters, including the size (class) of tidal channels, the number and length of channels of each order, and their spatial density and shape. These characteristics affect flooding and draining of the marsh surface and habitat for fish.

(f) Monitoring

Pursuant to the 1994 NJPDES Permit, PSEG initiated a comprehensive BMP which had been reviewed by MAC and approved by NJDEP that included vegetative and hydrogeomorphology monitoring. An IBMWP was developed pursuant to the 2001 Permit. The IBMWP was reviewed by the MAC and EEPAC, and approved by NJDEP. The IBMWP includes a complete description of the vegetative and hydrogeomorphic monitoring program that PSEG implemented to evaluate the success of the wetland restorations.

i. Vegetation Coverage and Geomorphology

Marsh cover types (including aerial extent of *Phragmites*, *Spartina* spp., and other desirable, naturally occurring marsh vegetation; non-vegetated marsh plain; internal water areas; and open water) have been monitored based on aerial false color infrared digital orthophotography, a standard method for characterizing ecological habitats by remote sensing. Vertical (orthogonal) photographs have been taken once per year, typically in late August through early October at the end of the growing season. Information on the photographic film is transferred to a geographic information system and analyzed to determine the following parameters:

- *Phragmites* coverage;
- desirable vegetation coverage;
- development and extent of drainage channels;
- drainage channel configuration; and
- total area covered by standing water at low tide.

In addition, photographs are analyzed qualitatively for other parameters, including:

- location and extent of low tide;
- location and nature of unplanned breaches in perimeter dikes;

- condition of planned breaches in perimeter dikes;
- erosion of perimeter and internal dikes and berms;
- migration or other changes in inlet location and condition;
- drainage channel configuration and location; and
- erosion in drainage channels.

ii. Vegetation Production

Vegetation production has been monitored in sample quadrats from transects located systematically to represent various habitats and conditions at each site. During the late summer when the peak seasonal biomass is present, quadrats have been selected randomly and macrophyte vegetation (both live and dead standing stalks and leaves) has been clipped, dried, and weighed. The resulting value is called the “peak season standing crop biomass,” which has been used to estimate production. These data are presented in comparison to data from the appropriate reference sites and representative literature values.

Algal productivity and biomass were also monitored at selected sites in core samples taken from sediments along the vegetation sampling transects. Oxygen production has been measured under full light conditions and oxygen consumption has been measured under full dark conditions. Gross and net production were calculated from these oxygen flux measurements. Algal biomass has also been measured as chlorophyll and phaeophyton concentration by solvent extraction. These data documented that the sites were contributing to the productivity of the Delaware even prior to the establishment of macrophyte vegetative cover on the sites (PSEG 1999a, Attachment G-2).

iii. Hydrology

Hydrologic monitoring has been conducted at each of the restored sites to monitor the restoration of appropriate hydroperiod. Tidal range data were used in conjunction with representative marsh plain elevations to calculate hydroperiods at each site and to gauge the progress of the restoration. The objective of the monitoring program was to provide quantitative measurements of water surface elevations within each site. The tide gauges were positioned either in the marsh channels or upon the marsh plain at all wetland restoration sites. Gauges located in tidal channels were positioned to characterize the tidal elevations throughout the site. The gauges located on the marsh plain were positioned to provide direct measurements of water surface elevations adjacent to tidal creeks or at locations remote from the tidal creek. The tidal elevation data were used to calculate the hydroperiod that is representative of the marsh plain elevations in the area around each tide gauge (PSEG 1999a, Attachment G-2).

iv. Fish Abundance, Composition and Food Habits Studies

PSEG also monitored species abundance and community composition in restored and reference marshes in different salinity regimes as a “yardstick” of the progress of the restoration, and to examine length and weight relationships for individuals of a subset of the RS (*i.e.*, bay anchovy, weakfish, spot and white perch) collected in each marsh and from the nearshore Estuary (PSEG 1999a, Appendix G-3).

In addition, food habits of fish utilizing restored wetlands were monitored and compared to the food habits of fish utilizing reference marshes to determine the type and quantity of prey consumed by bay anchovy, weakfish, spot, and white perch when they are present in the restored wetlands.

2. Restoration Design Approach for Diked Salt Hay Farms

The restoration designs for the diked salt hay farms utilized ecological engineering, as described above, to create tidal changes that promoted access for fish to the marsh plain, provided the proper hydrology to promote re-vegetation by *Spartina* spp. and other desirable, naturally occurring marsh vegetation, and provided for the exchange of detritus between the restored marsh and the Estuary. The restoration design also included the acquisition and preservation of upland buffer at the sites.

(a) Overview of Design Concepts for Salt Hay Farm Sites

Diked salt hay farms were considered amenable for restoration since they were historically tidal salt marshes before impoundments were constructed to restrict tidal flow for the production of salt hay grass. The restoration designs for the diked salt hay farms used ecological engineering to most effectively re-establish conditions suitable for the growth of *Spartina alterniflora* and other desirable species, provide tidal exchange with the Delaware Estuary, and protect properties adjacent to the sites.

The restoration designs optimized the use of natural factors including channel size and shape, drainage patterns, and ratio of marsh plain to open water to encourage natural engineering of the site. The designs at these sites were focused on restoration of tidal exchange through breaching of perimeter dikes, excavation and construction of tidal channels and inlets, and development of upland protection dikes. The designs maximized the area of each diked salt hay farm that would be subject to the full tidal cycle and were developed to assure inundation of the marsh plain during the hours of rising tide and drainage of the areas during the hours of falling tide. Additionally, areas for colonization by high marsh species were also created by selective placement of material excavated from channels (PSEG 1999a, Attachment G-2).

Computer hydraulic models were used to develop the restoration designs to ensure adequate tidal inundation/drainage at each site. Data from local tide gauges, detailed topographic surveys concerning the density and cross-sectional area of tidal channels in relatively undisturbed marshes adjacent to the restoration sites, and the locations of historic sluice gates and drainage ditches were incorporated into the models as baseline conditions. The computer simulations were used to test designs that determined the channel locations and dimensions and the number of tidal inlets needed to provide inundation and drainage of the sites to result in conditions suitable for colonization by *Spartina* spp. and other desirable, naturally occurring vegetation (PSEG 1999a, Attachment G-2).

Upon receipt of all necessary regulatory approvals (See Table VII-2), construction activities were begun at each of the diked salt hay farms. The construction time for the diked salt hay farms ranged from 6 to 16 months. During the construction period, revisions to engineering designs were necessitated by unexpected or evolving field conditions, additional data collection, the onset of critical habitat time restrictions, and the presence of threatened/endangered species. Changes that resulted in variances from the approved restoration plans were submitted to the appropriate regulatory agencies for approval, in accordance with specific regulatory program requirements (PSEG 1999a, Attachment G-2).

During construction, the sites were frequently monitored by scientists with expertise in the fields of wetland ecology, coastal hydrology, and estuarine systems. The scientists' recommendations based upon their observations of site conditions often were incorporated in the construction process through interaction with design engineers, construction personnel, and PSEG representatives. In addition to the construction review, monitoring of the marsh restoration process by the scientists provided oversight to assure that construction was proceeding in accordance with ecological engineering concepts. Further, frequent site visits by a team of wetland scientists provided feedback to design engineers. The feedback was an important component of site construction and provided design and site engineers with the guidance to make field adjustments consistent with environmental conditions found at the site (PSEG 1999a, Attachment G-2).

Once construction activities were completed, monitoring was begun to measure the effectiveness of the program to restore *Spartina* spp. and other desirable, naturally occurring marsh vegetation at the sites, reduce *Phragmites* coverage, and ensure appropriate hydroperiod on the marsh plain.

Following the completion of restoration construction, AM has been used to identify techniques to facilitate the natural formation of new minor channels and improve drainage of the sites. Activities that have been implemented subsequent to the completion of construction have included cleaning and widening of channels, channel notching, and temporary plugging of breaks in regional berms.

In addition, the incorporation of upland buffers into the design provided added ecological value to the restoration. Upland buffers are a key transitional habitat zone within the larger ecosystem of each restoration site. The buffer zone is an interface of terrestrial, brackish, fresh, and salt water environments. As the transitional zone between terrestrial and tidal environments, the buffer zone has a special bi-directional character for flows of energy, water, and materials between the tidal and terrestrial systems. Due to the exchange, the buffer zone plays an important role in primary productivity, secondary productivity, habitat diversity, water quality and water quantity effects (flood attenuation, flood storage, etc.). Upland buffers also provide space for the migration of salt marshes as sea level rises. Consistent with the integrated, ecosystem approach used in the restoration process, inclusion and protection of upland buffers has been an important consideration during the design of the diked salt hay farm restoration sites.

(b) Individual Site Designs for Diked Salt Hay Farms

As previously described, PSEG acquired three former diked salt hay farms for restoration. These sites are located in Dennis Township, in Cape May County, and in Maurice River Township and Commercial Township, both in Cumberland County (See Figure VII-3).

Although the restoration objectives for the three salt hay farms were similar in design and intent, different challenges were present at each site as a result of prior use patterns, environmental conditions, and socio-economic setting. The Commercial Township site has complicated hydrology, an expansive bayfront, and several hundred residences located in relatively close proximity. In contrast, the Dennis Township site has few residential or commercial properties nearby. The Maurice River Township site, also with few residential or commercial properties nearby, experienced dike breaches before PSEG acquired the site, resulting in inefficient tidal drainage and large areas of standing water. Each of these conditions resulted in site-specific engineering considerations that were incorporated into the final designs for each site.

Detailed descriptions of the wetland restoration activities that were implemented at each of the salt hay farm sites are provided in the following sections.

i. Dennis Township Restoration Site

DTRS covers 578 acres of wetlands and adjacent uplands and is located in Dennis Township, Cape May County, NJ. The site is bordered by West Creek on the west, the West Creek Gun Club on the north, East Creek on the east, and the Delaware Estuary on the south. Perimeter dikes were built around this area during the 1950s, eliminating normal tidal inundation over the entire site. During the 1980s, salt hay farming was abandoned on an approximately 195-acre area located between the West Creek Gun Club and East Creek due to the development of storm-related breaches in the perimeter dikes. Approximately 369 diked acres continued to be farmed for salt hay until acquired by PSEG as a wetland restoration site in 1995. This area constitutes the wetland restoration area at DTRS. In addition, there are 15 acres of upland buffer.

Figure VII-4 illustrates pre-restoration vegetation communities at DTRS. At that time a few minor breaches had developed in the perimeter dikes that resulted in flooding and ponding of the salt hay fields and the beginning of a return of desirable low marsh vegetation. The engineering design for restoration is depicted on Figure VII-5.

Six inlets in the perimeter dikes and approximately 17,000 ft (5,182 m) of larger drainage channel systems were incorporated into the design for the DTRS. The channels were excavated by hydraulic dredge or by other appropriate equipment and connected to existing channels within the site. The creation of major channels allowed tidal flow reintroduction from the new inlets to be conveyed throughout the restoration site. The excavated channels were designed to be trapezoidal in cross-section to promote the formation of gently sloping banks (to provide access to the adjacent marsh plain for small fish and crabs) and had a bottom elevation approximately one to two feet below mean low water to provide subtidal habitat for use by fish during low tide. Channels were also designed to limit flows during the normal tidal cycle to velocities below 2 fps to control sediment erosion. Breaches in the perimeter dikes for inlet formation were made after the channel excavation was completed to control the potential for erosion during construction.

Material excavated from the channels (approximately 85,000 cubic yards [64,987 m^3]) was used to fill areas of the site with sub-optimal elevations for growth of low marsh vegetation (*e.g.*, areas that would have been below mean tide elevation) and to establish marsh elevations for the establishment of high marsh species such as *Spartina patens*. Additional excavation material was used to construct dredge spoil containment areas, to fill in approximately 16 acres of open water ponds, and to construct a new upland dike to protect adjacent property owners and roadways from off-site flooding. The upland protection dike was constructed to a minimum elevation of 7.5 ft (2.3 m) NAVD. To minimize erosion, the dike was seeded with native grasses. Construction activities were conducted from February 1996 to August 1996.

The status of the restoration is presented below.

ii. Maurice River Township Restoration Site

MRTRS encompasses approximately 1,396 acres of wetlands and adjacent uplands and is located on either side of Thompson's Beach Road in Maurice River Township, Cumberland County, NJ. As early as 1810, perimeter dikes were constructed and water control structures were installed to eliminate normal tidal inundation over the area. As recently as 1992, a large portion of the farming area was vegetated with salt hay, extending inland from Thompson's Beach (on Delaware Bay) approximately 1.5 mi (2.4 km) and bounded on the east by Riggins Ditch and on the west by what is locally known as Adlers Ditch. Large areas of the site were also vegetated with dense stands of *Phragmites australis*. Unplanned breaches in the perimeter dikes developed subsequent to 1992 that resulted in uncontrolled flooding of the farming area as well as adjacent forest lands and elimination of the salt hay vegetative cover. This flooding occurred because these breaches were not associated with an interior channel system that allowed for a natural exchange of tidal flows. These pre-restoration vegetation features are depicted in Figure VII-6.

The restoration area at the MRTRS includes 1,135 acres. In addition, the site has 108 acres of upland buffer. Changes in the hydraulic characteristics of the site, implemented to restore tidal exchange and reduce open water pondings provided conditions suitable for development of low marshes dominated by *Spartina alterniflora*, as well as high marsh species (*e.g.*, *Spartina patens*). The engineering design for MRTRS restoration is depicted on Figure VII-7.

Hydraulic modeling conducted as part of the engineering design for this site indicated that widening of the existing breaches in the bayfront dike, the construction of two additional breaches in the perimeter dike and creation of new channel systems connecting to all four breach locations would provide the desired tidal exchange and maintain tidal flow velocities below those that would cause significant erosion. The construction of the additional breaches and interior channel system would also reduce the areas of ponded water at low tide and promote the growth of *Spartina alterniflora* on the extensive mud flats present

Four inlets and approximately 40,000 linear ft (12,192 m) of new channels were included in the design for MRTRS. The channels were excavated by hydraulic dredge or by other appropriate equipment and connected to existing channels within the site. The material excavated from the channels (approximately 518,000 yds^3 [396,039 m^3]) was used to fill existing drainage ditches that did not provide the desired tidal flow routing or to stabilize areas of the wetland to minimize future erosion or dike breaching. Fill was also used to create four areas, totaling approximately 110 acres, designed to provide high marsh habitat. The excavated channels were designed to be trapezoidal in cross section to promote the formation of gently sloping banks (to provide benthic habitat and fish access to the adjacent marsh plain) and had a bottom elevation approximately one to two feet below mean low water to provide subtidal habitat for use by fish during low tide. Channels were also designed to limit flows during the normal tidal cycle to velocities below 2 fps to control sediment erosion.

An upland dike was constructed between the wetland restoration area and one adjoining residential property. The dike provides flood protection to the property owner consistent with the level of protection provided before perimeter dikes at the site breached. Thompson's Beach Road, from Glade Road to the public access area, was also raised to provide continued access to public use facilities and maintain normal tidal flows within the wetland restoration area boundary along the western edge of the residential property. There are no other upland dikes at the site.

The status of the restoration and a discussion of AM at MRTRS is provided below.

iii. Commercial Township Restoration Site

CTRS covers approximately 4,171 acres in Commercial Township, Cumberland County, NJ. The site is situated along the shoreline of Delaware Bay at the northern margin of Maurice River Cove, approximately 18 mi (29 km) northwest of Cape May Point. The site is bounded to the east by the Village of Bivalve and the Maurice River; to the south by the Delaware Estuary; to the west by Dividing, Indian, and Hansey Creeks; and to the north by rural properties and the Village of Port Norris. The wetland restoration area at CTRS encompasses 2,894 acres and the site includes 339 acres of preserved upland buffer. An additional 938 acres within the preserved site boundary includes primarily wetland areas not requiring restoration improvements.

The CTRS is located along the Delaware Bay between Dividing Creek and the Maurice River and had been farmed for salt hay production for at least three generations. Prior to 1995, the site was vegetated predominantly by high marsh species such as *Spartina patens*, *Distichlis spicata*, and *Juncus gerardii* as well as *Phragmites australis*. In 1996, flooding of approximately half (48%) of the CTRS had occurred because of unplanned breaching of the perimeter dikes. The result of these breaches was expansive areas of standing water within the site, as the interior channel system present was inadequate to provide proper drainage to the Delaware Bay.

Limited salt hay farming was practiced on some un-flooded areas in the western portion of the site through the 1996 growing season. These pre-restoration vegetation features are depicted in Figure VII-8. The engineering design for restoration is contained in the site-specific Management Plan and is depicted on Figure VII-9. Hydraulic models used during preparation of the engineering design indicated that the restoration of normal tidal flow could be achieved by excavating channels leading inward from the inlets and connecting with existing channels at the site. The design for restoration included the formation of inlets, excavation of primary channels, creation of high marsh areas and internal berms with the excavated material, and construction of upland dikes where necessary.

Ten inlets and approximately 75,430 linear ft (22,991 m) of new channels were incorporated into the design for the CTRS. Major new channels were planned in a manner that would encourage minor channels to develop naturally. The major channels were excavated by hydraulic dredge or by other appropriate equipment and connected to existing channels within the site. The material excavated from the channels (approximately 886,000 yds^3 [677,396 m^3]) was used to create high marsh areas within the site. The excavated channels had a bottom elevation of approximately one to two feet below mean low water to ensure that subtidal habitat would be available for use by fish during low tide. The excavated channels were constructed to be trapezoidal in cross section to promote the formation of gently sloping banks (to provide benthic habitat and fish access to the adjacent marsh plain). Breaches in the perimeter dikes for inlet formation were made after the channel excavation was completed to reduce the potential for erosion during construction.

Internal berms were created within the restoration area to form hydraulic barriers between historic drainage regions, reduce wave action and wind fetch, and promote sediment deposition. Two types of internal berms were constructed: regional berms and fetch berms. Regional berms were generally oriented perpendicular to the shoreline and were constructed to an elevation of three feet North American Vertical Datum 1988 (“NAVD”). The purpose of the regional berms was to maintain distinct drainage areas until the marsh plain revegetated. Fetch berms were generally oriented parallel to the shoreline and were constructed to an elevation of two feet NAVD. As this site includes approximately three miles of bayfront, the fetch berms were constructed to minimize wind-driven waves across the site until the marsh plain was stabilized through re-vegetation, and to accelerate sediment accumulation. The regional berms and fetch berms were not intended to be permanent site features, but were intended to facilitate revegetation of the marsh plain.

To provide flood control protection comparable to pre-breach conditions, upland dikes were designed between adjacent low lying properties and the wetland restoration area. Three factors were evaluated to determine the designed crest elevation for the upland dikes (6 ft [1.8 m] NAVD): 1) the designed water surface elevation for the restoration site; 2) the height of breaking waves; and 3) the height of wave run-up on the dike face. The upland dikes were constructed using off-site material to have a top width of between five and ten feet and side slopes ranging from 3H:1V to 4H:1V. To prevent flooding of upland areas, cross-drains equipped with tide valves were installed in the upland dikes. The foot of dikes exposed to wave action at high tide were protected with broken clam and oyster shells to prevent erosion. The construction phase (*e.g.,* dredging, dike breaching) of the wetland restoration started in the fall of 1996 and was completed in the fall of 1997, returning daily tidal flows to the site.

The status of the restoration of the CTRS and AM activities are provided below.

(c) Restoration Status

The success of the restorations at each of the salt hay farm sites has been assessed based on the interim and final Success Criteria established for each of the sites (See VII-C-1 above). A summary of the restoration status with regard to these criteria as well as other aspects of the restoration process at the three sites are presented in the following sections.

i. Dennis Township Restoration Site

The construction phase of restoration at DTRS was completed in late August 1996. The dates established for meeting the interim and final vegetation coverage Success Criteria were October 2003 and October 2008, respectively. DTRS met the interim and final Success Criteria well in advance of the dates anticipated in the Management Plan for this site. Due to the rapid establishment of *Spartina alterniflora*, and the natural reduction of *Phragmites*, that occurred in the years following the completion of restoration, this site met the final vegetation coverage Success Criteria in 2000, eight years ahead of the anticipated schedule (See Figure VII-10). Relevant aspects of the restoration process that led to successful restoration at this site are summarized in the following paragraphs.

As discussed previously, a two-year lag period following the restoration of tidal flow was expected prior to the occurrence of measurable vegetative cover. During the 1997 to 1998 period, normal tidal hydrology was established at DTRS. The appropriate periods of tidal inundation and drainage of the marsh plain to promote sedimentation and the recruitment of seeds from nearby sources occurred early in the restoration process. As a result, the interim hydrologic criterion (which required that normal tidal flow be demonstrated at the end of the third year following completion of restoration, or in 1999) was actually satisfied in 1998.

The successful revegetation of DTRS has been documented through annual monitoring of vegetation coverage at the site. Following the completion of restoration activities in 1996, monitoring indicated that areas of unvegetated mudflat and shallow ponded water occurred over much of the site. The interim vegetative criterion for DTRS required that • 45% of the marsh plain (36% of the total marsh) be colonized by *Spartina* spp. and other desirable marsh vegetation by 2003. As indicated above, the establishment of normal tidal hydrology resulted in rapid recruitment of seed from adjacent marshes following the completion of restoration construction and by the end of the 1997 growing season, establishment of desirable vegetation had begun. As a result, *Spartina* spp. and other desirable species coverage accounted for 79% of the total marsh by 1998, and desirable species coverage has ranged between 80% and 87% of the total marsh between 2000 and 2004 (See Table VII-3; Figure VII-10). In addition to *Spartina alterniflora*, other salt marsh plants observed to have colonized the restored marsh include: *Spartina patens, Distichlis spicata*, *Eleocharis* spp., *Iva frutescens,* and *Limonium carolinianum.* The extent of *Phragmites australis*, on the other hand, has been reduced from 16% of the site in 1995 to less than 2% of the restoration area in 2004 (See Table VII-3; Figure VII-10).

The success of the restoration at DTRS can also be demonstrated by the development of the channels that provide habitat for estuarine fish and other organisms and provide a pathway for the export of detrital material to the Delaware. During 1997, the first growing season following restoration activities, only six primary channels occurred within the restoration area and only six channel classes. These were the constructed channels that initiated tidal exchange with the Estuary. Consistent with the ecological engineering approach that was incorporated into the restoration design, smaller channels developed as the marsh plain has continued to evolve. By 1999 (the first year that followed the two-year lag period that was anticipated for tidal hydrology to develop), the number of channel classes increased to 20, and has remained relatively constant until 2004, when it increased to 29 (See Table VII-4).

The development of smaller channels within the site is evident by the increase in average channel density (linear feet [or meters] of channel within an acre [or square meter] of marsh). PSEG has determined the average channel density at the DTRS annually based on mapping of channels as small as one meter in width based on stereoscopic interpretation of false color infrared aerial photographs (the same photographs utilized to map vegetation cover). Based on this mapping, the drainage density was only 180 ft/acre (0.01 m/m^2) in 1997. However, by 1999 the drainage density had increased to 528 ft/acre (0.04 m/m^2); and further increased to 783 ft/acre (0.06 m/m^2) by 2004 (See Table VII-4; Figure VII-10). The development of channels within DTRS is also documented by the increase in internal water areas, from approximately 2% of the restoration area in 1997 to over 5% in 2004 (See Table VII-

3). These data document that a channel network has developed at DTRS that will continue to provide optimum flooding and drainage of the adjacent marsh plain for aquatic organism access to the marsh and for detrital and nutrient exchange with the Delaware Estuary.

The success of the wetland restoration at DTRS is further indicated by the fact that only limited AM activities were required to complete the restoration. Following the completion of restoration activities, notching of the marsh plain was performed in a few locations to facilitate drainage of small ponded areas at low tide. No AM triggers were reached or exceeded at the DTRS site.

ii. Maurice River Township Restoration Site

The construction phase of restoration at MRTRS was completed in March 1998, and the dates established for meeting the vegetation coverage Success Criteria were October 2004 for the interim and October 2009 for the final. Due to the rapid establishment of *Spartina alterniflora* that occurred in the years following the completion of the construction, this site met the final vegetation coverage Success Criteria (71% coverage) in 2001, eight years ahead of the anticipated schedule (See Table VII-5; Figure VII-11). Relevant aspects of the restoration process that led to successful restoration at this site are summarized in the following paragraphs.

As discussed previously, a two-year lag period following the restoration of tidal flow was expected prior to the occurrence of measurable vegetative cover. During the 1998 to 1999 period, normal tidal hydrology was established at the MRTRS. Thus, the appropriate periods of tidal inundation and drainage of the marsh plain to promote sedimentation and the recruitment of seeds from nearby sources occurred early in the restoration process. As a result, the hydrologic criterion (which required that normal tidal flow be demonstrated at the end of the third year following completion of restoration, or in 2000) was actually satisfied in 1998.

The successful revegetation of MRTRS has been documented through annual monitoring of vegetation coverage at the site. Following the completion of the construction activities in 1998, monitoring indicated that areas of unvegetated mudflat and shallow ponded water occurred over much of the site. The interim vegetative criterion for MRTRS required that • 45% of the marsh plain (36% of the total marsh) be colonized by *Spartina* spp. and other desirable marsh vegetation by 2004. As indicated above, the establishment of normal tidal hydrology resulted in rapid recruitment of seed from adjacent marshes following the completion of restoration construction, and by the end of the 1998 growing season widespread establishment of *Spartina alterniflora* had begun.

High marsh species, such as *Spartina patens* and *Distichlis spicata*, also established on limited higher-elevation areas of the site (*e.g.*, high marsh fill areas). *Spartina* spp. and other desirable species coverage accounted for 59% of the restoration site by 1999, and desirable species coverage has remained between 69% to 72% of the total marsh between 2001 and 2004 (See Table VII-5; Figure VII-11). As a result of the rapid establishment of *Spartina* spp. and other desirable species cover at the site, mud flat and unvegetated marsh plain cover categories declined from a total of over 70% in 1996 to approximately 20% in 2001 through 2004. The extent of *Phragmites australis* has also been reduced from 7% of the restoration area in 1996 to less than 2% in 2004.

The success of the restoration at MRTRS can also be demonstrated by the development of the channels that provide habitat for estuarine fish and other organisms and provide a pathway for the export of detrital material to the Estuary. Prior to restoration, the marsh plain remained ponded or saturated for long periods as there was no network of channels to provide drainage of the site to the Estuary at low tide. The restoration implemented by PSEG created four primary channels leading to inlets and 14 secondary channels that provided for tidal exchange with the Delaware Estuary. By 2000, the first full growing season following the expected two-year lag period, 6 primary channels were present at the site and 19 channel classes; and by 2004, the number of channel classes increased to 34, providing a developed channel network for tidal exchange (See Table VII-6).

The development of smaller channels within the site is evidenced by the increases in average channel density. PSEG has determined the average channel density at the MRTRS annually based on mapping of channels as small as one meter in width based on stereoscopic interpretation of false color infrared aerial photographs (the same photographs utilized to map vegetation cover). Based on this mapping, the drainage density was only 40 ft/acre (0.3 cm/m^2) prior to restoration (See Table VII-6; Figure VII-11). Consistent with the ecological engineering approach that was incorporated into the restoration design, smaller channels developed as the marsh plain continued to evolve, and in 2000 the drainage density had increased by an order of magnitude to 415 ft/acre (0.03 m/m^2); and further increased to 567 ft/acre (0.04 m/m^2) by 2004 (See Table VII-6). These data document that a channel network has developed at the MRTRS that will continue to provide optimum flooding and drainage to the adjacent marsh plain for aquatic use and detrital and nutrient exchange to the Delaware Estuary.

The success of the wetland restoration at MRTRS is further indicated by the fact that no AM triggers were reached or exceeded at the site. No AM actions were required to complete the restoration.

iii. Commercial Township Restoration Site

The construction phase of restoration at the CTRS was completed in late November 1997, and the dates established for meeting the interim and final vegetation coverage Success Criteria are October 2004 and October 2009, respectively. Establishment of desirable vegetation has occurred at anticipated rates in the years following the completion of restoration. This site met the interim vegetation coverage Success Criteria in 2004 (See Table VII-7; Figure VII-12), and, based on 2005 field observations, is on track for meeting the final Success Criteria on or ahead of the anticipated schedule. Relevant aspects of the restoration process at this site are summarized in the following paragraphs.

As discussed previously, a two-year lag period following the restoration of tidal flow was expected prior to the occurrence of measurable vegetative cover. Tidal inundation measurements in 1999 documented that the hydrologic Success Criteria had been met. During the 1998 and 1999 AM inspections at CTRS, ponded areas within Region 3C were observed at low tide - indicating that drainage enhancements were necessary in order to promote re-vegetation by *Spartina* spp. Following the recommendation of the AM Team, and with EEPAC concurrence, PSEG performed notching and drainage ditch improvements during 2000 and 2001. These minor improvements provided for improved drainage to enable appropriate hydroperiod within these localized areas of the marsh plain.

The revegetation of CTRS has been documented through annual monitoring of vegetation coverage at the site. Following the completion of restoration activities in 1997, monitoring indicated that areas of shallow ponded water (flooded salt hay fields) and *Phragmites australis* occurred over much of the site. Establishment of adequate tidal drainage and re-vegetation by *Spartina alterniflora* has proceeded across the site from the southwest corner and bayfront toward the northeast, as was anticipated based on pre-construction surface elevations. Areas that were initially ponded have progressed to areas of mudflat, then mudflat with *Spartina alterniflora* to areas dominated by *Spartina alterniflora*. This revegetation is evidenced by an approximately 1,017-acre increase in *Spartina* spp. and other desirable marsh vegetation coverage from 1997 to 2004 (See Table VII-7; Figure VII-12).

During 2004 approximately 40% of the marsh was vegetated by *Spartina alterniflora* and other desirable species. An additional 417 acres or approximately 15% of the marsh was determined to be mud flat areas supporting developing stands of *Spartina alterniflora*. The improved drainage in Region 3C is also indicated by 2004 cover type mapping, which indicates that ponded water on the site decreased by approximately 130 acres from that present in 2003. It is anticipated that this region of the site will re-vegetate with seedlings and scattered clumps of *Spartina* spp. during the next several growing seasons. A further example of the success of the restoration at CTRS is the reduction in areas of *Phragmites*-

dominated marsh, which originally covered 1,232 acres (43%) of the wetland restoration area. *Phragmites*-dominated marsh was reduced to 135 acres (<5% of the total marsh area) as measured in 2004 (See Table VII-7; Figure VII-12).

The interim vegetative criterion for CTRS required that • 45% of the marsh plain (36% of the total marsh) be colonized by *Spartina* spp. and other desirable marsh vegetation by 2004. Although the interim vegetation criterion has been met, annual increases in vegetation coverage have been less than the 9% established as a threshold trigger. Vegetation mapping data for 2003 and 2004 indicate that the coverage of *Spartina alterniflora* has increased approximately 4% during this period. Based upon the rates of vegetation coverage that occurred at the DTRS and MRTRS once natural drainage was achieved, the increase of *Spartina* spp. coverage at CTRS is not expected to be linear over the forthcoming years, and it is anticipated this site will meet the final vegetative Success Criteria on or ahead of schedule.

The success of the restoration at CTRS can also be demonstrated by the development of the channels that provide habitat for estuarine fish and other organisms and provide a pathway for the export of detrital material to the Delaware Estuary. Since most of the site was flooded salt hay fields prior to restoration, there was essentially no internal channel system other than drainage ditches. The development of smaller channels within the site that followed restoration of tidal exchange with the Estuary is evidenced by the increases in average channel density. PSEG has determined the average channel density at the CTRS annually based on mapping of channels as small as one meter in width based on stereoscopic interpretation of false color infrared aerial photographs (the same photographs utilized to map vegetation cover). Based on this mapping, the drainage density was only 97 ft/acre (0.7 cm/m^2) in 1998 (See Table VII-8).

The continuing development of a natural drainage system within CTRS is indicated by increases in channel density in 2000 (188 ft/acre [0.01 m/m^2]), 2002 (374 ft/acre [0.03 m/m^2]), 2003 (476 ft/acre [0.04 m/m^2]), and 2004 (601 ft/acre [0.05 m/m^2]) (See Table VII-8; Figure VII-12). The number of classes of channels has also increased from 7 in 1997 to 42 in 2004. As a result of these increases in channel density and number of channel classes, the area of ponded water at CTRS has been reduced from 1,668 acres in 1997 to only 92 acres 2004. These data document that a channel network is developing at CTRS that will continue to improve flooding and drainage to the marsh plain for aquatic use and detrital and nutrient exchange to the Delaware Estuary.

D. Ecological Benefits of PSEG's Wetlands Restoration Measures For Fish Production (40 CFR §125.95(b)(5)(iii))

The implementation of the EEP has substantially increased the production of fish and shellfish by restoring degraded salt marshes within the Estuary; these marshes supply food sources and habitat including nursery and refuge areas. The intertidal marsh is itself an integrated wetland system that provides the most direct spatial link between land and the coastal waters. It is this wetland system that is the primary driver for the productivity of the entire coastal system (See Section 7). In fact, it is thought that more than half of the United States' fishery (Demers *et al.* 2000) and two-thirds of the world's fishery (Vega-Cendejas and Arreguin-Sanchez 2001) are directly dependent on estuaries.

1. Estuary-Wide Benefits to Fish and Shellfish

PSEG's salt-hay farm restoration program has increased primary production thus increasing the food source to and productivity of fish and shellfish in the Estuary. Food webs in healthy tidal marshes are of two fundamental types: grazing (on living plant material) and detritus-based (via decomposition) (Vernberg 1993). Grazing pathways involve direct consumption (herbivory) of macrophytes, like marsh grasses, as well as microscopic and macroscopic algae. Grazing on marsh grasses, such as *Spartina* spp. and *Scirpus* spp., is responsible for only about 9% of net primary production (Pfeiffer and Wiegert 1981). However, grazing by invertebrates and fish on bottom dwelling (epibenthic) and grass-stem dwelling (epiphytic) microscopic and macroscopic algae is a quantitatively important process in tidal marshes (Vernberg 1993).

Most of the energy from primary production in healthy coastal wetlands is passed through the food web via the detritus pathway. "Detritus" is the technical term for plant material that is decomposing and inhabited by a great variety of fungi, bacteria, yeasts, protozoans, nematodes, and other microscopic organisms that break down the plant material. It is largely the bodies of the decomposer organisms that serve as food from detritus.

In tidal marshes, standing dead shoots and leaves of *Spartina alterniflora* and other desirable, naturally occurring marsh vegetation are partially decomposed in place, and this energy is transferred to the marsh food web (Currin *et al.* 1995; Newell and Barlocher 1993) (See Section 7 of the Application). The remainder falls to the marsh surface and is decomposed in and on the sediment by microbes and invertebrates (Vernberg 1993). Energy from the plants is passed up the food web when the detritus (including the decomposer organisms) is eaten by other animals such as worms, snails, crabs, and fish that are in turn eaten by larger crabs and fish.

Decomposition of below-ground components of wetland grasses is of major importance in marsh energy flow. Decomposition within the sediment occurs at rates comparable to that of aerial parts of the plants (White and Howes 1994), and below-ground detritus can be a large component of the overall marsh food web (Howes *et al.* 1985). Below-ground biomass is passed up the food web via decomposition and a substantial portion is available to the aquatic web (Howarth and Teal 1980).

(a) Fish and Shellfish Depend Upon the Linked Estuarine and Near Shore Coastal Marine Ecosystems

The ecosystem within the Estuary provides a complex web of linked physical, chemical, and biological processes that impact the populations of fish and shellfish that live and visit the Estuary. For example, warmer water and favorable oxygen and salinity conditions contribute to the value of tidal wetlands and estuarine shallows as nursery areas enhancing growth and survival of fishes (Necaise *et al.* 2005; Peterson *et al.* 2004). Also, the physical structure (*i.e.*, marsh area and edge occurrence) also plays an important role in the overall contribution of the tidal marsh to fish production (Kneib 2003). The EEP has greatly increased marsh areas and therefore improved the physical structure of the Estuary, thus increasing fish and shell fish productivity. Further, the vegetation that is now available to the Estuary provides a direct supply of energy to microbes and invertebrates that breakdown this material into detritus, which is then available for consumption by fish and shellfish.

Research (Kwak and Zedler 1997; Riera *et al.* 2000; Wainwright *et al.* 2000) confirms that tidal marsh macrophytes contribute substantially to the secondary production of fish and shellfish in estuaries. Specifically, it is via detritus that much of the vast production of plant material from tidal wetlands enters the estuarine food web and provides trophic support to fish and shellfish. Productivity is high in these systems because “consortia” of primary producers “maximize use of available light and space,” nutrients are abundant, and tidal energy and circulation distributes resources effectively (See Section 7 of this Application). This increased primary production supports the high densities and biomasses of consumer fish and shellfish found in the Estuary.

Moreover, linkage to the wetlands is maintained in the food web as the larger species age and switch to a diet consisting primarily of forage fish (forage fish species feed throughout their lives on the estuarine invertebrates whose production is, in turn, allied closely to the tidal wetlands).

The linkages among coastal habitat components are critical for the production of fish and shellfish (See Section 7 of this Application). For instance, Simenstad *et al.* (2000) characterizes forage fish and other mobile organisms, such as crustaceans, as accounting for major fluxes of organic matter and nutrients associated with the Estuary; dissolved material is taken up by coastal plankton and then rapidly taken up by consumers (primarily filter feeding crustaceans); and fine particles are aggregated and passed to the benthos where the invertebrate community utilizes it for nutrient and energy resources (See Section 7 of this Application). These linkages all contribute to the intricate estuarine cycle that supports and promotes the production of fish, shellfish, and various other aquatic resources.

(b) Numerous Species Throughout the Estuary, Including the RS Identified in the IMECS, Derive Energy from Salt Marshes

Direct dietary linkages exist between the early life history stages of species affected by IM and E at Salem and the tidal wetlands of the Delaware Estuary. The early life history stages of resident and seasonally present RS, such as weakfish, striped bass, white perch, spot, Atlantic croaker, bay anchovy, and Atlantic silverside rely almost universally on food tightly linked to tidal wetland production (See Section 7 of this Application). Anadromous species such as American shad, alewife, and blueback herring also rely on food linked to tidal wetland production when present in the lower Delaware Estuary (PSEG 1999a, Appendix C). Both benthic and planktonic crustaceans (primary consumers that rely on detritus from tidal wetlands) and other invertebrates provide the dietary foundation for the young of these (and other) fishes. While the energy fixed by the plants is directly transferred to aquatic food webs through herbivore consumption and dissolved organic matter (“DOC”), the detrital pathway dominates the transfer of aboveground primary production to consumers (Alongi 1998). A recent publication by Elliott *et al.* (2002) summarized the importance of the estuarine linkage to the production of fish and shellfish and identified a key component of this linkage as the ability of the estuary to trap detritus thus providing an abundant food resource for aquatic species throughout the estuary and near shore ecosystems.

Stable isotope studies have been used by researchers in the Delaware to determine the linkages between tidal wetlands and estuarine fish production. These studies use conservative (*i.e.*, not changed by biochemical processes) markers associated with specific types of potential food sources. This allows investigators to determine the type of plant, algae, or other material a fish used to build its body mass (See Section 7 of this Application). The isotope studies reveal a strong signature of tidal marsh production in the biomass of ecologically and commercially important fish species including bay anchovy, white perch, and weakfish (Litvin and Weinstein 2003). These studies also provide evidence of trophic linkages to tidal wetlands from the substantial contributions of the tidal marshes to dissolved organic material in the estuarine water column and to the nutrient dynamics of the Estuary (See Section 7 of this Application). Through the trophic relay (*i.e.*, processes directly linking tidal wetland production to the open estuary and coastal ocean fisheries)

(Kneib 2000), consumer biomass produced via primary production arising on tidal marshes is distributed throughout the Estuary and linked to coastal waters.

As mentioned earlier, fish and shellfish derive energy from detritus that is created by the decomposition of vegetation (primary production). Although aboveground vegetation is the predominant form of primary production, there is a significant contribution to the production of detritus and subsequently primary and secondary consumers from belowground biomass. While all vascular plant production processes occur in the leaves (because light is the driving energy source), a substantial quantity of material is translocated into underground root and rhizome systems and not measured with standard techniques for primary production. Additional forms of primary production include benthic micro- and macro-algae (living on the sediment surface), epiphytic algae (living on plant stems), phytoplankton (algae living in the water column), phytoneuston (algae living at the surface of the water), and microbial autotrophs (bacteria and other microbes that can derive energy from light or inorganic chemicals). PSEG has only accounted for the increase in aboveground production in its estimates in VII-E below. Therefore, these estimates likely understate the increased production of fish and shellfish associated with the salt hay farm restoration.

As stated, the aboveground production is consumed by microbes and other organisms and broken down into detritus for the consumption by fish and shellfish. In addition, primary production also directly enters the Estuary as DOC and accounts for about 9% of the net primary production (Turner 1978). Although this value is uncertain, it appears that DOC may contribute substantially to estuarine food webs because of the high trophic quality of the autochthonous estuarine material.

(c) Recent Studies Have Shown that There Is Little Loss of Primary Production from Estuarine/Coastal System to the Open Ocean

Contrary to prior thinking, there is little primary production lost from the Estuary to the open ocean due to the boundary (*i.e.*, the continental shelf) between these two water bodies (See Section 7 of this Application). The region of the continental shelf acts as a barrier between a set of highly open, linked coastal subsystems and a distinctly different system (the open ocean) that operates on a separate trophic foundation, primarily plankton dynamics (Barnes and Mann 1991; Mann and Lazier 1996). There is evidence of a coastal “front” that contributes to the boundary effect (separating coastal processes from those of the open ocean) in the Mid-Atlantic (Mann and Lazier 1996). This front effectively “locks” coastal production into the coastal ecosystem, making the coastal system a highly productive, insular, integrated unit, separated from the plankton-fueled open ocean. Where coastal waters meet the open ocean over the continental shelf, a number of processes filter the products of the Estuary and shelf and cycle them directly into the coastal system. Thus, primary production originating in the coastal ecosystem is consumed and converted in the coastal system (Liu *et al.* 2000) and, therefore, the wetland productivity is entirely available for fish production within the coastal ecosystem.

2. In-Marsh Benefits to Fish and Shellfish

Many species of finfish and their prey use marshes as forage areas, nursery sites, and refuges. The finfish and crustacean community of grassy marshes and marsh creeks is typically enriched seasonally in individuals of forage species and commercially and recreationally valuable taxa (Ayvazian *et al.* 1992; Baltz *et al.* 1993; Hackney *et al.* 1976; Kneib 1984; Peterson and Ross 1991; Rakocinski *et al.* 1992; Rogers *et al.* 1984; Ross and Epperley 1985; Rountree and Able 1992a, 1993b; Rountree and Able 1993; Shenker and Dean 1979; Smith *et al.* 1984; Sogard and Able 1994; Weinstein and Brooks 1983; Zimmerman and Minello 1984; Zimmerman *et al.* 1990a, 1990b).

Several ecological processes lead to enriched fish and shellfish populations and communities in marshes. At the level of forage species, direct feeding on invertebrates in and on marsh substrates is a key process (Boesch and Turner 1984; Feller *et al.* 1990; Hodson *et al.* 1981; Jeffries 1975; Kneib 1984; Valiella *et al.* 1977; Vince *et al.* 1976; Weisberg *et al.* 1981; Weisberg and Lotrich 1982). Within intertidal portions of estuaries (including vegetated marsh), some feeding by predatory fish probably occurs in more open areas and edges, indicating direct trophic transfer of forage species biomass (Kneib 1986; Minello and Zimmerman 1992; Rountree and Able 1992a, 1992b; Wells *et al.* 1973). In general, the three-dimensional structure of marsh systems (grass stems, crustacean burrows, creek banks, and pools) provides a refuge from predation (Kneib 1987; Minello *et al.* 1989; Minello and Zimmerman 1991; Reis and Dean 1981; Zimmerman *et al.* 1984), allowing the accumulation of biomass by populations of forage species and small individuals of other species. This biomass accumulation is enhanced physiologically by favorable temperature and salinity relationships available to resident and migrant species utilizing marsh habitats (Deegan 1990; Horne and Campana 1989; Kneib and Stiven 1978; Peters and Boyd 1972; Peters and Kjelson 1975).

(a) PSEG Has Also Demonstrated that Numerous Species, Including the RS Identified in the IMECS, Utilize the Marshes for Key Life History Functions

Many variables influence fish and crab use of marsh and adjacent habitats in Delaware Bay. While there are many estuarine-dependent fish in the Estuary, either as transients or residents, studies conducted by PSEG have identified “marsh dependent" species. Almost all species which use marshes do so on time scales that vary from decades, years, seasons, or tides. The possible exceptions are small species such as mummichog and sheepshead minnow which are largely restricted to marshes, especially the latter.

The seasonal variability in marsh use by various species is evident from the seasonal patterns of fish use of the Delaware (Able *et al.* 2002; Grothues and Able 2003). This same pattern is evident for other estuarine marshes in the Middle Atlantic Bight (Able and Fahay 1998; Martino and Able 2003). Egress from marshes is most evident in the fall, with falling temperatures, when some species become more abundant in the deeper portions of the lower Estuary before they leave the Estuary entirely on the way to thermal refuges in deeper or more southern waters (Able and Brown 2005). The tidal variation in use of marshes is evident from ultrasonic tracking of striped bass which enter marsh subtidal creeks at low tide to feed on fishes leaving intertidal creeks at low tide (Tupper and Able 2000).

Despite the transient nature of fish use of marshes, and the difficulty of comparing abundance across bay and river habitats because of the necessity of using different gear types in different habitats (Able 1999) it is clear that large numbers of fishes and blue crabs use marshes in the Delaware Estuary as either juvenile habitat, feeding areas (Nemerson and Able 2003), and potentially refuges from predation. This pattern of extensive use of marshes extends to larger fishes as well, such as for striped bass (Nemerson and Able 2003; Tupper and Able 2000) and a variety of other species (Able *et al.* in prep., Attachment 4-5).

(b) PSEG Has Demonstrated that The Restored Marshes Have Faunal Communities with Structure and Function Similar to the Structure and Function in Natural Marshes

To demonstrate that the restored marshes have faunal communities with structure and function similar to the structure and function of natural marshes, the salt hay farm restorations were compared to reference marshes using different measures of habitat quality in the context of Essential Fish Habitat—*i.e.*, those waters and substrate necessary for spawning, breeding, feeding, or growth to maturity (Able 1999; Schmitten 1999) for the dominant fishes in restored and reference marshes. Pre-(1995) and post-(1998 to 2004) restoration measures (species composition and relative abundance) and post-restoration quantitative measures (fish species abundance, composition, and growth) were compared across habitat types (large and small marsh creeks) in two restored marshes and one reference marsh over the study period from April to November, 1998 to 2004.

i. Benthic Invertebrates

Changes in benthic invertebrates were monitored over a four-year period following the restoration of the DTRS to natural tidal flows and compared to these same measures at a nearby reference marsh (Moores Beach-West) (Taghon *et al.* in review).

A rapid response of the invertebrate community was characterized by two phases, 10 to 100-fold increases in abundance of the major taxa within the first few months, followed by continued increases in abundances over the next three years to equal to or greater than the reference marsh (Taghon *et al.* in review). More specifically, oligochaetes, which do not possess a dispersing larval stage and usually slowly colonize created marshes, became very abundant within the first few months, reaching densities similar to the reference marsh (=100 individuals per 11 cm^2). Other typical marsh invertebrate taxa, including *Streblospio benedicti*, capitellid polychaetes, harpacticoid copepods, and nematodes also quickly became equally or more abundant in the restored marsh.

ii. Horseshoe crabs

Horseshoe crabs were absent from the two sampled salt hay farms prior to restoration (before 1996) because there was no access to tidal flow except during the winter when these crabs are typically not collected in estuaries (Botton and Haskin 1984; Botton and Ropes 1987). However, before the restoration of MRTRS, thousands of horseshoe crabs were stranded on-site due to natural breaching of the dikes from storms and erosion (PSEG 1999a, Exhibit G-2-12). Once the restoration process restored normal daily tidal inundation, horseshoe crabs no longer become stranded on the site. After restoration in 1996, abundance expressed in terms of catch per unit effort (“CPUE”) at the restored sites was typically equal to or greater than the reference site. The exceptions were in 1999 when abundance at both restored sites was slightly lower and again in 2002 when abundance at CTRS was lower than the reference site. Abundance at DTRS was markedly greater than the reference site in 1997 and 2003. Thus, horseshoe crabs have responded favorably to the restoration.

iii. Blue Crabs

Marshes are important habitats for various life history stages of many invertebrates, yet it has not been clear how blue crab use natural or restored marsh habitats during much of their benthic life. An investigation of the response of blue crabs to marsh restoration compared abundance (CPUE), mean size and size frequency distribution, sex ratio, and molt stages of crabs in the recently restored marshes at DTRS and CTRS to that of the reference marsh at Moores Beach (Jivoff and Able 2003). Blue crabs were either equally or more abundant in the restored marsh, the incidence of molting was in most cases similar, and population sex ratios and sizes were indistinguishable in restored and reference marshes, suggesting that blue crabs have responded positively to restoration of former salt hay farms in the mesohaline portion of Delaware Bay.

iv. Diamondback Terrapins

Diamondback terrapins were not likely abundant in the salt hay farms prior to restoration (before 1996) because there was no tidal flow, except during the winter when they are inactive and buried in the mud (Burger 1996; Hurd *et al.* 1979). After restoration in 1996, abundance (CPUE) increased at DTRS with abundance values frequently higher than at the Moores Beach-West reference site. The abundance values at CTRS were always lower except during 1998. It is not clear why CTRS had fewer terrapins.

v. Pre- vs. post-restoration comparisons of fishes

Fishes were sampled prior to restoration at the CTRS and DTRS in order to provide a basis for comparison to the post-restoration condition (Able *et al.* 2000, 2004). In both restored sites, fish species richness and abundance increased dramatically immediately after restoration. Also, immediately after restoration, total fish abundance and abundance of the dominant species, relative to the Moores Beach-West reference marsh, was often much greater, at DTRS, while at CTRS these values were similar to the reference marsh. The quick response and success of the restoration, was attributed to the return of tidal flow, increased marsh area and edge in intertidal and subtidal creeks, thus providing habitat for resident and transient young-of-the-year fishes (Able *et al.* 2000, 2004).

vi. Post-restoration vs. reference marsh comparisons of fishes

Intertidal marsh creek fish assemblages varied markedly over the period of study. Higher initial abundance of intertidal creek fish is indicated by the higher abundance found for all included species except weakfish. The transient marsh species Atlantic silverside, Atlantic croaker, Atlantic menhaden, bay anchovy, and spot had a higher affinity for DTRS. Individual dominant marsh species abundance data indicate that these transient marsh species were routinely more abundant at the restored sites in the initial years, with the DTRS having greater values than those at the CTRS. Transient species then gradually diminished through time to converge with reference site abundance levels. Conversely, resident marsh species (mummichog and sheepshead minnow) abundance was generally greater at the reference marsh. Resident species, however, exhibited more variability and no discernable trends following restoration.

The fish assemblage in subtidal creeks responded in a highly variable fashion to changes in the restoration sites relative to the Moores Beach-West reference site. Created (restored) and reference subtidal creeks experienced similar ranges in environmental factors intrinsic to marshes that have been previously shown to influence fish assemblage (*i.e.,* salinity, temperature, dissolved oxygen). Other factors, such as larval supply to the mouths of these marshes can vary independently among marshes and independent of restoration-induced changes in establishing annual assemblages. The sampled intertidal creeks were created to allow tidal inundation of the marsh surface and are thus relatively simple features experiencing no restoration intervention after initial flooding, although they may continue to change under the influence of natural and anthropogenic factors on the intertidal marsh. Thus, the lack of a trend is not surprising; created creeks functioned immediately as fish habitat in a way that mimicked similar creeks in the reference marsh and they continued to do so after the nine-year period of evaluation. Scouring or accretion of these creeks as a function of their design at creation or as a function of subsequent changes to the marsh surface, (*i.e.*, vegetation type and coverage, hydrology) may yet change their function relative to those at reference sites but at a greater than decadal time scale.

vii. Conclusions

An evaluation of the success of the restoration of former salt hay farms was placed in an Essential Fish Habitat context in order to address both structural (species composition, abundance) and functional (feeding, growth, survival, production) attributes of the restoration (See Attachment 4-6, Table 8). Of the structural comparisons, almost all faunal responses were estimated to be positive, with very few negative. The evaluations of species composition were consistently positive, as were those for abundance, including fish assemblages, a variety of fish groups as well as benthic invertebrates, blue crabs, horseshoe crabs and diamondback terrapins. Further, the response of fishes was quick and dramatic with assemblages and abundance of individual species on the marsh surface and in intertidal and subtidal creeks occurring within one to two years (Able *et al.* 2000, 2004). This response, which was quicker than that of the vegetation, implies that the fish were more dependent on access to the marsh surface and intertidal and subtidal creek habitats than the vegetation. A similar positive response was evident for other ecologically and economically important species such as blue crabs, horseshoe crabs and diamondback terrapins. These advantages of restoration were persistent in the early (Able *et al.* 2000, 2004; Jivoff and Able 2003) and late stages of this study, as evident in this analysis, and thus appear to be self-sustaining, an important consideration in marsh restoration (Zedler *et al.* 1997).

However, because the evaluation of the fish response was of such relatively long duration, the intertidal creeks of the restored marshes, which initially had higher abundances, became more like the reference marsh creeks over time. As a result, during the last two years of the study they were essentially identical assemblages. This did not occur in the subtidal creeks which approximated the assemblage characteristic throughout the nine years of observation.

While an increasing emphasis on evaluating the functional significance of marshes has often been identified (Zedler *et al.* 1997; Zedler and Lindig-Cisneros 2000), this is one of the most comprehensive evaluations of restored marsh function in North America and probably the world. Thus, the overwhelming consensus, for the marshes examined in detail, is that the response of the fauna to the salt hay farm restoration was successful as measured by structural and functional responses.

While the response at the CTRS was uniformly positive, some parts of this former salt hay farm remain unvegetated and the CTRS has not yet met the final Success Criteria (See VII-C above). The relatively brief evaluation of the MRTRS also indicated that the response of the fishes was positive and consistent with that for the other former salt hay farms.

3. Other Ecological Benefits

Beyond the quantitative and qualitative contribution made by marsh productivity to the functioning of estuarine and coastal systems, functional marshes have a number of other, less easily quantified ecological values (PSEG 1999a, Attachment G-2). These ancillary values include water quality improvement, flood control, support for species other than the finfish and shellfish species at issue, and pollution control. In the highly developed Delaware drainage, the latter is likely to be particularly important. Marshes open to the estuary trap sediments which are the main mechanism of contaminant transport in estuaries. In marshes, organic contaminants are degraded by biological and physical processes and metals are sequestered in the sediments beyond the reach of organisms. Thus, marshes open to the estuary can help reduce contamination by controlling both the bioavailability and the bioaccessibility of potentially toxic compounds released elsewhere. This function cannot be performed by diked marshes, which have only minimal connection with the drainage basin as a whole. Other, less tangible benefits of open marshes are aesthetic, recreational, and educational, and are generally nonconsumptive or involve only low levels of exploitation.

E. Quantification of Ecological Benefits of Wetland Restoration Measures (40 CFR §125.95(b)(5)(iii))

40 CFR §125.95(b)(5)(iii) of the Final Rule requires the calculation of "...the production of fish and shellfish that you will achieve with the restoration measures...", and the estimation of the "...reduction in fish and shellfish impingement mortality and/or entrainment that would be necessary ... to comply with 40 CFR §125.94(c)(2)." Both types of estimates (*i.e.*, benefits from meeting performance standards, and benefits from restoration measures) are presented in this section. In addition, as required by 40 CFR §125.95(b)(5)(iii), uncertainties in estimates of production from the restoration measures, and the timeframe within which production is expected to accrue, are discussed in VII-E.

1. Benefits from Meeting Performance Standards

As described in VII-A-5 above, in order to compare production attributable to the restoration measures with benefits due to reducing IM and E, losses due to IM and E were expressed in terms of production lost (pounds, wet weight per year). The annual losses for the Calculation Baseline conditions, described in IV-G and IV-H above (IMECS), were translated into units of annual production lost (using the methods described in Attachment 7-1 of this Application) for the purpose of addressing 40 CFR §125.95(b)(5)(iii).

Because the vast majority of fish and shellfish lost to IM or E at Salem are age-0, *i.e.*, within the first year of life (See IV-IMECS), and because of the critical role of estuaries as nursery grounds for fish and shellfish (See VII-D above and Section 7 of this Application), estimates of production gained due to restoration and production lost due to impingement mortality and entrainment focused on age-0 fish and shellfish. Accordingly, estimates of annual production lost included the biomass on the date of impingement mortality or entrainment plus the production forgone from the date of impingement mortality or entrainment to what would have been the first birthday of the organism.

(a) Applicable Standards

In accordance with 40 CFR §125.94(b)(1) and (2), and as discussed in VII-A-1 above; the §316(b) Standards applicable to Salem include reductions in IM and E. The applicable Restoration Standards at 40 CFR §125.95(b)(5)(iv) also apply. The §316(b) Standard for IM applicable to Salem is a reduction in IM of 80% to 95% from the Calculation Baseline IM. The §316(b) Standard for E applicable to Salem is a reduction in E of 60% to 90% from the Calculation Baseline E.

(b) Required Reduction in Impingement Mortality

As described in V-E, Salem has achieved compliance with the §316(b) Standard for reduction in IM through the use of improved continuously rotating modified-Ristroph traveling screens and the fish return system. The Station achieved an 88% reduction. Therefore, benefits from the wetland restoration measures are not needed for the purpose of complying with the requirements of 40 CFR §125.94(c)(1). For this reason, benefits from reducing IM are not included in the assessment required by 40 CFR §125.95(b)(5)(iii).

(c) Required Reduction in Entrainment

The average annual (2002 to 2004) production lost due to E at Salem under Calculation Baseline conditions was estimated to be 9,674,481 lbs (4,388,271 kg) (wet weight). This estimate is based on the biomass of organisms at the time they are entrained plus the production forgone for those organisms from the date of E to what would have been the first birthday of the organism (See Attachment 7-1 of this Application). Annual estimates of production lost due to entrainment were based on estimates of entrainment of the fish RS (*i.e.*, American shad, Atlantic menhaden, Atlantic silverside, alewife, Atlantic croaker, bay anchovy, blueback herring, spot, striped bass, weakfish, white perch, and bluefish).[3]

The expected benefit due to reducing E to the level required by the Entrainment Performance Standard is computed by multiplying the production lost under Calculation Baseline conditions by 0.6 (*i.e.,* 60%). Therefore, the expected annual benefit from meeting the requirements of the §316(b) Standard for E is 5,804,689 lbs (2,632,963 kg) wet weight, (*i.e.*, 9,674,481 lbs [4,388,271 kg] x 0.6).

2. Ecological Benefits from Wetland Restoration Measures: Production of Biomass of Secondary Consumers

The estimate of production of biomass of secondary consumers attributable to the restored salt hay farm marshes was based on empirical data on the biomass of aboveground vegetation within the restored salt hay farm marshes (See Attachment 7-1 of this Application). The vegetation data (PSEG 2003a, 2004a, 2005a) were used to estimate aboveground primary production (*i.e.*, production of aboveground

[3] Based on the NJDEP-approved IBMWP, the 13 species PSEG identified as RS for the CDS comprise more than 98% of the age-0 production foregone entrainment biomass calculated using the modeling described in Attachment 6-12 to this Application.

marsh vegetation) within the salt hay farm marshes. To convert the primary production to production of secondary consumers, three trophic transfers were considered: 1) vegetation to the detrital complex, 2) detrital complex to primary consumers, and 3) primary consumers to secondary consumers (See Attachment 7-1 of this Application).

The average annual (2002 to 2004) production of all secondary consumers (including organisms other than age-0 fish) attributable to the salt hay farm marshes, under the scenario of all sites having met vegetative Success Criteria, was estimated to be 18,575,270 million lbs (8,425,601 million kg) (wet weight) per year. As noted in Section 7-III of this Application, aboveground production is only a portion of the total primary production, and therefore, these estimates likely under-represent the total secondary production attributable to the salt hay farm marshes. Further, the estimates of production from the salt hay farm restoration sites are likely understated because they omit contributions from benthic algae and below ground plant production and omit recycling of production back to lower trophic levels during the trophic transfer process.

3. Uncertainty in Estimates of Production Attributable to Restoration Measures

Because the salt hay farm restoration measures are already functioning, uncertainty is much less than would be the case for restoration measures that were only in the planning stage. Uncertainty was addressed using empirical data from the restored salt hay farm sites and from DNREC. To address uncertainty associated with possible model mis-specification errors, multiple, independent methods were used to estimate production attributable to the salt hay farm restoration sites. To address sampling error and interannual variability, multiple years of data were analyzed. The variability among year-specific estimates of production reflects within-year sampling error and interannual variability in production. These analyses are described in Section 7 of this Application, which also discusses the conservative assumptions underlying the estimates of production. As stated above, the production of secondary consumers was likely under-estimated and therefore the production estimates are conservative.

4. Timeframe for Achieving Increased Production from Restoration Measures

40 CFR §125.95(b)(b)(iii) requires that applicants using increased production from restoration measures include a discussion of the time frame when the ecological benefits are expected to accrue. PSEG is relying on the increased

production of fish and shellfish from the fully restored salt hay farms to achieve compliance with the §316(b) Standard for E.

As discussed above, PSEG is relying on the production of vegetation from the fully restored salt hay farms to increase incrementally the production of fish and shellfish in the Estuary. Two of the salt hay farms are fully restored. DTRS met the Success Criteria for vegetative cover in 2000. MRTRS met the Success Criteria for vegetative cover in 2001. CTRS met the interim criteria for vegetative cover in 2004 and, based upon 2005 field observations, is expected to be fully restored in or before 2009.

F. Documentation that Restoration Measures in Combination with Design and Construction Technologies Meet Requirements (40 CFR §125.95(b)(5)(iv))

40 CFR §125.95(b)(5)(iv) requires evidence to document that "restoration measures in combination with design and construction technologies and/or operational measures, or alone, will meet the requirements of 40 CFR §125.94(c)(2)." In VII-E-1 above, estimates of the benefits of achieving the applicable performance standards (*i.e.*, expected annual gain in production of age-0 fish) are described, and in VII-E-2 above, estimates of the benefits attributable to the restoration measures (*i.e.*, estimated annual production of age-0 fish) are described. In this Section, estimates of the benefits due to installed design and construction technologies are presented. In order to combine the benefits of the installed design and construction technologies with the benefits from restoration measures, these benefits must also be expressed in terms of production of secondary consumers.

Also in this Section, the combined benefits from restoration measures and from design and construction technologies are compared to the benefits expected from achieving the applicable performance standards.

40 CFR §125.95(b)(5)(iv) of the Final Rule also requires that, for out-of-kind restoration measures, the demonstration that restoration measures produce a sufficient level of ecological benefits should be based on "a watershed approach to restoration planning" and consider "applicable multi-agency watershed restoration plans, site-specific peer-reviewed ecological studies, and/or consultation with appropriate federal, state, and Tribal fish and wildlife management agencies." As discussed in VII-A and VII-C above, and in Section 7 of this Application and Attachments 4-5 and 4-6 to the CDS, PSEG's salt hay farm restoration measures were based on a watershed approach with active, ongoing participation by fish and wildlife management agencies, and with consideration of many site-specific peer-reviewed ecological studies.

1. Reduction in Entrainment Due to Design and Construction Technologies

In order to estimate the reduction in entrainment due to design and construction technologies, the fates of organisms that would have been entrained under the Calculation Baseline conditions were determined for the Proposed Conditions. Some of those organisms will be entrained under the Proposed Conditions, and some, due to the installation of the improved modified-Ristroph traveling screens, will be impinged instead. The reduction in entrainment was computed as the difference between 1) the number of those organisms that would have been entrained under Calculation Baseline Conditions, and 2) the number of those organisms that will be entrained or will be lost due to impingement under Proposed Conditions. For this calculation, all organisms entrained are assumed to die, but organisms that will be impinged under Proposed Conditions are assumed to have a chance of survival due to the improved modified-Ristroph traveling screens and bi-directional fish return system (See Attachment 4-4 for discussion of estimates of impingement survival rates).

The estimates of annual numbers of fish lost used in the calculations of reduction in E due to design and construction technologies were translated into units of annual production lost (pounds, wet weight per year) using the methods described in Attachment 7-1.

The average annual (2002 to 2004) reduction in production lost (Calculation Baseline Conditions vs. Proposed Conditions) was estimated to be 332,204 lbs (150,685 kg) (wet weight) per year. Therefore, the average annual combined benefit (in accordance with 40 CFR §125.95(b)(4)(i)(C)) is the production of 18,907,474 lbs (8,576,286 kg) wet weight, per year of secondary consumers, which includes the species of fish entrained at Salem. 332,204 lbs (150,685 kg) is attributable to the installed design and construction technologies; 18,575,270 lbs (8,425,601 kg) is attributable to the restoration measures.

2. Comparison of Benefits from Meeting Performance Standards to Combined Benefits from Design and Construction Technologies and Restoration Measures

The expected benefit from meeting the §316(b) Standard for E is the production of an additional 5,804,689 lbs (2,632,963 kg) (wet weight) of age-0 fish per year (See VII-E-1-(c) above). The estimated combined benefit from the installed design and construction technologies and restoration measures is the production of 18,907,474 lbs (8,576,286 kg) (wet weight) of secondary consumers per year (See VII-E-2 above).

These estimates document the fact that the restoration measures in combination with design and construction technologies exceed the requirements of 40 CFR §125.94(c)(2) for entrainment. Furthermore, as discussed in Section 7 of this Application, the estimates of production attributable to the restored salt hay farm sites most likely underestimate the increased production due to conservative assumptions (*e.g.*, below ground production and benthic algae are not included in the production estimates) underlying the methods used to compute the estimates.

G. Adaptive Management for Implementing, Maintaining, and Demonstrating Efficacy of Wetland Restoration Measures (40 CFR §125.95(b)(5)(v))

1. Introduction

This section presents PSEG's AM Program for implementing, maintaining, and demonstrating the efficacy of the restoration measures that have been implemented. Further detail regarding the AM process is described above in VII-C-1-(e).

(a) PSEG's Adaptive Management Program Since 1995

As discussed in detail in VII-C above, PSEG developed an AM Program to monitor, guide, and respond to the temporal process of restoration by providing a means for implementing interim actions to help assure that final restoration goals are met (PSEG 1999a, Attachment G-2).

PSEG's AM Program is technically rigorous and based on thorough scientific peer review. Input from stakeholders and independent scientists from NJDEP and EEPAC will continue as the AM is implemented at CTRS until final Success Criteria are met.

(b) PSEG's Monitoring Program Since 1995

PSEG's monitoring programs, including the 1994 BMP and the 2002 IBMWP, were designed and implemented to assess vegetative, geomorphic, hydrologic, and faunal responses to restoration in the context of the Success Criteria and other ecological measures of restoration success. The data collected from these programs has been analyzed and the results have been published in peer-reviewed journals (See VII-C above) (See Table VII-9). The results confirm that fish and shellfish in the Estuary have benefited from the increase in detrital production from the restored sites and that a wide variety of fish and shellfish use the restored marshes as habitat for feeding, nursery and refuge (See VII-D above).

(c) Restoration Status

The success of the restorations at each of the three former salt hay farm sites has been assessed based on the interim and final Success Criteria. As described in VII-C above, DTRS and MRTRS both met the final Success Criteria years in advance of the anticipated dates. These sites have continued to meet the final Success Criteria; therefore, monitoring, maintenance, and inspection, including AM, are no longer required at these two sites. CTRS has met the interim Success Criteria and is on-track for meeting the final Success Criteria by the NJDEP-approved deadline and therefore, AM will continue at this site.

(d) Summary and Conclusions

To date, PSEG's wetland restoration and preservation program has fully met all of the Permit requirements. The restoration program was implemented in accordance with procedures, processes, and schedules established in the 1994 NJPDES Permit and NJDEP Management Plans. Required acreage was acquired and preserved. The restoration effort was designed and implemented in accordance with the NJPDES Permit and Management Plans, and federal, state, and local Permits. Because PSEG has met the NJDEP-approved Success Criteria for both DTRS and MRTRS, the AM and Monitoring Programs described below in VII-G of the RP will only apply to CTRS.

2. Monitoring Plan

Below is an overview of PSEG's proposed monitoring plan with respect to: vegetative parameters, including quantitative field sampling and aerial photography; hydrogeomorphic parameters; and monitoring frequency. CTRS will continue to be monitored annually, including vegetative cover mapping, quantitative field studies, and hydrogeomorphic monitoring to ensure the final Success Criteria are met. DTRS and MRTRS have met their restoration goals, are now self-sustaining tidal marsh as demonstrated by two years of follow-up success monitoring, and require no further annual monitoring. Monitoring of the Moores Beach-West reference marsh will continue for comparison to data from the CTRS.

(a) Vegetation Monitoring Parameters

This section describes the field sampling program and aerial photography components of the vegetation monitoring program.

i. Quantitative Field Sampling

Quantitative field sampling will be performed annually along transects and within plots located at CTRS and the Moores Beach-West reference marsh until CTRS has met the final vegetative Success Criteria for two years subsequent to the year the Success Criteria are initially met. Random quadrats (0.25 m^2) will be located along each of the transect alignments and within the plots historically sampled by PSEG. The field data that will be collected within these quadrats will include the percent of plant foliar and stem aerial coverage (as viewed from above by an observer standing at a point adjacent to the quadrat), the approximate canopy height for each species, and flowering status. Within a subset of these quadrats, all living and standing non-living vegetation will be collected and sorted into dominant/co-dominant groups. The vegetative material will be dried and the total weight will be determined.

ii. Vegetative Cover

Annual aerial photography will be acquired for CTRS and the Moores Beach-West reference marsh until CTRS has met the final vegetative Success Criteria for two years subsequent to the year the Success Criteria are initially met. This photography will be acquired at a nominal scale of 1:9600 (*i.e.*, 1 in. = 800 ft [1 cm = 96 m]) at the end of the growing season during the mid-day period and at low tide. Geodetic control will be established to allow aerotriangulation of the images and subsequent preparation of digital orthophotographs of each site. This digital aerial photography will be the basis for the monitoring of the development of vegetative cover. Images will be analyzed quantitatively for *Phragmites* coverage and desirable vegetation coverage.

(b) Hydrogeomorphic Monitoring Parameters

Quantitative analyses of the development of hydrogeomorphologic features on CTRS will be performed based on the annual aerial photography. Hydrogeomorphology of the Moores Beach-West reference marsh is relatively stable and does not require annual monitoring. The following parameters will be quantified as part of this evaluation:

- channel classification (order);

- determination of the total number of channels in each order;
- calculation of bifurcation ratio;
- calculation of channel frequency;
- calculation of total length (sinuous length);
- calculation of total linear length;
- calculation of average channel length;
- calculation of channel length ratio;
- calculation of percent of total channel length;
- calculation of average channel sinuosity; and
- calculation of drainage density.

3. Activities to Ensure Efficacy of Restoration Measures, and Process for Revising Restoration Plan (40 CFR §125.95(b)(5)(v) (B) and (C))

As indicated in VII-G-1, the AM Program that PSEG has been implementing at CTRS will continue to be implemented at this site to ensure the efficacy of the restoration measures until the final vegetative Success Criteria are met. To ensure efficacy of restoration measures, the monitoring data that will be collected along with site visits from the AM Team and/or site managers will be used to gauge how the CTRS is responding to the restoration efforts.

(a) Monitoring Programs

Vertical aerial photographs have been and will continue to be taken once per year, typically in late August through October at the end of the growing season. Images of the CTRS will be analyzed quantitatively for:

- *Phragmites* coverage;
- desirable vegetation coverage;
- development and extent of drainage channels; and
- drainage channel configuration.

In addition, photographs will be analyzed qualitatively for other parameters, including:

- location and extent of low tide ponding;
- location and nature of unplanned breaches in perimeter dikes;
- condition of constructed inlets;
- erosion of perimeter and internal hydrology dikes and berms;
- migration or other changes in inlet location and condition;

- drainage channel configuration and location; and
- erosion in drainage channels.

Field observations will be made at CTRS during periodic site visits by restoration implementation staff and property managers and during the regular site visits by the AM Team. These observations provide verification of information obtained from other monitoring programs and aerial photographs. They also provide information impossible to obtain by remote sensing. Field observations will include:

- locations of premature breaches in internal site berms;
- locations of premature failures of perimeter dikes;
- condition of constructed inlets; and
- areas of unexpected erosion, excessive drainage, or sediment deposition.

(b) Adaptive Management Program

PSEG's AM Program has used and will continue to use ongoing observation and response conducted by an AM Team. The AM Team will make periodic visits to CTRS to evaluate progress and observe conditions. Problems such as premature dike breaches, sediment erosion, poor drainage, sedimentation, or other conditions that might ultimately interfere with restoration success will be addressed on an ongoing basis. In this way, the restoration process will be kept on track and the likelihood of timely success is maximized.

AM Team observations will be supplemented by information from site managers and others in regular contact with the restoration areas who conduct routine inspections of the sites with a specific emphasis on:

- monitoring restoration status;
- identifying maintenance concerns;
- observing public use of the sites;
- observing wildlife and waterfowl use of the sites; and
- evaluating effectiveness of design and engineering.

Identified problems, such as premature berm breaches, sediment erosion, poor drainage, sedimentation, or other conditions that might ultimately interfere with restoration success, will be addressed on an ongoing basis using a suite of corrective action approaches and tools.

If CTRS were to trigger any of the thresholds established by the AM Program, additional data collection and/or corrective measures may be implemented, with appropriate NJDEP approval. Upon determination that corrective measures are necessary, PSEG, in consultation with members of the EEPAC, or any similar advisory committee, and the resource management agencies, will evaluate feasible alternatives for the resolution of an identified problem; and, after review and approval of the proposed corrective measure(s) by NJDEP, PSEG will implement the appropriate corrective measures.

(c) Restoration Plan Review and Revision Process

A process for revising the Management Plans required under Salem's 1994 and 2001 NJPDES Permits was developed and approved by NJDEP. Because it has been successfully used for more than 10 years, PSEG proposes that a similar process be used for any amendments or revisions to CTRS RP that may be required in the future.

A draft of the proposed amendment(s) to the RP would be provided to the EEPAC or any similar advisory committee established under Salem's next NJPDES Permit for review and comment. Copies of the draft proposed amendments would also be sent to NJDEP. EEPAC members would then provide their comments to PSEG for PSEG's consideration in developing the proposed amendment to the RP for NJDEP's final approval. PSEG would then submit the final proposed amendment to NJDEP. NJDEP would then review the final proposed amendments and either approve, approve with modifications, or reject the final proposed amendment to the RP.

(d) Conclusions

As the successful restoration of DTRS and MRTRS demonstrates, PSEG has put in place the appropriate measures to ensure efficacy of the restoration. PSEG will continue to implement a monitoring program to assess the restoration at CTRS which has met the interim Success Criteria and is well on its way toward meeting the final Success Criteria. The monitoring program includes annual mapping of vegetative cover, quantitative sampling of vegetation, and hydrogeomorphic monitoring. PSEG's AM Team will continue to visit CTRS to assess the restoration progress and recommend any corrective measures, if necessary, to ensure the complete restoration of CTRS is fully achieved.

4. Past and Ongoing Consultation with Appropriate Federal and State Fish and Wildlife Management Agencies (40 CFR §125.95(b)(5)(vi))

As discussed in the VII-A above, PSEG's wetlands restoration program was developed and implemented in close coordination with various federal and state fish and wildlife management agencies including NMFS, USFWS, DNREC, NJDEP and USEPA (collectively, “F&W Agencies”) with responsibility for protecting the aquatic resources of the Delaware Estuary. NJDEP’s wetlands and fisheries scientists were involved in the development of the restoration program and the other F&W Agencies were involved in the review process. A brief summary of each is provided below.

First, NJDEP wetlands and fisheries scientists conducted a detailed review of PSEG’s (1993a) proposed wetlands restoration program. The issues they reviewed included: the sites proposed for restoration; the linkages between the species of concern and salt marshes; the variables used in the aggregated food chain model used to estimate the number of acres to be restored; and the regulatory controls to ensure the success of the program.

The other F&W Agencies were involved in the public comment period on the 1993 Draft Permit; NJDEP responded to their comments and incorporated provisions in the 1994 NJPDES Permit addressing their comments (NJDEP 1994a, 1994b). Some of the F&W Agencies also participated in the public comment process on the 2000 Draft NJPDES Permit; NJDEP again responded to the comments (NJDEP 2001b). A summary of the major comments related to the wetlands restoration program in connection with the issuance of the 1994 and 2001 NJPDES Permits is provided below.

USEPA submitted detailed comments on the 1993 Draft Permit (USEPA 1993). With respect to the wetlands restoration program, USEPA questioned whether the restoration of tidal wetlands would benefit the species of concern (*e.g.*, bay anchovy, spot, white perch, and weakfish). NJDEP (1994c) prepared a detailed response that indicated that detailed information on the life history functions and habitat requirements of these species had been included in the Administrative Record for the Permit and provided USEPA with copies of the supporting materials that formed the basis for its response. NJDEP stated that the information demonstrates that these species utilize the marsh ecosystem as a food source both directly while in the marsh and indirectly while in the open waters of the Estuary. NJDEP also indicated that salt marsh provides critical habitat and refuge for these species during certain life stages. Finally, NJDEP noted that the record included information demonstrating that increases in salt marsh results in increased biological productivity in the estuaries. USEPA reviewed and approved the final Permit (USEPA 1994).

NMFS, USFWS, and DNREC also submitted comments on the wetlands restoration program. For example, NMFS, DNREC and USFWS all submitted comments urging NJDEP to require that a comprehensive biological monitoring program be developed. They also urged that there be adequate oversight provided to the design and implementation of the monitoring and wetlands restoration programs and questioned whether PSEG should implement or fund the programs. They also questioned if the number of acres being restored were adequate. NJDEP

(1994a, 1994b) made revisions to the monitoring and restoration programs to address these comments and also established the requirement for advisory committees comprised of regulator and independent scientists. NJDEP (1994b) also explained that it had reviewed the acreage required and was satisfied the number of acres being restored would adequately offset losses at the Station. As discussed in II and VII above, PSEG was required to establish two advisory committees, the MAC and the MPAC, with responsibility for providing advice on the BMP and the Management Plans, respectively. The representatives serving on these committees are identified below in the discussion of the EEPAC.

PSEG's 1999 Renewal Application for Salem synthesized all the data and information PSEG collected from 1995 through 1998 regarding the wetlands restoration program and the faunal response to the restoration. These syntheses were prepared by recognized experts in wetlands, coastal processes and estuarine fisheries. PSEG provided the MAC and MPAC members with copies of the information and had the scientists who prepared the synthesis present the information to the MAC and MPAC (See Table VII-1 [May 25, 1999 MPAC and June 2, 1999 MAC meetings]) (PSEG 1999c). These multi-day meetings with the scientists who prepared Salem's 1999 Application (PSEG 1999a) provided the MAC and MPAC members an opportunity to review and discuss the information.

As noted above, the MAC and MPAC committees were combined to form the EEPAC under the 2001 NJPDES Permit. As required under the 2001 NJPDES Permit (NJDEP 2001a), the EEPAC provides ongoing advice to PSEG regarding both the wetlands restoration program and the monitoring program, including the components of the monitoring program that specifically address the status of the wetlands restoration and the response of the fishery to the restoration.

EEPAC includes representatives of NMFS, USFWS, DNREC, ACOE, USEPA, DRBC, and NJDEP. USEPA and DRBC also had been represented on MAC/MPAC. The regulatory scientists that have served on EEPAC or MAC/MPAC have been highly qualified, with areas of expertise directly relevant to the restoration program. For example, the NMFS scientists have studied the relationship between coastal marshes and finfish production, and have published articles in peer-reviewed journals. USFWS, DRBC, NJDEP and DNREC fisheries scientists have been responsible for assessing the status of the Estuary's fish and are well-versed in their life histories and the linkages between marsh and fish production. USEPA's representative was responsible for USEPA's wetlands program for Region II, which includes the Delaware. NJDEP's and DNREC's wetlands scientists were responsible for their respective state's programs in the region of the restoration sites.

NJDEP has been an integral part of the restoration program and the processes that triggered comments from the F&W Agencies. NJDEP's Division of Water Quality has been involved in all aspects of the advisory committees since their initial formation. The comments submitted by the F&W Agencies have been submitted to NJDEP either as comments on draft Permits or through the advisory committee processes; they are part of the administrative record for this Permit and are in the possession of NJDEP. Therefore, PSEG is not resubmitting copies to NJDEP at this time.

5. Peer Review of Restoration Plan (40 CFR §125.95(b)(5)(vii))

USEPA's Final Rule provides that, upon request of NJDEP, PSEG must have the RP peer-reviewed. As NJDEP (1994a, 2001a) required under Salem's 1994 and 2001 NJPDES Permits, the plan for the restoration and the monitoring program, have been peer reviewed by independent scientists approved by NJDEP. In addition, numerous articles relating to the wetlands restoration program have been published in peer-reviewed journals (See Table VII-9).

These "peer review" committees (*i.e.*, MAC, MPAC, and EEPAC) have met numerous times since 1995 and have reviewed all aspects of the wetlands restoration program, including: the design of both the restoration effort and the monitoring program; the implementation of the restoration effort; the reports of the AM Team and the recommendations for corrective actions; results of the vegetative and hydrological monitoring; compliance with the vegetative and hydrological Success Criteria; the faunal response to the restoration; and PSEG's estimates of increased production from the restoration.

(a) EEPAC Includes Independent Scientists Who Were Chosen in Consultation with NJDEP

As required under Salem's 1994 and 2001 NJPDES Permits, the MAC/MPAC and EEPAC included scientists with expertise in both wetlands and aquatic resources (NJDEP 1994a, 2001a). The design of the restoration program (*i.e.,* the Management Plans) was reviewed by MPAC and continues to be reviewed by EEPAC. The 1994 Permit stated for the MPAC that:

> The Permittee shall request, subject to the Department's approval, a coastal geologist and two scientists with appropriate expertise, to serve on the MPAC…

The 2001 NJPDES Permit included similar language. PSEG nominated the following scientists to serve on the MPAC/EEPAC:

- Michael Bruno, Ph.D., Director of the Davidson Laboratory and a Professor at Stevens Institute of Technology;

- Eugene Turner, Ph.D., a Professor at Louisiana State University; and
- William J. Mitsch, Ph.D., a Professor Ohio State University and recipient of the Stockholm Water Prize (2004) presented by the King of Sweden.

NJDEP approved the three nominees, who served on the MPAC and who continue to serve on EEPAC.

For the MAC, the 1994 NJPDES Permit required that:

> …, the Permittee shall request, subject to the Department's approval, at least three scientists having … expertise [in the aquatic resources of the Delaware Estuary] to serve on the MAC…

Again, the 2001 NJPDES Permit included similar language. PSEG nominated the following scientists to serve on the EEPAC/MAC:

- Edward A. Houde, Ph.D., Professor at the University of Maryland's Chesapeake Biological Laboratory;
- Ronald T. Kneib, Ph.D., Senior Research Scientist at the University of Georgia's Marine Institute at Sapelo Island; and
- Nancy Rabalais, Ph.D., Professor at the Louisiana Universities Marine Consortium.

NJDEP approved the three nominees, who, with the exception of Dr. Rabalais who resigned for personal reasons, continue to serve on the EEPAC.

In addition to these independent scientists initially appointed to MAC and MPAC, three additional independent scientists were nominated by the Delaware Riverkeeper and other intervenor groups and approved by NJDEP; they are:

- Joseph K. Shissler, former Professor at Rutgers University who served on MPAC;
- Joseph Miller, formerly with USFWS' New Jersey office who served on MAC; and
- Richard B. Deriso, Ph.D., Associate Adjunct Professor at Scripps Institution of Oceanography, who served on MAC.

Drs. Shissler and Deriso continue to serve on EEPAC. In addition, Tony Totah, of Clean Ocean Action, was appointed to serve on EEPAC in 2004 at the request of intervenor groups.

(b) Peer-Reviewed Publications on Various Aspects of Wetland Restoration Program

In addition to the peer review of the Management Plans, many of the participants in the restoration effort as well as other scientists who have studied the program have prepared papers. The articles cover all aspects of the program from PSEG's reliance on the principles of ecological engineering to the use of stable isotopes to track trophic transfer of energy from *Spartina* to juvenile weakfish in the open waters of the Estuary. More than 70 papers have been accepted for publication in peer reviewed journals. A special edition of the journal, Ecological Engineering, is devoted to PSEG's wetlands restoration program. Table VII-9 lists all of the papers related to EEP that have been published or accepted for publication as of late 2005.

6. Description of Information to Be Included in Bi-Annual Status Reporting (40 CFR §125.95(b)(5)(viii))

The information to be included in an annual report to NJDEP is described below. Although the Final Rule requires the submission of a Bi-Annual Report, PSEG is proposing to submit a report annually by June 30th as is currently required under Salem's NJPDES Permit. Annual mapping of vegetative cover is conducted during the peak growing and the subsequent data analysis requires approximately six months to complete. This schedule is also consistent with the requirements of PSEG's LURP-site status reports for CTRS.

(a) Quantitative Field Sampling

PSEG will report on the results of its clip plot monitoring program, including: plant foliar and stem aerial coverage; the approximate canopy height; the flowering status; and total weight of dried vegetative material. This data will be reported for the CTRS and the Moores Beach-West reference marsh until the CTRS has met the final vegetative Success Criteria for two years.

(b) Vegetative Cover

Based on the interpretation of the false color infrared photography, PSEG will report vegetation coverage and unvegetated coverage for both CTRS and the Moores Beach-West reference marsh. This data will be reported for CTRS and the Moores Beach-West reference marsh until CTRS has met the final vegetative Success Criteria for two years.

(c) Hydrogeomorphic Parameters

Based on the interpretation of the false color infrared photography, PSEG will report on the following parameters for the CTRS: channel classification (order); determination of the total number of channels in each order; calculation of bifurcation ratio; calculation of channel frequency; calculation of total length (sinuous length); calculation of total linear length; calculation of average channel length; calculation of channel length ratio; calculation of percent of total channel length; calculation of average channel sinuosity; and drainage density. This data will be reported for CTRS and the Moores Beach-West reference marsh until CTRS has met the final vegetative Success Criteria for two years.

VIII. INFORMATION IN SUPPORT OF A SITE-SPECIFIC DETERMINATION OF BEST TECHNOLOGY AVAILABLE BASED ON THE COST-COST TEST (40 CFR §125.95(b)(6))

In accordance with 40 CFR §125.95(b)(6) of the Final Rule, PSEG is submitting the following information in support of a site-specific determination of BTA for Salem based on USEPA's cost-cost test. The cost-cost test allows the owner or operator of a Phase II facility such as Salem to demonstrate that the "cost of complying with the applicable performance standards would be significantly greater than the costs considered by the [US]EPA for a like facility when establishing such performance standards" (69 Fed. Reg. 41603).

A. Introduction

The cost-cost test "ensures that the overall rule remains economically practicable for facilities subject to today's rule" (69 Fed. Reg. 41603). USEPA recognizes through the cost-cost test that there a number of site-specific factors that may significantly affect the cost and practicability of installing certain technologies for meeting the §316(b) Standards.

In particular, USEPA may not have identified the technology that would be required to meet performance standards or anticipated all site-specific costs a facility could incur, including the additional retrofit costs that would make costs higher for an existing facility than for a newer facility. For example, existing facilities, in general, have less flexibility than new ones in selecting the location of technologies or modifying their cooling water intake structures. "[US]EPA believes that the cost-cost site-specific compliance alternative is *necessary* to ensure that the rule is economically practicable for existing Phase II facilities" (69 Fed. Reg. 41603, emphasis added).

B. Alternative Technological and Operational Measures

Section 4-VIII-B provides a brief overview of the five types of alternative technological or operational measures PSEG assessed in the cost-cost analysis. Because there are six variations of the seasonal flow reduction alternative and two closed-cycle cooling alternatives, a total of 11 technological or operational alternatives were evaluated. The selected alternatives are categorized by whether they are technological measures that modify the existing CWIS or are operational measures that reduce flow rates. The following subsections summarize these measures and the process by which the alternatives were developed.

1. Selection of Alternative Technological and Operational Measures for Consideration

Alden Research Laboratory, Inc. (”ARL”) developed a list of specific alternatives—based upon a set of screening criteria—from a larger number of alternatives that, in theory, might be applicable at Salem. The screening process is described in detail in Section 6-II and Attachment 6-2 of this Application. Five general alternatives were selected for evaluation at Salem—two alternatives that involve modifications to the existing CWIS and three types of flow modifications. The five types of alternatives are:

1. sound deterrent system (*i.e.*, a fish diversion device);
2. dual-flow fine-mesh (0.5 mm) screens;
3. seasonal flow reductions with variable speed drives;
4. revised refueling outage schedule; and
5. retrofit to closed-cycle cooling using cooling towers.

2. Technological Measures

Based on the ARL screening study results (See Attachment 6-2), two intake technologies were selected for detailed evaluation. For more details on the selected alternatives, see Attachment 6-1 of this Application.

(a) Sound Deterrent System

This alternative uses a fish behavioral barrier that emits sound to deter select fish species from becoming impinged at the Station. The system components would include sound generators that would be designed to operate at all water levels and create a sound barrier that would cover the width of the intake. This alternative survived the preliminary screening process because a sound barrier was found to be effective for some species as a result of Salem-specific studies (a multi-sensory hybrid intake protection technology (“MSHIPT”) study that included a sound barrier) conducted as required by Custom Requirement G.5 of the 2001 Salem NPDES permit. This alternative would have been eliminated from the universe of options because it reduces only IM (based on results of the Phase 1 and Phase 2 MSHIPT feasibility studies discussed in Attachment 6-1 of this Application). Since fish do not develop the organs/structures required to hear until they are well into their juvenile stage, sound deterrents cannot reduce entrainment. Additionally, some species, such as blue crab, actually are attracted to the cooling water intake structure by the sound.

(b) Dual-Flow Fine-Mesh (0.5 mm) Screens

Dual-flow fine-mesh screens are designed with a dual-flow entry/single-flow exit configuration. The screens are also equipped with fish lifting buckets, a low- and high-pressure spraywash system for fish and debris removal, and a fish and debris return trough. This alternative would be designed to achieve an approach velocity of 0.25 ft/sec (through-screen velocity of 0.5 ft/sec).

Use of fine-mesh would reduce entrainment losses by preventing early life history stages from being entrained through the Station's CWS. The screens would reduce carryover of fish and debris in the circulating water system. The alternative would result, however, in some shift in the relative number of organisms that are entrained versus impinged. Specifically, some smaller organisms currently entrained would become impinged under this alternative. The net effect of the alternative depends, in part, on the organisms' impingement survival rate relative to its entrainment survival rate.

3. Operational Measures

The operational measures considered in this cost-cost analysis all reduce the CWS flow rates on a seasonal or a year-round (continuous) basis. Reducing flow on a seasonal basis and shifting refueling outages such that flows are reduced during periods of peak organism abundance would reduce the number of organisms entrained or impinged at the CWIS. It should be noted that although shifting refueling outages would result in reduced effects during that period, there would be an increase in the effects during the current refueling outage period. Installation of a closed-cycle cooling system would achieve continuous flow reduction.

(a) Revised Refueling Outages

This operational measure involves changing the timing of the planned refueling outages to coincide with more biologically active periods in the Estuary. Nuclear plants, including Salem, require periodic outages for refueling. Planned refueling outages are periods during which one of the two Salem units is shut down to undergo refueling. However, one CWP is kept in operation during a refueling outage; therefore, the net effect of each refueling outage is to reduce flow by approximately 42% (7 vs. 12 pumps operating).

Currently, each of the Salem units undergoes refueling every 18 months in either spring or fall. The revised refueling outages alternative involves changing the timing of the planned refueling outages to occur during summer (the period of peak biological productivity) and winter while meeting several constraints. Attachment 6-8 of this Application provides further details on the constraints and feasibility of this alternative. Adjusting the refueling outage schedule would result in a potential reduction in IM and E if the outages were timed to coincide with periods of higher biological productivity.

(b) Seasonal Flow Reductions with Variable Speed Drives

The seasonal flow reductions alternative involves installing variable speed drive controllers (also referred to as variable frequency drives) to the existing pump motors to control circulating water flow. The variable speed drives allow control of the circulating water pump speed, and therefore the water intake velocity and volume in response to seasonal fluctuations in aquatic life that would allow reduced flow during periods of high fish activity. The specific alternatives considered in this assessment involve flow reductions of 10%, 20%, and 45% during the summer months (early June through early September). The associated costs of the flow reduction modifications differ considerably depending on whether the change in cooling water temperature, or • T, is allowed to vary freely or is held constant. The cooling water temperature change is allowed to vary with flow up to a limit of 27.5°F under the former situation and held constant at 15°F by reducing Station power (so as to minimize increased entrainment losses from higher temperatures) under the latter situation.

Thus, a total of six seasonal flow reduction scenarios are considered. These are described as follows:

- *Seasonal flow reduction of 10% with constant • T*. Cooling water flow would be reduced by 10% during a 13-week period where the numbers of organisms are typically highest and the resultant reductions in loss greatest. The temperature differential would be held constant at 15°F.
- *Seasonal flow reduction of 20% with constant • T*. Same as above except that the seasonal flow reduction would be 20%.
- *Seasonal flow reduction of 45% with constant • T*. Same as above except that the seasonal flow reduction would be 45%.
- *Seasonal flow reduction of 10% with variable • T*. Cooling water flow would be reduced by 10% during a 13-week period where the numbers of organisms are typically highest and the resultant reductions in loss greatest. The temperature differential would be allowed to vary with flow up to a 27.5°F limit.
- *Seasonal flow reduction of 20% with variable • T*. Same as above except that the seasonal flow reduction would be 20%.
- *Seasonal flow reduction of 45% with variable • T*. Same as above except that the seasonal flow reduction would be 45%.

(c) Retrofit with Closed-Cycle Cooling System

A closed-cycle cooling system would substantially reduce Salem's intake flow and thus IM and E. Two closed-cycle cooling alternatives are considered–mechanical draft cooling towers and natural draft cooling towers. These two options are briefly discussed below.

i. Retrofit with Mechanical Draft Cooling Towers

One option for converting Salem's OTCW system to a closed-cycle cooling system would require installation of two, 24-cell mechanical draft cooling towers. In addition, the conversion would involve installation of various additional equipment, including new pumps to pump cooling water and make-up water and also significant modifications to existing Station piping and structures. One of the disadvantages of this alternative is that the plume generated from mechanical draft towers may present problems related to fogging and icing in certain weather conditions. Also, the particulate air emissions from mechanical draft cooling towers are generally much higher than the emissions from an equivalent natural draft cooling tower. A more detailed technical discussion of this alternative is provided in Attachment 6-10 of this Application.

ii. Retrofit with Natural Draft Cooling Towers

The natural draft cooling towers alternative would involve installing two new counter-flow type natural draft towers, one for each Salem unit. Compared to mechanical draft cooling towers, natural draft towers produce less noise and air emissions but are somewhat more expensive to build and aesthetically more imposing. Attachment 6-9 of this Application provides further technical discussion of this alternative.

4. Alternative Technological and Operational Measures and §316(b) Final Rule Requirements

Implementation of the closed-cycle cooling alternatives would meet requirements for BTA as stated in 40 CFR §125.94(a)(1)(i) of the Final Rule:

> You may demonstrate to the Director that you have reduced, or will reduce, your flow commensurate with a closed-cycle recirculating system. In this case, you are deemed to have met the applicable performance standards and will *not* be required to demonstrate further that your facility meets the impingement mortality and entrainment performance standards specified in paragraph (b) of this section.

USEPA, however, rejected requiring the retrofit of existing facilities operating on estuaries, tidal rivers, or oceans because of the lack of cost-effectiveness and concerns regarding potential energy impacts (69 Fed. Reg. 41606). PSEG's assessments of the costs of this alternative are consistent with USEPA's conclusions.

Dual-flow fine-mesh screens, which have a maximum through-screen intake velocity of 0.5 ft/s, would also meet the requirements as stated in 40 CFR §125.94(a)(1)(ii):

> You may demonstrate to the Director that you have reduced, or will reduce, your maximum through-screen design intake velocity to 0.5 ft/s or less. In this case, you are deemed to have met the impingement mortality standards and will not be required to demonstrate further that your facility meets the performance standards for impingement mortality specified in paragraph (b) of this section…

C. Comprehensive Cost Evaluation Study (40 CFR §125.95(b)(6)(i)(A))

Facilities that request a site-specific BTA determination because the costs of meeting the applicable performance standards are significantly greater than those considered by USEPA (the cost-cost test) are required to submit a Comprehensive Cost Evaluation Study as well as a Site-Specific Technology Plan. The Comprehensive Cost Evaluation Study includes detailed engineering cost estimates to document the costs (design and construction costs, operational measures, and/or restoration measures at the facility) that would be incurred to meet the applicable §316(b) Standards, a demonstration that the costs exceed those considered by the Administrator in establishing the applicable performance standards, and engineering cost estimates of implementing the Site-Specific Technology Plan (*i.e.*, the technology plan that comes as close as practicable to the §316(b) Standards without resulting in costs that are significantly greater than the costs considered by the Administrator). Attachments 6-3 to 6-10 of this Application provide detailed engineering cost estimates for the various technological and operational alternatives considered, in compliance with the requirements of the Comprehensive Cost Evaluation Study. These cost analyses form the bases for the cost-cost test comparisons. Summaries of the major components of costs included in the cost-cost test are provided below in Section 4-IX in the context of the cost-benefit test.

D. USEPA Cost Estimate

This section summarizes the cost estimate developed by USEPA for use in the cost-cost test for Salem. The Final Rule lays out five steps that the facility must follow to adjust USEPA's cost estimates and thus be in a position to compare its own estimates with those developed by USEPA (69 Fed. Reg. 41644). Detailed descriptions of the cost calculations to develop an appropriate USEPA cost value are provided in Attachment 6-23 of this Application.

USEPA modeled the "addition of fine-mesh screens to an existing traveling screen system" as the compliance technology for Salem. Using the information and instructions detailed in the Final Rule for calculating the costs that the Administrator considered, including the presentation of the information as annualized costs in 2002 dollars (converted using Engineering News Record construction cost index), and the information provided for the Salem facility, the total annualized cost for this technology at Salem is $854,420. This total cost estimate consists of annualized capital and net operating and maintenance ("O&M") costs of $842,248 and annualized pilot study costs of $11,992.

E. Cost Estimates for Technological and Operational Measures Alternative and Comparisons with USEPA Cost Estimate (40 CFR §125.95(b)(6)(i)(B))

Table VIII-1 compares the annualized costs of the technology USEPA modeled (addition of fine-mesh screens to an existing traveling screen system) with costs for the alternative technological and operational measures considered for Salem. (The sound deterrent system and seasonal flow reduction alternatives with variable • T are not included since they are predicted to yield negative benefits—that is, increases in IM and/or E that result in a negative value for benefits—as discussed in Section 6 of this Application.) The relevant alternatives (*i.e.*, those that provide positive IM /E benefits) are divided into two groups based on whether or not they are predicted to meet §316(b) Standards. Table VIII-2 shows the added annualized costs of the relevant alternatives relative to the technology modeled by USEPA, putting the information into the same format as developed for the costs the Administrator considered for Salem (*i.e.*, annualized costs in 2002 dollars).

The annualized costs of each alternative intake technology are summarized and compared to USEPA's cost estimate below, beginning with the technologies that meet §316(b) Standards. Consistent with the Preamble to the Final Rule, the values are measured in 2002 dollars (69 Fed. Reg. 41644).

1. Cost-Cost Comparisons for Alternative Technological and Operational Measures That Meet §316(b) Standards

(a) Dual-Flow Fine-Mesh Screens

The total annualized cost of dual-flow fine-mesh screens is $36,375,000, which is $35,521,000 more than the annualized cost of the technology modeled by USEPA.

(b) Mechanical Draft Cooling Towers

The total annualized cost of mechanical draft cooling towers is $126,090,000, which is $125,235,000 more than the annualized cost of the technology modeled by USEPA.

(c) Natural Draft Cooling Towers

The total annualized cost of natural draft cooling towers is $122,420,000. This alternative results in annualized costs that are $121,565,000 more than the annualized cost of the technology modeled by USEPA.

2. Cost-Cost Comparisons for Alternative Technological and Operational Measures That Do Not Meet §316(b) Standards

(a) Revised Refueling Outage Schedule

The total annualized cost of the revised refueling outage schedule is $12,199,000, which is $11,345,000 more than the annualized cost of the technology modeled by USEPA.

(b) Seasonal Flow Reduction with Constant • T

The total annualized cost of the seasonal flow reduction alternatives with constant • T range from $30,343,000 for 10% reduction to $127,907,000 for 45% reduction. These three alternatives would cost from $29,489,000 to $127,052,000 more than the USEPA modeled technology.

F. Conclusions

The cost-cost comparisons lead to the following two conclusions.

1. Cost Estimates for All Relevant Technological or Operational Alternatives Are Significantly Greater Than USEPA's Cost Estimate

Although there is no specific definition of "significantly greater," the results clearly indicated that the costs for the seven alternatives are all significantly greater than the alternative modeled by USEPA. The costs comparisons show that additional annual costs of the relevant alternatives (relative to the cost of less then $1 million per year calculated by USEPA) range from about $11 million per year for the revised refueling outage schedule) to over $120 million per year per (for the cooling tower alternatives and the 45% seasonal flow with constant • T alternative). Even if analyzed under a "wholly disproportionate" test similar to that utilized by NJDEP to evaluate the 1999 Application, PSEG is still entitled to a site specific determination of BTA because the ratios of the costs of the alternatives to USEPA's assumed costs are at levels commensurate with those ratios previously deemed "wholly disproportionate" by NJDEP in its cost-benefit analysis.

In its response to comments document for the final rule, USEPA stated that…"[i]t is [US]EPA's position that the determination of what constitutes 'significantly greater' should be determined on a case-by-case basis, based upon the cost tests presented by the applicant" (316bEFR.034.037). USEPA explained that a case-by-case application was appropriate because:

> such a standard preserves reasonable discretion for the Director to compare assessments of costs and/or benefits, and make determinations that ensure that the costs of the rule are economically practicable or that there is a reasonable relationship between the costs of cooling water intake technology and the environmental benefits associated with its use. Numerous factors are considered in assessing costs and benefits, and use of a general standard allows an appropriate consideration of the totality of these factors under the rule (316bEFR.006.003).

Although as noted above there is no specific criterion for judging whether the costs are "significantly greater," the results indicate that the costs for the seven relevant alternatives all are "significantly greater" than the cost of the alternative modeled by USEPA by any reasonable yardstick. The cost comparisons show that the *additional* annual costs of the relevant alternatives (relative to the cost of less than $1 million per year calculated by USEPA) range from about $11 million per year (for the revised refueling outage schedule) to over $120 million per year (for the cooling tower alternatives and the 45% seasonal flow with constant • T alternative). In addition, the magnitude of these costs relative to USEPA's cost assumption for Salem is at a level similar to the magnitude of costs relative to the corresponding benefits presented in PSEG's 1999 Application that were determined by NJDEP to be wholly disproportionate. If the wholly disproportionate test was met in the 1999

Application, it is clear that the significantly greater test can also be met under the Final Rule. Finally, it is noted that in its comments to the proposed rule, NJDEP requested that "significantly greater" be defined in the context of comparing costs and benefits as a range between 6:1 and 7:1. If NJDEP's concept is applied to the cost-cost evaluation, it still follows that the costs for the seven relevant alternatives are significantly greater than the costs calculated by USEPA.

2. Salem Is Entitled to a Site-Specific Determination of Best Technology Available

Because the technological and operational alternatives that meet the Final Rule requirements appear to have significantly greater total annualized costs than the USEPA cost estimate, Salem is entitled to a site-specific determination of BTA, in accordance with 40 CFR §125.95(b)(6) of the Final Rule. As discussed throughout this Application, the technological, operational, and restoration measures implemented and proposed to be continued at Salem are the only components of a reasonable BTA determination for the Station.

IX. INFORMATION IN SUPPORT OF A SITE-SPECIFIC DETERMINATION OF BEST TECHNOLOGY AVAILABLE BASED ON COST-BENEFIT ANALYSIS (40 CFR §125.95(b)(6))

In accordance with 40 CFR §125.95(b)(6) of USEPA's §316(b) Regulations, PSEG is submitting the following information in support of a site-specific determination of BTA for Salem based on cost-benefit analysis.

> [US]EPA decided to use a comparison of a facility's costs to the benefits of meeting the performance standards at the facility (a ''cost-benefit test'') as another basis for obtaining a site-specific determination of BTA to minimize adverse environmental impact. … By requiring best technology available to minimize adverse environmental impact, section 316(b) invites a consideration of both technology and of environmental conditions, including the potential for adverse impacts, in the receiving waterbody. [US]EPA believes it is a reasonable interpretation of the statute to allow the Director to consider the results of meeting the performance standards in terms of reducing environmental impacts (*i.e.*, the benefits) in cases where the costs of installing the technology are significantly greater than the reduction in environmental impacts would warrant (69 Fed. Reg. 41603-04).

A. Introduction

Cost-benefit analysis is an economic tool for deciding how to put society's scarce resources to their best use. This approach involves systematic enumeration of costs and benefits that would accrue to members of society if a particular project were undertaken. Cost-benefit analysis provides an *ex ante* perspective; a project is evaluated in advance to aid in deciding in what form it should be undertaken and, indeed, whether the project should be undertaken at all. The US Office of Management and Budget ("OMB") summarizes the role of cost-benefit analysis in evaluating policy alternatives as follows.

> A good regulatory analysis is designed to inform the public and other parts of the Government (as well as the agency conducting the analysis) of the effects of alternative actions. Regulatory analysis sometimes will show that a proposed action is misguided, but it can also demonstrate that well-conceived actions are reasonable and justified.

> Benefit-cost analysis is a primary tool used for regulatory analysis. Where all benefits and costs can be quantified and expressed in monetary units, benefit-cost analysis provides decision makers with a clear indication of the most efficient alternative, that is, the alternative that generates the largest net benefits to society (OMB 2003).

The rationale for undertaking a cost-benefit analysis of a particular decision—such as the decision on additional alternative technological or operational measures at Salem—is to allow society's resources to be put to their most valuable use. In choosing among alternatives, the basic cost-benefit principle is to select the alternative that produces the greatest net benefits (*i.e.*, benefits minus costs) (see, *e.g.*, Boardman *et al.* 2001). It is possible that all project alternatives produce net benefits that are negative, or have costs greater than benefits (if so, the calculation yields net costs rather than net benefits). In that case, the higher value alternative is to "do nothing," which at least produces a net benefit of $0 (*e.g.*, Boardman *et al.* 2001).

1. Alternative Technological and Operational Measures

The following are the five types of alternative technological and operational measures considered for the cost-benefit analysis:

1. sound deterrent system (*i.e.*, a fish diversion device);
2. dual-flow fine-mesh (0.5 mm) screens;
3. seasonal flow reductions with variable speed drives;
4. revised refueling outage schedule; and
5. retrofit with closed-cycle cooling using cooling towers.

Because there are six variations of the seasonal flow reduction alternative and two closed-cycle cooling alternatives, there are a total of 11 technological or operational alternatives. These alternatives are summarized above in Section 4-VIII and described in greater detail in Section 6 of this Application and associated Attachments cited therein.

2. Overview of Cost-Benefit Analysis

The cost-benefit analysis presented here includes cost and benefit estimates for potential alternative technological and operational measures at Salem. Cost-benefit analysis allows the owner or operator of a Phase II facility such as Salem to demonstrate that the "costs would be significantly greater than the benefits of complying with such performance standards at the facility" (69 Fed. Reg. 41603). As noted, the §316(b) Standards applicable at Salem are reductions in IM of 80% to 95% and reductions in E of 60% to 90% from the Calculation Baseline IM and E.

B. Comprehensive Cost Evaluation Study (40 CFR §125.95(b)(6)(i)(A))

As is the case with the cost-cost analysis presented in VIII above, facilities that request a site-specific BTA determination because the costs of meeting the applicable performance standards are significantly greater than the benefits, are required to submit a Comprehensive Cost Evaluation Study. As noted above, detailed engineering cost estimates for the various alternative technological and operational measures are provided in Attachments 6-3 to 6-10 to Section 6, in compliance with the requirements of the Comprehensive Cost Evaluation Study. Because the benefit information is summarized in terms of the present value as of January 1, 2007 and is measured in 2005 dollars, the cost information is presented in the same format for the cost-benefit comparisons.

The following sections provide summaries of the three major categories of costs identified in Section 6: (1) construction costs; (2) O&M costs; and (3) costs of reduced energy and capacity, sometimes referred to as power costs. All three categories constitute social costs that would be incurred if an alternative were implemented. The social cost estimates used for the cost-benefit analyses include some power costs—specifically the relatively small additional social costs related to changes in energy prices due to reduced output (whether during construction downtime or continuing operations) and two small elements of air emissions costs—that are not included in the cost information developed for the cost-cost test because these costs do not translate into net revenue losses to Salem (as discussed in Section 6-V of this Application); cost-benefit results excluding these additional power costs are included in the sensitivity analyses.

1. Construction Costs

Construction costs consist of the capital, labor, and material costs associated with the construction and installation of the alternative technological and operational measures. Construction cost estimates are based on detailed engineering inputs provided by Sargent & Lundy (“S&L”). S&L provided detailed estimates of the overnight capital costs of each alternative as well as estimated cash flows that allowed the development of annual construction cost estimates for each alternative. Attachments 6-3 through 6-10 of this Application provide information on the construction cost estimates from S&L.

Overnight capital costs are engineering estimates of the costs of installing the necessary structures and modifications using real prices (in this case, 2005 prices) for materials, equipment, and labor, and assuming the modifications can be completed immediately (*i.e.*, “overnight”). 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 or through other capital investments during the interim. In addition to overnight cost estimates, Attachments 6-3 through 6-10 of this Application also provide estimates of the duration and timing of capital outlays for each alternative. The time required to complete construction differs substantially among the alternative technological and operational measures. With the exception of the revised refueling outage alternative, which does not involve construction, the construction times for the alternatives range from 2.5 years (sound deterrent system alternative) to over 7 years (dual-flow fine-mesh screens alternative). The overnight cost estimates and the information regarding the timing of expenses are combined to yield estimates of the annual expenditures associated with construction of each alternative. Attachment 6-21 of this Application presents these annual values as well as the calculated present values.

2. Operating and Maintenance Costs

Many of the alternative technological and operational measures involve the installation of equipment that would require ongoing upkeep. Maintaining this equipment entails O&M costs. Also, implementation of some alternatives would affect the O&M costs for the facility as a whole.

Ongoing O&M costs consist of annual labor costs, annual monitoring and inspection costs, and periodic component replacement costs. Increases in auxiliary load requirements due to operation of the equipment are included as power costs in the analysis. (See Section 6-III of this Application for more details.) S&L provided estimated annual O&M costs for each alternative. Attachments 6-3 through 6-10 of this Application present these estimates. In addition, Attachment 6-11 of this Application presents estimated baseline O&M costs at Salem—that is, the O&M costs that Salem would incur without the installation of any of the alternative technological or operational measures. The net O&M costs of each alternative are the estimated costs for the alternative net of any cost savings (*i.e.*, baseline O&M costs that would no longer be incurred under implementation of the alternative). For example, the dual-flow fine-mesh screens alternative would require O&M costs for the new screens, but these O&M costs would replace (in part) the baseline O&M costs associated with the existing screens. Thus the net O&M costs capture the incremental O&M costs of each alternative relative to baseline costs.

Annual O&M costs would begin after the completion of construction required for a particular alternative (*i.e.*, in 2008 or later for alternatives that require more than one year of construction). Once begun, the annual O&M costs would be incurred in each year until the assumed years in which the two Salem units would cease operation.

3. Costs of Reduced Energy and Capacity

Some of the alternative technological and operational measures evaluated in this cost-benefit analysis would lead to reductions in energy output and capacity at Salem. The real-resource costs of such reductions form an important part of the potential real-resource costs of each alternative. (The reductions in Salem output and capacity also lead to reduced Salem revenues.) The real-resource costs include the costs of replacement power—as measured by the relevant energy and capacity prices—net of any cost savings at Salem.

Power costs can arise both during construction outages and during continuing operations. In either situation, the reduction in energy and capacity may be large enough to affect market prices. Power costs during continuing operations and during construction outages are discussed separately below. Section 6-III of this Application treats these topics in more detail.

(a) Costs of Reduced Output and Capacity During Continuing Operations

Some of the alternative technological and operational measures would decrease the annual energy output and available capacity at Salem without reducing any operating costs at Salem. Thus Salem would continue to operate with unchanged variable costs, but would generate less energy output and would offer less available capacity. In this case, the need for replacement energy and capacity would result in real-resource costs (and net revenue losses) that are not offset by any costs avoided at Salem. Reductions of this type come from two sources:

- Performance penalties, or decreases in the Station’s efficiency, which reduce the maximum amount of energy that can be generated at Salem in any single hour. Thus, after a performance penalty, Salem would incur the same costs per hour of generation but would generate less energy per hour. For example, closed-cycle cooling systems, once installed, would operate with increased cooling water temperatures, and, consequently, increased turbine backpressure. The increased backpressure would reduce the maximum amount of energy that Salem could generate in any single hour. Seasonal flow reductions would also decrease the efficiency of the cooling system at Salem. Any performance penalties from the alternative technological and operational measures would reduce both the energy output and the available capacity at Salem.

- Parasitic losses, or increased auxiliary load requirements, reflect increases in the amount of energy that Salem requires for operation during generation. Energy production requires some energy use, and any energy used by a facility reduces the portion of the facility's net energy generation that translates into net energy output. Parasitic losses from the technological and operational measures alternative would reduce both the energy output and the available capacity at Salem.

Some alternative technological or operational measures would result in performance penalties, some would result in parasitic loses, and some would result in both performance penalties and parasitic losses. Either of these two effects at Salem would require replacement energy and capacity from other facilities. In addition, as discussed below, some of the seasonal flow reduction alternatives would result in ongoing performance penalties that would be substantial enough to affect energy prices—and thus the cost of replacement power—on an ongoing basis.

(b) Costs of Reduced Output and Capacity During Construction and Refueling Outages

During an outage, the relevant unit at Salem (the unit undergoing the outage) would not generate any energy, and none of its capacity would be available. As part of normal operating procedure, the units at Salem undergo periodic outages for refueling or maintenance purposes. The changes in outages for the cooling tower alternatives and for the revised refueling schedule alternative are discussed below.

i. Cooling Towers

The cooling tower alternatives would require outage time—in addition to baseline outage time—for each unit when the connections are made between the new cooling towers and the generating equipment. This additional outage would result in real-resource costs (as well as Salem revenue losses). In contrast, the installation of other alternative technological or operational measures could be scheduled to occur during baseline outages, and thus would not result in any real-resource costs related to outages for installation purposes.

Since a unit outage takes the relevant unit offline, a unit outage would result in costs avoided at Salem (the avoided cost of nuclear fuel, for example). These avoided costs would partially offset the real-resource costs of replacement energy and capacity (and the revenue losses to Salem). The outages required for the cooling tower alternatives would be substantial enough—due to the size of the units at Salem and the lengths of the outages—to lead to increases in energy prices and thus increases in the social costs of replacement power. Although these price increases reflect additional social costs, they would not translate into additional revenue losses to Salem.

ii. Revised Refueling Outage Schedule

Since the costs of replacement energy and capacity vary by season, the magnitude of the potential real-resource costs of an outage depends on the timing of the outage. Thus revising the refueling outage schedule to move outages into seasons with more expensive replacement energy and capacity would result in real-resource costs, even though the outage period would be the same. Because the units would be out of service for the same amount of time, the revised refueling outage schedule alternative, unlike the cooling tower alternatives, would not result in any net costs avoided at Salem.

C. Benefits Valuation Study (40 CFR §125.95(b)(6)(ii))

Facilities are required to submit a Benefits Valuation Study if they seek a site-specific BTA determination because the costs of meeting the applicable performance standards would be significantly greater than the benefits. This study—also referred to as the “Valuation of Monetized Benefits of Reducing Impingement and Entrainment” study—requires facilities to submit the following: descriptions of the methodologies used to estimate the benefits (including commercial, recreational, and ecological benefits as well as non-use benefits, if applicable); bases for the assumptions and quantitative estimates; analyses of the effects of significant sources of uncertainty on the results; narrative descriptions of any non-monetized benefits; and, if requested by the Director, a peer review of the items submitted in the Benefits Valuation Study.

The potential social benefits measure the value that individuals in society place on the changes in fish populations that would, in theory, result from the introduction of the various alternative technological and operational measures at Salem. This subsection discusses the biological estimates, methodology of benefits valuation as well as other topics pertinent to benefits estimation required under 40 CFR §125.95(b)(6)(ii) of the Final Rule. More detailed information on the benefits assessment is presented in Section 6-IV of this Application.

1. Methodology of Benefits Valuation (40 CFR §125.95(b)(6)(ii)(A))

In its regional benefits analyses for Phase II facilities, USEPA groups benefits into four major categories, as shown in Figure IX-1. The four quadrants of the benefits circle are the four categories of benefits. The four quadrants are labeled

"Market," "Nonmarket Direct Use," "Nonmarket Indirect Use," and "Nonmarket Nonuse." The figure gives specific types of benefits that might be relevant in each of the four quadrants. This framework is consistent with the framework discussed in USEPA's (2000) Guidelines for Preparing Economic Analyses ("Guidelines") document, which lists essentially the same four general benefit categories.

The discussion presented below summarizes the three benefits categories for which quantitative dollar estimates are developed in this cost-benefit analysis: commercial use benefits; recreational use benefits; and indirect use benefits related to forage fish effects. These correspond to the three categories quantified in the Final Rule (with the indirect use benefits referred to as "ecological benefits" in the §316(b) Regulations). Other benefits categories were considered but determined to be either irrelevant or not likely to be significant at Salem. The reasons for not monetizing non-market, non-use benefits are discussed below in this section. Other categories that are not monetized are discussed in qualitative terms in Section 6-VI of this Application and in Section 4-IX below.

(a) Commercial Use Benefits

Commercial fishing benefits (the major market benefit category) are quantified in the analysis. Market benefits consist of primary products that are bought and sold as factors of production or final consumption products. Increases in the numbers of adult fish caught by commercial fishermen and sold in various fish markets throughout the United States would constitute potential market benefits. The Salem cost-benefit evaluation therefore monetizes commercial fishing benefits. Detailed valuation of commercial fishing benefits is the subject of Attachment 6-14 of this Application. Other types of market benefits are assessed qualitatively, as discussed under Section 4-IX below.

(b) Recreational Use Benefits

Individuals can benefit from improvements in recreational opportunities and aesthetics that are provided by ecosystems. However, unlike the commercial benefits described above, these recreational benefits have no explicit market value but rather constitute a non-market use benefit. Increases in the number of fish species whose adults are valued by recreational anglers would yield recreational benefits. Recreational fish benefits include both additional harvested fish and additional fish caught and released. Details of the recreational fishing analysis are described in Attachment 6-15 of this Application.

(c) Ecological (Forage) Use Benefits

The use benefits of an ecosystem can also include indirect benefits in the form of ecosystem services. Because of interdependence of species within an ecosystem, species without commercial or recreational values may have indirect effects on species that do have direct use values. In particular, changes in forage fish species that serve as food sources (*i.e.*, contribute to the survival and weight gain) for commercial and recreational species can lead to indirect use benefits. Moreover, early life stages of commercial/recreational species themselves constitute forage.

The calculation of ecological use (indirect) benefits uses the production foregone model to estimate the amount of commercial and recreational biomass that would result from the effects of impingement and entrainment on both forage species and the early life stages of commercial/recreational species. (The sum of these two groups is referred to as forage fish in this assessment.) Attachment 6-12 of this Application provides details on the production foregone model. This assessment quantifies the ecological use benefits (categorized as non-market indirect use benefit in Figure IX-1) due to additional forage fish.

(d) Non-market Non-use Benefits

The last major category of benefits—non-use benefits—are benefits that are not associated with any direct use by either individuals or society. These benefits arise if individuals value the change in an ecological resource without the prospect of using the resource or enjoying the option to use it in the future. As noted in the USEPA (2000) Guidelines, estimating non-use benefits requires the use of a contingent valuation ("CV") (*i.e.*, survey) approach, which can be costly to implement correctly. Thus, it is important to determine first whether non-use benefits are likely to be significant and worthy of monetization in order to avoid committing to an expensive analysis that would not provide useful information.

Several criteria can be used to determine whether potential non-use benefits should be monetized. One set of criteria is detailed in the Preamble to USEPA's Final Rule (69 Fed. Reg. 41648). Another set of criteria is provided by the economic literature on non-use valuation. Both sets of criteria and their applications to Salem are discussed in detail in Attachment 6-16 of this Application. These two sets of criteria are summarized below.

The Preamble to the Final Rule recommends that studies consider both the "magnitude and character of ecological impacts implied by the results of the impingement and entrainment mortality study and any other relevant information" (69

Fed. Reg. 41648) in determining whether to monetize non-use benefits. USEPA then specifies that non-use benefits should be monetized if the IMECS determines that substantial harm is done to one or more of the following:

1. a threatened or endangered species;
2. the sustainability of populations of important species of fish, shellfish, or wildlife; or
3. the maintenance of community structure and function in a facility's waterbody or watershed (69 Fed. Reg. 41648).

These criteria provide the conditions for determining whether potential non-use benefits should be monetized. If the results of the biological assessments show that these conditions are not met, then according to the §316(b) Regulations, non-use benefits should not be monetized.

A second set of criteria is provided by the economic literature on non-use valuation. Freeman (2003) reviews the literature on non-use values and considers situations in which non-use values are likely to be significant. Freeman suggests the following two operative criteria for evaluating whether non-use value for fish protection is likely to be significant:

1. the resource is unique; and
2. the loss would be irreversible or subject to a long recovery period.

If both of these criteria are not met, non-use values are likely not to be important. As Freeman notes, "resources such as ordinary streams and lakes or a subpopulation of a widely dispersed wildlife species are not likely to generate significant nonuse values because of the availability of close substitutes" (Freeman 2003).

Even if non-use benefits were expected to be significant and the USEPA criteria for monetization were met, monetization may not be feasible. The USEPA in the Final Rule provides the following footnote caveat after noting the situations in which non-use benefits should be monetized:

> In cases where harm cannot be clearly explained to the public, monetization is not feasible because stated preference methods [i.e., contingent valuation] are not reliable when the environmental improvement being valued cannot be characterized in a meaningful way for survey respondents (69 Fed. Reg. 41648).

Moreover, in determining whether or not to quantify non-use benefits, it is important also to consider the costs and other difficulties of developing reliable information. The USEPA (2000) Guidelines provide the following guidance with regard to assessing benefits,

> Resources should be focused on benefit categories that are likely to influence policy decisions. To use time and resources effectively, analysts must weigh the costs of conducting additional analyses against the usefulness of the additional information provided for decision making… [S]ome categories of benefits may not be assessed either because they are expected to be small or because the costs or time needed to quantify them far exceed the time or resources appropriate for analysis of the particular policy (USEPA 2000).

CV, a stated preference method, is the only established method capable of estimating non-use values. It is expensive and time-consuming to conduct a sound and reliable CV study and, as noted above, the CV may not provide reliable results if the nature of the benefits would be difficult to portray to survey recipients. Attachment 6-16-1 of this Application outlines best practices and recommended guidelines for conducting CV studies. These guidelines have been developed by various governmental agencies and are consistent with guidelines found in the economic literature.

Determination of whether non-use benefits are significant and should be monetized based on these two sets of criteria clearly depends on biological assessments of the individual circumstances. Detailed biological information regarding Salem's effects is provided in Section 5 of this Application and summarized in Attachment 6-16 as it pertains to the conditions outlined in USEPA Final Rule and the economic literature for determining the significance of potential non-use benefits. Brief summaries are provided below.

i. No Harm to Threatened and Endangered Species

This section considers how operations at Salem could potentially affect species classified as threatened or endangered by USFWS and NMFS. The Estuary is a part of the habitat of six aquatic species listed as either threatened or endangered. They are the shortnose sturgeon (endangered) and five species of sea turtle: the green sea turtle (threatened), hawksbill sea turtle (endangered), Kemp's Ridley sea turtle (endangered), leatherback sea turtle (endangered), and loggerhead sea turtle (threatened).

As discussed in Section 4-IV above, historical and continued biological assessments by PSEG at Salem have concluded that Salem has not had an adverse effect on these species. In addition, numerous government-issued "no jeopardy" determinations support and (see Attachment 4-3) confirm PSEG's conclusions that Salem's operations have not had adverse effects on threatened or endangered species. It can, therefore, be determined that USEPA's first criterion for monetizing nonuse benefits, regarding substantial harm to a threatened or endangered species, is not met.

ii. No Harm to the Sustainability of Populations of Important Species of Fish, Shellfish, or Wildlife

The second criterion for determining whether non-use benefits should be monetized relates to whether a facility's operations have caused or will cause substantial harm to the sustainability of populations of important species of fish, shellfish, or wildlife. The §316(b) Regulations do not define the term "sustainability of populations of important T&E species." However, the term can be, and generally is, interpreted to relate to large and potentially irreversible reductions in abundance, changes in age/size structure, increases in mortality rates, or reductions in reproduction rates that threaten the ability of the population to sustain itself. Sustainability in the context of fish populations refers to the ability of populations to persist through time while continuing to perform their normal ecological function and, in the case of economically important species, support normal human uses on a sustained basis (see Section 5-V of this Application).

Previous Salem NJPDES Renewal Applications have used site-specific data to evaluate whether the Station's operations have caused or will cause substantial harm to fish populations. A similar assessment is also used in Section 5 of this Application. Specifically, evaluation of USEPA's second criterion uses two benchmarks: (1) a continuing decline in population abundance benchmark; and (2) a stock jeopardy benchmark. The former evaluates whether past operations have had an adverse impact, while the latter evaluates whether operations could result in future adverse effects. Separate assessments using these two benchmarks (provided in Section 5) indicate that the operation of the CWIS at Salem has not caused and will not cause substantial harm to the sustainability of populations of important species of fish, shellfish, or wildlife. Therefore, USEPA's second criterion for monetizing nonuse benefits is not met.

iii. No Harm to the Maintenance of Community Structure and Function of the Delaware Estuary

In Section 5-VII of this Application, over 30 years of data from the Delaware Estuary are used to evaluate whether Salem's operations have harmed the balanced indigenous community of the Delaware Estuary. The analysis takes into account, among other factors, changes in water quality, fishing pressure, and habitat. Three separate benchmarks are used to evaluate this:

1. whether the same indigenous species have been present over time (*i.e.*, species presence/absence in pre-operational versus operational periods) ("species presence");
2. whether the abundance of aquatic species has fluctuated within the anticipated range ("fluctuations within anticipated range"); and
3. whether there have been irruptions of nuisance, non-indigenous species or species indicative of degraded conditions ("nuisance conditions").

More specific details of these three approaches are described in Section 5 of this Application. Results from the three separate measures show that Salem has not caused substantial harm to the maintenance of community structure and function of the Delaware Estuary. Therefore, USEPA's third criterion for determining whether to monetize potential non-use benefits is not met.

iv. Uniqueness and Irreversibility

As noted above, the economic literature on non-use valuation provides additional guidance on situations in which non-use values are likely to be significant. Freeman's (2003) review of the literature on non-use values suggests two operative criteria (noted earlier) for evaluating situations in which non-use values are likely to be significant.

Based upon the analyses and information in Section 5, operations at Salem do not lead to losses in the Estuary of the sort described by Freeman as likely to be significant. Although the Delaware Estuary could be considered as a unique resource, the relevant resource in this case is the set of changes in fish populations due to fish protection alternatives at Salem. Results of the biological assessment lead to conclusions that "Salem has not caused, and will not cause, substantial harm either to the fish community of the Delaware Estuary or to any RIS species" (Section 5-VII). Moreover, the various benchmarks and analyses lead to conclusions that "Salem has not upset or modified the balanced indigenous community of the Delaware Estuary" (Section 5-VII) and that there has been "long-term increases in the abundance of populations of alewife, American shad, Atlantic croaker, blue crab, striped bass, weakfish, and white perch…in the Delaware Estuary over the period of operation of Salem" (Section 5-VII). Thus, introduction of alternative technological or operational measures would not prevent the loss of these species, because their viability is not threatened. This case thus corresponds to a situation in which subpopulations of widely dispersed species are affected by the alternatives and, as Freeman notes, "resources such as ordinary streams and lakes or a subpopulation of a widely dispersed wildlife species are not likely to generate significant nonuse values because of the availability of close substitutes" (Freeman 2003).

v. Conclusions on Non-use Benefits

Based on the application of the criteria in the Final Rule as well as the criteria in the economic literature—using the biological information in Section 5 of this Application—non-use benefits are not likely to be significant and do not require monetization in light of the changes in fish populations that result from any of the alternative technological and operational measures at Salem.

D. Documentation of Assumptions (40 CFR §125.95(b)(6)(ii)(B))

This section summarizes various assumptions used to develop the quantitative benefit estimates, including: the estimates of mortality due to impingement and entrainment; commercial benefits; recreational benefits; and ecological benefits.

1. Impingement Mortality and Entrainment Estimates

Attachment 6-12 of this Application details the biological modeling with respect to the alternative technological and operational measures considered at Salem. This Attachment also develops estimates of the changes in equivalent adult fish weight, expressed in terms of pounds of harvested fish, for each of the RS under each of the technological and operational alternatives considered. Loss estimates were developed for each alternative and also for the current CWIS and CWS operations in place. The change in pounds of fish associated with each alternative relative to the current controls in place represents the gains expected to be realized from implementation of each measure. Stated differently, these biological benefits represent the additional benefits relative to the existing technological and operational measures at Salem due to the different alternatives. (Not all the alternatives result in additional benefits; the following alternatives actually result in negative benefits—all three seasonal flow reduction alternatives with variable • T and the sound deterrent system alternative.) The gains for the top predator species (weakfish, white perch, and striped bass) include the changes in the harvest due to increases in forage and non-forage RS captured by the production foregone model. See Attachment 6-12 for further details and the calculated loss estimates.

2. Commercial Benefits Values

The commercial values used in the assessment are based on ex-vessel prices as reported by NMFS, which publishes annual values for the various commercial species evaluated in this assessment. Specifically, the commercial prices used are based on average real (in 2005 dollars) prices over a 10-year period, from the years 1994 to 2003. The prices are calculated from yearly averages as reported by NMFS for the relevant species' ranges. See Section 6-IV and Attachment 6-14 of this Application for further details and assumptions.

3. Recreational Benefits Values

The recreational value was estimated based upon the benefits transfer method. In particular, the recreational value was developed using a detailed statistical analysis (meta-analysis) that incorporates information from the relevant individual recreational fishing valuation studies (using travel cost demand models and random utility models). The meta-analysis estimates a relationship between the marginal value that recreational anglers place on a pound of caught fish and the catch rate–a marginal benefit curve for pounds of recreationally caught fish. Since the increases in pounds of harvested fish would likely also coincide with increases in amounts of caught and released fish, the meta-analysis marginal value for pounds of harvested fish includes the value for corresponding caught and released fish. As explained in more detail in Attachment 6-15 of this Application, this assessment provides an economically sound basis for estimating the potential benefits of additional recreational catch due to implementation of technological and operational alternatives at Salem.

4. Ecological (Forage) Benefits Values

In addition to potential commercial and recreational benefits from implementation of the alternatives, other ecological benefits include indirect benefits in the form of ecosystem services. As noted above, because of interdependence of species within an ecosystem, species without commercial or recreational values may have indirect effects on species that do have direct use values. As a result, changes in these species can have value through their effect on populations with direct value.

Forage fish are fish that are not caught but rather are a food source for commercial/recreational fish. In the case of the technological and operational alternatives being considered, the additional forage fish that would be saved could provide additional food to predator and scavenger fish species (*i.e.*, contribute to the survival and weight gain) that have commercial and/or recreational values. The benefits assessment therefore includes the effects of forage fish changes as an indirect ecosystem effect. See Section 6-IV and Attachment 6-12 of this Application for more details.

5. Conservative Benefit Assumptions

The assessment also makes several conservative (*i.e.*, overstates benefits) assumptions regarding the benefits calculations that have implications for the overall results. Specifically, the assessment ignores natural biological compensatory mechanisms that operate to maintain fish populations despite losses at early life stages (*e.g.*, PSEG 1999a, Appendix I). Including this phenomenon would reduce the effects of CWIS-related mortality at Salem on the population of adult fish and correspondingly may result in substantially smaller estimated benefits than the ones used in the analyses. Another conservative assumption is to ignore potential increases in fishing costs, which may reduce or even eliminate the benefits to commercial fishermen from the greater catch. (The assessment also assumes there are no gains to consumers through lower prices; as discussed in Attachment 6-14 of this Application, this assumption is warranted since retail prices likely would not change significantly due to the greater catch.) As discussed in Attachment 6-14 of this Application, USEPA in its §316(b) analyses related to the Final Rule only applied a fraction (0 to 40%) of the commercial benefits to account for increased fishing costs (USEPA 2004). Since these potential costs are ignored, the estimated commercial fishing benefits would tend to be overstated. Also, the value per pound of the non-RS is assumed to be the same as the weighted average value for the RS (excluding Atlantic menhaden and bluefish). This assumption tends to overstate the non-RS value, and therefore total benefits, since the other species are likely to be less desirable than the RS.

E. Determination of Entrainment Survival (40 CFR §125.95(b)(6)(ii)(B))

The estimate of E presented in the IMECS and used in DCTP and RP to assess compliance with the §316(b) Standards and the Restoration Standards assumed 100% mortality, as required by the Final Rule. The estimates in the site-specific cost-benefit analysis assume that some organisms survive entrainment. In the event NJDEP rejects PSEG's use of entrainment survival in Section 4-IX of the CDS, Attachment 6-27 of this Application provides the results of an alternative cost-benefit analysis that assumes no entrainment survival (*i.e*., 100% entrainment mortality).

1. Site-Specific Study Plan

PSEG had conducted site-specific entrainment survival studies at Salem pursuant to a plan of study previously reviewed by NJDEP and approved by USEPA (NJDEP 1994b). In addition, PSEG has most recently conducted a comprehensive evaluation of the prior entrainment study at Salem along with entrainment survival studies at other power plants with design and operational characteristics similar to

Salem's (PSEG 2004b, Attachment 8). Together these constitute PSEG's site-specific entrainment survival plan ("ESP") at Salem.

2. Documentation of NJDEP's Approval of Entrainment Survival Plan

PSEG (2005b) submitted its ESP to NJDEP for review and approval. Although NJDEP has not yet provided a response, PSEG has used entrainment survival values in calculating the benefits of alternative technological and operational measures in Section 4-IX of the CDS. Given the long-standing regulatory acceptance of PSEG's use of entrainment survival in estimating entrainment losses at Salem, this is a reasonable approach. Tables IX-1 and IX-2 provide the entrainment survival values expressed as mortality rates PSEG used in this cost-benefit analysis (See Attachment 4-4).

From the Final Environmental Impact Statement for Salem (AEC 1973) through PSEG's 1999 Application for Salem, there has been recognition that some organisms survive entrainment at Salem. PSEG's use of entrainment survival in estimating entrainment has been reviewed by Versar (1989) and ESSA (2000), the independent contractors retained by NJDEP to review PSEG's (1984) initial §316(b) Demonstration for Salem and Appendix F of PSEG's (1999a) previous Application.

Versar (1989) concluded:

> …there is little evidence to suggest that total through-plant mortality was seriously underestimated. The mortality rates reported by [PSEG] are consistent with those observed in laboratory studies and reported at other facilities…Estimates of through-plant mortality…are based on best methods reasonably achievable and can be accepted without modification.

ESSA (2000) noted:

> Small fish can survive passage through the CWS if the duration of the transit time is not too long. Survival for eggs and larvae is significantly lower…The entrainment and impingement values…were generated from estimates of the density of each RIS (by life stage and by day) in the intake and then mortality numbers were estimated using various parameters. This method makes a lot of sense since it allows one to generate realistic daily patterns and then change the parameters in order to assess the effects of alternate intake protection strategies and technologies.

NJDEP also has acknowledged that not all organisms entrained at Salem would be subject to 100% entrainment mortality (NJDEP 1994b).

3. Estimates of Entrainment Losses for Cost-Benefit Analysis

Table IX-3 includes estimates of entrainment losses for Current Conditions and Proposed Conditions, respectively. These estimates incorporate entrainment survival, based on the factors described above.

F. Results of Cost-Benefit Analysis (40 CFR §125.95(b)(6)(ii))

Table IX-4 presents the present values of the costs of the alternative technological and operational measures considered in this Application, and Table IX-5 presents the present values of the benefits. Present values are calculated as of January 1, 2007 and are measured in 2005 dollars. These two sets of results are brought together in Table IX-6, which gives the present values of the net costs (*i.e.*, total costs less total benefits) of the alternatives. (These results are summarized in terms of net costs rather than net benefits because all of the alternatives have costs greater than benefits.) Figure IX-2 shows the present values of total costs and total benefits of the alternatives, and Figure IX-3 shows the present values of the net costs.

1. Elimination of Alternatives Dominated by Other Alternatives

Before considering the cost-benefit results, as with the cost-cost test results, it is useful to eliminate the alternatives with negative benefits. In addition, the cost-benefit comparisons should eliminate alternatives that are dominated by one or more of the other alternatives. An alternative is dominated by another if it offers the same or smaller benefits but has higher costs. For example, the revised refueling outage schedule yields potential benefits of $0.35 million with costs of about $118 million. It dominates the 10% seasonal flow with constant • T alternative because the latter has the same benefits ($0.35 million) and higher costs ($273 million). To take another example, the 45% seasonal flow reduction with constant • T alternative is dominated by both cooling tower alternatives because the seasonal flow option offers lower benefits at higher costs. Moreover, the mechanical draft cooling tower alternative is dominated by the natural draft cooling tower alternative because natural draft provides the same benefits but costs less.

This process of eliminating dominated alternatives results in four alternative technological and operational measures that are not dominated. The present values of total costs, total benefits, and net costs for these four non-dominated alternatives are presented in Table IX-7 and discussed below. All present value estimates are in 2005 dollars.

2. Results for Non-dominated Alternatives

(a) Revised Refueling Outage Schedule

The present value of the total costs of the revised refueling outage schedule is estimated to be about $118 million, and the present value of the total benefits, $0.35 million. The present value of net costs is thus about $117 million.

(b) Dual-Flow Fine-Mesh Screens

The present value of the total costs of dual-flow fine-mesh screens is estimated to be about $236 million, and the present value of the total benefits, $0.45 million. The present value of net costs is thus about $236 million.

(c) 20% Seasonal Flow Reduction with Constant • T

The present value of the total costs of 20% seasonal flow reduction with constant • T is estimated to be about $529 million, and the present value of the total benefits, $0.73 million. The present value of net costs is thus about $529 million.

(d) Natural Draft Cooling Towers

The present value of the total costs of natural draft cooling towers is estimated to be about $995 million, and the present value of the total benefits, $6.29 million. The present value of net costs is thus about $989 million.

G. Analysis of the Effects of Significant Sources of Uncertainty on the Results of the Assessment (40 CFR §125.95(b)(6)(ii)(C))

Cost-benefit analysis is widely used to support better decision-making and to allow society's resources to be put to their most valuable use. The benefit and cost estimates used to perform the analysis are typically not known with certainty, however. The results presented in IX-F above and in Section 6-VI of this Application represent the most plausible estimates of uncertain cost and benefit elements. The purposes of conducting uncertainty analyses—in this case, sensitivity analyses and Monte Carlo analyses—are to acknowledge and measure the effects of various uncertain elements. These two well-accepted methods of evaluating uncertainty are provided in detail in Section 6-VIII of this Application and Attachments cited therein. These methods are summarized below.

Proper treatment of uncertainty provides useful information to help identify BTA at Salem and, indeed, uncertainty analyses are increasingly used in regulatory contexts to help support the decision-making process. The results of the basic cost-benefit analysis can be considered robust if they do not change when the uncertain factors are taken into consideration. Although it is impossible to fully account for all sources of uncertainty, it is widely acknowledged that good economic analyses should address sources of uncertainty that could significantly affect the results. For example, USEPA's 2000 Guidelines stress the importance of focusing on key variables when conducting sensitivity analyses:

> For most applied economic analyses, a full sensitivity analysis that includes every variable is not feasible. Instead the analyst must limit the sensitivity analysis to those input parameters that are considered to be key or particularly important (USEPA 2000).

Significant sources of uncertainty were evaluated with respect to the both benefits and costs estimates. See Section 6-VIII of this Application for further details. The significant sources of uncertainty with respect to both the costs and the benefits are discussed below.

1. Sensitivity Analysis

Sensitivity analysis provides a means to determine the effects of different input parameters on the overall results—in this case, the net costs of the various alternative technological or operational measures.

> The purpose of sensitivity analysis is to acknowledge the underlying uncertainty. In particular, it should convey how sensitive predicted net benefits are to changes in assumptions. If the sign of net benefits does not change when we consider the range of reasonable assumptions, then our analysis is robust and we can have greater confidence in its results (Boardman *et al.* 2001).

Sensitivity analysis involves varying key input parameters, one at a time, over an appropriate range to determine their effects on net costs. Sensitivity analysis should be limited to key input parameters, and conducting a full sensitivity analysis that includes every variable is usually not feasible (USEPA 2000). Section 6-VIII of this Application provides results of the sensitivity analyses. In particular, the Section and Attachments cited therein evaluates the sensitivity of the results to several key assumptions including (1) the discount rate (*i.e.*, rate used to discount costs and benefits to present values); (2) entrainment survival; (3) life-extension of the Salem units; (4) a different measurement of commercial fish values (that increases commercial benefits); (5) exclusion of certain small power costs (specifically those not included in the costs used for the cost-cost test), and (6) a change in the baseline flow assumption. Detailed discussions of these sensitivity analysis cases are provided in Section 6-VIII of this Application. Tables IX-8 through IX-14 summarizes the results of these sensitivity analyses.

2. Quantitative Monte Carlo Analysis

Quantitative Monte Carlo analysis, or Monte Carlo simulation, is a computer-based method of analysis (*e.g.*, Boardman *et al.* 2001). It uses statistical sampling techniques to approximate a probability distribution that cannot be derived analytically. The analysis repeatedly samples from the probability distributions of the major uncertain inputs to the model. The probability distributions capture the range of possible values the inputs might take and the likelihood of the occurrence of these values. Input values associated with higher probabilities will be selected more often during the simulation, while input values associated with lower probabilities will be selected less often. More detailed discussions of this approach are provided in Attachment 6-25 of this Application.

The impingement and entrainment estimates were developed through detailed biological modeling. These estimates, which predict biological increases in fish populations from implementation of alternative technological and operational measures considered in this assessment, are uncertain. Two major sources of uncertainty related to these estimates are the inter-annual variability in IM and E (for constant water withdrawal rates) and inter-annual variability in age-0 survival. Attachment 6-25 of this Application discusses in detail how these two factors were considered in the uncertainty analysis.

Commercial and recreational fishing prices are other sources of uncertainty in the benefits estimates. As discussed earlier, the commercial fishing benefits are calculated based on ex-vessel fish prices. In the uncertainty analysis, probability distributions were developed to capture the variability around the commercial prices based on historical information. The recreational fish values, detailed in Attachment 6-15 of this Application, were developed using a statistical meta-analysis of the marginal value of increased catch. Based on the results, the variability in the estimated parameter and the average catch rate used were modeled to derive the marginal recreational value.

Together with the cost probability distributions (see Attachment 6-25 of this Application), the benefit probability distributions discussed above are used to calculate estimates of net costs (*i.e.*, costs minus benefits); as noted above, the results are summarized in terms of net costs rather than net benefits because costs exceed benefits for all alternatives. See Section 6-VIII and Attachment 6-25 of this Application for detailed discussions of the analyses, including major uncertain factors and input distributions.

Table IX-15 summarizes the results of the Monte Carlo analyses.

H. Peer Review of Benefits Valuation Study, Upon Request of the Director (40 CFR §125.95(b)(6)(ii)(D))

NJDEP's review of PSEG's 1999 Application included review by ESSA of Appendix F, which included a cost-benefit analysis (NJDEP 2000b). Included on the ESSA team was Kim Rollins, Ph.D., a Professor of natural resources economics at the University of Guelph. Dr. Rollins conducted a thorough review of the 1999 cost-benefit analysis and concluded the results were sound (ESSA 2000). The methods PSEG used in this Application are similar to those in the 1999 Application, although the cost-benefit analysis has been modified to conform to the Final Rule.

In the event NJDEP determines that a peer-review would be required of the Benefits Valuation Study presented in the CDS, PSEG will cooperate with NJDEP in establishing a peer-review panel and will work with the panel during its review of the Benefits Valuation Study for Salem.

I. Non-monetized Benefits That Would Be Realized if Salem Met the Performance Standards (40 CFR §125.95(b)(6)(ii)(E))

The benefits assessment for the cost-benefit analysis considers the relevant benefit categories identified in the Final Rule as well as those described in the USEPA (2000) Guidelines and USEPA's (2004) §316(b) regional benefits analyses for Phase II facilities and quantifies the relevant and significant benefits categories. Several other benefits components (*i.e.*, positive social effects) are not quantified in this assessment because they were assessed to be either irrelevant or likely insignificant. In some cases, the necessary information to make a full assessment was not available. The non-quantified benefits include the value of additional fish available for bait that may not be captured in the commercial benefit values and bird watching benefits (due to potential increases in bird populations due to greater fish populations). These benefits were not included because they were determined to be insignificant components of benefits. Detailed discussions are given in Section 6-VI of this Application for non-quantified benefits, as well as for non-quantified costs.

J. Conclusions

The cost-benefit results lead to the following two conclusions.

1. Costs of All Technological and Operational Alternatives Are Significantly Greater Than Benefits

As discussed in Section 4-VIII of this Application, USEPA has not defined the term "significantly greater" in the §316(b) Regulations but offered in its preamble to the proposed §316(b) rule that "significantly greater" is less than "wholly disproportionate," the standard for new facilities (and the standard that had been used in prior permitting cases pursuant to USEPA's Draft Guidance) (67 Fed. Reg. 17145-46).

The cost-benefit test results presented earlier show that the costs exceed benefits by a substantial amount for all the relevant alternative technological or operational measures. With regard to the non-dominated alternatives, three of the four alternatives (revised refueling outage, dual-flow fine-mesh screens, and 20% seasonal flow reduction with constant • T alternatives) result in total benefits of less than $1 million compared to total costs that range from $118 million to more than $500 million. (As noted in IX-B above, costs and benefits are reported as present values as of January 1, 2007 in 2005 dollars). The other alternative, natural draft cooling tower, results in total benefits of about $6 million with costs of almost $1,000 million.

Although there is no clear criterion for "significantly greater," it is clear that the costs are "significantly greater" than the benefits for all the relevant alternatives. The cost comparisons are at a similar level to that presented in PSEG's 1999 Application upon which a determination was made that the costs of the evaluated technologies were wholly disproportionate to the benefits of those technologies. If the wholly disproportionate test was met in the 1999 Application, it is clear that the significantly greater test can also be met under the Final Rule. Finally, it is noted that in its comments to the proposed rule, NJDEP requested that "significantly greater" be defined in the context of comparing costs and benefits as a range between 6:1 and 7:1. If NJDEP's concept is applied to the cost-benefit evaluation, it still follows that the costs for the seven relevant alternatives are significantly greater than the benefits. The sensitivity and uncertainty analyses performed for this evaluation of alternative technological and operational measures at Salem, discussed above and presented in greater detail along with results in Sections 6-I and 6-VIII of this Application, indicate that this conclusion is not altered when uncertainties are taken into account.

2. Salem Is Entitled to a Site-Specific Determination of Best Technology Available

Because all the relevant alternative technological and operational measures have costs that are significantly greater than their potential benefits, Salem is entitled to a site-specific determination of BTA, in accordance with 40 CFR §125.95(b)(6) of the Final Rule. As discuss throughout this Application, the technological, operational and restoration measures implemented and proposed to be continued at Salem are the only components of a reasonable BTA determination for the Station.

X. SITE-SPECIFIC TECHNOLOGY PLAN REQUIRED IN CONJUNCTION WITH SITE–SPECIFIC BTA DETERMINATIONS (40 CFR §125.95(b)(6)(i)(C) AND (iii))

PSEG is submitting this Site-Specific Technology Plan in conformance with the Final Rule. USEPA's regulations provide that facilities can achieve compliance with either the §316(b) Standards or site-specific performance standards through the implementation of technological, operational, or restoration measures. This Site-Specific Technology Plan is based on the results of the cost-cost evaluation and the cost-benefit evaluation that demonstrate that PSEG is entitled to a site-specific determination of BTA because its costs are significantly greater than USEPA's assumed costs for a facility similar to Salem and the cost of implementing additional measures are significantly greater than the value of the benefits that would be realized.

A. Narrative Description of Measures Selected in Accordance with Site-Specific Performance Standard (40 CFR §125.95(b)(6)(iii)(A))

As the cost-cost assessment in VIII and the cost-benefit assessment in IX above demonstrated, Salem is entitled to a site-specific determination of BTA under either test. Moreover, as discussed below, these assessments clearly show that PSEG meets the site-specific standard through the innovative and state-of-the-art technological, operational and restoration measures PSEG has already implemented under Salem's 1994 and 2001 NJPDES Permits. A brief summary of these measures follows. For detailed descriptions of technological and operational measures, see Section 4-V above.

1. Technological Measures

The technological measures utilized at Salem to meet the site-specific standard for reductions in IM include multi-speed continuously operating improved modified-Ristroph intake screens and the bi-directional fish return system. The screen modifications include: (1) ¼ in. by ½ in. smooth mesh screen panels; (2) the hydrodynamically superior composite-material fish buckets; (3) the redesigned flap seals; (4) the improved spray wash system with low and high-pressure nozzles and debris shields; and (5) the bi-directional fish return system with fiberglass troughs and with enhanced intersection of the fish and debris troughs. These technologies are described in detail in V-C above. In addition, the magnitude of these costs relative to the corresponding benefits is at a level similar to the magnitude of costs relative to the corresponding benefits presented in PSEG's 1999 Application that were determined by NJDEP to be wholly disproportionate. If the wholly disproportionate test was met in the 1999 Application, it is a clear given that the significantly greater test can also be met under the Final Rule. Finally, it is noted that in its comments to the proposed rule, NJDEP requested that "significantly greater" be defined in the context of comparing costs and benefits as a range between 6:1 and 7:1. If NJDEP's concept is applied to the cost-benefit evaluation, it still follows that the costs for the seven relevant alternatives are significantly greater than the corresponding benefits.

2. Operational Measures

Continuously operating traveling screens with four fully automated, shifting speeds is the operational measure in-place at Salem that contributes to the Station's meeting the site-specific standard for reductions in IM. The continuous operation of the screens causes less accumulation of debris, is more effective in assisting fish and debris removal to their respective troughs, and lowers through-screen velocity thus enhancing the survivability of the smaller fish that are impinged.

3. Restoration Measures

As described in detail in VII-C-2 a and b above, PSEG has restored 4,400 acres of formerly diked salt hay farms to fully functioning salt marshes to achieve compliance with the §316(b) Standard for reduction in E. These restored salt marshes are increasing the production of fish and shellfish in the Estuary, including the RS for Salem. A detailed description of the salt hay farm restoration sites is provided in VII-A and VII-C-2-c above. The restoration sites are: the DTRS, the MRTRS and the CTRS. Both DTRS and MRTRS have met the final NJDEP-approved Success Criteria established in the Management Plans for those sites. The CTRS has met the interim Success Criteria on schedule and is on schedule for meeting the final Success Criteria (See VII-C).

B. Engineering Cost Estimates Documenting the Costs of Implementing the Measures Identified in the Site-Specific Technology Plan (40 CFR §125.95(b)(6)(i)(C))

The existing technological, operational, and restoration measures meet the site-specific BTA standard for Salem. Since these measures have already been implemented, most of the implementation costs already have been incurred. Ongoing maintenance costs for the existing technological, operational, and restoration measures are presented in Attachment 6-11 and Attachment 6-26 of this Application. These technological, operational, and restoration measures constitute the baseline conditions for purposes of the cost-cost and cost-benefit tests, *i.e.*, these existing measures represent the baseline against which the potential alternative measures are being compared.

C. Engineering Estimates of the Efficacy of the Proposed and/or Implemented Measures (40 CFR §125.95(b)(6)(iii)(B))

In V and VII above, PSEG has documented the efficacy of the existing technological, operational, and restoration measures based upon years of post-implementation monitoring. A summary of this information is provided below.

1. Site-Specific Evaluation of Suitability of Technological Measures for Reducing Impingement Mortality and/or Entrainment Based on Representative Studies on Similar Waterbodies and/or Prototype or Pilot Studies

Since the issuance of Salem's 1994 NJPDES Permit, PSEG has studied and demonstrated the efficacy of the technological and operational measures by conducting impingement survival studies to assess the increased impingement survival due to the improved CWIS technology (PSEG 2004b, Attachment 9). These studies showed that the improved modified-Ristroph intake screens and bidirectional fish return system produce substantial reductions in IM at Salem.

2. Site-Specific Evaluation of Suitability of Wetlands Restoration for Increasing Production of Fish and Shellfish to Offset Impingement Mortality and/or Entrainment Based on Representative Studies on Similar Waterbodies and/or Prototype or Pilot Studies

PSEG's restoration program was developed and implemented with guidance from NJDEP and numerous federal and state fish and wildlife agencies and was peer-reviewed by independent scientists approved by NJDEP. To ensure efficacy of restoration measures, monitoring data will be collected on changes in vegetation cover, hydrogeomorphology, and faunal response to the restoration measures until the NJDEP-approved Success Criteria are met at each site. The results of the extensive monitoring at the restored sites confirm that fish and shellfish in the Estuary have benefited from the restored sites and that a wide variety of fish and shellfish use the restored marshes as habitat for feeding, nursery, and refuge (VII-D above).

PSEG has also used vegetation cover data that was used together in an AFCM to develop estimates of the increased production of fish and shellfish (See VII-E above and Section 7 and Attachment 7-1 of this Application). The increased production of fish and shellfish are producing ecological benefits (*i.e.,* increased production of fish and shellfish) for the Estuary that are substantially greater than the fish and shellfish lost due to entrainment at Salem.

D. Restoration Plan In Conformance with 40 CFR §125.95(b)(5)(iii)(B)

As thoroughly explained in VII above, PSEG has substantially increased the production of secondary consumers and has therefore offset the loss of these organisms through IM and E at Salem. The restoration program was designed, implemented, and completed (for two of the three restoration sites) in accordance with procedures, processes, and schedules established in the 1994 NJPDES Permit and NJDEP Management Plans. PSEG prepared site-specific designs following detailed investigation of geomorphological, hydrological, and biological conditions at each restoration site, as well as in adjacent natural marshes. Taken together, the understanding of wetland function developed on both estuary-wide and site-specific bases allowed PSEG to optimize engineering parameters and maximize the opportunity for restoration success.

PSEG is proposing to continue to implement the AM Program and vegetation and hydrogeomorphological monitoring at CTRS until two years after this site achieves compliance with the NJDEP-approved Success Criteria. The details of this monitoring program are provided in Attachment 4-7 to this CDS.

E. The Proposed and/or Implemented Measures Achieve an Efficacy as Close as Practicable to the Applicable Performance Standards Without Resulting in Costs that Are Significantly Greater than either USEPA's costs or the Value of the Benefits (40 CFR §125.95(b)(6)(iii)(C))

The alternative technological and operational measures included in PSEG's detailed analysis represent all the alternatives found to be potentially applicable at Salem (See Section 6-II and Attachment 6-2 of this Application). These alternatives were evaluated under both the cost-cost test and the cost-benefit test.

With regard to the cost-cost test, the costs of the biologically effective alternatives were compared to the cost estimated by USEPA for its modeled technology. All relevant alternatives were found to have significantly greater costs than USEPA's cost estimate (See VIII above). Thus, the existing technological and operational measures achieve an efficacy as close as practicable to the applicable performance standards.

With regard to the cost-benefit test, the costs of all relevant alternatives were compared to their potential benefits. Results of these analyses indicate that the costs are significantly greater than the benefits for all the alternatives (See IX above). This means that none of the alternative technological, operational, and restoration measures that could potentially be implemented at Salem comply with the criterion in the cost-benefit test. In all instances, the costs would be significantly greater than the benefits. Thus, the existing technological, operational, and restoration measures achieve an efficacy as close as practicable to the applicable performance standards without resulting in costs that are significantly greater than the benefits. This result reflects the state-of-the-art technological and operational measures and the enormously successful restoration measures that already have been implemented at Salem and the lack of cost-effective technologies or operational measures to provide additional benefits at Salem.

F. Design and Engineering Calculations, Drawings and Estimates Prepared by a Qualified Professional to Support the Estimates in the Plan (40 CFR §125.95(b)(6)(iii)(D))

With this CDS, PSEG is submitting engineering calculations and drawings as well as the calculations of production estimates.

1. Engineering Drawings

As discussed above in V-G, although engineering drawings have been submitted to and reviewed by NJDEP and their consultants on numerous occasions, PSEG is again providing the engineering drawings that depict the components of the CWIS that contribute to reductions in impingement mortality and entrainment. Figures V-4 through V-7 are engineering drawings that depict the four components of the improved modified-Ristroph traveling screens including screen mesh panels, composite material fish buckets, neoprene flap seals, and spray wash system that have reduced IM and/or E at Salem. The engineering drawing provided as Figure V-8 depicts the bi-directional fish return system that functions to reduce IM. PSEG has also submitted engineering drawings for the salt hay farm restoration sites. Figures VII-5, VII-7, and VII-9, respectively, depict the engineering drawings for the construction activities at DTRS, MRTRS, and CTRS.

2. Estimates

The estimated reduction in IM and E due to technological and operational measures are described above in V and the estimated increase in the production of these organisms from the restoration measures are described in VII above.

(a) Impingement Reduction

Based solely on technological and operational measures, PSEG has achieved a substantial reduction in IM, which satisfies the site-specific requirement for Salem.

(b) Entrainment Reduction

Based on a combination of technological measures including the improved mesh screens and restoration measures implemented at the salt hay farm wetland restoration sites, PSEG has achieved compliance with site-specific standard for reductions in E. The combination of the reductions due to technological measures and the increase in production due to the salt hay farm restoration has demonstrated a substantial increase in the production of fish and shellfish.

XI. VERIFICATION MONITORING PLAN (40 CFR §125.95(b)(7))

In this CDS, PSEG has demonstrated that Salem meets the §316(b) Standards based on existing technological, operational and restoration measures. Compliance with the §316(b) Standard for IM reduction is achieved based on (1) the improved modified-Ristroph intake screens and the bi-directional fish return system; and (2) the continuous operation of the multi-speed traveling screens to minimize the time a fish remains impinged. Compliance with the §316(b) Standard for E reductions are due to (1) the improved design of the screen panel mesh which allows smaller organisms to not be entrained, and (2) increases in production of fish and shellfish due to the restored wetlands. In the VMP, PSEG is only required to address monitoring related to verifying the efficacy of design and control technologies and the operational measures.

The improved modified-Ristroph intake screens with fish buckets and the bi-directional fish return system have been fully installed and operational at Salem since 1997. As indicated in V above, PSEG has conducted seven years of post-installation monitoring of IM and the data from the most-recent three years is provided in the DCTP. No further biological verification monitoring is required to demonstrate the efficacy of the installed design and construction technology and operational measures. As discussed in the TIOP (See VI above), PSEG will continue: to provide training to its employees who operate and maintain the CWIS; to inspect the screen panels, fish buckets, flap seals, spray wash system and bi-directional fish return system; to implement the preventative maintenance activities; and to address all work orders generated relating to these CWIS components. These activities will ensure, to the maximum extent practicable, that these CWIS components will continue to function as intended to reduce IM to levels that meet the applicable §316(b) Standard.

As discussed above, PSEG is relying on both technological and restoration measures to meet the §316(b) Standard for reductions in E. Consequently, the VMP is complemented by the monitoring component of the RP, described in VII above. PSEG anticipates that the Department will incorporate requirements for conducting these monitoring programs and for submitting the required reports in Salem's renewal NJPDES Permit. PSEG has, therefore, prepared Attachment 4-7 to the CDS, which is a proposed Monitoring Plan for Salem to replace the IBMWP (PSEG 2002a), required under Salem's current NJPDES Permit (NJDEP 2001a).

A. PSEG's Monitoring Pursuant to the NJPDES-Required BMWP and IBMWP Satisfy the Requirements for Two Years of Post-Installation or Implementation Monitoring (40 CFR §125.95(b)(7)(i))

As discussed in II and V above, PSEG was required to install the improved modified-Ristroph intake screens with fish buckets pursuant to Salem's 1994 NJPDES Permit. That Permit required that the screens be installed on one unit first to allow both an assessment of the operability of the design as well as side-by-side impingement survival studies (NJDEP 1994a). PSEG completed the required operability assessment and impingement studies, upgraded the motors on the first unit and installed the screens with upgraded motors on the second unit (PSEG 1999a, Attachment G-1). From 1999 through 2004, PSEG conducted intensive monitoring of impingement abundance and initial mortality (PSEG 2000, 2001, 2002, 2003, 2004, 2005). PSEG also conducted additional latent impingement mortality studies during 1999, 2000 and 2003 (PSEG 2004b, Attachment 9). In the DCTP (See V above) PSEG demonstrated compliance with the §316(b) Standard for reductions in IM based on the improved modified-Ristroph traveling screens and bi-directional fish return system. PSEG also demonstrated partial compliance with the §316(b) Standard for E based on the configuration of the screen mesh. Since PSEG has conducted extensive post-installation monitoring spanning more than five years, no additional verification monitoring for the design and construction technologies and operational measures being relied upon for compliance with the §316(b) Standard for IM is being proposed or is required.

B. Proposal for Addressing Naturally Moribund Fish and Shellfish (40 CFR §125.95(b)(7)(ii))

One of the requirements of the VMP is a proposal on how naturally moribund (and dead) fish and shellfish that enter the cooling water intake structure will be identified and taken into account in assessing success in meeting the §316(b) Standards. The IM and E data contained in the IMECS, IV above, and the performance standard calculations presented in the DCTP and RP, V and VII above respectively, already account for naturally moribund fish and shellfish, to the extent practical. Inclusion of naturally moribund organisms in the estimates of IM or E would artificially inflate losses. Therefore, PSEG's approach for addressing naturally moribund organisms can be considered a conservative factor when demonstrating compliance with the §316(b) Standards.

1. Juvenile Fish and Larvae

There is no practical method to identify naturally moribund juvenile fish and larvae in impingement and entrainment samples, therefore, no adjustments were made for dead or moribund fish or shellfish in determining compliance with the IM or E standards. All larval and juvenile fish and shellfish, regardless of condition, were included in the appropriate entrainment or impingement loss estimates. Inclusion of these individuals is conservative in that E and/or IM estimates will be overestimates.

2. Eggs

PSEG's estimates of E do account for moribund eggs collected in entrainment samples. PSEG has used an established protocol that is based on documented laboratory practices for ichthyoplankton data processing. This protocol is described below.

Standard ichthyoplankton entrainment samples are collected and immediately preserved with a 10% formalin-rose bengal solution. The samples are then sent to the laboratory where they are washed to remove the formalin. At this point, they are removed, enumerated, and stored in 40% isopropanol. During this process, the viability of fish eggs is determined.

Egg viability was determined on the basis of clarity of the perivitelline space and integrity of the embryo and yolk material. Any egg with a clouded perivitelline space or non-intact yolk or embryo was deemed “non-viable.” Such eggs were not included in any further processing and were not included in estimates of fish egg entrainment.

C. Description of Information for Inclusion Status Reports to NJDEP (40 CFR §125.95(b)(7)(iii))

As discussed above, PSEG proposes to submit combined reports that will include the information required under both the VMP and the RP, as defined in Attachment 4-7. Because the design and construction technologies and operational measures have already been subject to intensive monitoring and documentation the focus of the status reports will be on efficacy of the restoration measures. For consistency with other reporting requirements, PSEG proposes that status reporting occur on an annual basis until such time as the activities described in the RP are complete.

As with other NJPDES-required monitoring and inspection data and information and as required under 40 CFR §125.97(a) of the Final Rule, PSEG will retain the information and data that PSEG relied upon in preparing these reports. This information will be available to NJDEP upon request.

XII. CONCLUSIONS

PSEG, in this CDS, has submitted all information required for NJDEP to make a determination of BTA for Salem under 40 CFR §125.95. PSEG has submitted the information on the source water, CWIS and CWS, as required under 40 CFR §125.95(a) and §122.21(r). PSEG has also submitted all of the information necessary for a CDS under 40 CFR §125.95(b).

PSEG has implemented state-of-the-art CWIS technology at Salem. The improved modified-Ristroph traveling screens are equipped with ¼ in. by ½ in. Smooth-Tex ® mesh screen panels, hydrodynamically improved composite fish buckets, improved flap seals and improved high and low pressure spray wash system. Salem's CWIS is also equipped with a fiberglass bi-directional fish return system. The multi-speed traveling screens operate continuously. The biological efficacy of these measures has been demonstrated based on multiple years of post-installation monitoring and analysis.

PSEG's implementation of these design and construction technologies and operational measures described in greater detail in the DCTP (See V above) has ensured that Salem is in compliance with the §316(b) Standard for reductions in IM. The average annual (2002 to 2004) Calculation Baseline Conditions IM was estimated to be 370,242 lbs (167,939 kg); the average annual (2002 to 2004) Proposed Conditions IM was estimated to be 43,568 lbs (19,762 kg). This reduction in IM of 326,674 lbs (148,177 kg) (wet weight) per year is an 88% reduction from Calculation Baseline Conditions to Proposed Conditions. The technological and operational measures in place at Salem have reduced IM to meet the §316(b) Standard for IM of a reduction 80% to 95%.

PSEG is relying on existing technological measures (*i.e.,* reconfigured mesh on screen panels) and the salt hay farm wetland restoration to meet the requirements for reductions in E in USEPA's Final Rule. As described above, the new configuration of the screen mesh reduces entrainment. In addition, PSEG restored 4,400 acres of formerly diked salt hay farms to functioning salt marsh. The success of the restorations at each of the three former salt hay farm sites (*i.e.,* DTRS, MRTRS and CTRS) has been assessed based on NJDEP-approved interim and final Success Criteria. As described in VII-C above, DTRS and MRTRS both met the final Success Criteria years in advance of the anticipated dates. CTRS has met the interim Success Criteria and is on-track for meeting the final Success Criteria.

In this CDS, PSEG has demonstrated that the restoration of these three sites has also resulted in an increase in production of fish and shellfish sufficient to meet the applicable requirements in USEPA's §316(b) Regulations at 40 CFR §125.94(c)(2) and §125.95(b)(5)(iv) for reductions in E when coupled with the design and construction technologies. PSEG has demonstrated that the there has been a 0.3 million pound (0.14 million kg) reduction in E from the Calculation Baseline E due to the design and construction technologies, and a 18.6 million lbs (8.4 million kg) increase in production of fish and shellfish due to the salt hay farm restoration program. When compared to the reduction required by the performance standard a 60% reduction from the Calculation Baseline E of 9.7 million lbs (4.4 million kg), PSEG has clearly demonstrated that the restoration measures are producing benefits that are substantially similar to or greater than the benefits that would have been achieved by meeting the applicable §316(b) Standard for E. Therefore, Salem clearly meets the standards applicable when out-of-kind restoration measures are used (40 CFR §125.95(c)(2) and §125.95(b)(5)(iv)).

Results of the cost-cost test indicate that the costs for potential alternatives are “significantly greater” than the cost of the alternative technological measure modeled by USEPA by any reasonable definition of “significantly greater.” The cost comparisons show that the additional annual costs of the relevant alternatives (relative to the costs calculated by USEPA) range from about $12 million per year (for the revised refueling outage schedule) to over $100 million per year (for the cooling towers and 45% seasonal flow with constant • T alternative). Because all of the technological or operational measures that meet the Final Rule requirements appear to have significantly greater total annualized costs than the USEPA cost estimate, Salem is entitled to a site-specific determination of BTA, in accordance with 40 CFR §125.95(b)(6) of the Final Rule.

PSEG conducted a site-specific cost-benefit study that assessed the relative costs and benefits of 11 alternative technological and operational measures. The cost-benefit test results show that the costs exceed benefits by a substantial amount for all the relevant alternative technological or operational measures. Three of the four alternatives (revised refueling outage, dual-flow fine-mesh, and 20% seasonal flow reduction with constant • T alternatives) result in total benefits of less than $0.5 million compared to total costs of $118 million to over $500 million. The natural draft cooling towers alternative resulted in total benefits of over $6 million but with total costs of almost $1 billion. Although there is no clear criterion for “significantly greater,” it is clear that the costs are “significantly greater” than the benefits for all the relevant alternatives. Because all 11 alternative technological and operational measures have significantly greater costs than potential benefits, Salem is entitled to a site-specific determination of BTA, in accordance with 40 CFR §125.95(b)(6) of the Final Rule.

Regardless of the alternative NJDEP uses to determine Salem’s compliance, this CDS clearly demonstrates that the existing technological, operational and restoration measures PSEG has implemented to address IM and E at Salem have produced results that meet USEPA's §316(b) Regulations. No further measures are required.

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